# Supporting Cisco (*Coregonus artedi*) Restoration in the 1836 Treaty Waters of Lake Michigan


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# Chapter 1: Project Overview

## Treaty Fishing in Lake Michigan

Before European settlers inhabited the area, Native Americans, specifically the Anishinaabe peoples, fished sustainably in the Great Lakes and inland lakes for centuries. Spearfishing and net fishing were and are still used by Native fishers in Lake Michigan. Native fish species are consumed by Odawa (also known as Ottawa) tribes in subsistence and commercial fisheries (Great Lakes Indian Fish and Wildlife Commission 2014).

President Andrew Jackson signed the Indian Removal Act in 1830, which authorized the forced removal of thousands of indigenous people from their homelands on the 'Trail of Death.' Fearing removal, Odawa and Ojibwe groups sent delegates to Washington, D.C. to negotiate what would be known as the 1836 Treaty of Washington. Anishinaabe tribes ceded (sold) Odawa lands to the U.S. government. In return, the signatory Anishinaabe tribes secured their rights to fish, hunt, gather, and remain in the ceded territories (Figure 1). It is important to note that the U.S. government did not grant Native Americans treaty rights; in reality, treaty rights to hunt, fish, and gather were retained throughout the colonial era (and into our current era of settler colonialism) and secured in intergovernmental negotiations. Misconceptions about treaty rights would be the basis of contests from non-Native residents around the Great Lakes in the mid- to late-20$^{th}$ century.


*Figure 1: Boundaries of the 1836 Treaty of Washington D.C. land and water. Green areas delineate territory ceded from Anishinaabe tribes and sold to the U.S. government in exchange for the retention of*

*hunting, gathering, and fishing rights. Dark black lines enclose the Great Lakes waters that are managed and utilized by Anishinaabe tribes.*

In 1971, A.B. LeBlanc, an enrolled member of the Bay Mills Indian Community, was arrested by a Michigan Department of Natural Resources conservation officer for commercial fishing without a license, as well as fishing with an illegal gill net. The State of Michigan's defense was that the Chippewa and Ottawa Indians gave up their rights to use resources in the ceded territories when they signed the treaties. The 1976 *People v. LeBlanc* case, decided in the Supreme Court of Michigan, established that state regulation of Indian fishing is only valid if Indian fishing endangers the state fishery.

In response to this ruling, the U.S. government filed a suit against the State of Michigan in 1973 on behalf of the Bay Mills Indian Community. The lawsuit alleged that Anishinaabe signatories of the 1836 Treaty could fish in designated waters of Lakes Michigan, Huron, and Superior (Figure 1). Several tribes, including LTBB, joined the litigation. The 1979 *US v. Michigan* decision reaffirmed the 1836 tribes' rights to fish in the off-reservation ceded waters of Lakes Michigan, Huron, and Superior.

In 1985, in response to multiple suits involving state and tribal conflicts over Indian fishing rights, a Consent Order was signed between the Bay Mills Indian Community, the Sault Ste. Marie Tribe of Chippewa Indians, the Grand Traverse Band of Ottawa and Chippewa Indians, and the State of Michigan. In 2000, the Consent Decree was modified and signed by the three aforementioned tribes, the Little River Band of Ottawa Indians, LTBB (which gained federal recognition in 1994), and the State of Michigan. Under the 2000 Consent Decree, the Chippewa Ottawa Resource Authority (CORA) was established to coordinate efforts by tribes to manage and fish the treaty waters. CORA's usefulness to the member tribes is contest among LTBB fishers and leaders, some of whom believe that CORA is an effort by the State of Michigan to avoid negotiating with individual tribes as sovereign nations. An inter-governmental Technical Fisheries Committee was also founded to advise management decisions, bringing together tribal and non-tribal managing bodies. The 2000 Consent Decree is valid for 20 years, and preparations for the 2020 Consent Decree are underway.

## History and Culture of the Anishinaabe People

The Anishinaabe tribes are groups of indigenous North American tribes around the Great Lakes, and the larger group to which the client, the Little Traverse Bay Bands of Odawa Indians (LTBB), belongs. Anishinaabeg (plural form) can be classified into three main tribes that have very similar dialects and cultures: the Ojibwe (also called Chippewa or Ojibwa), the Odawa (also spelled Ottawa), and the Bodewadmi (Potawatomi). This grouping is also known as the Council of Three Fires. The Ojibwe are considered the "oldest brother" and are the keeper of the faith. The Odawa people are the middle brother and the keeper of the trade. The Bodewadmi, as the youngest brother, are the keeper of the fire. Other tribes associated with the Anishinaabeg include the Oji-Cree, Mississauga, Métis, and other Algonquin peoples. Anishinaabemowin, the Anishinaabe language family, is taught widely around the Great Lakes Basin.

Odawa, or Ottawa, tribes have been living in Northern Michigan and around Manitoulin Island for centuries. Like other tribes living in the Great Lakes region, they have developed a dependence on water for fishing, travel, and recreation. *Wiigwaasi-jimaanan*, or birchbark canoes, were used for travel on the Great Lakes and inland waterways, and are still used today in wild rice harvesting (Wisconsin, n.d.).

Historically, the Odawak were semi-nomadic and migrated seasonally. With almost no permanent year-long settlements, Odawa territory stretched from the northern part of contemporary Michigan to southern Ontario. European settlers and Christian missionaries forced the Odawak to adopt English life ways and religion, demanding that Odawa men cut their long hair and remove their earrings and nose rings (for the *ogemak*, or leaders). By the 1850s, the church was the center of Odawa life in Michigan, with services often led in the Odawa language (McClurken 1991).

Residential boarding schools for Native American children were also established by the U.S. and Canadian governments. The most notorious was the Carlisle Indian Industrial School in Pennsylvania, which ran from 1879 to the early 1900s. Children were forbidden from speaking their native languages, practicing their religions, or keeping their hair long. As a result, tribal cultures from across the continent were all but lost. Today, language revitalization efforts are funded by tribal governments, the Bureau of Indian Education, and the US Department of Education (Department of Education 2017). LTBB has a robust language and culture revitalization program spearheaded by their Gijigowi Anishinaabemowin Language Department.

## Ecology of Lake Michigan

Lake Michigan has experienced drastic physical and ecological change in the last half century. Extensive river modification, deforestation, and chemical pollutants altered the physical landscape surrounding Lake Michigan from European contact until the mid-1900s. Following the industrialization of Midwestern cities, a suite of invasive aquatic species altered the ecological composition of Lake Michigan and the “invasion meltdown” was facilitated by increased connectivity to other water bodies for shipping. Notably, alewife (*Alosa pseudoharengus*) devastated planktivore populations following their introduction in the early 1900s (Madenjian et al. 2008). Zebra mussels (*Dreissena polymorpha*) colonized much of Lake Michigan, and were quickly proceeded by quagga mussels (*Dreissena bugensis*) even more fit to colonize soft substrate of Lake Michigan (Evans et al. 2011; Vanderploeg et al. 2010). To control alewife populations, managers stocked exotic Pacific salmon (*Oncorhynchus spp.*), and alewife populations declined in the 1970s across Lake Michigan. Compounding the oligotrophic effects of *Dreissenid* mussel filtering, *Bythotrephes longimanus*, a predatory cladoceran zooplankton, has lowered zooplankton abundances across the lake (Pothoven and Fahnenstiel 2014; Tuchman and Barbiero 2004). Planktivorous fish biomass is also decreasing (Vanderploeg et al. 2012). Today, Lake Michigan faces an imbalanced food web of too many predators, too few forage fishes, and low primary and secondary productivity.

Cisco (*Coregonus artedi*) was once one of the most abundant prey fish in Lake Michigan (Smith 1968; Smith 1972). The native planktivore supported a robust fishery and was the main prey for the lake’s top predator, lake trout (*Salvelinus namaycush*; Smith 1968; Smith 1972). Due to overharvesting, introduced species, and habitat destruction, cisco populations plummeted in the mid-1900s and have yet to recover to pre-crash abundances in northeastern Lake Michigan (Baldwin et al. 2009). Anecdotal evidence suggests that a population is growing and is concentrated in Grand Traverse Bay (unpublished data, Randall Claramunt, Michigan Department of Natural Resources, and Kevin Donner, Little Traverse Bay Bands of Odawa Indians). However, little is known about the contemporary ecology of *C. artedi* in northeastern Lake Michigan.

Tribal, state, and federal managers are seeking a solution to the predator-prey imbalance, and restoring cisco populations has been suggested as one such solution (Povolo et al. 2016).

There is disagreement among managers about the best restoration strategy. Options include stocking from Lake Michigan source from remnant populations, stocking from Lake Superior source populations, restoring spawning habitat, curbing catch rates, and 'doing nothing.' This project sought to provide information to managers to help with restoration decisions.

Specifically, this project sought to answer four questions about cisco in northeastern Lake Michigan: (1) What do Little Traverse Bay Bands of Odawa Indians citizens think about Lake Michigan management and cisco restoration?; (2) How many cisco are there in Little Traverse Bay?; (3) What is the cisco growth pattern in northern Lake Michigan?; and (4) What is the food available to and diet of larval cisco in northeastern Lake Michigan? To accomplish the first task, we conducted 24 semi-structured interviews with LTBB citizens, targeting leaders, elders, and fishers. To accomplish the second task, we analyzed pelagic fish abundance using hydroacoustic techniques. To help answer the third task, we aged cisco based on otolith sectioning and modeled growth using von Bertalanffy equations. We explored the fourth question by analyzing nearshore zooplankton composition and larval stomach contents

This project sought to increase LTBB sovereignty by creating science meaningful to the people that physically, spiritually, and mentally depend on the quality of and access to Lake Michigan natural resources. Lake Michigan's altered condition is a direct consequence of European colonization of the Great Lakes region, and continued mismanagement continues a legacy of ignoring the needs, desires, and treaty rights of indigenous communities. While the information about cisco ecology in this report can be useful to managers, what the authors hope to impart is that all stakeholders, but *especially* those historically marginalized in natural resource decisions, matter.

# Chapter 2: Little Traverse Bay Bands of Odawa Indians' Perspectives on Lake Michigan Management, Conditions, and Cisco Restoration

by April Richards, Albany Jacobson Eckert, and Jillian Mayer

## Abstract

When considering restoration strategies, it is crucial to involve the communities who may be impacted. As the Little Traverse Bay Band of Odawa (LTBB) Natural Resource Department (NRD) makes management decisions, and as managers consider restoration options for cisco (*Coregonus artedi*), it is crucial to understand how the community is impacted by conditions and whether they support restoration efforts. To address this question, we conducted 24 semi-structured interviews with tribal citizens, leaders, elders, and fishers on current conditions, utilization, individual and community perspectives on cisco restoration and restoration strategies, and future management directions. We found that all interviewees utilize the lake and the land in some way (food, crafts, culture, medicine, and activities). Most interviewees supported the restoration of native species, including cisco, but perceived that others in the community would not support cisco restoration without education. Interviewees consistently noted that ecosystem health was essential to tribal citizens' mental, spiritual, and physical health.

## Background

The Anishinaabe tribes, including the Little Traverse Bay Bands of Odawa Indians (LTBB) have a long history of hunting, fishing, and gathering in the Great Lakes region. The utilization of Lake Michigan's natural resources existed prior to and after European settlement of the region, and has continued into the current era of hegemonic settler colonialism (Bonds and Inwood 2015). Anishinaabe citizens have maintained relationships to the land and water near their homelands despite centuries of intentional disruption by settlers. Today, many tribes, including LTBB, run language revitalization programs, are reinvigorating cultural practices, and manage the natural resources on their treaty land for citizens' benefit. Indigenous voices have been minimized at best and violently silenced at worst in the names of (settler) conservation, sustainability, and natural resource management. Anishinabek philosopher Eric Whyte (2015) defines colonialism itself as a type of environmental and climatic change, and describes how climate change has acted to intensify colonialism (the concepts are interchangeable and unordered – we cannot have one without the other). In this spirit, we see the poor state of Lake Michigan's fisheries as a direct, even intentional, result of European colonization of the Great Lakes region. As three graduate students, one Anishinaabe and two non-indigenous, interested in working for just and sustainable fisheries management in the Great Lakes, we excitedly agreed to conduct ecological and social science research with LTBB.

Our first task in this project was to document the perspectives of LTBB citizens regarding Treaty lake and land use, Lake Michigan management and conditions, and cisco restoration. The LTBB Natural Resources Department (NRD), as well as several non-tribal management agencies, are interested in exploring the restoration potential of cisco (*Corgeonus artedi*), a native planktivore, to potentially stabilize the predator-heavy Lake Michigan food web. Because natural resource issues are social and political undertakings, not merely questions of ecology, gathering the thoughts of stakeholders is essential to crafting successful policy. LTBB NRD tasked us with gathering data on citizens' perspectives, so that they can make socially sustainable natural resource policy within the 1836 Treaty waters they manage. We achieved this by conducting voluntary semi-structured interviews with 24 tribal citizens. We understand that this is not a representative sample of the community, given that LTBB has almost 5,000 enrolled citizens. Nevertheless, we believe the perspectives of these participants are useful to LTBB NRD because they include important fishers, leaders, and elders within the community.

In addition to providing useful data to LTBB NRD, we also hoped to document and elevate LTBB perspectives on Lake Michigan management for non-tribal managers (e.g. the State of Michigan and the US federal government). Non-tribal managers today have an opportunity to reverse the centuries-old trend of marginalizing indigenous needs, at least in the field of fisheries management in Lake Michigan, if they listen to and respect the perspectives of indigenous stakeholders. Ultimately, we must recall that "decolonization is not a metaphor" (Tuck and Yang 2012) and truly just, sustainable, moral natural resource policy should prioritize indigenous tribal sovereignty over all else; 'listening' and 'respecting' may not be sufficient. Until physical decolonization (i.e. the removal of settlers from power and place), however, non-tribal Lake Michigan managers can, at the very least, listen to tribal citizens and give them more seats at the management table.

## Materials and Methods

### Conducting Interviews

To investigate the perspectives of LTBB citizens regarding Lake Michigan management, conditions, and cisco restoration, we conducted 24 semi-structured interviews. Interviews were conducted individually or in pairs and interviewees included elders, leaders and fishers, and other tribal citizens who did not fit into any of the three previous categories (Figure 2). All interviewees were LTBB citizens and some hold several of the aforementioned identities (Figure 2). Interviewees were considered tribal elders based on the tribe's distinction of citizens over the age of 55 (Little Traverse Bay Bands of Odawa Indians

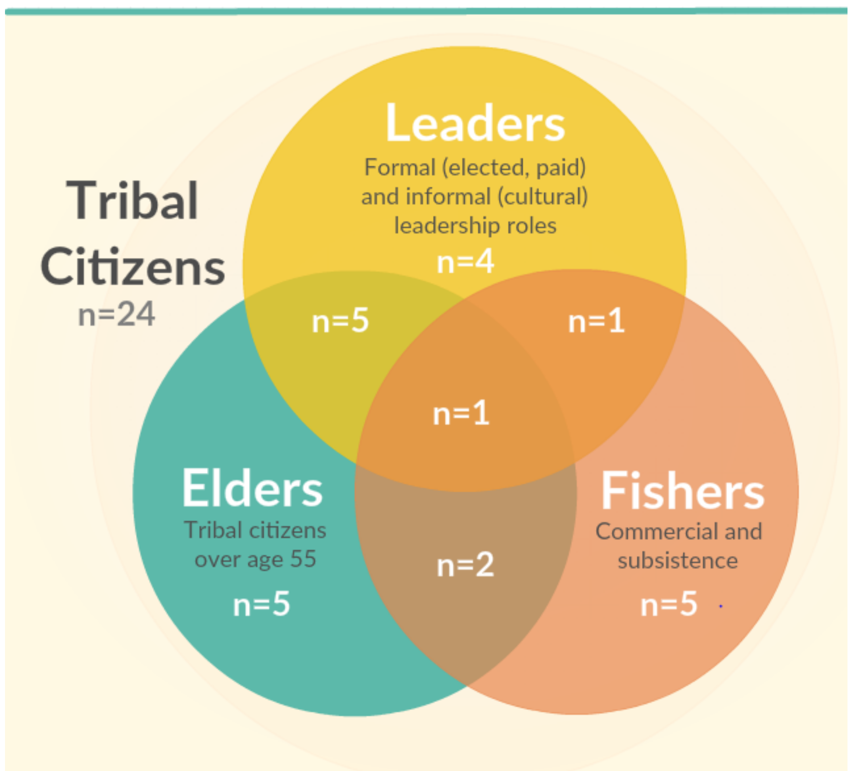


*Figure 2: The identities of tribal citizens interviewed. One interviewee is not included in the Venn diagram because she held none of the three mentioned identities. She is included in the sample size (n = 24).*

2014). Tribal leaders were defined as those citizens who hold formal (elected or paid) and informal (social or cultural) leadership roles within the community, either currently or historically. Current commercial and subsistence fishers, as well as citizens with a history of fishing for subsistence or income, were included in the category of tribal fishers. Participants were recruited through informational newsletters delivered to tribal citizens by email and recommendations made through the LTBB Natural Resource Department (Appendix A).

Interviews were conducted in homes, workplaces, boat loading docks, and restaurants near Harbor Springs, Michigan, and one interview was conducted in Ann Arbor, Michigan. Interviews took place between July 10, 2017 and August 25, 2017. Each interview lasted between 30 minutes and 2 hours. There were 21-26 multi-part questions asked of each interviewee, and the number of questions depended on the identity (Figure 2) of the interviewee: tribal leaders and elders were asked 25 questions, fishers were asked 26 questions, and other members were asked 21 questions. Interview questions can be found in Appendix B.

Interviews were organized into seven categories:

1. Interviewee Background and Tribal Relationship

Participants were asked to introduce themselves and explain their relationship to and/or position within the LTBB community. Responses from these questions were used to assign participants to groups: leader, elder, fisher, or a combination.

2. Perspectives on current conditions

Participants were asked a series of questions about the conditions of Lake Michigan, including; a description of current conditions and how conditions have changed, impacts of these changes on the tribe, expectations for future conditions, lake management, and the status of fish communities.

3. Utilization of Natural Resources

Questions in this section assessed whether LTBB citizens used their treaty rights and what types of resources they harvest. This section also assessed familiarity with cisco and lake whitefish, use of cisco and whitefish, and the tribe's relationship to cisco and whitefish. Additionally, elders were asked about the resources harvested by their parents and their parents' relationship to cisco and lake whitefish.

4. Individual Perspectives on Cisco Restoration

For interviewees unfamiliar with the condition of Lake Michigan, we read a brief summary explaining the predator-prey imbalance and lack of prey fish. We then questioned interviewees about their knowledge of cisco restoration efforts and whether they supported cisco restoration.

5. Community Perspectives on Cisco Restoration

Interviewees were also asked about their thoughts on how community members would feel about cisco restoration and whether tribal leaders support cisco restoration. Additionally, tribal leaders were asked how inter- or intra-tribal government interactions might influence a restoration process.

6. Restoration Strategies

Participants were asked questions about several restoration strategies that might be considered for restoring cisco, including; monitoring without action, stocking, and stopping the stocking of Lake Michigan with nonnative predators. They were also asked who should lead restoration efforts between states, tribes, and federal agencies.

7. Final thoughts on Priorities to Improve Lake Conditions

The final question of our interviews was a hypothetical exercise that asked interviewees to imagine that they had the final decision on how to improve the conditions of Lake Michigan. Based on responses, we created a list of management priorities to guide the Natural Resource Department.

## Post-Interview Processing

We recorded all interviews, and full interviews were later transcribed by employees of the University of Michigan Services for Students with Disabilities department. Interviewees were required to sign consent papers to be voluntarily interviewed per IRB guidelines. Interviewees were also presented with an additional consent form, the LTBB Oral History Deed, which granted us permission to give the interview recordings to the LTBB Department of Records and Archives. If interviewees declined to sign the Deed, all identifiable information will be removed from the interviews before the Department of Records and Archives receives them. The Department of Records and Archives catalogs oral histories by LTBB citizens. By giving these interviews to the Department, these citizens' perspectives will be preserved for future generations.

Interview responses were coded by question section using an inductive approach. First, the coder familiarized themselves by reading the section of the interview. Next, they identified codes and by clustering related codes created emergent themes. When possible, identified codes were kept as verbatim quotations to avoid simplifying the thoughts, feelings, and ideas expressed by the interviewees.

Sections of the interviews were coded by different students. Emergent codes were identified, and themes created by clustering related codes. Whenever possible, identified codes were kept as verbatim quotations to avoid simplifying the thoughts, feelings, and ideas expressed by the interviewees. Consensus on themes and codes was reached by peer review and discussion. No software beyond Microsoft Word and Excel was used. April Richards coded sections "Perspectives on Current Conditions" and "Final Thoughts." Albany Jacobson Eckert coded "Individual Perspectives on Cisco Restoration" and "Restoration Strategies." Jillian Mayer coded "Utilization of Natural Resources" and "Community Perspectives on Cisco Restoration." Kayla Musil and Jonah Eisenberg coded information on interviewee background and tribal relationship, which was used to create identity categories of interviewees (Figure 2).

# Results

## Perspectives on Current Conditions

Responses to questions on the conditions of Lake Michigan, including current and historical; fell within three general themes: i) social and ecological conditions of Lake Michigan, ii) impacts on utilization of lake resources, and iii) actions that address or fail to address conditions (Figure 3). These themes influence each other, for example, the social and ecological conditions of the lake impact how people utilize the lake and utilization of the lake can impact the conditions. Each of these themes contained subcategories (Table 1).

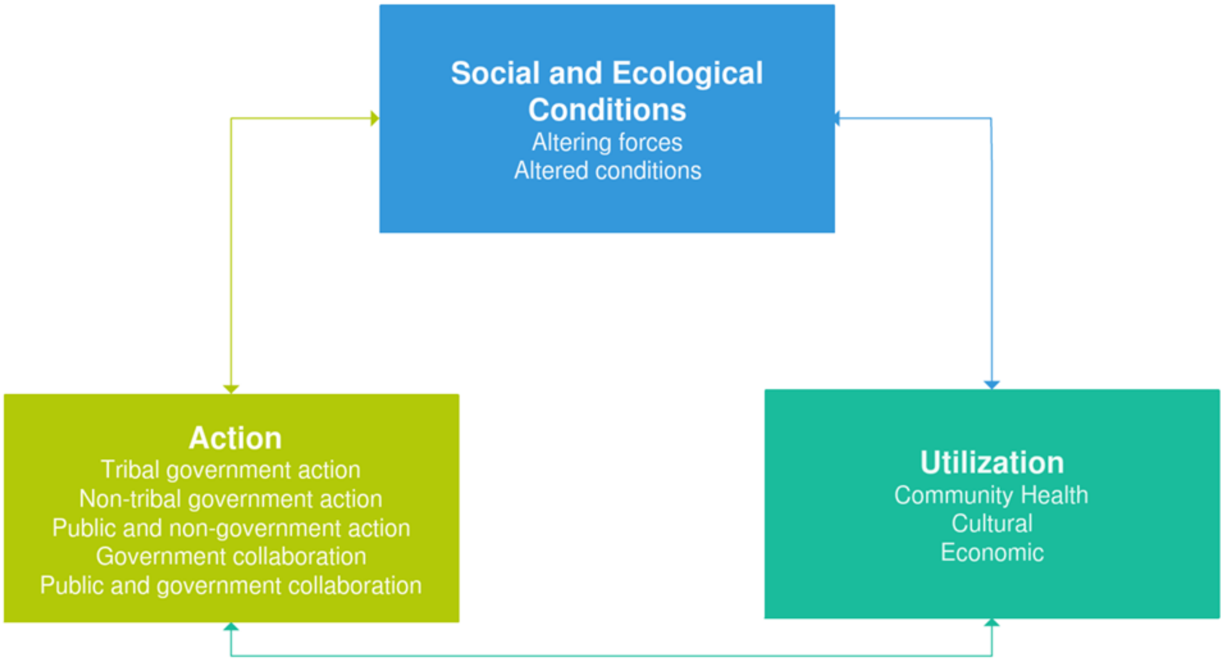


*Figure 3: Emergent themes describing participants' responses to the Conditions of Lake Michigan section.*

*Table 1: Emergent themes and codes from the Perspectives on Current Conditions section of interviews.*

Perspectives on Current Conditions

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| Physical and ecological conditions | Altering forces (21) | *Social, political, chemical, or biological factors influencing lake conditions, including; pollution and polluting entities, pipelines, policy, climate change, invasive species, habitat loss, privatization of land and water, and increased populations.* | "You know Mother Earth is a living being and so like anything else, she changes, and she goes through cycles and so you know that there's a purpose or reason that the invasives are coming and that maybe some indigenous types of animals and plants and people are then becoming something different than what they were."<br><br>"I know climates are changing and everything's shifting and we're losing our ice up there, that's melting away."<br><br>"There was company that is basically draining the lakes and selling the water" |
| | Altered conditions (22) | *Physical and ecological conditions that have changed, including; native species, habitats, water levels, water quality, ice cover, and public access.* | Barriers to public access of the lake and lake resources by private property owners<br><br>"The other big threat looming out there is climate change. So the lakes are warming up and we are seeing less ice coverage....Eggs are laid in spring or in the fall that if there are no ice…there's not any ice coverage, then they're getting beat up by wave action and then we're theorizing right now anyways, then that makes them less viable. But that's something that is a direct product of climate change that people haven't really looked at and that's just the way the lakes have evolved."<br><br>"We're already seeing it. Walleye come back, whitefish are going down. Whitefish like it colder. Walleye like it warmer." |
| Utilization | Community health (12) | *Impacts or potential impacts of lake conditions on community health, including: diet, food safety, and physical safety/health risks.* | "I think it has in a positive way and that it has caused…well you know fish are vital to us as a community. And we're getting even more knowledge related to that, that diabetes is out of control in our communities. I understand, I have a greater understanding that we will be healthy if we eat those foods that are indigenous to our area."<br><br>Concerns about beach closures due to pollutants, contaminants, bacteria, etc…<br><br>Well, are fish coming out of the Great Lakes, are they, is it really healthy to eat? I mean, you hear about all the contaminants and mercury and all this other stuff, and so you wonder. Is it really, really healthy for us still? I don't know. I know it used to be. Is it still? |

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|---|---|---|
| Cultural impacts (14) | *Impacts or potential impacts of lake conditions on culture, including: ability to exercise treaty rights, recreation, language, relationships, traditions, and passing of traditional ecological knowledge.* | "It's not just something for me to weave and to you know harvest and remember my ancestors with, I help them with that purpose. Because our people have always done that kind of thing, you know. It's a much bigger concept then all of that. I'm just not weaving stuff for the…because it looks pretty, I'm helping them by creating purpose again for them within our life."<br><br>Connections between efforts towards language revitalization and connections to natural resources.<br><br>"I mean they don't, there's not as many tribal fishermen anymore you know to keep up the tradition. Like in Charlevoix, I think there's maybe two boats out there that go out. And there's a lot of water you know, a lot of fishing land out there where they could fish, but they I don't know, not enough of them take up the tradition like they used to."<br><br>"There's an oral history as far as you know a continuity from people who have always fished. We've always had some fishing community or fishing members in our community, fishing families. Yeah, so I think if that goes away, we may lose some of that. You know some of those things are kind of just held within those families and if the line stops, that may be lost you know from our community" |
| Economic impacts (16) | *Impacts or potential impacts of lake conditions on economic well-being of community members, including: fishing and fishing conditions, costs of damaged equipment, management priorities, and lake conditions.* | "Commercial fishermen really use it. That's their income. That's their way of life."<br><br>"Now again, I don't think very well. You know and I fished Little Bay De Noc....And I like to go there because of the diversity that's there. But what I saw there was the same thing situation that the fish were being overharvested."<br><br>"You know we had them, but there's not too many of them that are operating anymore....And the reason for that is, is because I think the markets out there are pretty well established, you know and so they're not buying fishing from anyone else."<br><br>Lake conditions (algae/slime/mud) impacting the ability to fish and damaging equipment.<br><br>"Well, the one that I hear about the most is, if you talk to fishermen, that they can't help but catch a lot of the lake trout and, you know, it's harder for them to find whitefish. So, you know, the fact that the feds have stressed trout restoration as being the primary, um, the primary aim, doesn't take into account, uh, historic fisheries and what, um, commercial fishermen and especially native fishermen in particular are looking for and what they can sell."<br><br>"I think if there's like an oil spill, I don't know if you call it a spill if one of the pipelines breaks. I mean it could take, it could take I don't know 20-25 years to clean it up, billions of dollars, and the impact you know to the economy, to recreational tourism, and to the wildlife in the area, and to the fish, it's going to be pretty high." |

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| Action- addressing or failing to address conditions and utilization | Tribal government action (13) | *Attempts by tribal governments to manage or respond to lake conditions, including; policy creation, fishing closures, stocking, and prioritizing of species and/or stakeholders* | On hatchery: "... and so I hope that [the] techniques and processes that you're using are congruent to Anishinaabe traditions."<br>Lack of public knowledge of the tribes management efforts<br>"I think to a certain degree, well I think you know to a large extent that as CORA exists right now, it doesn't necessarily in my opinion benefit the tribes. And I think it's more dysfunctional than helpful." |
| | Non-tribal government action (12) | *Attempts by tribal governments to manage or respond to lake conditions, including; policy creation, fishing closures, stocking, and prioritizing of species and/or stakeholders* | "The State they just need to get more in touch with the people that are utilizing the lake you know, not just for a sport fishing activity, but for a way of life."<br>"The manner in which that we've been able to start working with the other entities, I think is better than it has. And has percolated down a little bit into our community. You know our community in general has been, continues to be to a certain degree very mistrusting of government, of the State of Michigan, of the Feds, because they've always come forward with a certain amount of well we are interested in your issues and we're looking to be your beneficiary or your trust responsibility, take that seriously, but their actions don't necessarily represent that." |
| | Public and non-government action (9) | *Action by non-governmental individuals or groups to manage or respond towards lake conditions, including; voting, activism, and organizing.* | "We've got to inform the voters and put people in there that know what they're doing"<br>"And so with the Standing Rock just kind of struck me more, even more so, to be aware and involved and supportive of the water protection efforts" |
| | Government collaboration- tribal and non-tribal governments (14) | *Collaboration between tribal and non-tribal governments to manage or respond to lake conditions, including; research, policy, education and transparency, adaptation, and other management efforts.* | Concern about a lack of collaboration between the state and tribes.<br>Federal and state governments treat tribes as one unit rather than independent governments with different needs and agendas.<br>"Too much influence from the feds and not enough asking states and tribes for input and coming to more of a consensus."<br>"I think we're really going to need to be intentional as far as the management agencies. So that's going to include the tribes, that's going to include the states and the Federal government, and the provinces. So the Great Lakes involve you know nine states and two providences and 30-plus tribes live within the Great Lakes region alone." |
| | Public and government collaboration (14) | *Collaboration between the public and governments to manage or respond to lake conditions, including; education and transparency, adaptation, and other management efforts* | "And finally people became aware that there was something going on and my belief is, in fact I know it to be true, that the DNR doesn't tell us everything that we need to know."<br>"That's going to be the problem, but you know we've been taught over the years, over the centuries, how to live with climate change. And so we need to be thinking about that ourselves, how do we adapt? What medicines? What foods? What the ways of shelter? Weather patterns, you know all these kinds of things are things that we need to be thinking about and preparing for. And all of them are going to affect the lakes." |

## Perspectives on Social and Ecological Conditions

When discussing the social and ecological conditions of Lake Michigan, interviewees described how conditions had been altered and the forces altering those conditions. Altering forces include social, political, chemical, or biological factors. Twenty-one participants identified altering forces, including; pollution and polluting entities, pipelines, climate change, invasive species, habitat loss, policy, increased privatization of land and water, and increased population density of the nearshore region. Altered conditions identified by participants included changes in native species, habitats, water levels and water quality, ice cover, and public access to the lake. One elder and leader noted shifts in fish populations due to climate change, “We’re already seeing it. Walleye come back, whitefish are going down. Whitefish like it colder. Walleye like it warmer.”

## Perspectives on Utilization of Lake Resources

Responses about the social and ecological conditions of Lake Michigan indicate that both influence the utilization of lake resources by tribal citizens. These conditions were described in terms of community health, cultural, and economic impacts. Community health impacts (or potential impacts) were discussed by twelve interviewees and included changes to diet based on fish available, concerns on food safety, and about physical safety. Some of these impacts were described as the result of forces altering the conditions of the lake.

Changes in the diets of Anishinaabe people, historically fish-based and drastically changed by the US government’s commodities programs that delivered rations of Westernized foods (e.g. flour, beef, beans, sugar, and lard) (Naramore, 2011), has been further influenced by the overfishing of native fish, introduction of non-native species (which created further pressure on native species) and also by concerns about food safety due to contaminants found in fish. Some interviewees also mentioned concerns about the physical safety in some areas of the lake that has led to beach closures, generally caused by fecal contamination. The altered conditions of the lake have also had cultural impacts on LTBB citizens, including; decreasing the ability to exercise treaty rights, restricting recreation, and loss of language, relationships, traditions, and the passing of traditional ecological knowledge. One weaver, elder and leader, described the purpose of her art as a connection to her ancestors and expressed concerns about invasive species (i.e. phragmites) and pollutants affecting the indigenous plant species, cattail and bulrush necessary for her craft. Seven participants, including elders, leaders, and fishers, expressed concerns about the loss of fishing knowledge and traditions resulting from the decline in the number of fishers in their community (due to aging and lack of young people entering the field). However, participants also noted that as conditions have changed there were movements in their communities to reclaim the relationship between people and natural resources. For example, LTBB has a language revitalization program, discussed by two elders and leaders, to foster a reconnection to the environment as participants in the program learn Anishinaabemowin.

Responses indicate that the altered conditions of Lake Michigan also impact the economic well-being of community members, primarily fishers. Fourteen of the 16 participants that mentioned economic impacts discussed impacts on fishers or fisheries. The fishers and fisheries are impacted by changes in fish populations and lake conditions, by damaged equipment, and management priorities. Algal blooms and zebra mussels have limited fishing zones and damaged fishing equipment. One leader discussed how changes in fish populations and management priorities have limited fish that can be harvested and sold by fishers: “Well, the one that I hear about the most is, if you talk to fishermen, that they can't help but catch a lot of the lake trout and, you know, it's harder for them to find whitefish. So, you know, the fact that the feds have stressed trout restoration as being the primary, the primary aim, doesn't take into account, uh, historic fisheries and what, um, commercial fishermen and especially native fishermen in particular are looking for and what they can sell."

Another leader stressed the potential economic repercussions of a potential oil spill in regions of the Great Lakes used to transport oil: "I think if there's like an oil spill, I don't know if you call it a spill if one of the pipelines breaks. I mean it could take, it could take I don't know 20-25 years to clean it up, billions of dollars, and the impact you know to the economy, to recreational tourism, and to the wildlife in the area, and to the fish, it's going to be pretty high."

## Perspectives on Actions that Address or Fail to Address Conditions

Several types of action are taking place in reaction to changing social and ecological conditions of the lake and utilization were mentioned by participants. These actions also influence conditions and utilization. Actions addressing or failing to address conditions of the lake were grouped by the entities engaging in these actions: i) tribal governments, ii) non-tribal governments (federal and state agencies), iii) public and non-governmental groups, iv) collaboration between tribal and non-tribal governments, and v) public and government collaborations.

The actions of governments (tribal and non-tribal) were attempts to manage or respond to lake conditions. Actions discussed by interviewees included policy creation, fishing closures or restrictions, fish stocking and restoration, and the selection of which species and stakeholders to prioritize. Thirteen interviewees, from all interviewee groups, discussed actions by the LTBB and other tribal governments, such as management efforts by the Natural Resource Department. One interviewee noted that there is a lack of public knowledge of the tribes' management efforts. Comments on non-tribal government action discussed the prioritization of sports fishing and a disconnect from the needs of other people, especially tribal citizens. Actions by the public or non-governmental groups in response to lake conditions or utilization restrictions included voting, activism, and community organizing.

Fourteen interviewees discussed the collaboration, or potential for collaboration, between tribal and non-tribal governments to respond to lake conditions. This collaboration includes research, policy, education, adaptation, and other management efforts. A leader suggested, "We're really going to need to be intentional as far as the management agencies. So that's going to include the tribes, that's going to include the states and the Federal government, and the [Canadian] providences. So, the Great Lakes involve you know nine states and two providences and 30-plus tribes live within the Great Lakes region alone."

While mentions of public action focused around activism and organizing, the collaboration between public and governments largely addressed transparency of the government. There is a recognition that effective action will include both governments and the community. For example, one leader and fisher explained, "I'm hopeful that people like yourself and the State and the Feds and the Tribes can work together, all the stake holders involved around these Great Lakes, can hopefully at least maintain it or even make it a little better." Actions by tribal and non-tribal governments, the public, and collaborations between these groups have potential to impact the social and ecological conditions of the lake and the utilization of natural resources.

## Utilization of Natural Resources

All participants reported that they utilized Lake Michigan or tribal land in some capacity (Table 2). Common activities reported included hunting, fishing, and gathering, maple syrup reduction, swimming, and using the lake for spiritual purposes. Fifteen participants reported that they consumed aquatic organisms like fish, mollusks, and amphibians from Lake Michigan. Specifically, participants mentioned that they utilized the following organisms: catfish, bluegill, burbot, carp, crab, frogs, lake trout, lake whitefish, perch, rainbow trout, rock bass, salmon, smallmouth bass, suckers, sunfish, and walleye. Note that there are no crabs in Lake Michigan – participants may have meant crayfish, or have mistaken a marine species for a freshwater one. Interviewees' frequency of eating fish varied. Ten participants said they regularly eat fish. Of those, most ate fish several times weekly (n = 6), and an equal number ate fish several times monthly (n = 1) or yearly (n = 1). When asked directly about cisco consumption (n = 2), one tribal leader said they had eaten cisco once, and one elder said they did not recall ever eating cisco. All had eaten lake whitefish. Sources of fish included one's self, friends, family members, Muskegon, Charlevoix, Shelby Township Farmers Market, local restaurants, the LTBB NRD, and Bell's Fishery before it closed in 2016. Bell's Fishery was a fish processing facility and restaurant owned and operated by the Sault Ste. Marie Tribe of Chippewa Indians, and the only Tribal-owned processing facility in Michigan.

Twelve participants reported that they hunted and gathered food from Tribal land, including acorns, apples, blackberries, blueberries, deer (*waawaashkeshi*), duck, morel mushrooms, rabbits, strawberries, and wild turkey. Four participants harvested traditional medicines (*obzechgun*) like mullein, medicine stones, peppermint, spearmint, sweetgrass, tobacco, and willow bark for aspirin. Nine interviewees regularly gather materials for traditional crafts, including black ash, bones, bulrush, diamond willow bark, eagle feathers, glass, Petoskey stones, and porcupine quills. With these materials, participants reportedly make arrowheads, baskets, cradleboards, and walking sticks. One participant noted the importance of knowing when to harvest certain materials: "The only time you can harvest [diamond willow] is the time of the fireflies, because the temperature is right, and the water is in the wood yet."

Beyond utilizing physical commodities from the lake and land, eight participants (elders and leaders) shared that the natural world has spiritual significance for them. The lake and land are part of their personal and spiritual identities - an intangible but nevertheless important aspect of their physical, emotional, and community's health. To participants, the quality of the lake and land is tied up with their own physical and mental health, which makes it difficult to prioritize management concerns. One elder reminded us that "what happens to [Earth] is what happens to us. We drink that water. We eat those fish. We harvest those plants, even down to the stones. When somebody gives you a choice, do you want to cut off your right hand or left food? Which one is more important? There's not a choice. It's all important." Tribal citizens literally depend on the lake and land for sustenance, but also for spiritual needs. "Besides the plants, the fish, the water itself is ceremony. I mean it's who we are. It's so much more than food. It's also food for your spirit," noted another elder.

Most interviewees reported a historical family relationship to natural resources (n = 11), but fewer are currently involved in fishing, hunting, or gathering (n = 8). Of those that reported past familial utilization of the lake or land, participants identified the following family members as historical users: mother, grandmother (often referred to as making fish head soup), father, brothers, sisters, and a great-grandfather. Participants noted that they had lost their connection to the lake and land due to colonization, urbanization, and development of northern Michigan. This alienation from ancestral ways of living has de-incentivized utilizing natural resources: “My grandfather was a good hunter. My great-grandfather was a good hunter. As Native people that at one time subsisted off the land, hunted and fished and harvested things, we knew what to do with it. The necessity of respecting that resource so that our descendants would have access to it. Now we can’t do that, see.”

Eight participants noted their brothers, cousins, sons, grandsons, great-granddaughters, daughters, nieces, and nephews exercise their treaty rights to hunt, fish, and gather. Hunting, fishing, and gathering for subsistence is not a solitary activity - benefits other family members. “My niece and nephew-in-law had a child and they went and learned to make birch bark baby carrier. And they went out and harvested the materials they needed for that.” Fishing is a particularly collaborative and community-oriented activity: “[Fishing] is subsistence not just for you but for your extended family. You share with your mom or your aunt or your grandma.” Indeed, most elders reported receiving fish from family members, further corroborating the assertion of fishing as a community affair.

We asked participants about historical and contemporary tribal relationships to cisco and whitefish. Five explained a strong pre-European-contact (“pre-contact”) relationship to both fish. Whitefish has always been and continues to be an important fish to the tribe, but one participant spoke directly about cisco: “cisco used to be the main thing that they used to go out and get in the wintertime.” Two citizens said that the tribal relationship to cisco declined due to a decline in consumer demand for cisco and the price of equipment for catching them: “You’re talking about a whole separate set of gear and they’re not worth a whole lot,” so tribal fishers no longer target them. The majority of participants said the tribal relationship to both fish, but especially cisco, declined due to the ravages of colonialism and overfishing. “The herring, according to my father and them, there was a lot of herring. Now Lake Huron, they stayed the same, and Lake Superior. But Lake Michigan they just seemed to, in fact they’re nonexistent now,” noted one fisher. Due to the lack of cisco in Lake Michigan, tribal citizens’ relationship to the fish has weakened: “You eat what’s available to you. Cisco have been on the decline for so long that I don’t recall if I’ve had any cisco in years.” Even before the decline of cisco in Lake Michigan, centuries of contact and control by European-descended peoples worked to alienate Tribal citizens from their ancestral lands and waters. “There’s a certain diet and a certain way of life that we had as a people that was disrupted when the Europeans came.”

Six participants asserted that though tribal citizens’ relationship with cisco and whitefish has been interrupted, the relationship is getting stronger. “There’s been a notion in the last ten years especially that concerning our...spiritual and mental health...that we try to return to as many of the former practices as possible. Those practices link us to the land in a way that going to the supermarket doesn’t do. I’m a big proponent of food sovereignty and exercising our treaty rights on the lakes,” an elder noted. Some participants noted that attitudes towards cisco are improving as citizens come to understand the potential economic benefit to a more diverse Lake Michigan fishery: “It may be another species, kind of a third leg to a stool, where you got whitefish and lake trout, and if we can get some cisco, that would provide at least some more harvest opportunity.” Two interviewees attributed an increased tribal interest in cisco to the research and management work of the NRD.

Four participants said that the contemporary tribal relationship to cisco is still weak, largely due to cisco’s low economic value: “Whitefish has always been...the preferred fish to eat and it’s also the preferred by the non-tribal community. It has the highest price.” One fisher noted that cisco is not wanted by local buyers, and sometimes fishers must go to other states to sell cisco. Several elders remain hopeful that the Tribe's ties to cisco and native species in general, will improve as citizens re-learn the old ways of relating to the natural world.

We assessed the participants' knowledge of cisco. Seventeen of twenty participants asked had heard of cisco; three had never heard of cisco. Most participants described cisco as "the other whitefish." One noted that "they're pretty, they're blue, they're round, they're bony," but otherwise akin to whitefish. Two participants commented on the taste of cisco, and both thought whitefish tastes better. Without prompting, four participants, all elders and/or fishers, discussed low cisco populations in Lake Michigan. One fisherman said that he releases any cisco he catches, in an effort to help the population: "This market wants them, but they can do without right now, because the stocks need support and love and I'm going to give it to them." One Tribal leader explicitly discussed the ecological importance of cisco in Lake Michigan: "More diverse systems are more resilient systems, if you got a system with just two species that occupy 80% of the biomass and something happens, you know those are very volatile systems."

Interviewees held local knowledge about best places and times to catch cisco. In Lake Michigan, "around the fourth of July" is the best time because "that's when they're getting ready to spawn. That's when the Mayflies hatch. That season's only probably, I'd say three weeks long." Two fishers noted that cisco stocks were better in Lake Superior, but patchy: "Lake Superior catch...you set for them, you're liable to get pure cisco lift. But then the next day or next month, they're gone. They just seem to school around the lake."

Currently, LTBB's Tribal fishery does not generate substantial profits for fishers or the Tribe. Some citizens believe a Tribal-owned fish processing facility and market would economically help current fishers and the Tribe and create a lower barrier to entry for new Tribal fishers. Bell's Fishery was one such facility, operated out of Mackinaw City, Michigan by the Sault Ste. Marie Tribe of Chippewa Indians. It closed in 2016. Current fishers and their family members had the strongest opinions on Bell's and a hypothetical new facility. Two interviewees believed that Bell's closed due to poor management practices, including letting fish spoil and demanding too high prices to buyers. They hoped these errors would not be repeated in a future Tribal processing facility. They also expressed concern over a new facility having sufficient connections to liquidize the fish: "They got to keep up daily with the fish buyers and they got to establish a fish buy that's going to stand by them." Three fishers believed a new tribal-owned facility would be neutral or negative for them. One noted that he can "do [processing] faster by myself. That will be more hands in my business and I don't need them in my business." Another reminded us that not all LTBB fishers live on 1836 treaty land, so a facility near Harbor Springs "wouldn't mean a lot to us because we're on the other side of the lake." Three other interviewees said they thought a tribal processing facility would be beneficial. One former fisher noted that he wouldn't need much to incentivize him to fish again, all he would need was some "electricity and ice and a table. I would definitely use it. And what would that mean to me, I'm speechless. That would mean a lot. That would mean everything." Another noted that when he fished for Bell's, "I fished for the Nation. My fish went to help our people."

Though opinions on a new tribal-owned facility are mixed among current and former tribal fishers, it would probably lend support to new fishers. There are currently three to six LTBB fishers (depending on the year), but no new fishers are emerging. Interviewees identified several barriers to new Tribal fishers. Most commonly, participants expressed a need for a profitable and consistent outlet for fish. Older fishers have cultivated relationships with buyers for years, and younger fishers do not have these connections. Currently, Tribal fishers sell their catch to: Big Stone Bay Fishery, word-of-mouth to individuals throughout the state, family and friends, individual or organizational buyers in Charlevoix, Mackinaw, St. Ignace, Big Bay de Noc, Naubinway, or Harbor Springs. A Tribal processing facility may alleviate young fishers' lack of buyer networks: "That would bring in the younger generation. If all you got to do is go out there and catch a couple hundred pounds and I can turn it into decent money, then hell yeah, why not." Fishers express that there is often a surplus of catch but nowhere to put it, so establishing consistent buyers is key. Most fishers would jump at the chance to fish for Tribal citizens and get paid by the tribe, but one elder noted the lack of appetite for a diversity of native fishes among Tribal citizens: "They're not eating lawyers. They're not eating sucker-head soup anymore. And they're not eating cisco. If it's trout, they turn their nose up. I want whitefish. I want whitefish."

The next most commonly reported barrier to young fishers was the fishing industry inherent lack of consistent profits. Whether because the availability of fish changes seasonally or the prices of fish changes with consumer demand, fishers cannot count on a steady income. As one former fisher noted, "From April through November you would make it with fairly good money. After that you were starving through December to April. There was never enough money. [In winter you'd] mend nets." One fisher said that the change in fish communities in Lake Michigan is another barrier for young fishers. Specifically, the increase in lake trout and decrease in whitefish populations make fishing difficult, since lake trout are worth less. Another fisher noted that young or potential fishers do not have the necessary equipment and buying these is a barrier to the profession: "I go through three, two pairs [of oilers] in a year. They rip. You get the sleeves, you get the glove, your hard hat. I mean you got to have the equipment and the Tribe should offer that to a first-time person." This same fisher also pointed out that a love for the water is another requirement of the job, and he did not perceive this passion in younger generations.

Finally, participants expressed concern about the future quality of Lake Michigan and tribal land because it would or is currently affecting their utilization of natural resources. Most interviewees (n = 3) considered water pollution to be the biggest threat to their utilization of resources. Two participants said that standards for clean water have decreased, which puts health and habitat at risk: "Once what was considered potable water has changed. It's worse. We're drinking worse water now." Another attributed the water pollution to recreational boating: "I think a lot of that is about pleasure craft. They've done a lot to contaminate our waters." Many more participants expressed concern over Enbridge Pipeline 5's potential effects on water quality, but not in this section of the interview. One elder and fisher lamented the pollution of tribal land by chemical fertilizer: "Up in the U.P., you won't have a lot of chemical farming up there, so you won't have that kind of influence in the systems. So, whatever you harvest up there is cleaner than it is from down here. You have areas here where every year they use chemicals to raise the ability of the ground to support growth." One fisher, having watched the decline in biomass of native fish over decades, was nervous that Lake Michigan is dying: "There probably won't be anything in it in 50 years. Everything will be dead. Except for the carp. But even they'll run out of stuff to eat."

The breadth of activities and services that the land and Lake facilitate underscores their importance to tribal citizens. All interviewees noted that they utilized the natural world for materials, foods, medicines, spiritual needs, or identity formation. Many participants have familial ties to the land and water that stretched from pre-contact until now. Citizens are tied spiritually, physically, emotionally, and economically to the health of the ecosystem on Treaty land and waters.

*Table 2: Emergent themes and codes from the Utilization of Natural Resources section of interviews*

Utilization of Natural Resources

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| Ecosystem Services | Culture and Identity (n=8) | *Beyond physical commodities from the lake and land, participants shared that the lake and land have spiritual significance for them. The lake and land are part of their personal identities - an intangible but nevertheless important part of their relationship to themselves.* | "Besides all the plants, the fish, the water itself in ceremony. I mean it's who we are. It's just…it's so…I don't know, you can't really…I mean it's more…it's so much more than food. That's what I mean. It's also food for your spirit. There's sacred things that I just…that are there."<br><br>"I remember as a child we used to do fish dances and I was told that it originally became started because...the men used to go out and fish...And then they'd bring the fish back and share it with everybody. And then so they would have a celebration maybe to pray for the fish and men that they would have a good catch and they would be safe."<br><br>"We're the sum of our relationships. When we have…when our relationship with part of the natural world becomes impaired or cut off, we become less."<br><br>"we need to be able to maintain the relationship we have with these various other beings. And those relationships, that community of relationships that we're a part of is what gives us our strength."<br><br>"what happens to her [Earth] is what happens to us. It's just that simple. So yeah, you know, we drink that water. We eat those fish. We harvest those plants, even down to the stones, you know. And so it's like when somebody gives you a choice, do you want to cut off your right hand or your left foot? Which one is more important? It's…there's not a choice. It's all important." |
| | Fish, molluscs, & amphibians (things from the water) (n=15) | *Aquatic organisms utilized by participants* | Catfish, perch, sunfish, walleye, frogs, crab, rainbow trout, suckers, carp, salmon, smallmouth bass, lake whitefish, lake trout, rock bass, bluegill, burbot, |
| | Source of fish | *Lists sources that participants obtain any species of fish from* | Bell's Fishery (past), Charlevoix, NRD, friends, family, Muskegon (Jenson's), Freshwater Grill (restaurant?), Shelbytown farmer's market |
| | Food (n=12) | *Food hunted and gathered* | Deer (waawaashkeshi), morels (mushrooms), blueberries, strawberries, acorns, wild rice, rabbits, duck, turkeys, apples, blackberries |
| | Medicine (n=4) | *Traditional medicines (obzechgun) harvested* | Mullein, sweetgrass, tobacco, willow bark (aspirin), medicine stones, peppermint, spearmint |

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| | Crafts (n=9) | *Participants gather materials for traditional crafts* | Materials: Diamond willow, eagle feathers, bones, black ash, Petoskey stones, glass, bullrush, porcupine quills<br><br>Crafts themselves: walking sticks, cradleboards, baskets, arrowheads,<br><br>Knowledge of when to harvest:<br>"The only time you can harvest [diamond willow] is the time of the fireflies...Because the temperature is right and the water is in the wood yet. It's still really wet." |
| | Activities | *List of activities that lake and land facilitate* | Hunting, fishing, gathering, deer-hunting, elk-hunting, maple syrup reduction, berry-picking, mushroom-picking, swimming |
| Concern about future quality of lake and land | Pollution of water (n=3; elders & fishers) | *Standards for clean water have decreased and recreational boating has increased, so citizens are concerned their lake and drinking water is polluted.* | "I think a lot of that fish is about pleasure craft. They've done a lot to contaminate our waters. Harbor Springs, our harbor was the deepest fresh water harbor on the Great Lakes. And it isn't anymore."<br><br>"once what was considered potable water has changed. It's worse. We're drinking worse water now than they did back then." |
| | Pollution of land (n=1; fisher/elder) | *Pollution of land through chemical fertilizers leads to contaminated harvesting grounds* | "Up in the U.P. you don't have a lot of chemical farming up there, so you won't have that kind of influence in the systems. So whatever you harvest up there is cleaner than it is from down here. You have areas here where every year they use chemicals to raise the ability of the ground to support growth." |
| | Nothing will be alive in lake (n=1) | *Dead lake* | "And there probably won't be anything in it in 50 years. 50-60 years. Everything will be dead. Except for the carp. But even they'll run out of stuff to eat." |
| Family ties to lake & land | Past family fishing, hunting, and gathering (n=11) | *Participants' parents and grandparents fished and/or hunted and gathered* | Loss of connection to fish: "[My parent's] ate it. I don't know how much involvement they had with the fish. A lot of that was lost. And some of it's coming back. But, ya know, just something to eat."<br><br>Loss of connection to land: "My grandfather was a good hunter. My great grandfather was a good hunter, you know. But as Native people that at one time subsisted off the land, hunted and fished and harvested things, we knew what to do with it. The necessity of respecting that resource so that our descendents would have access to it and it would sustain in their life as well. Now we can't do that, see."<br><br>Relatives who fished, hunted, or gathered: mom, grandma ("made fish head soup"), dad ("he was a commercial fisherman all his life"), brothers, sisters, great-grandfather |

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| | Family currently involved in fishing, hunting, or gathering (n=8) | *Participants' relatives that currently exercise their treaty rights to hunt, fish, and gather* | Relatives who currently fish, hunt, or gather: brother, cousins, son, self, grandsons, great-granddaughters, daughters, niece, nephew-in-law<br><br>Relatives gathering (because everyone else talked about fish): "My niece and nephew-in-law had a child and they went and learned to make...birch bark baby carrier. And they went out and harvested the materials they needed for that."<br><br>Collaborative spirit of fishing: "You know and it's subsistence is not just for you but for your extended family. So you know you share with your mom or your aunt or your grandma, you know my boys." |
| Eating fish (n=10) | Several times yearly (n=1; high-ranking elected official) | | 2-3x/year |
| | Several times monthly (n=1; tribal official) | | "At least monthly" |
| | Several times weekly (n=6; all officials or elders) | | 2-3 times/week, but only when lived in UP and fished in Lake Superior<br><br>Couple x/week |
| | Frequency of eating cisco (n=2 asked; n=1 eaten) | | When asked directly (n=2), one tribal official said they had eaten it once, and another elder said they did not recall ever eating it. |
| Knowledge of cisco | Heard of cisco: yes (n=17/20) | | "Yes" |
| | Heard of cisco: no (n=3/20) | | "No" |
| | Cisco are like whitefish (n=3) | | "It's the other whitefish." |
| | Physical appearance of cisco | | "I know they're pretty, they're blue, and they're round. They're bony."<br>Otherwise, look like whitefish |
| | Whitefish are better (n=2) | | "I don't think the cisco tastes as good as the whitefish." |
| | Cisco stocks are in trouble (n=4; all elders or fishers) | | Releases all cisco this fisher catches: "This market wants them, but they can do without right now, because the stocks need support and love and I'm going to give it to them you know."<br><br>From NRD, tribal official kept current on stocking efforts |

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| | Best time to catch cisco (n=2) | "Around 4th of July that's target time for lake herring. That's when they're getting ready to spawn. That's when Mayflies hatch. That season's only probably -- I'd say three weeks long. As long as the flies were hatching and the fish were there. So the flies go away and the fish go back in deeper water."<br><br>Lake Superior better for catching, though patchy: "Lake Superior catch…you set for them, you're liable to get pure cisco lift. But then the next day or next month, they're gone, you know, they just seem to school around the lake." (two participants said Lake Superior was where to catch cisco) |
| | Ecological importance (n=1; official) | "Cisco is I think is an important part of the Lake Michigan environment. It's something that were interested in finding out where it's at as far as the food chains are....You know more diverse systems or more resilient systems, if you got a system with just two species or two dominant species that you know occupy 80% of the biomass and something happens, you know those are very volatile systems." |
| Tribal processing facility | Bell's facility failed due to bad management (n=2; both elders & fishermen) | "There was a lot of goofy management with the market and stuff like that you know. I mean I had to quit when I would come there and the fish that I brought the day were still on ice in the cooler. That's when I know what I'm doing isn't being appreciated, they're not taking care of it, I'm going over here."<br><br>"They wanted too much money for the quality of fish they had. We bought fish there on the way back one time. And they were right on the verge of spoiling. And they were selling them over the counter." |
| | Tribal processing facility would be positive (n=3) | "When Bell's was open, I fished for the Nation, you know what I mean? My fish went to help our people"<br><br>"If the tribe could get some electricity and ice and a table you know for me, I would definitely use it. And what would that mean for me, I'm speechless. I mean what you know that would mean a lot. That would mean everything." |
| | Tribal processing facility would be neutral or negative (n=3; two current fishers, one elder past fisher) | "I can do it faster by myself. And that will be more hands in the…my business and I don't need them in my business."<br><br>"It wouldn't mean a lot to us because we're on the other side of the lake." - not all LTBB fishers live within treaty lands |
| | Concern about insufficient connections or outlet for fish (n=3; all fishers or elders) | "They got to keep up daily with the fish buyers and they got to establish a fish buyer that's going to stand by them." |

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| Tribal relationship to cisco and whitefish | Strong pre-contact tribal relationship with cisco and whitefish (n=5) | "Cisco used to be the main thing that they used to go out and get...in the wintertime." |
| | Tribal relationship declined due to economy (cisco was not profitable) (n=2) | "If you were out there with a trawler and you could trawl up you know a couple thousand pounds, then it would probably be a different story because then you're looking at more money. But gill netting wise for them they're specifically targeting them with gill nets. You're talking about a whole separate set of gear and they're not worth a whole lot, you know." |
| | Tribal relationship declined due to colonialism and overfishing (n=8) | "There's a certain diet and a certain way of life that we had as a people that was disrupted...when the Europeans came. But there's been a notion in the last ten years especially that concerning our health, our spiritual and mental health as well, that we try to return to as many of our former practices as possible. Those practices link us to the land in a way that going to the supermarket doesn't do. I'm a big proponent of food sovereignty and exercising our treaty rights on the lakes."<br><br>"The fish seem to, the herring, according to my father and them there was a lot of herring, but then they moved around. They were down south too. Then they seemed to recede back north. You wouldn't get herring until you got about half way up Lake Michigan. Now Lake Huron, they stayed the same, and Lake Superior. But Lake Michigan they just seemed to, in fact they're nonexistent now. I mean there's fish out there, you'll get them yet, but you wouldn't get them in numbers."<br><br>Unknown relationship because colonization: "I guess it would be safe to say it's not a common in teachings and stories that I've heard. And things that are you know it's just some common things that are intact, a lot of stuff is not intact and being revitalized, and searching, we're searching for whether we're searching for that relevance of that fish and the stories behind it and the teachings and purpose of you know why it's relevant to us, versus whether we're searching for our ceremonies and how to do them right."<br><br>"You eat what's available to you. Cisco have been on the decline for so long that I don't recall if I've had any cisco in years." |
| | Contemporary tribal relationship to cisco on the upswing (n=6) | Because of NRD: "I think our DNR is doing a real good job managing these fish."<br><br>Cisco would be good for tribe and whole lake ecosystem: "It may be another species kind of a third leg to a stool where you kind of got whitefish and lake trout and if we can get some cisco, you know that would provide at least some more harvest opportunity." |

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| | Contemporary tribal relationship to cisco still small (n=4) | | Preference for whitefish (based on economy): “whitefish has always been you know kind of the preferred fish per se to eat and it’s also the preferred by the non-tribal community as far as market. You know it has the highest price.”<br><br>“The fishermen that I use to talk to...they would sometimes have to go...all the way to Chicago...Because they couldn't sell it anywhere in the State of Michigan.” |
| Barriers to tribal fishermen | Inconsistent profits (n=2; both fishers) | Whether because the availability of fish changes with seasons or the price of fish changes with consumer demand, fishers cannot count on steady profits | “From April through November, you...would make it with fairly good money. After that, well everybody says you were starving through December to January, February, March, April. There never was enough money... [In winter you would] mend nets, make nets.” |
| | Change in fish community composition; not sufficient profitable fish (n=1, fisher) | The fish community in northern Lake Michigan has changed to be trout-heavy and whitefish-poor | “When I first started there were fish. There were fish. So that’s you know, give you an idea of what it’s like now. It’s different. The fish aren’t…they’re trout. If you’re going to go out and catch anything, it’s trout.” |
| | Need for profitable outlet (n=7; all fishers but one elder) | Young fishermen do not have the connections to sell their fish | “So if you have that other, those other outlets to get rid of your catch, it will make a big difference. And that would bring in the younger generation to do it too. I mean if he’s like all you got to do is go out there and catch a couple hundred pounds and I can turn it into, you know into decent money, then hell yeah, why not, you know.”<br><br>Often a surplus of fish and nowhere to put it: “What am I going to do with all this fish? I couldn’t get rid of it. Well, some of it I’d clean it. I’m not throwing back anything really hardly generally ever.”<br><br>Lack of tribal appetite for a diversity of fish: “They’re not eating lawyers. They’re not eating sucker head soup anymore. And they’re not eating cisco. What they go for is they go in there and they want whitefish. And if it’s trout, then they turn their nose up. I want whitefish. I want whitefish” |
| | Current outlet for tribal fishers | | Big Stone Bay, word-of-mouth to individuals, advertise on social media, family & friends, Charlevoix, Mackinaw, St. Ignace, Big Bay de Noc, Naubinway,<br><br>One participant (fisher): “I don’t bring my fish to Charlevoix or Mackinaw. I want to keep them here.” |
| | Lack of equipment (n=1; fisher) | *Young tribal fishers do not have the necessary equipment* | “I go through three, two pairs [of oilers] a year. They rip. You get the sleeves, you get the gloves...your hard hat. I mean you got to have the equipment and I think the tribe should offer that to a first-time person.” |
| | Do not enjoy fishing (n=1; fisher) | *Young tribal fishers do not know or like the lake* | “They got to like the lake first.” |

## Individual Perspectives on Cisco Restoration

There were four broad themes identified among respondents' answers: i) Awareness; ii) Motivations and attitudes; iii) Current conditions; and iv) Cultural connections. Awareness refers to personal knowledge of cisco, public knowledge of cisco, ecological understanding, and knowledge relating to an opinion. Awareness of cisco, restoration, and ecology influenced the attitudes people held towards tribal and non-tribal management. All 11 people who mentioned personal knowledge of cisco knew very little or nothing at all about NRD restoration efforts, or about cisco as a species. This makes sense because cisco stocks plummeted in the mid-20$^{th}$ century and ceased to be a significant fishery. Out of 24 people interviewed, 22 said that they support cisco restoration in Lake Michigan. One did not know, and one did not support cisco restoration. The one who did not support cisco restoration rather prioritized reducing the number of lake trout in Lake Michigan (Figure 4).

Motivations and attitudes towards ecological restoration in Lake Michigan showed a variety of relationships to other management and fishing sectors. Some tribal members noted tensions between LTBB and non-tribal management agencies, like the MDNR or some federal organizations. Interviewees generally expressed disagreement with federal and state management strategies for stocking non-native species like salmon or not regarding tribal management agencies as equal authorities for management in the 1836 waters of Lake Michigan. Economic issues were a source of disagreement as well, particularly with state and commercial fishers: "I would say that the budgetary efforts and expenditures lean way more towards sports fishing and tourism than they do to maintaining a healthy ecological balance."

The current conditions in relation with cisco restoration discussed included not only environmental issues of Lake Michigan, but also efforts of the LTBB NRD to restore native species. One tribal leader offered their thoughts on current LTBB native species restoration: "And my opinion that the lake should be managed for the benefit of native species. Cisco is a native species to Lake Michigan. I think that's something that we're really interested in. You know we've done a lot of work trying to figure out how to rear cisco. That's another great benefit of our hatchery, though it's small scale, they're really working on some innovative stuff on figuring out how best to raise cisco." Interviewees also made comparisons of current lake conditions to past conditions. Specifically, some elders remembered cisco or other native species being more abundant in Lake Michigan during their youth more than fifty years ago: "The fish seem to, the herring, according to my father and them there was a lot of herring, but then they moved around. They were down south too. Then they seemed to recede back north. You wouldn't get herring until you got about half way up Lake Michigan. Now Lake Huron, they stayed the same, and Lake Superior. But Lake Michigan they just seemed to, in fact they're

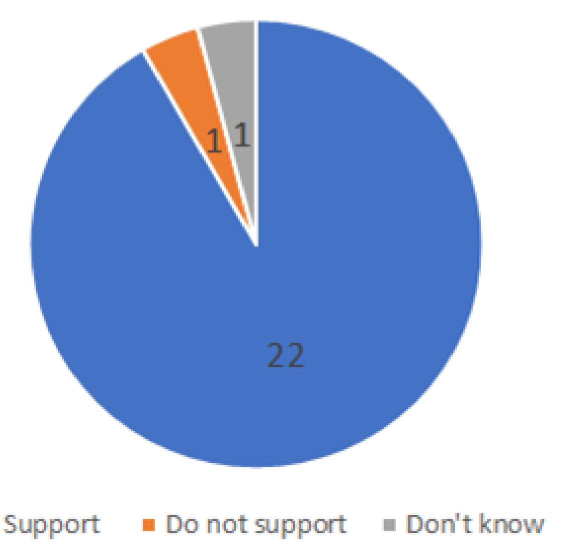


*Figure 4: Summary of answers to the question "Do you support cisco restoration in Michigan?"*

nonexistent now. I mean there's fish out there, you'll get them yet, but you wouldn't get them in numbers. You couldn't catch maybe 800 or 1,000 ton or anything like that."

Lastly, cultural connection was the other main theme we found from the interviews. Many interviewees tied their opinions about the lake and ecological restoration into Odawa culture. Thinking ahead seven generations is the standard for Anishinaabe leaders when considering decisions. The Odawa people are also closely tied with their sense of place: The Great Lakes provide plentiful aquatic habitat for fishing and boating.

## Community Perspectives on Cisco Restoration

When asked whether members of their community or tribe care about cisco and cisco restoration, participants' answers fell into two categories: yes (n = 8) and no (n = 13). The breadth of answers that interviewees gave for the community supporting cisco restoration were broad (Table 3). One individual, a tribal leader, simply answered that "[yes], I think people would understand [cisco restoration] pretty easily." The rest of interviewees elaborated on their thoughts. One fisher stated that the tribe "got the hatchery. They got to do something with it. I mean why not use it." One tribal leader said the community would support cisco restoration because it is a source of food. Also remarking on the utility of cisco as an economic resource, two elders offered that larger cisco populations would boost the local economy in northern Michigan by necessitating that people buy "the gear to do it. So that's helping out the people that's selling fishing gear and bait and boats and motors." Two elders noted that cisco is "pretty easy fish to catch" for recreational and commercial fishers and would therefore be supported by community members.

Other interviewees did not connect cisco to the economy or utility, but rather to tribal futurity and identity. Two interviewees, a leader and leader/fisher, stated that the community would support cisco restoration because it would ensure a better future for human and Lake Michigan. They both connected caring for future community members and caring for the earth: "I would put it in a broader --- they care about mother nature, the earth, the fish, the animals. I think they care about the whole," and "the community, they understand what's right. They're all not pirates of the sea. They ain't all trying to rob a living out there or get ahead by not caring about the lake. Some of them have a conscience about how important [ecosystem function and health] is. Maybe you might not see the great difference in your time here, but you're setting it for somebody that will." These participants connected cisco restoration to restoring Lake Michigan as a whole (the definition of "restoring" Lake Michigan was not discussed in this section of the interviews). Connecting cisco restoration and, by proxy, ecosystem wellbeing, one leader/fisher stated that his community is interested in cisco because caring for the earth features prominently in tribal traditions: "Most of the community is in support of keeping a healthy environment for Mother Nature. I mean, it's in most of the ceremonies, most of the teachings."

By comparison to the "yes, my community cares about cisco/restoration" camp, the reasons people gave for perceiving that their community does not support cisco restoration fell into relatively fewer trains of thought, or sub-themes. Most people who believed their community did not care about cisco were hopeful that members could/would support restoration with education or personal experience with cisco. Six interviewees - three leaders, two fishers, and one elder - believed that their community did not currently support cisco restoration but only needed education around whole ecosystem functioning and native species to support restoration. In their eyes, the community lacked knowledge about cisco's role in a 'restored' Lake Michigan ecosystem: "I think if you were able to spend the moment and say these are native species and we're looking to reintroduce them. We think they fit here...yeah, people are not going to be opposed to it." Interviewees repeatedly mentioned that in order for the community to support cisco restoration, they need to know that the species is native and benefits other species they care about: "it's native to the lake and belongs there...just as well as the sturgeon does. I mean cisco belongs right with it. It's like the corn, beans, and squash growing together. Got to have that perch in between that cisco."

Two participants expressed that the community needed education about how to cook cisco, and how cisco can bolster personal and community health. Because cisco have been largely absent from tribal citizens' diets for years, these two interviewees said community members do not support its restoration. They would, they expressed, if they knew its health benefits and how to process it: "we used to be fish eaters" but now eat "beef;" "educating them about the benefits for the lake and then also benefits for them personally and the community would [build support for restoration]."

One interviewee, an elder/fisher, said that community members simply do not know what cisco are and therefore are indifferent or opposed to restoration: "They probably honestly do not understand how important they are...because I haven't seen any community outreach to tell the citizens why cisco is important. I don't have faith that any person off the street knows what a cisco is and why we need it in a lake I mean."

Citing a low return-on-investment for cisco restoration, two interviewees - one elder and one fisher - said that "the tribe is going to put out the money to make rearing to get the cisco, and they never see them." The fisher cited the now-closed Bell's Fishery and stated that community members would not support cisco restoration because Bell's "wasn't profitable." However, he also noted that Bell's had non-economic benefits to the tribe: "the tribal community really liked getting all the fish, the benefits of that. Especially those who don't have access to fish."

Five interviewees (one elder/leader, two elders, and two fishers) cited the community's lack of relationship and personal connections with cisco or Lake Michigan as a hindrance to their support for restoration: "it's hard to say for someone that has not ever fished to take and say, well, we're going to do this and we're going to do that with lake herring, if he's never fished them" and "most of them aren't thinking much about them because they're not on the lakes fishing."

When asked whether tribal leaders support cisco, participants again answered either "yes" or "no" and gave varied reasons. Although we did not define 'leader,' participants' answers suggest that most took 'leader' to mean elected and paid official. Slightly more participants believed that leaders do (n = 4) than do not (n = 3) support cisco restoration. Among those that think leaders do not support cisco restoration, two believed leaders "first care about getting reelected" and only "mumble... the right words during election time." One fisher believed that leaders do not support cisco restoration because they, like the rest of the community, do not have personal experience with the lake and are therefore neutral or against restoration. This individual believed that "tribal leaders don't know much about cisco and should listen to fishermen" because of the leaders' lack of "experience catching trout and cisco and whitefish."

One interviewee, an elder/fisher, expressed optimism that leaders could/would support cisco restoration if they knew about the "positive effects, and the possibilities that could develop out of a better fishery." This interviewee was the only one to express optimism through education, in contrast to the nine interviewees who said the community could/would support restoration with education.

Three interviewees stated that leaders currently support cisco. One, a leader, offered no explanation but said “yeah, I think they would, absolutely.” One elder stated that leaders support restoration because they are a food source for citizens. Another elder/fisher stated that the leader who supported cisco restoration was fisher himself, and thus had personal experience with cisco and supported restoration.

One interviewee, an elder/fisher, offered that there is a differential amount of support for cisco restoration based on age and life experience: “the traditional ones, they would. Because it was there to begin with. The younger ones, I’m not sure. If there’s no interest in something, it just kind of goes other their head. I mean, with the technology we have today, it’s just like there’s no need for them to be interested. We’ve never been hungry. Never had to scrounge up food. Everything’s given to them. That’s just how society is nowadays.” This somewhat nihilistic attitude was not necessarily reflected in our interviews, as people from many places on the ‘traditionalist’ spectrum were interviewed. However, we did not interview any youth.

Four participants pointed out that the tribe’s current strong relationship to lake whitefish dictates support or lack thereof for cisco restoration. Either community members care about whitefish over cisco, e.g. “what they’re concerned about is the economy...and cisco doesn’t bring any money and whitefish does,” or cisco’s importance/relation to whitefish makes members support it (“they taste similar to a whitefish...yeah, people are not going to be opposed to it” and “not knowing how important cisco is to keeping whitefish” hinders their support). The importance of whitefish is continually highlighted, even when talking about another species of fish.

*Table 3: Emergent themes and codes from the Community Perspectives on Cisco Restoration section of interviews*

Community perspectives on Cisco Restoration

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| Community supports cisco (n=8) | Simply: yes (n=1; leader) | *Simply responded that the community would support cisco restoration, without offering follow-up* | "I think people would understand [cisco restoration] pretty easily" |
| | The tribe may as well use the hatchery (n=1; fisher) | *The tribe has already invested in a hatchery, so they may as well use it to raise and stock cisco* | "Why not? The got the hatchery. They got to do something with it. I mean why not use it. Use the facility and do what you go to do." |
| | Need to restore the lake for future human and non-human (ecosystem) benefit (n=2; leader & fisher and fisher) | *Restoring the whole lake, including cisco, will ensure a better future for future generations and the future of the lake* | "The community, the people, they understand what's right you know. They're all not pirates of the sea. They ain't all trying to rob a living out there...or get ahead by not caring about the lake. Some of them have a conscience about how important [ecosystem functioning and health] is. Maybe you might not see the great difference in your time here, but you're setting it for somebody that will."<br><br>"I would put it in a broader -- like I said, they care about mother nature, the earth, the fish, the animals. I think they care about the whole." |
| | Food source (n=1; leader) | *Cisco has been and could be a larger part of citizens' diets* | "we're fishermen and you know we count on that fish, some of them to feed their families and stuff, so there's concerns there." |
| | Economic stimulation (n=2; elders) | *Restored cisco populations would be a positive for the local economy of northern Michigan* | "[To fish cisco you would] have to have the gear to do it. So that's helping out the people that's selling fishing gear and bait and boats and motors and stuff like that. So for the economy itself, it'd probably be good." |
| | Easy fish to catch (n=2; elders) | *Cisco are an easy fish to catch for both recreational and commercial fishers* | "Yes, very much so. Because they're pretty easy fish to catch." |
| | Tribal history and identity (n=1; leader & fisher) | *Tribal citizens are interested in restoring cisco (and the rest of the Lake Michigan ecosystem) because caring for Earth features prominently in tribal traditions* | "Most of the community is in support of keeping a healthy environment for mother nature. I mean, it's in most of the ceremonies, most of the teachings. I would think there would be support." |

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| Community does not support cisco (n=13) | Education around whole ecosystem functioning and/or native species needed leaders, 1 elder, 2 fishers) | *The community lacks knowledge about cisco's role in the functioning of a native Lake Michigan ecosystem, so does not currently support restoration* | "We don't have that level of understanding or awareness, but I don't think that means that they don't…that they wouldn't value cisco and I think that they do value ciscos, especially when they get a better idea of it as it a native species."<br><br>"I think the cisco have not really been present in the landscape for a long enough time that most people would have a hard time telling the difference between a cisco and a whitefish. Now, I don't think that means that they don't care about them. I think if you were able to spend the moment and say these are native species and we're looking to reintroduce them. We think they fit here. They taste very similar to a whitefish. They're related. Yeah, people are not going to be opposed to it."<br><br>"It's just better for the whole you know. It's native to the lake and belongs there you know just as well as the sturgeon does. I mean cisco belongs right with it, you know. It's like the corn, beans, and squash growing together you know. Got to have that perch in between that cisco." |
| | Education needed about cooking cisco and community or personal health (n=2; fisher and leader) | *Because cisco have been largely absent from tribal citizens' diets for years, they do not support cisco restoration. If they knew how to cook it, and its health benefits, they would.* | "I think there is a push to get away from the beef that the community has learned to expect as a source of protein in their diet where we used to be fish eaters and if we knew how to prepare the fish too."<br><br>"So you think that educating them about the benefits for the lake and then also benefits for them personally and the community health would [encourage support for restoration]." |
| | Lack of relationship with cisco or the lake (n=5; 1 elder & leader, 2 elders, 2 fishers) | *Community members do not have personal connections or experiences with cisco or Lake Michigan, which hinders their support for cisco restoration* | "Most of them aren't thinking much about it. Most of them aren't thinking about them very much because you know they're not on the lakes fishing. I would think that the majority of the cisco probably are going to be hook and line fishermen, okay, that are going…that they're going to run, be interacting with the cisco."<br><br>"Well... it's hard to say for someone that has not ever fished to take and say, well, we're going to do this and we're going to do that with lake herring, if he's never fished 'em." |
| | Too costly to stock, with no benefit (n=2; elder, fisher) | *To restore cisco, LTBB would have to spend money on stocking but would likely never catch the adult cisco. The return-on-investment would be low.* | "So I don't know if they would support it. I doubt it. I doubt it… Well the tribe is going to put out the money you know to make rearing or whatever to get the cisco and they never see them."<br><br>"I don't think so. We bought that Bell's Fishery you know because we were fisher people. Unfortunately, that didn't you know wasn't profitable. But the tribal community really liked getting all the fish, you know, the benefits of that. Especially those who don't have access to fish." |

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| | Education needed about what cisco are (n=1; elder & fisher) | *Many community members simply do not know what cisco are, and therefore do not support restoration (are indifferent)* | "That's the main thing. I don't know how many know about them."<br><br>"They probably honestly do not understand how important they are… Because I haven't seen any community outreach to tell the citizens why cisco is important and why we would need to tell our citizens that. I don't have faith that any person off the street knows what a cisco is and why we need it in a lake I mean." |
| Leaders do not support cisco (n=4) | Leaders only care about getting elected (n=2; elder & fisher, leader) | *Leaders (elected officials) do not intrinsically care about cisco, they care mostly about re-election* | "I'm sure they're mumbling about it. The right words during election time."<br><br>"I think tribal leaders first care about getting reelected. So whatever they think the voters are going to be most concerned about concerns them the most." |
| | No relationship with the lake or cisco, and should listen to those who do (n=1; fisher) | *Most people's, including leader's, lack of personal experience with cisco or Lake Michigan leads them to not support cisco restoration. Therefore, they should listen to people who do have experience with the fish: fishers.* | "A lot of people probably don't understand why [tribal fisher's] do what we do and it sometimes I think it's just one person to another how they are that day and whatever they want to vote for cisco money to go for cisco, and not understanding...the full dynamics and not having experience catching trout and cisco and whitefish."<br><br>"Tribal leaders don't know much about cisco, and should listen to fishermen" |
| | Leaders do not care (n=1; elder) | *No explanation offered or no follow-up asked* | "I think it would be nil." |
| | Education about positive effects on community needed (n=1; elder and fisher) | *Leaders do not currently support cisco restoration, but they could if they knew about the myriad benefits* | "I don't think…I don't know how much they know about it, because you don't hear a lot about it. I think the more education they have that they probably would. Because they'd realize the positive effects, you know, and the possibilities that could develop out of a better fishery." |
| Leaders support cisco (n=3) | Leaders do care (n=1; leader) | No explanation offered or no follow-up asked | "Yeah, I think they would, absolutely." |
| | Cisco are good to eat (n=1; elder) | Leaders support cisco because they are a food source | "I don't know why not. It's the best eating fish, you know. And the Indians are, most of them that's their main source of food you know." |
| | Personal experience necessary (n=1; elder/fisher) | Leaders support if they have personal experience with cisco or the lake | "At least one person would on the tribal council because that's my son and he's a fishermen" |

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| Differential support for cisco based on citizens | No sub-themes (n=1;eldler & fisher) | *There is a differential support for cisco restoration based on age and life experience. This somewhat nihilistic attitude was not necessarily reflected in our interviews, though we did not interview any youth.* | "The traditional ones, they would. Because it was there to begin with. The younger ones, I'm not sure. If there's no interest in something, mm, it's just kind of goes over their head. Uh, I mean, with the technology we have today, it's just like there's no need for 'em to be interested. We've never been hungry. Never had to scrounge up food. Everything's given to 'em. That's just how society is nowadays." |
| Relationship to cisco based on relationship to | No sub-themes (n=4; leader & fisher, leader, fisher, elder & fisher) | *Tribe's current strong relationship to lake whitefish dictates support or lack thereof for cisco restoration* | "I think they'd care more about the whitefish than the cisco."<br><br>"They taste very similar to a whitefish. They're related. Yeah, people are not going to opposed to it."<br><br>"not knowing how important cisco is to keeping whitefish."<br><br>"No, the only…what they're concerned about is the economy, is the economy part of it, because they're just trying to etch out a living. And cisco doesn't bring any money and whitefish does." |

## Restoration Strategies

We identified six themes within responses to questions on restoration strategies: i) Internal (LTBB) efforts; ii) External (non-LTBB) efforts; iii) Awareness; iv) Odawa tribal sovereignty; v) Tribal fishing; and vi) Social issues. Internal efforts concerned current LTBB NRD management strategies, attitudes toward fish stocking, current trends in fishing and lake conditions, attitudes toward management, and attitudes about cisco restoration. Tribal members who talked to us tended to support restoration strategies guided by scientific research. Intertribal relations regarding restoration were also discussed, with some interviewees supporting more collaboration between Great Lakes tribes: "if you could get the tribes together…that's a stronger voice than just one of the tribes." Others also pointed out how other tribes in the Great Lakes prioritize ecological restoration: "I'm sure it varies from tribe to tribe, how they feel about restoration and this whole topic of, whatever you call it, conservation, ecology, environmental justice, whatever. I mean, I'm sure all the tribes, some of them are really interested and maybe others not so much."

Mentions of external (non-LTBB) Lake Michigan management efforts included tribal influence on other management sectors, attitudes about politics, racism, Western attitudes toward ecology and management (as opposed to indigenous views), relationships to other fishing sectors, collaboration or comparison between tribes, collaboration with other non-tribal management agencies, and attitudes toward non-tribal management efforts. This theme focused mainly on interviewees' views toward non-LTBB restoration in Lake Michigan, including other Great Lakes tribes. Also, one interviewee noted that non-Native Michigan residents spread anti-Indian rumors during LTBB's litigation to expand the reservation boundaries: "…there's a law firm with…somebody that understands Indian law that's going down and telling people that Indians are going to come in and they're going to do this and they're going to do that…it's just fear mongering and it's an attempt to make this particular law firm rich."

Awareness of Great Lakes ecology was mentioned in responses, with ecological awareness and general knowledge of cisco dominating the topic. Seventeen people alluded to ecological awareness of the cisco restoration processes in Lake Michigan, and 6 people mentioned their level of knowledge regarding cisco in Lake Michigan. In general, interviewees did not demonstrate extensive knowledge of cisco life history or ecology, or even that it existed in the Great Lakes. Others referred to predator-prey interactions between cisco and other species: "I don't know that the salmon are, or I mean the lake trout are targeting the cisco necessarily, but there's something there that's keeping them from being abundant like they used to be. So, you've got to figure out if it's the actual water itself…or you've got to find out if they're being preyed upon."

Odawa tribal sovereignty was the fifth theme. Fish consumption, tribal commercial fishing, fishing habits, access to fishing rights, and native species all made an appearance. The most mentioned category out of this theme was fishing habits (n = 12). Specifically, people spoke about how different management strategies implemented by LTBB would affect people's decision to fish for cisco or other species. Our questionnaire for interviews (see Appendix B) included a section asking for people's opinions regarding hypothetical management strategies. One interviewee mentioned the impacts of a potential moratorium on cisco fishing: "You could put a moratorium on cisco right now, because nobody's catching them. But if we put a moratorium on cisco and two years from now there's a lot more and people are running into them a lot and they're like what are these fish, and then they're figuring out that they can catch them and somebody eats one and thinks they're delicious, then…there will be I think negative blow back [because] they're all over the place."

Finally, social issues were another important topic identified within responses. The most mentioned aspect was economic interests, with 10 people talking about it. Money was a motivation for people preferring certain hypothetical management/restoration strategies over others. For example, the market value of cisco compared to other fish like salmon is low, so some respondents did not immediately prioritized cisco as a target for restoration.

## Final Thoughts and Future Management Directions

The final question of the interview was designed to give insights on management actions that the interviewee supports. The interviewee was asked to imagine they are the person making the final decision on how to improve the conditions of Lake Michigan and then asked, "What do you think should be done to improve the conditions of Lake Michigan?" Interviewee responses varied, but primarily focused on the ecological management efforts, the removal of pollutants, collaborative action, and community and youth education (Table 5).

*Table 4: Issues that should be prioritized while attempting to improve the conditions of Lake Michigan, including; physical pollutants, collaborative action, education, and ecological management.*

Priorities for Improving Lake Michigan

| | | | |
|---|---|---|---|
| Physical pollutants | Monitor threats (1) | *Scientific monitoring of possible threats to lake conditions* | "I think the threat that exists there, not only the immediate threat, but the long-term effects that is not being measured or considered such as the cement plants, such as the nuclear plants." |
| Physical pollutants | Remove threats (7) | *Physical removal of polluting sources* | "I'm saying that all of the sources of pollution right now need to be removed"<br>"Shutting down pipeline before a catastrophic event unfolds" |
| Physical pollutants | Prioritize lake health (2) | *Reconsider the priorities of our communities with a focus on long-term sustainability and lake health* | "Focused on short-term economic gain over long-term wellbeing of lake"<br>"hasn't impacted enough to make people realize enough, but just it's huge, huge for our future" |
| Collaborative Action- Opportunities and Barriers | Between tribal governments (3) | *Partnering with other Great Lakes tribes to address environmental concerns* | "I'd love to see it holistic, whether it's Lake Michigan and lake Huron together, I'd love to see a holistic plan, whether it's with our brothers and sisters in the Wisconsin tribes"<br>"You know all five Nations come together and all start doing it, before you know it in another 10-15 years might be a whole again." |
| Collaborative Action- Opportunities and Barriers | Between tribal and non-tribal governments (2) | *Collaboration between state, federal, and tribal governments to address environmental concerns* | "Partnerships to gather resources between the states and the feds and the tribes"<br>"We're dealing with the lakes geopolitically as with boundaries. The lakes no know boundaries. The water knows no boundary. The pollution knows no boundary. The fish don't either."<br>"We had a real difficult time communicating across border politically." |
| Collaborative Action- Opportunities and Barriers | Role and well-being of tribal fishers (3) | *Need for meaningful involvement, and consideration of well-being, of tribal fishers in management decisions* | "And these guys on CORA are not fishermen, they're listening to the State to get their information. And it's just not, it's not really working for the fishermen."<br>"But coming from a fisherman's point of view, coming from being an elder from…my grandfather, my dad, and my sons, they all believe in the fish is what keeps the Indians alive. I mean we're all derived from a fish, so they think. And that's the way I think too, because we're all raised through fish. We're all fish. That's all I got to say."<br>Fishers have some of the most risk, but no influence |
| Collaborative Action- Opportunities and Barriers | Corporate mistrust (2) | *Apprehension to collaboration with private corporations* | Mistrust of corporate interests. Not aligned with the interest of the lake/ecosystem. |

| | | | |
|---|---|---|---|
| Community and Youth Education | Youth education (3) | *Engaging and educating youth on natural resources issues* | "You know, that's the future. Get them on board. Because that's the next generation."<br>"Plan to educate needs to be well thought out and "approved"" |
| | Community education (2) | *Engaging and educating the larger communities on natural resources issues* | Using firsthand experience integrated into the education goal.<br>"Any kind of news from the Department of Resources, Natural Resources, I would appreciate anything" |
| Ecological Management | Climate change (2) | *Mitigating and adapting to climate change* | "Take climate change seriously. Because that is going to affect our lakes" |
| | Water management (4) | *Historic improvements and concerns about water quality and the removal of water* | "Water quality is getting better over time since I've been a youngster"<br>"Make sure the freighters change their bilged water when they come through"<br>"I would decrease the taking of the water, you know, and hauling it away" |
| | Manage invasive species (6) | *Management and removal of non-native species* | "I would get rid of the zebra mussels and quagga mussels, and salmon and alewife." |
| | Support native species (8) | *Actions that support native species, including; habitat restoration, stocking, and prioritizing species.* | Predator/prey dynamics impacted by overstocking predators (e.g. trout).<br>"Whitefish, I would make a priority. I just think whitefish is a priority and not just whitefish, but what whitefish eat in their habitat you know as a whole." |
| | Research and management (5) | *Conducting research, restoring habitat, and management philosophies* | "I would base the decision on science. What can we do in the immediate term in terms of, uh, of habitat, what can we do to improve that? And at the same time, while we're working on those, what is the most viable stocking option if that's the species that we want to bring back more?"<br>"We need to learn that the lake is a dynamic system that incorporates the spring water from this land right where we're sitting, as well as the runoff from the trees and everything that happens from the rains and you know that there's a…there's this ecosystem that is the lakes are part of all of that." |
| | Facilitate connection to water (1) | *Advocating for cultural connection to the water* | Get people back in touch with the water. Build support for the waters. |

Based on the responses from our final question, the priorities expressed by interviewees for improving Lake Michigan and to guide the LTBB Natural Resource Department are:

1. Prioritize lake health, monitor for threats, and advocate for the removal of all pollutants and polluting sources
2. Increase collaboration and communication with other Great Lakes tribes
3. Increase collaboration and communication with other government agencies (state and federal)
4. Emphasize the well-being of tribal citizens and fishers
5. Incorporate fishers in decision making processes
6. Build alliances with organizations interested in lake and ecosystem health, but understand that LTBB citizens may be apprehensive to collaborate with private corporations
7. Engage youth and the larger community in natural resources issues. Support firsthand experience with natural resources
8. Manage and prevent invasions of non-native species and prioritize native and culturally important species
9. Assist in mitigating climate change and help the community adapt to climate change
10. Address community concerns about water quality and advocate for access to clean water
11. Conduct research and manage ecosystems based on data driven process and congruent with Anishinaabe traditions
12. Facilitate a connection between the people and the water through education, outreach, and programming

## Conclusion

The 24 interviews conducted examined the perspectives of LTBB tribal citizens, leaders, elders, and fishers on current conditions, utilization of lake resources, cisco restoration, community perspectives, restoration strategies, and management priorities. Interviewees described lake conditions in terms of altered and altering social and ecological conditions, impacts on utilization (community health, cultural, and economic), and actions that respond to changes in conditions and utilizations. All interviewees report utilizing natural resources in some way, including as food, medicine, activities, or traditional crafts. When asked about personally supporting cisco restoration, almost all interviewees reported that they would support restoration efforts. When asked about their perception of community support for cisco, there was no clear consensus. Thus, most participants personally support cisco restoration, but perceive that others in their community do not. Interviewees described a lack of knowledge and relationship with cisco and/or the lake. They also described high costs as barriers to community support of certain restoration strategies, like stocking. Lastly, we identified a list of interviewee priorities to guide LTBB Natural Resource Department decision-making.

Due to time constraints, we were able to interview 24 tribal citizens This is a relatively low number representing only 0.005% of the population. Thus, the responses might not be completely representative of the perspectives of LTBB tribal members. Additionally, there was a bias towards interviewing individuals strongly affiliated with the Natural Resource Department due to our dependence on the department for participant recruitment. Nevertheless, we believe these results are useful to the NRD and non-tribal managers because they include influential members of the community. In the future, the perspectives of more tribal citizens and those outside of the three main groups we interviewed, particularly those of young people, should be considered.

# Chapter 3: Cisco (*Coregonus artedi*) Population Estimates in Little Traverse Bay Using Hydroacoustic Analysis

by April Richards

## Abstract

In 2014, the Little Traverse Bay Bands of Odawa (LTBB) Natural Resource Department (NRD) invested in hydroacoustic technology (Biosonics) to increase its fisheries management capacity in northeastern Lake Michigan. The tribe determined it was necessary to examine the composition and abundance of the pelagic fish community, including cisco (*Coregonus artedi*), in Little Traverse Bay as the agency considers the potential for cisco restoration in Lake Michigan. Little Traverse Bay is important to the tribe due to its location adjacent to the LTBB reservation. To evaluate abundance of pelagic fish in Little Traverse Bay, we conducted a hydroacoustic survey and collected data over two nights between August 24 and 25, 2017. The survey covered 97.63 km and collected fish samples using fourteen pelagic trawls and five suspended gillnet sets. Using the EchoNet2Fish package in RStudio, we developed estimates of alewife (*Alosa pseudoharengus*), rainbow smelt (*Osmerus mordax*), and unidentified coregonids, likely either bloater (*Coregonus hoyi*) or cisco, using the nearest trawl method. Large cisco, analyzed separately, were the only fish larger than 200 mm captured in the suspended gillnets and we assumed all targets with targets strengths of 34, -33, -32, -31, -30, and -29 were cisco greater than 350 mm. Our analysis estimated a population of 15,620 cisco, or 1.93 cisco per hectare in Little Traverse Bay. These results provide a baseline estimate to monitor changes in the cisco population over time. Additionally, this study demonstrated the ability of the LTBB NRD to contribute to lake-wide population estimates conducted by federal and state agencies.

## Introduction

Historically, cisco (*Coregonus artedi*) were the most abundant fish in the Great Lakes region, but populations declined due to overfishing, invasive species and habitat destruction (Baldwin et al. 2009). Restoration in Lake Michigan is being considered as a possible solution for improving the current predator-prey unbalance. In order to develop a restoration plan, a baseline assessment of current cisco and other pelagic prey fish community composition and abundance is necessary.

Previous efforts to estimate prey fish biomass and examine the status of pelagic Lake Michigan fish using hydroacoustic surveys have been conducted by state and federal agencies including the U.S. Geological Survey (USGS), U.S. Fish and Wildlife Service (USFWS), and the Michigan DNR in the late summer and early fall from 1992 to 1996 and from 2001 to 2015 (Warner et al. 2015). Combined data from midwater and bottom trawls with acoustic data provided species-specific estimates for alewife (*Alosa pseudoharengus*), rainbow smelt (*Osmerus mordax*), and bloater (*Coregonus hoyi*). Although, a population is known to exist in Grand Traverse Bay these surveys have not provided estimates for cisco because researchers did not catch cisco in their midwater or bottom trawl surveys. Additionally, the area covered in these surveys has not included bays in the past. This study is the first to document cisco abundance using hydroacoustic analysis in Little Traverse Bay.

The standardization of acoustic data collection conditions is important to collect consistent data that can be used for evaluating abundance trends. Factors that should be considered include seasonality and water temperature, and time of day, as well as other sources of light. The interagency hydroacoustic survey conducted in Lake Michigan takes place in the late summer and early fall when the lake experiences thermal stratification, the layering of water by temperature. Water in the epilimnion is heated by the sun and cold, denser water sinks to the hypolimnion. The metalimnion, or thermocline, is a thin layer between the epilimnion and hypolimnion that experiences more rapid temperature changes than the upper and lower layers. Collecting acoustic data while the lake is stratified allows for the incorporation of fish behavioral ecology to increase accuracy of acoustic abundance estimates (Brandt et al. 1991).

Acoustic data is collected at night due to the diurnal vertical migration of pelagic species and to minimize the effects of fish avoidance, which can lead to underestimation (Fréon et al. 1993). A study by Luecke and Wurtsbaugh (1993) also found that moonlight and daylight impact acoustic estimates of pelagic fish abundance suggesting that even at night, light conditions must be standardized. It is therefore crucial that these factors are incorporated into data collection procedures across agencies to develop standardized protocols and accurate data of lake-wide estimates of community composition and abundance.

In 2014, the Little Traverse Bay Bands of Odawa (LTBB) Natural Resource Department (NRD) purchased Biosonics, Inc. hydroacoustics equipment with the goal of building management capacity to improve Great Lakes fishery management. The tool would allow the NRD to collect data to inform management of fisheries in northern Lake Michigan more effectively. This increased capacity, allows for increased ability for interagency collaboration with ongoing lake-wide pelagic prey fish abundance estimate efforts. Accordingly, the LTBB NRD is conducting research to assess the potential for cisco restoration in northeastern Lake Michigan including an evaluation of cisco abundance in Little Traverse Bay. To contribute to that effort, we supported LTBB personnel to estimate cisco abundance using hydroacoustics, pelagic trawls, and gillnets surveys in key regions of the 1836 Treaty Waters, including Little Traverse Bay.

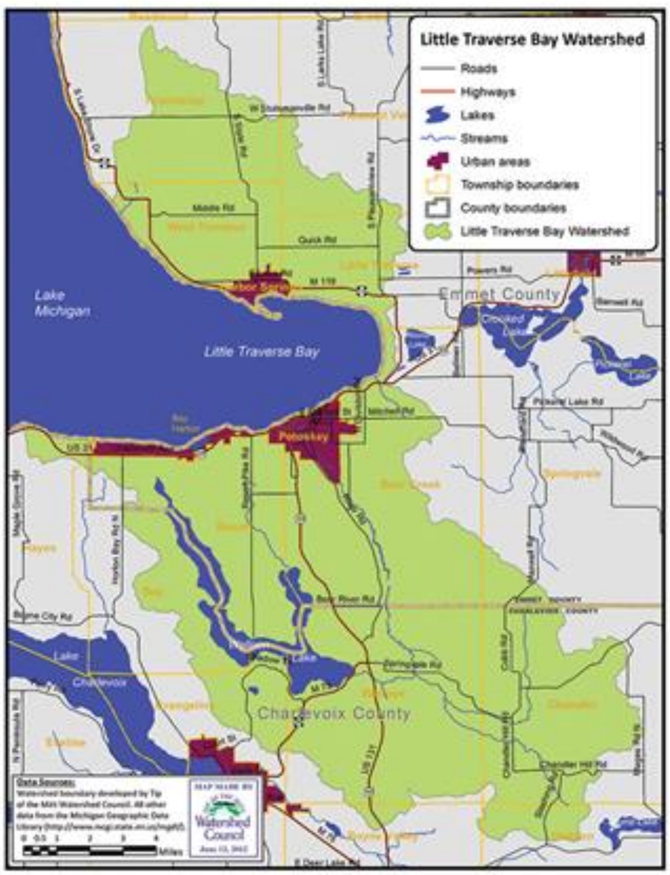


*Figure 5: Little Traverse Bay and the Little Traverse Bay Watershed (Tip of the Mitt Watershed Council, 2007).*

## Methods

Hydroacoustics utilize sonar technology for monitoring underwater physical and biological characteristics, including collecting data on fish and habitat. Hydroacoustics is an important tool in acquiring data to estimate population abundance, that can be utilized for management, because it samples nearly the entire water column quickly, providing continuous sampling along transects. Target strengths, a measure of reflectivity, can be used to identify fish species and size. This study uses hydroacoustic techniques to estimate the abundance of pelagic prey fish populations in Little Traverse Bay in northeastern Lake Michigan, including cisco, bloater, alewife, and rainbow smelt. To identify the species in the hydroacoustics signals we sampled the pelagic fish community of Little Traverse Bay using pelagic trawls and gillnets.

## Materials and Methods

### Study Area

Little Traverse Bay is the fourth largest bay on Lake Michigan, following Green Bay, Grand Traverse Bay, and Bay DeNoc. The bay, 16 kilometers (10 miles) shoreline and 5.6 km (3.5 mi) wide has a surface area of approximately 116.5 km$^2$ (45 mi$^2$) and drains 450.7 km$^2$ (174 mi$^2$) of land from the Little Traverse Bay Watershed into Lake Michigan (Figure 5) (Tip of the Mitt Watershed Council, 2007). In some areas, the bay reaches a depth of up to 518 km (200 ft). The total area of Little Traverse Bay is 81 km$^2$ (8105 hectares).

The study area is adjacent to the LTBB reservation. Therefore, it is an established focus of the tribe's management efforts in Lake Michigan. No hydroacoustic data from Little Traverse Bay had been collected, or included in lake-wide population estimates, until 2016 when the LTBB NRD began collecting preliminary data (Donner 2015).

### Hydroacoustics Survey Design

To conduct the hydroacoustic surveys, we used an 18-foot (5.5 m) fishing boat, the *Lund*, which was fitted to deploy the equipment necessary for hydroacoustics. We collected acoustics data with Biosonics, Inc software, *Visual Acquisitions 6.1*. A Garmin GPS sensor collected our location and recorded it into Visual Acquisitions. One of the goals of our study, was to refine and establish the standard operating procedures for future LTBB NRD hydroacoustic data collection (Appendix D). We chose to follow recommendations of Lake Michigan researchers and collected our data during the late summer/early fall, at night, and with minimal moonlight (Luecke & Wurtsbaugh 1993). Our data collection took place over two nights, August 24-25, 2017. Due to potential effects of the daylight and moon phase on pelagic fish behavior and acoustic estimates (Luecke & Wurtsbaugh 1993), data collection did not begin until at least one hour after sunset and concluded at least one hour before sunrise (approximately 9:00 p.m. to 4:00 a.m.). Additionally, we attempted to collect data close to the new moon (August 21, 2017) to minimize the effects of moonlight, moon illuminance on the night of data collection was approximately 9% and overcast conditions likely limited moon light effects even further.

To design the survey transects we overlaid a 0.55 by 0.55 km grid on a map of Little Traverse Bay and along a gridline we traced transects 1.1 km apart. While conducting the survey and due to a lack of accurate bathymetric data in the bay to the needed scale, we used the boat's Lowrance Fish Finder to indicate a depth of 10 meters where the transects ended. Our target

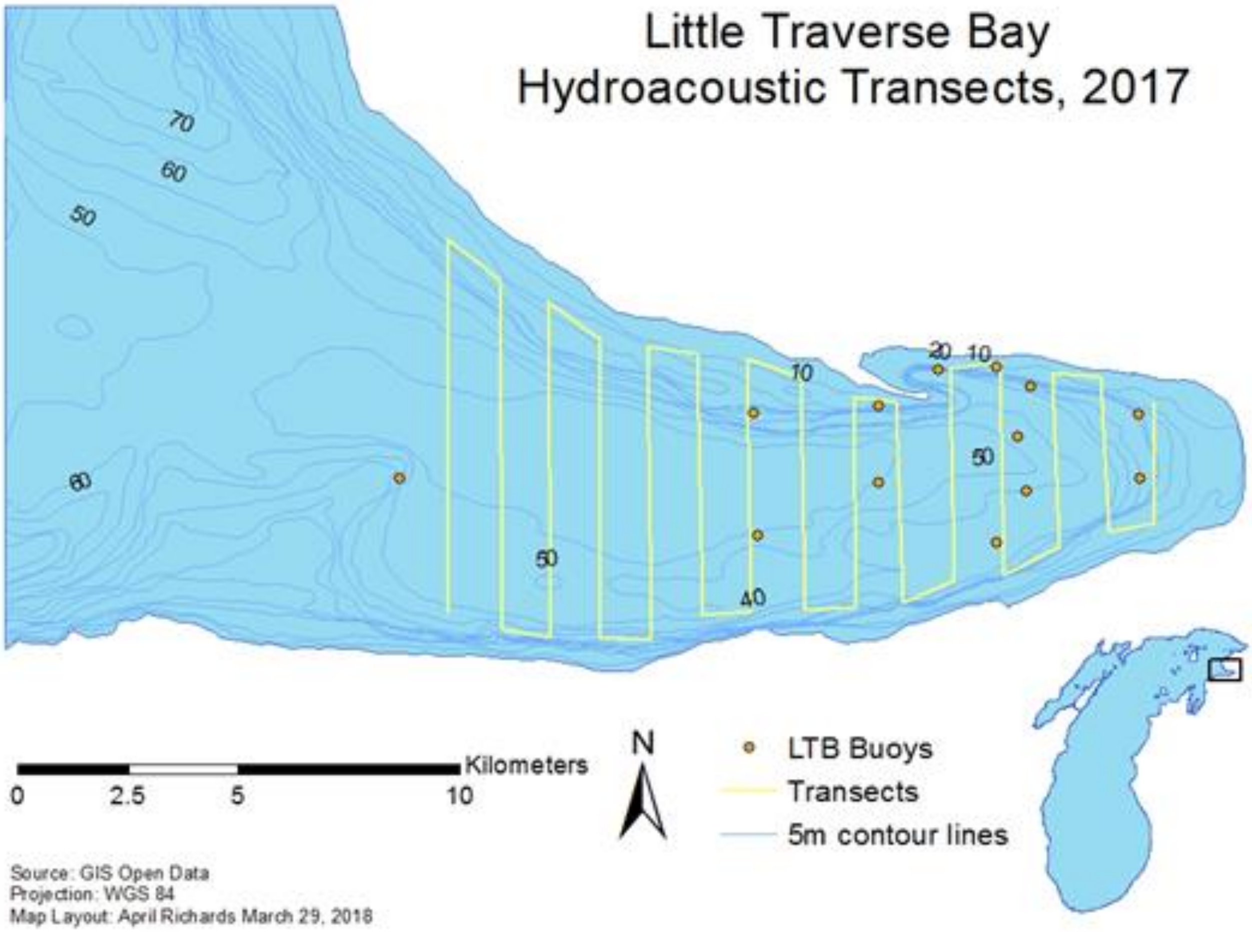



*Figure 6: Hydroacoustic data collection transects for August 2017.*

driving speed was 5 mph (8 kph) and our speed ranged from 4.7 to 4.9 mph (7.6 to 7.9 kph). Over the two survey nights, we covered 97.63 km (60 mi) of Little Traverse Bay (Figure 6).

During the survey, we collected a temperature profile using a YSI Professional Series temperature probe to determine the depth of temperature stratification. Surface water temperature and thermocline depth are used in the data analysis process to assist with species identification based on patterns in fish behavior, such as location of trawl capture (epilimnion or hypolimnion).

Wave height is a factor which can be restrictive to data collection, particularly on a small vessel. Ideal conditions for data collection includes wave heights below 0.45 m (1.5 ft). Our data collection on night 1, beginning August 24, 2018 at 9:00 pm, had wave heights above optical conditions between 1:20 to 3:00 am (UGLOS 2017; Figure 7). The average wave height for night 1 was 0.38 m with a range of 0.23 to 0.51 m. Wave height for night 2 remained optimal throughout data collection with an average height of 0.21 m, ranging between 0.11 to 0.31 m.

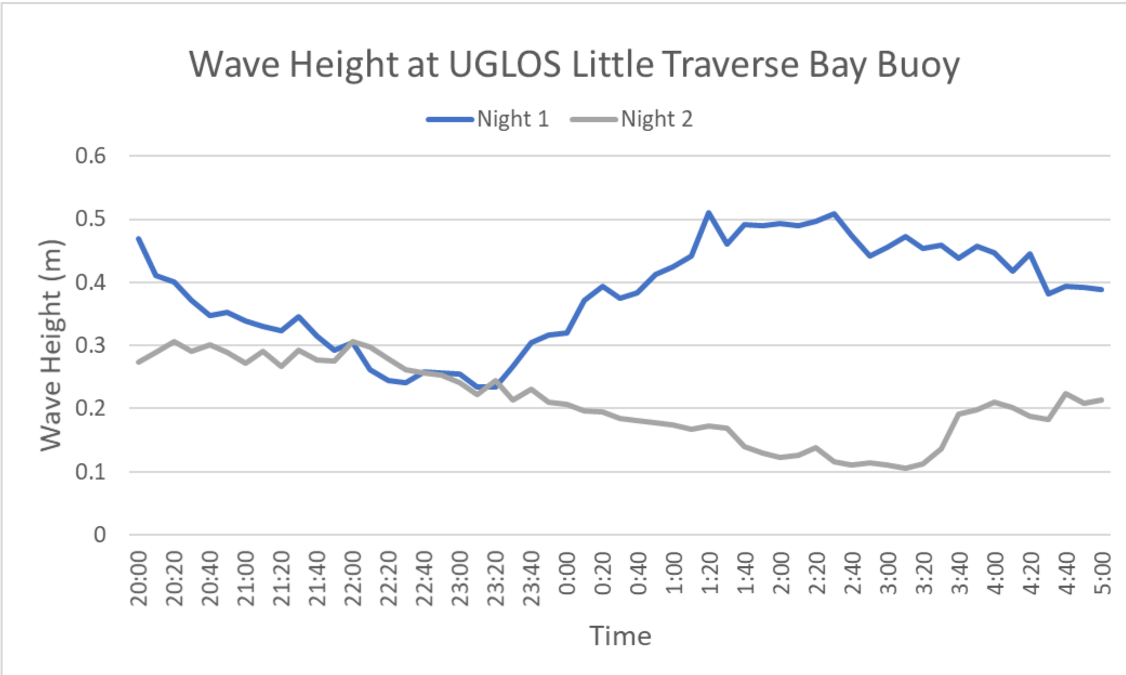



*Figure 7: Wave height at Little Traverse Bay during the hours of data collection (UGLOS 2017).*

## Fish Composition and Sampling Using Gillnets and Pelagic Trawling

We sampled fish using both gillnets and pelagic trawls to identify species composition of the hydroacoustic signals (Figure 8).

### *Gillnet Surveys*

We targeted large pelagic prey fish using gillnets due to the limitations of the LTBB trawl survey gear which does not effectively sample fish greater than 200 mm (7.8 in). We set 9 gillnets in Little Traverse Bay during July and August with mesh sizes between 31 and 51 mm (bar measurement) or 2.5 to 4 in (stretched measurement). Five of these nets, were suspended gillnets and four were set on the bottom. Bottom gillnets contributed to other seasonal surveys in addition to providing insights to where we should set our suspended nets and pelagic trawl but were not considered in our population estimates.

We suspended gillnets using floats attached to ropes and hooked to the net on each panel. Once deployed, the ropes would unroll to the desired depth (20 m) and be suspended in the water column rather than touch the bottom to allow for exclusive sampling of pelagic species. We used three nets with varying lengths and heights for suspended gillnet sets (Table 5). We left each suspended set to soak for an average of 20.8 hours, varying between 18 and 22 hours.

*Table 5: Suspended gillnet surveys in Little Traverse Bay in 2017.*

| Suspended set | Date | Soak time *hrs* | Length *m* (ft) | Height m (*ft*) |
|---|---|---|---|---|
| 1 | 8/1/2017 | 18 | *152.4* (500) | *4.9* (16) |
| 2 | 8/9/2017 | 21 | *121.9* (400) | *4.9* (16) |
| 3 | 8/9/2017 | 22 | *243.8* (800) | *1.8* (6) |
| 4 | 9/6/2017 | 21 | *121.9* (400) | *4.9* (16) |
| 5 | 9/6/2017 | 22 | *152.4* (500) | *4.9* (16) |

### *Pelagic Trawl Surveys*

Using a pelagic trawl with a 9.2-meter (30 ft) headrope, we attempted sixteen and completed fourteen 30-minute trawls. Nine hauls were conducted within the epilimnion and five within the hypolimnion. We trawled during two nights from approximately 9:00 p.m. to 4:00 a.m. on August 15-17, 2018. The boat maintained average speeds between 2.6 and 2.9 nmph (4.8-5.4 km/hr) during the hauls. We attached a Marport trawl monitor to the trawl behind the headrope to record temperature, head and footrope depths, and pitch and roll angles of the trawl headrope.

We sampled with both gillnets and trawls along each shoreline (north, south, and east) parallel and perpendicular to bathymetric contours. Yule et al. (2013) found that correlations between true species composition and species sampled were highest when more fish are captured and so we used historic catch data and gillnets set in the early summer to target locations with high pelagic fish abundance. All fish caught in the gillnets and trawls were counted, measured, and weighed. When possible data on sex, maturity, and aging structures were also collected.

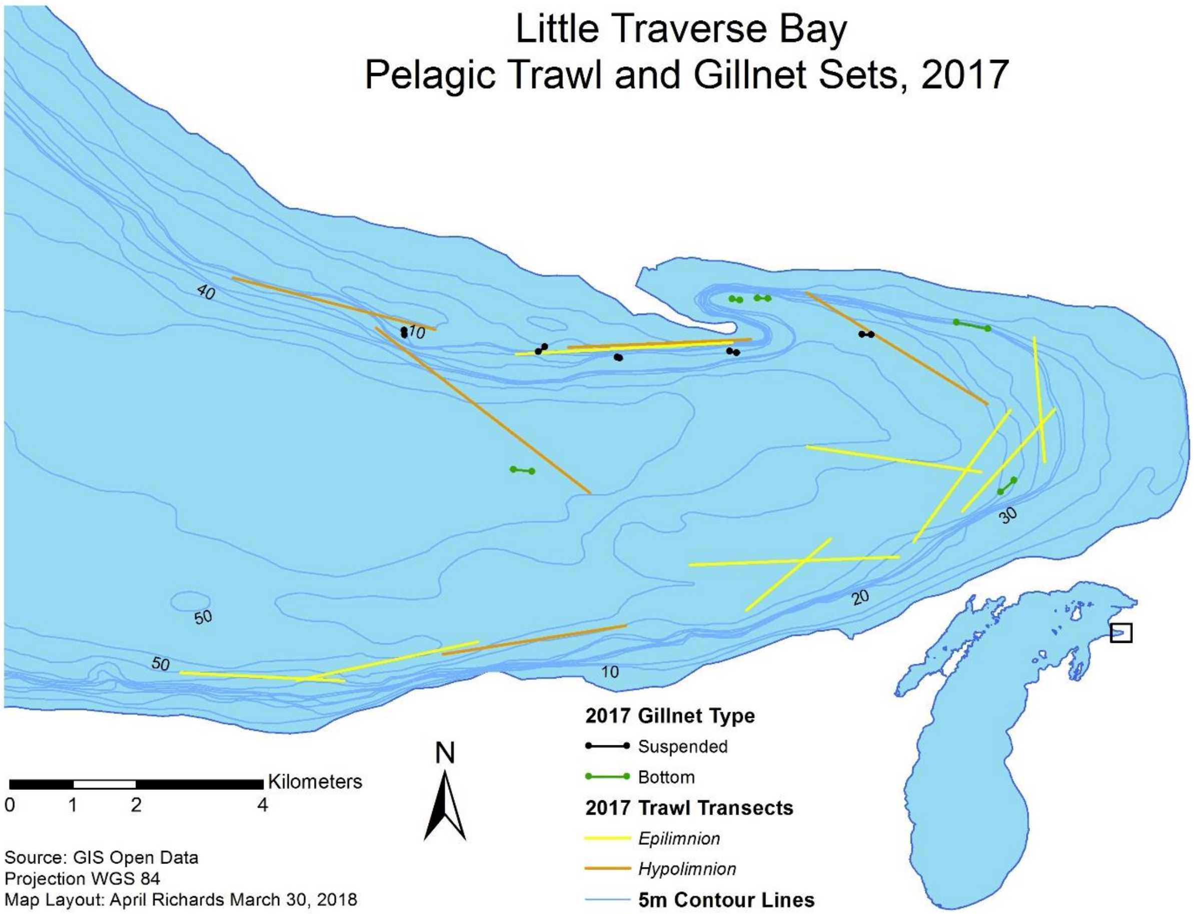



*Figure 8: Location of pelagic trawl and gillnet survey in Little Traverse Bay 2017.*

## Hydroacoustic Data Analysis

We processed the hydroacoustics data with Echoview 6.1. The top and bottom lines, representing the lake surface and bottom, were scrutinized to correct for overlap with bottom structures and identify abnormalities in the data. We used the EchoNet2Fish R package version 0.2.11.9000, standard for USGS acoustic analysis (Adams 2017), to combine our acoustics survey data with our trawl catches to estimate fish population abundance. Using EchoNet2Fish, we assigned individual targets identified in the acoustic data to a species using target strengths, size (length), and the species composition of the nearest trawl using the Near method for coregonids, rainbow smelt, and alewife. We were unable to incorporate our gillnet data with the analysis that used Echonet2Fish due to restrictions in the code and so we estimated large pelagic targets separately.

The Near method, discussed by Yule et al. (2013), determines the shortest Euclidean distance between an acoustic transect and a trawl sample. Echonet2Fish determines the nearest trawl transect to the target, relates its target strength to size using a target strength equation, and determines the probability that a target is a certain species. Gillnet data was not considered in this analysis. To estimate large pelagic targets (cisco) we assigned fish captured in gillnets targets strengths based on the equation:

$$TS = 21.9 \log_{10} L - 67.2,$$

where TS is target strength and L is fish length (Rudstam et al. 1987). The minimum length of adult cisco, the only fish caught in suspended nets, in Little Traverse Bay was 350 mm and target strengths for cisco were between -34, -and -29.

# Results

## Fish Species Composition of Gillnet and Trawl Samples

Gillnets set in Little Traverse Bay during July and August caught a variety of species including coregonids, salmonids, perch, smelt, and alewife. However, cisco was the only species above 200 mm caught in nets suspended in the pelagic zone. Two of the five suspended sets caught cisco, both in the 37mm mesh.

Pelagic trawls captured coregonids, rainbow smelt, alewife, round gobies, and spot tail shiners. The catches of round gobies and spot tail shiners were likely because trawling was conducted in areas that were too shallow as neither species are pelagic fish. We did not develop bay-wide estimates for these species. The coregonids caught in the trawl were likely bloater but could have been juvenile cisco. These samples were sent for genetic testing for species determination and are reported as unidentified coregonids.

Trawl samples were organized by those caught in the epilimnion or hypolimnion trawl hauls (see Figure 9). The epilimnion was dominated by non-native rainbow smelt and 87 percent of smelt were caught in the epilimnion hauls. Few alewives were captured at either depth in the water column, but the majority were caught in the epilimnion. Most (87%) of the unidentified coregonids were caught in the hypolimnion.

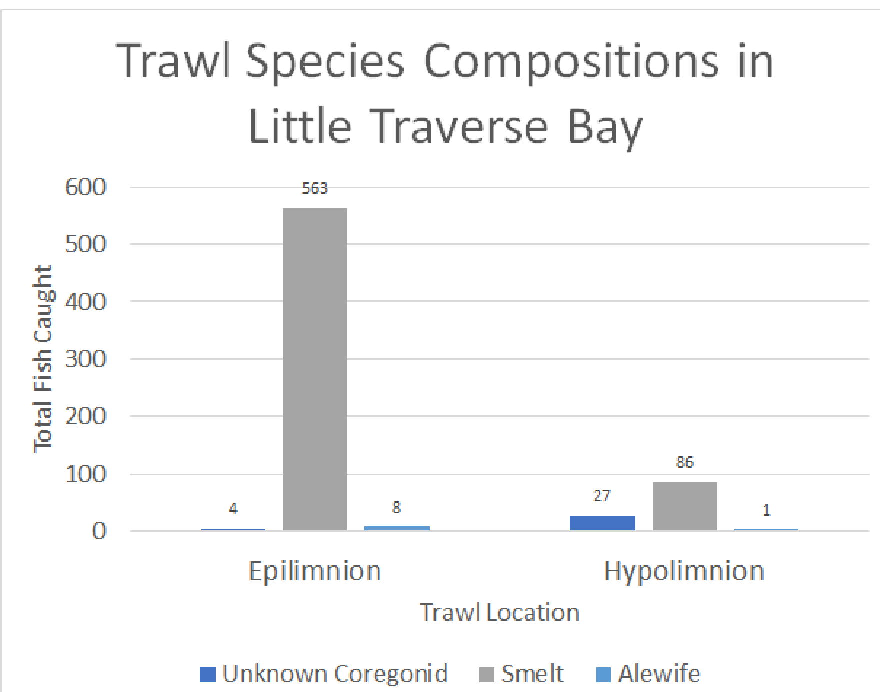



*Figure 9: Trawl species composition in Little Traverse Bay by location in water column.*

## Hydroacoustics Abundance Estimates

The only species caught in the suspended gillnets were cisco, so we assumed that any target greater than 350 mm was a cisco. Accordingly, our analysis estimated a population of 15,620 adult cisco, or 1.93 cisco per hectare in Little Traverse Bay.

Alewife, smelt, and unidentified coregonids had much higher densities than cisco (Table 6). Alewife had a density of 65.51 per hectare (105.8 gph), a total of nearly 600,000 fish (2.82 tons). Rainbow smelt were most abundant with a density of 4149.06 per hectare (8882.56 gph), a total of over 38.5 million fish (101.49 tons). According to our acoustic estimates both alewife and smelth were concentrated in the epilimnion (89 and 87 % respectively). Coregonids (unidentified) had a density of 42.13 per hectare (295.23 gph), a total of just under 2 million fish (28.12 tons). Coregonids were concentrated in the hypolimnion, 82 percent.

*Table 6: Hydroacoustic abundance estimates by species and location in the water column. in number per hectare (nph) and grams per hectare (gph), total number (n) and grams (g) and total population estimates (tons).*

| | Epilimnion density nph (*gph*) | Hypolimnion density nph (*gph*) | Epilimnion Total n(*g*) | Hypolimnion Total n(*g*) | Total n(*g*) | Total *(tons)* |
|---|---|---|---|---|---|---|
| Alewife | 65.51 | 9.11 | 530952.35 | 68208.51 | 599160.87 | |
| | *105.80* | *227.70* | *857525.55* | *1705012.78* | *2562538.32* | *2.82* |
| Smelt | 4149.06 | 650.79 | 33628093.45 | 4873107.02 | 38501200.48 | |
| | *8882.56* | *2681.74* | *71993133.73* | *20080848.51* | *92073982.24* | *101.49* |
| Unidentified | 42.13 | 211.15 | 341467.28 | 1581071.35 | 1922538.63 | |
| Coregonids | *295.32* | *3087.24* | *2393559.64* | *23117247.04* | *25510806.68* | *28.12* |

During night one of our acoustic data collection, the data we collected displayed at an angle on the Echoview software due improper towed body weighting caused by transducer placement during data collection (Rudstam & Sullivan, n.d.). We discussed possible impacts of this error on fish estimates in the discussion.

## Discussion

Historically, the pelagic Great Lakes was largely comprised of coregonids and cisco were among the most abundant species in Lake Michigan. However, disturbances in trophic niches caused by overfishing and the introduction of invasive species resulted in collapsed cisco populations that have been unable to recover in most regions. Small populations, most notably in Grand Traverses Bay, have survived and now management agencies are considering the potential of cisco restoration in Lake Michigan. However, there is not an abundance estimate of cisco in Lake Michigan. Our hydroacoustic analysis of Little Traverse Bay aimed to assess cisco and other pelagic prey fish populations with the hope of gaining insight into restoration potential.

Our results show that the pelagic fish community of Little Traverse Bay in Lake Michigan is still largely dominated by non-native species (i.e. rainbow smelt and alewife). The adult cisco population is low with just under two cisco per hectare. However, with this acoustic analysis, we obtained baseline population estimates for cisco in Little Traverse Bay which will be crucial for monitoring how the population changes over time and the effects of management efforts. Combined with population size, data on age structures and diet compositions of cisco will be important in determining the health of the population and taking appropriate management actions.

## Limitations and Next Steps

There were limitations in our population estimates as we developed our methodology for future acoustic estimates. First, due to limitations in the EchoNet2Fish R package (0.2.11.9000) that we were unable to overcome, we had to estimate cisco populations separate from the other fish populations. Also, we could only estimate adult cisco in Little Traverse Bay, which is valuable, but it could be useful to estimate younger cisco populations, especially due to the stocking of juveniles by the LTBB NRD. Second, we included fewer hypolimnion hauls than epilimnion hauls which may have led to an underestimation of our unidentified coregonids (likely bloater). Lastly, our data from night 1 of hydroacoustic data collection was biased due to the angle of our acoustic transducer when placed on the vessel. According to Rudstam & Sullivan (n.d.), a tilted transducer can impact target strength distribution and measurements. We hypothesize that this error may have resulted in an underestimation of fish size and as a result, an overestimation of small fish (smelt and alewife) and underestimation of large fish (bloater and cisco). Rudstam & Sullivan (n.d.) state that this effect can impact comparisons between years and regions of the lake; however, during night 2 we developed a more useful method of mounting the transducer to set it perpendicular to the water. In comparisons between years and regions, our night 2 data will still be a useful in comparisons of fish populations.

Future studies by the LTBB NRD need to include an equal number of epilimnion and hypolimnion trawl effort. It will be also needed to work out some problems with the Echonet2Fish package to allow for the incorporation of both trawl and gillnet catch compositions into determining the species of each target. Lastly, we hope the survey will expand the coverage of nearshore waters adjacent to the LTBB reservation.

## Potential for Lake-Wide Management Efforts

In addition to developing baseline estimates for Little Traverse Bay, the Little Traverse Bay Bands of Odawa Natural Resource Department has demonstrated its proficiency in the collection and analysis of hydroacoustic data. This increase in management capacity is significant for increasing the role of LTBB in lake management, particularly in contributions to the multi-agency hydroacoustic lake-wide estimates. Already, the 2017 lake-wide estimate includes data from our sampling. Additionally, following the successful completion of Little Traverse Bay acoustic data collection, the NRD assisted in collecting data for Grand Traverse Bay during the November spawning season due to concerns about the impacts of boat size on cisco estimates.

Due to time, energy, and budget constraints lake-wide hydroacoustic estimates require a multi-agency approach. During the 2017 surveys, the U.S. Geological Survey, Michigan Department of Natural Resources, and U.S. Fish and Wildlife collaborated to sample Lake Michigan. With the increased participation of LTBB NRD in the assessment efforts in northeastern Lake Michigan, we were able to increase the area covered in the assessment . Particularly, the NRD increased the coverage of bay regions and shorelines (Figure 10).

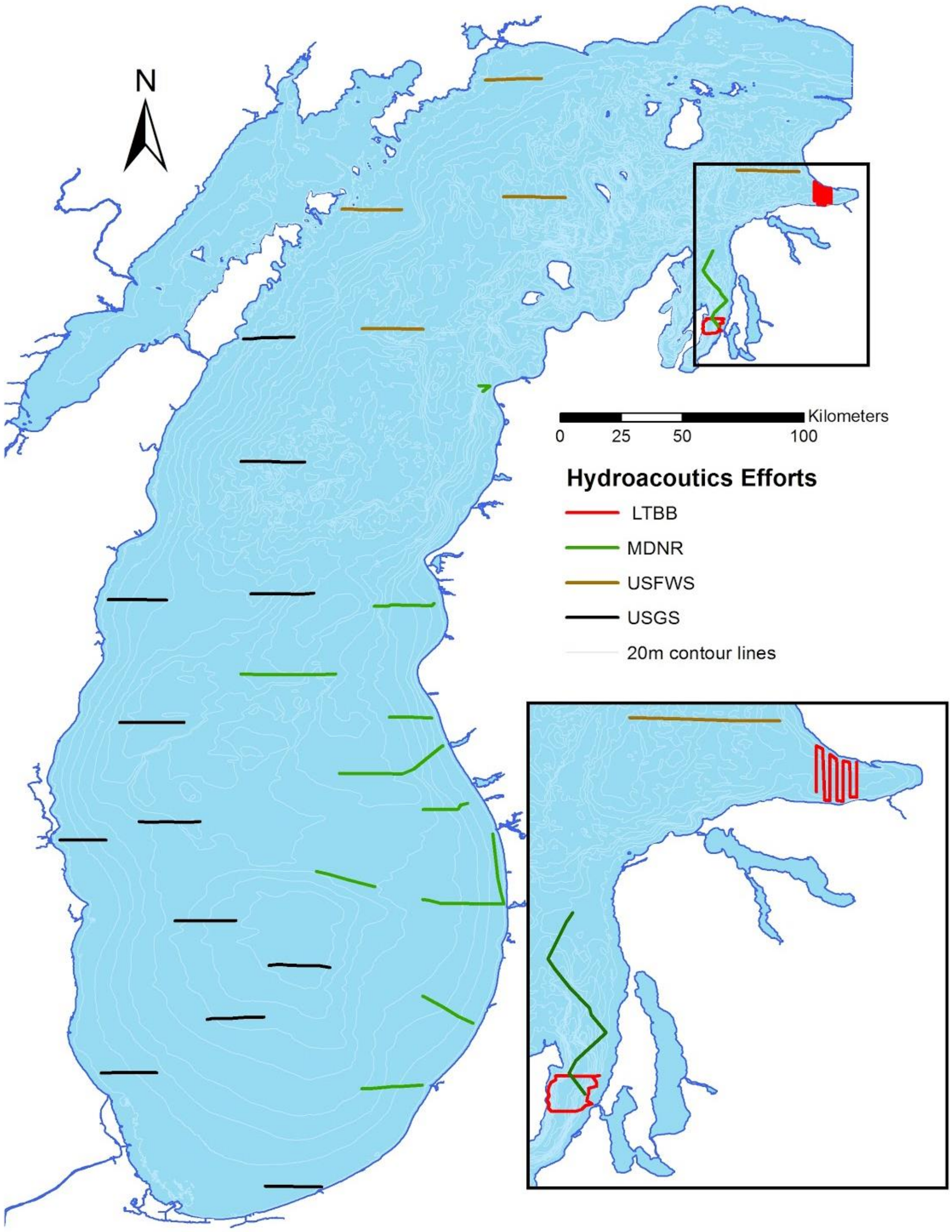



*Figure 10: Transects included in hydroacoustic population estimates for Lake Michigan.*

# Chapter 4: Age-Length Growth Model for Cisco (*Coregonus artedi*) in Lake Michigan

by Albany Jacobson Eckert


## Abstract

Currently, there are no models available to represent growth of cisco in Lake Michigan. To generate data needed to develop a growth model for Lake Michigan cisco, we collected otoliths from individuals caught in gillnet surveys. These gill net surveys were conducted in the 1836 Treaty waters of Lake Michigan in 2013, 2016, and 2017. Otoliths were extracted, thin-sectioned and annual rings were identified by four different agers. Length-weight relationships were developed using a von Bertalanffy growth model for the whole sample, and for females, and males which are known to growth at different rates. Age readings between the two groups of agers differed significantly (overall distributions differed by an average of -0.4466). Parameters of the von Bertalanffy growth model ($L_{inf}$, K, and t0) differed with sex, location, and year caught. However, parameters also varied significantly when the model was fit with age data from different readers. The residual sum of squares for all derived von Bertalanffy growth model parameters was over 18,000, suggesting that our age readings did not provide robust data for a model and thus the models are not a good predictor of growth. Due to the smaller sum of squares in the overall, female, and male von Bertalanffy curve fitting, the model from the less experienced age group seemed more reliable. This study provides a preliminary model to estimate cisco age-length relationship which can be used to characterize the age structure of cisco populations in the northeastern region of Lake Michigan.


## Introduction

Population dynamics of remnant cisco (*Coregonus artedi*) populations in Lake Michigan is poorly understood. But other studies of cisco population structure have been conducted in Lake Superior (Yule et. al., 2008; Stockwell et. al. 2009) and Lake Ontario (Carl and McGuiness 2006). In recent years, cisco numbers in Lake Michigan have been on the rise in Grand Traverse Bay, as invasive pelagic species populations are dwindling. Encouraged by these signs, the Little Traverse Bay Bands of Odawa Indians (LTBB) Natural Resource Department (NRD) is heading a cisco population assessment in the 1836 Treaty waters of Lake Michigan (Smith et. al. 2016).

One of the NRD's research goals is to determine the age structure of remnant cisco populations in Little Traverse Bay and other areas in Lake Michigan where cisco are found. To that end it is necessary to develop an age length key and a growth model for the cisco in the 1836 Treaty waters. This information is necessary for management decisions including in the selection of restoration strategies which could include stocking. Additionally, a length-weight relationship is needed for cisco in Lake Michigan to compare to other populations in the Great Lakes.

Cisco life history traits vary across the Great Lakes. In Lake Superior, individuals older than age 5 were found to be mature (Yule et. al. 2008) while in Green Bay, Lake Michigan, cisco were determined to be mature at 3 years old (Smith 1956). This study was conducted to shed light on the growth patterns of cisco in Lake Michigan, which can be used to further compare variations of cisco growth across the Great Lakes.

## Materials and Methods

In order to quantify cisco growth, we used a von Bertalanffy growth model (VBGM). The model was developed by Ludwig von Bertalanffy to quantify growth in many species not limited to fish (1938). The VBGM is one of the most widely-used fisheries stock assessment tools. VBGM functions based on individual length take the form of

$$length \sim L_{inf}(1 - e^{-K(age - t_0)})$$

where $L_{inf}$ is the average maximum length of the organism, K is the growth rate coefficient, and $t_0$ is the average time at which length = 0. The variable $t_0$ is not biologically significant but is used to derive the other variables.

In order to to implement the model we determine cisco age based on otoliths. Otoliths (literally, "ear bones" in Latin) and other calcified structures like cleithra (jaw bones) and dorsal spines are routinely used for aging fish. Scales are also commonly used for aging. Extraction of otoliths and cleithra is lethal to the fish. But dorsal spines and scales can be cut or scraped off, and the fish released back into the water alive. Otoliths are considered to be more accurate than scales, especially for cisco older than 5 years old (Stockwell et. al. 2009). For that reason, we decided to use otoliths for determining cisco ages.

There are multiple ways to process otoliths for aging. Two commonly used methods are "crack and burn" and thin sectioning. Crack and burn involves breaking otoliths in half and holding one half to a flame to darken the annuli (growth rings) and enhance contrast between the annuli and the rest of the otolith. Then, roasted otolith halves are mounted vertically in putty and then a drop of mineral oil is added to the darkened tops, so that they appear clear under a microscope. There is a risk of burning otoliths too much, using this method, and darkening the annuli so much that they are unreadable. A more foolproof method is thin sectioning the otolith. Thin sectioning uses a slow-speed double-bladed circular saw to slice epoxy-embedded otoliths on their transverse axes at the widest point. The thin sections are mounted on microscope slides and polished until they are thinner and more transparent, so light can pass through. In this study, we used thin sectioning.

## Sample Collection

Cisco were collected in 2013, 2016, and 2017, at various times throughout the year (May to November) in gill net surveys administered by LTBB. Specimens collected in these surveys aged and their stomach contents and gill rakers were analyzed for genetic surveys. Monofilament gill nets ranged from 400 feet to 800 feet in length. The depth of water that the nets were set in ranged from 3 meters to 70 meters. Nets were set in six northern Lake Michigan sampling areas (Figure 11) and left overnight. Mesh sizes ranged from 2.5 to 4.0 inches (stretched), in 0.5-inch increments. Specimens were frozen after collection and thawed when otoliths and other biological samples, like stomachs and gill rakers, were extracted. We sawed off the heads and pulled both otoliths out with tweezers from the vestibular labyrinth. Sometimes only one otolith could be recovered. Otoliths were placed in sampling envelopes and labeled with the specimen's ID.


*Figure 11. Cisco sampling locations in 2013, 2016, and 2017. Numbers represent the total amount of cisco caught at each site over the three years. Map background from Google Maps.*

## Otolith Preparation

All otolith preparation was done in the LTBB NRD fisheries lab in Harbor Springs, MI. One otolith from each pair was cleaned and embedded in a 4:1 weight ratio of epoxy and hardener. Then, embedded otoliths were sliced on the transverse axis using a Buehler double-bladed saw with 0.7 mm blade separation. Thin sections were attached to microscope slides with super glue and the slides labeled. Sandpaper with 600 to 2000 grain was rubbed on the thin sections to grind the slices down and make them more transparent.

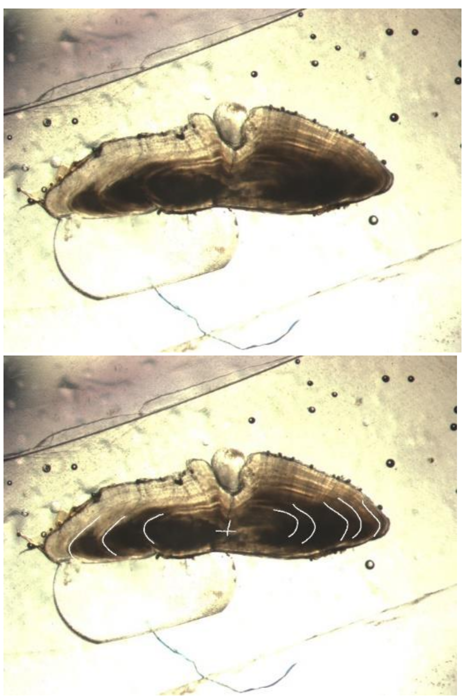
## Otolith Reading

Using a Nikon Eclipse Ci microscope and a QImaging camera and software (from Micropublisher), otoliths were displayed at 4x zoom, images were captured, and saved (Figure 12a). Using ImageJ software, the annuli (dark rings) were marked (Figure 12b). Readers aged along the major axis (from the sulcus to the widest points on the image) but if rings were unclear, then they used a different axis where the rings could be readable. Because the samples were collected in the summer and fall, and growth is rapid during those times of the year (therefore the outer edges would be more transparent), edges were not counted. Three other readers, a University of Michigan undergraduate student; a researcher from LTBB; and one researcher from the Michigan Department of Natural Resources (MDNR), aged the samples. To avoid bias, the readers had no prior knowledge of the biodata available for the corresponding specimens.

Some images were unreadable, or agers disagreed widely. Agers differed in experience with reading otoliths, the two UM students were "less experienced" (Group A) and the LTBB and MDNR readers were "more experienced" (Group B). For this paper, final ages in the two ager groups were determined by the author as follows:

(a) if the two reader ages were the same, there was automatic agreement;
(b) if the estimated ages differed by one year, the lower estimate was recorded;
(c) if the ages were two years apart, the average was recorded; and
(d) if the ages differed by more than two years, the two readers looked at the otoliths marked in ImageJ and compared where each reader had marked the annuli in order to reach a consensus for the final age. But if no agreement was reached after the two readers consulted with each other, then the sample information was not used in the analysis.

From over 300 otolith samples prepared, ages for 272 otoliths were included in the final database.



a)

b)

*Figure 12. Image of otolith from a male specimen (a) before and (b) after marking annuli in ImageJ software. The sulcus (center) is marked with a cross in the middle. The markings indicate an age reading using the major axis. Some otoliths marked in ImageJ had readings with unequal numbers of markings on each side, in which case, the average was taken. If more than two axes were used, the most frequent age estimate was used as the final age for each reader. In Group A, the estimates for this fish were 4 and 6. The individual was determined to be 5 years old in Group A. For Group B, the two readers guessed 5 and 6, so the final age was decided as 5 for Group B. Edges were not counted.*

## Age-Length Based Growth Modeling

R software was used for analysis (R Core Team 2016). Von Bertalanffy curves were fitted using Ogle's FSA R package (2018) for sexes combined and also male and female cisco data sex, year caught, and location caught. Parameters from each VBGM ($L_{inf}$, K, and t0) were outputted and their significance computed (Table 4). Location data was only used in modelling if n > 30 in a given location.

## Length-Weight Modeling

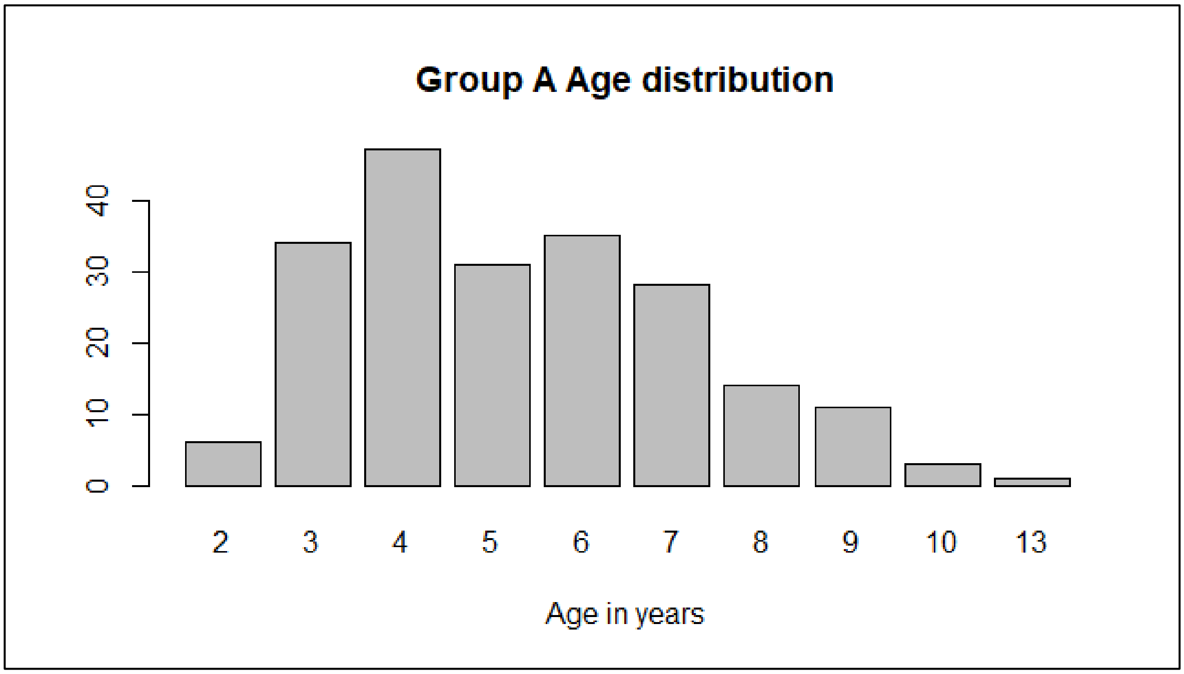
For females, males, and the overall samples, length-weight relationships were modelled and graphed in R (Table 3; Figure 13). A nonlinear least squares model was used and the desired equation was as follows:

$$weight \sim a + b^{length}$$

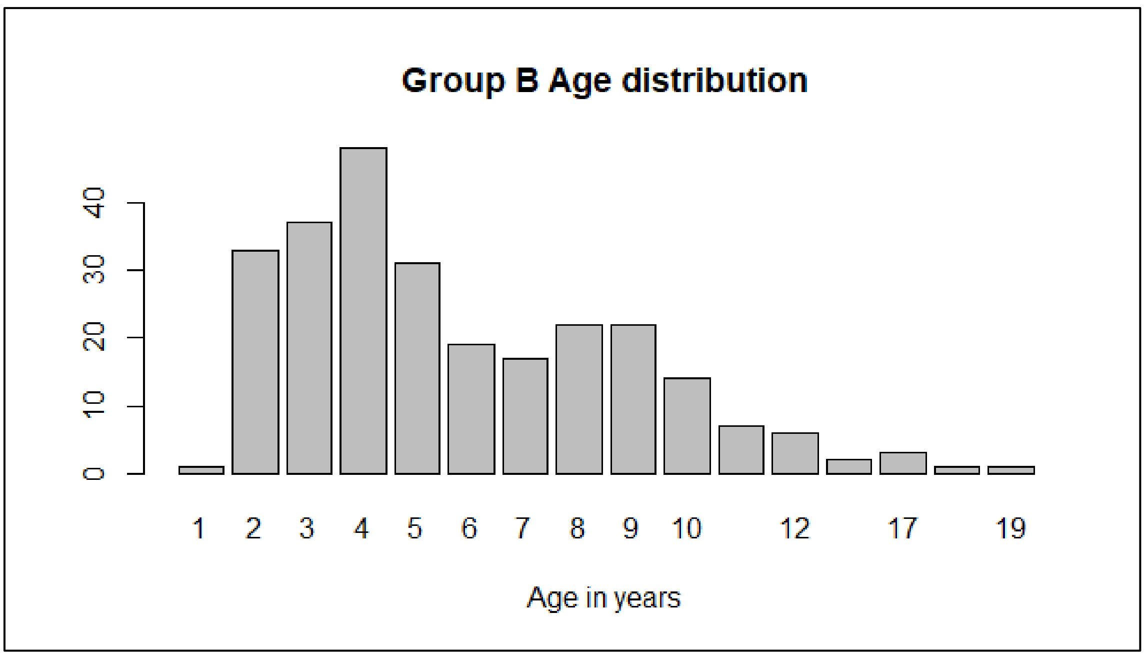
A length-weight model could be used to compare somatic growth of cisco in Lake Michigan to that of populations in other Great Lakes.

## Results

Group A aged 206 specimens, while Group B aged 259. The median age for the male and female distributions in both groups was 5. Still, Group A and Group B differed significantly in overall age estimations. Group B had higher maximum age estimations in both male and female samples (17 for female, 19 for male). Paired t-tests were conducted for females and males to compare Group A and Group B ages. Overall Group A and Group B age averages differed by -0.4466. T-value for the overall difference was -2.9888, degrees of freedom (df) was 205, and the p-value was 0.003143. For females, there was no significant age estimation difference at $\alpha = 0.05$. The difference between the average age of Group A and B was -0.2924528, the t-value was -1.5705, df = 105, and p-value = 0.1193. In males, the mean of the differences was -0.583333, t = -2.3812, df = 95, and p-value = 0.01925.

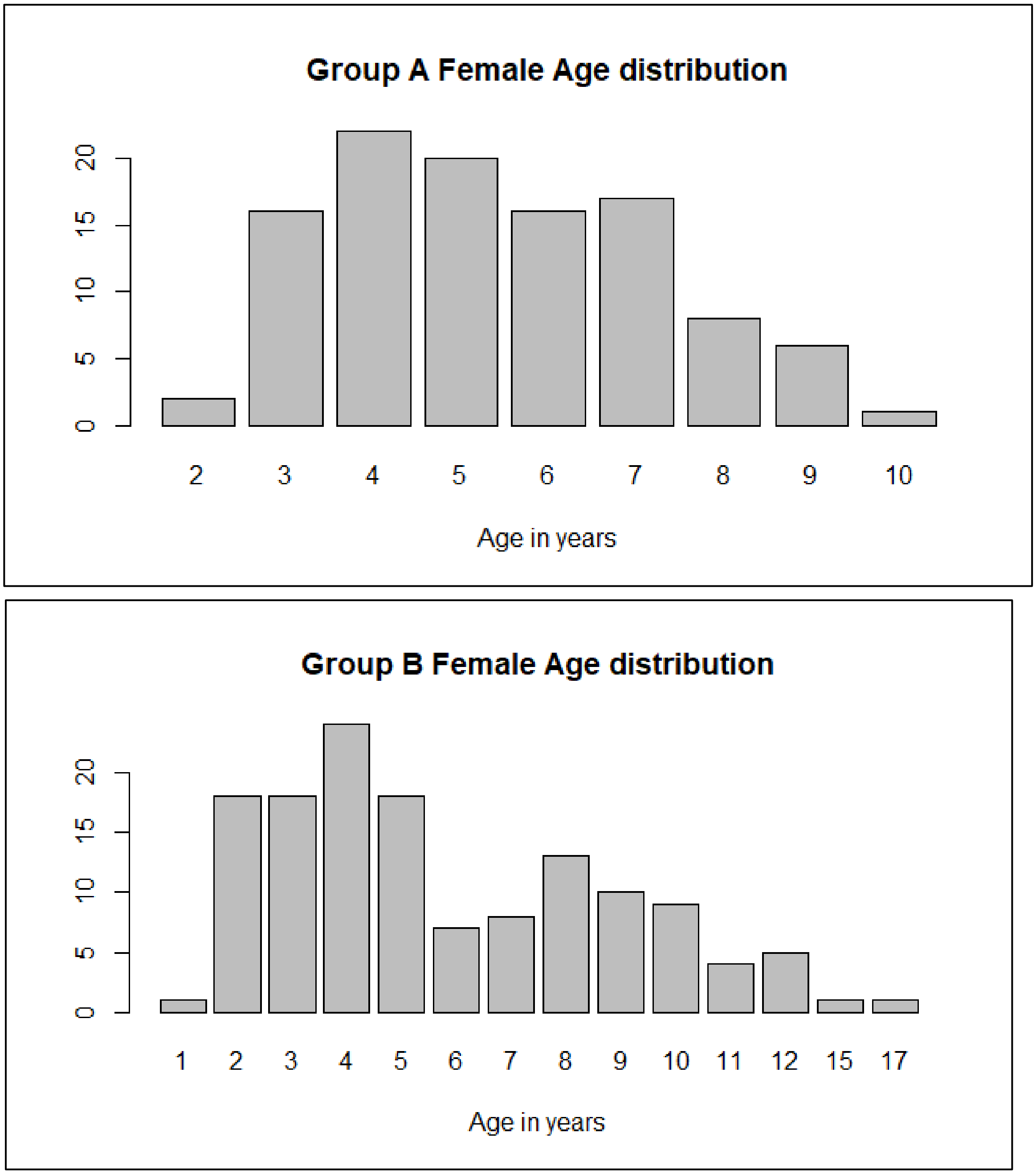



a)



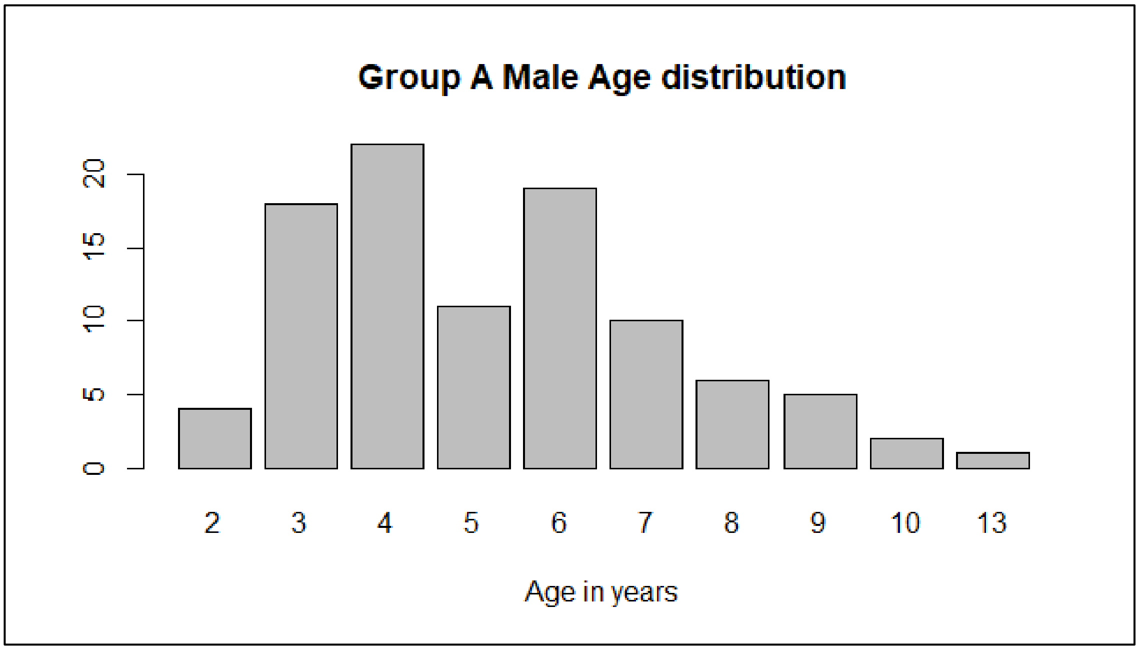

b)

*Figure 13 a) and b). Overall age distributions for both groups.*

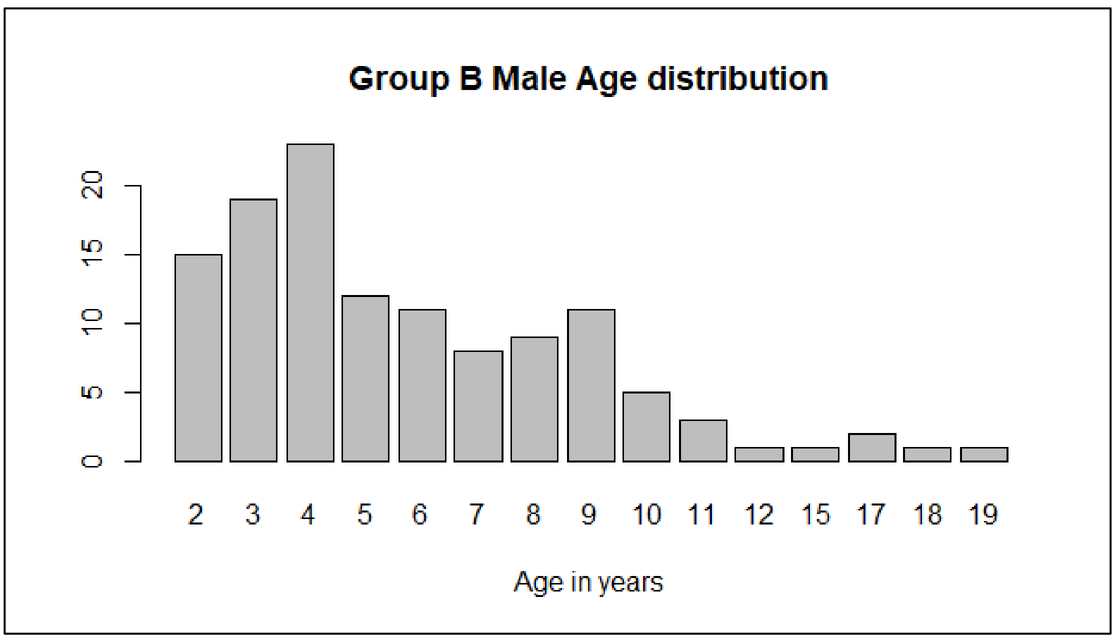


c)
d)

*Figure 13 c) and d). Female age distributions for both groups.*




e)




f)

*Figure 13. Age distributions from the samples. Age distributions were derived for both groups overall (a and b) and by sex (female (c and d), male (e and f)).*

## Length-Weight Relationships

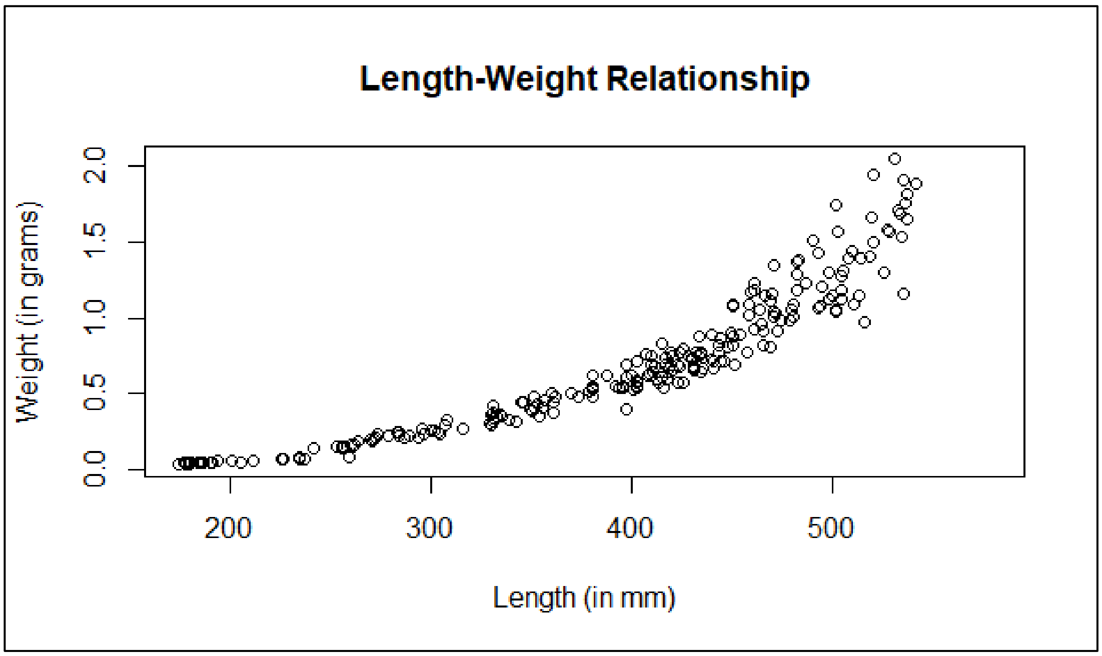
Relationships between length and body weight were calculated. The relationships followed an exponential form:

$$weight \sim a + b^{length}$$

The variable a, which is the weight intercept when length is 0, is not biologically significant (because all of the weight intercepts were found to be negative), but is used to derive the growth rate, b. Variables a and b were calculated for the overall samples, and each sex, and all variables were found to be mathematically significant at the $\alpha = 0.01$ level. All categories (overall, female, and male) had the same growth rate estimate. In males, the residual sum of squares was the lowest of the three categories, while the overall group had the highest residual sum of squares (Table 7).

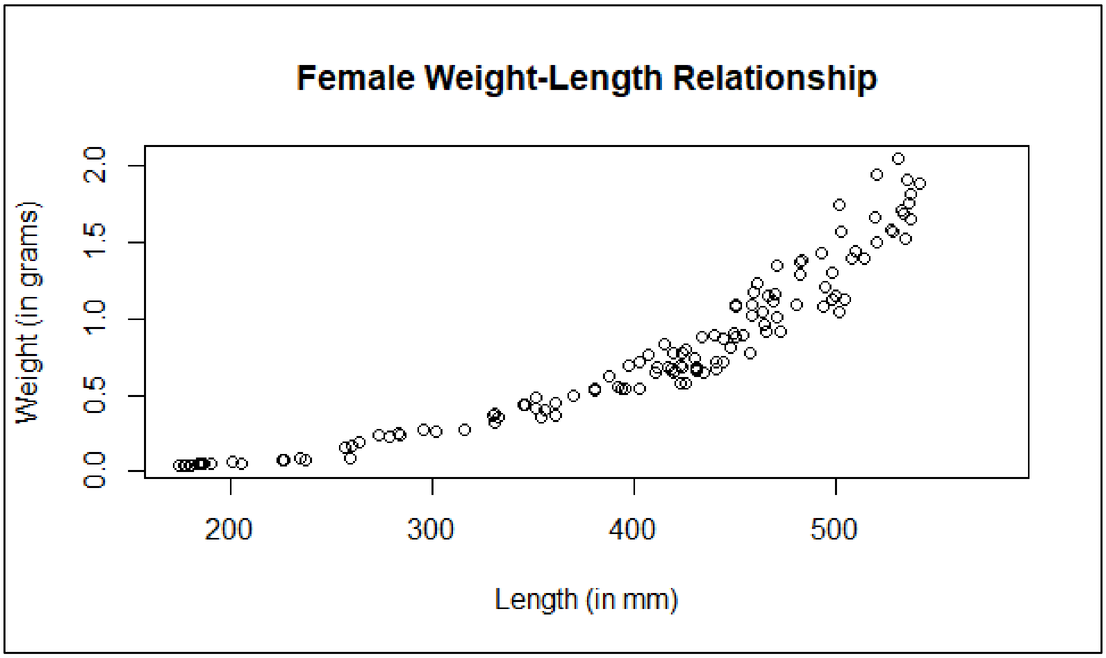
*Table 7. Length-weight relationships for overall, females, and males. The variable a represents the weight intercept where length is 0 and b represents the growth rate. The sexes of 5 individuals were not recorded.*

| | a | | b | | Residual Sum of Squares |
|---|---|---|---|---|---|
| | Estimate | p-value | Estimate | p-value | |
| Overall (n = 272) | -1.602 | << 0.01 | 1.002 | << 0.01 | 5.66 |
| Female (n = 142) | -1.638 | << 0.01 | 1.002 | << 0.01 | 3.62 |
| Male (n = 125) | -1.501 | << 0.01 | 1.002 | << 0.01 | 1.04 |

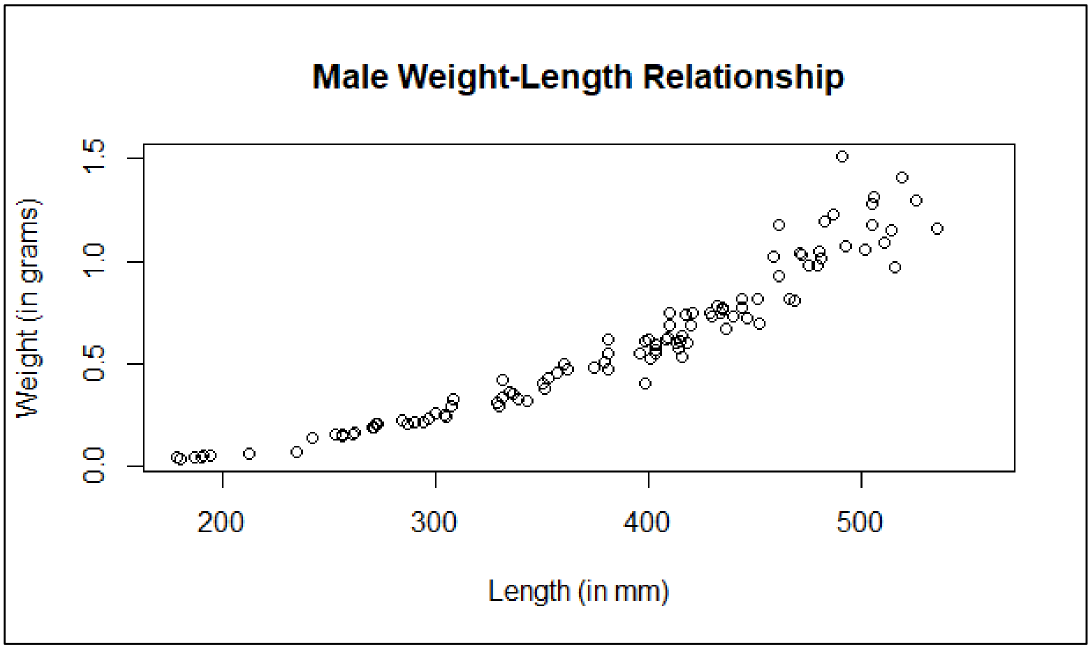


a)

*Figure 14a. Overall length-weight relationship for samples.*




b)




c)

*Figure 14. Weight-length relationships were found for all samples (a), females (b), and males (c).*

## Von Bertalanffy Curve Fitting

The von Bertalanffy growth curves took the form

$$length \sim L_{inf}\left(1 - e^{-K(age - t_0)}\right)$$

where $L_{inf}$ is the asymptotic average maximum length of the organism, K is the growth rate coefficient, and $t_0$ is the average time at which length = 0. The variable $t_0$ is not biologically significant, but it is used to extrapolate other variables. Parameters were estimated in R using Derek Ogle's FSA package (2018).

SAll of the VBGM outputs had residual sum of squares over 18,000. All of the $L_{inf}$ estimates were significant at the $\alpha = 0.01$ level. Three K estimates were significant at $\alpha = 0.01$: Group A overall, Group B overall, and Group B female. None of the $t_0$ estimates were found to be significant at the $\alpha = 0.01$ level (Table 8).

a)

b)

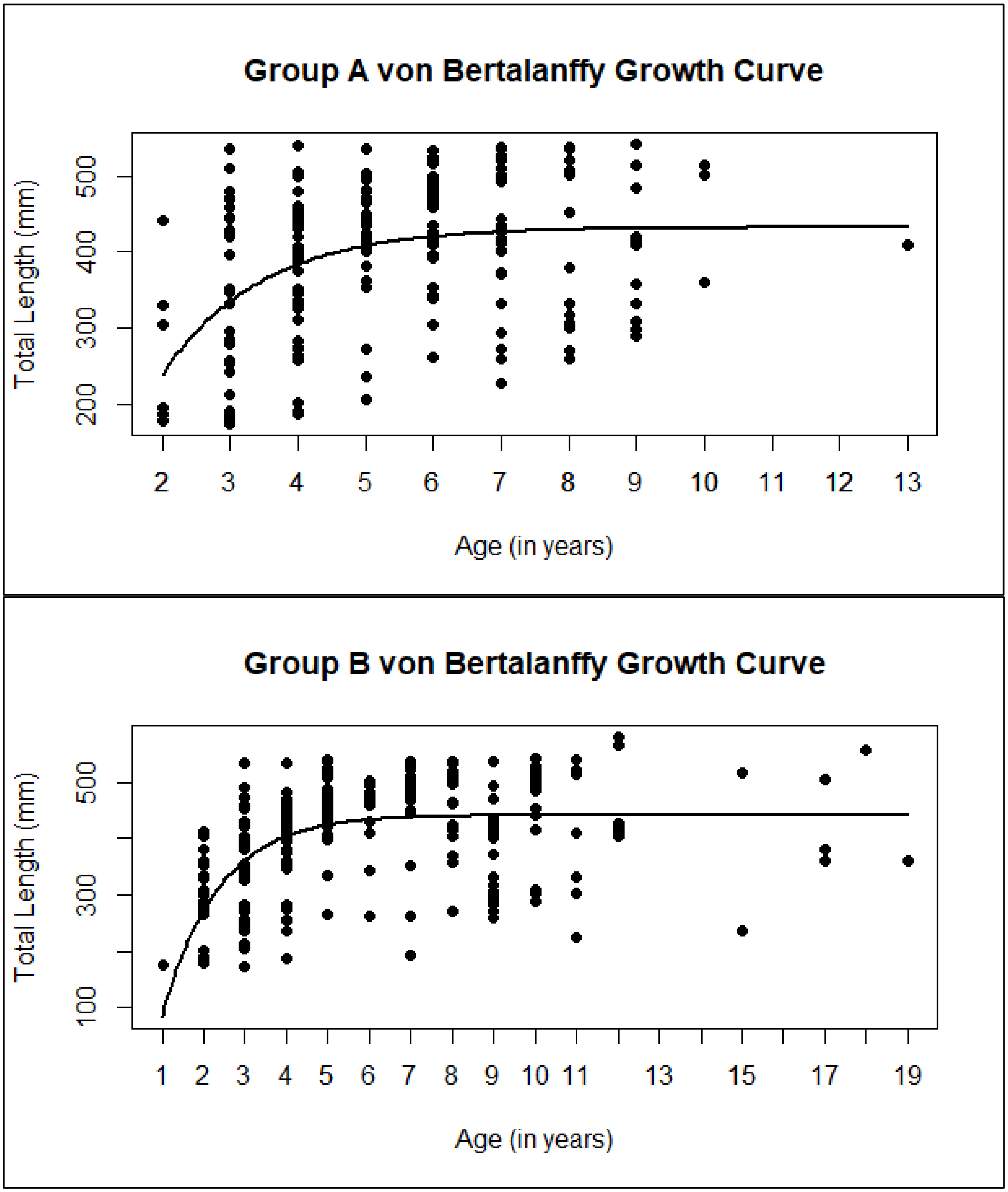
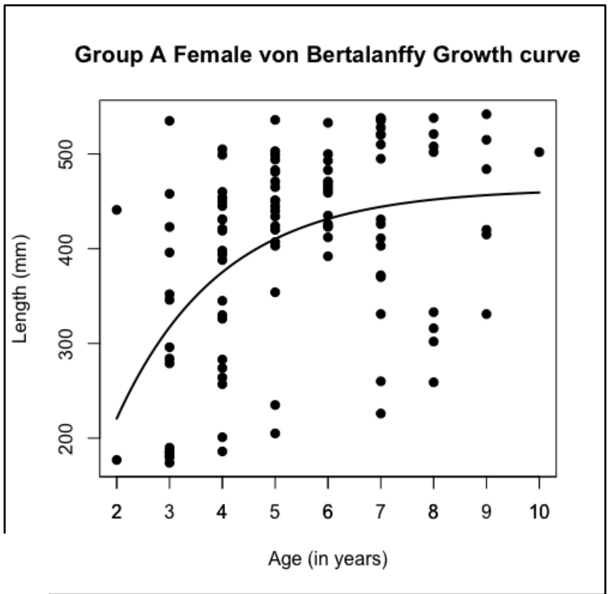
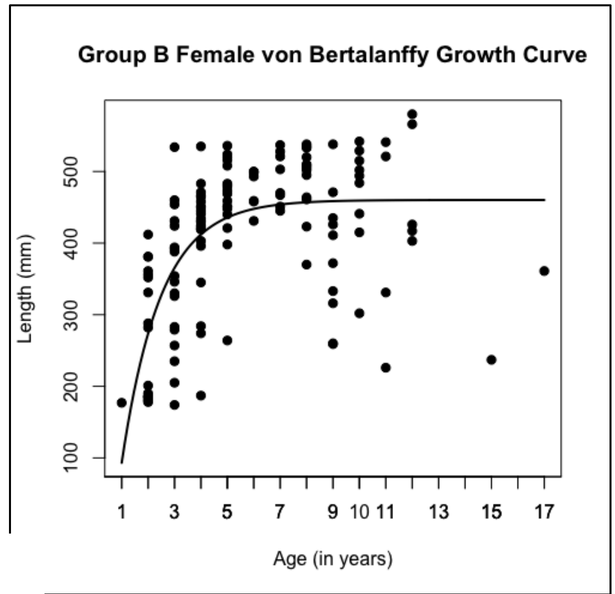


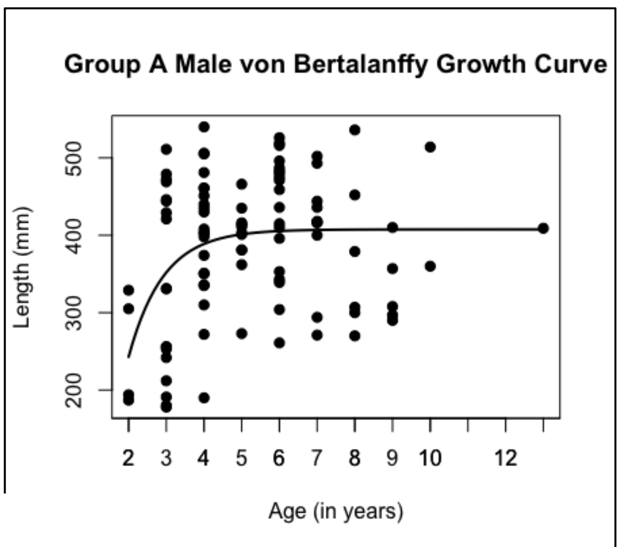

*Figure 15a) and b). Overall von Bertalanffy curves for both groups.*



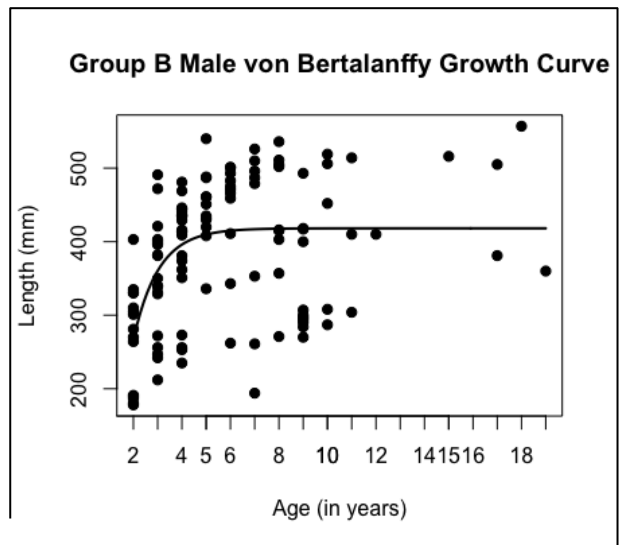

c)




d)




e)




f)

*Figure 15. Von Bertalanffy curves for overall in Groups A and B (a and b) and by sex (Group A female (c), Group B female (d), Group A male (e), Group B male (f)).*

*Table 8. Parameters and residual sum of squares found from fitting VBGMs using Ogle's FSA package (2018).*

| | $L_{inf}$ | | K | | $t_0$ | | **Residual sum of squares** |
|---|---|---|---|---|---|---|---|
| | estimate | p-value | estimate | p-value | estimate | p-value | |
| Overall | | | | | | | |
| A (n = 206) | 432.2805 | << 0.01 | 0.6896 | 0.00114 | 0.8408 | 0.1084 | 1,690,000 |
| B (n = 259) | 441.4443 | << 0.01 | 0.7486 | << 0.01 | 0.7181 | 0.0032 | 1,800,000 |
| Female | | | | | | | |
| A (n = 108) | 463.5753 | << 0.01 | 0.5057 | 0.0248 | 0.7220 | 0.3948 | 921,000 |
| B (n = 137) | 460.2059 | << 0.01 | 0.6767 | << 0.01 | 0.6656 | 0.0245 | 938,000 |
| Male | | | | | | | |
| A (n = 98) | 407.5512 | << 0.01 | 1.0856 | 0.0190 | 1.1651 | 0.0208 | 717,000 |
| B (n = 122) | 418.1316 | << 0.01 | 0.9617 | 0.00488 | 0.9421 | 0.02539 | 811,000 |

## Discussion

Growth rates and parameters derived from this study may be indicative of cisco populations in Lake Michigan, which can aid agencies like LTBB in their future management efforts. Other studies that evaluated coregonid growth rates within the last ten years using a von Bertalanffy curve were scant, with only a few studies showing K, the growth rate coefficient. The K values in this study were generally larger than those found in other studies. Stockwell et. al. (2009) modelled cisco growth in Lake Superior using age classes from 1984, 1988, 1989, and 1990, and comparing growth rates with year class strength. The K values increased from 1984 to 1988, then decreased from 1988 to 1990: 0.43 in 1984, 0.57 in 1988, 0.47 in 1989, and 0.39 in 1990. The authors had expected continuous decline in the value of K from 1984 to 1990, but since K had increased from 1984 to 1988, they concluded that growth of cisco in Lake Superior were not density-dependent. No parameters for the separate sexes were specified.

Other growth studies with significant usage of von Bertalanffy curves targeted whitefish (*Coregonus clupeaformis*), a closely related fish to cisco (Beauchamp et. al. 2004; Cook et. al. 2005). Beauchamp et. al. (2005) found no significant difference in the growth rate of females compared to males, but growth rates in both sexes were highly correlated. The K value for both sexes was approximately 0.25, lower than the ones derived in this study. Beauchamp et. al. sampled from 5 sites in Lake Michigan from 1979 to 1998. Cook et. al. also derived a von Bertalanffy curve for whitefish, but in Lake Erie (2005). Age classes sampled in that study were from 1989-1994 and 1995-2001. In the former group, the growth rate coefficient was higher in males than females (0.401 and 0.280). In 1995-2001, both sexes had similar K values (0.3180 for males and 0.310 for females). Again, the K values in this study are generally higher than all of the K values in the previous studies that I had mentioned. Temporal variation has to be taken into account – the studies I have discussed refer to populations in the 1970s to 1990s.

A major part of this study was to find the differences in age distributions and growth patterns between males and females. The age distributions of Group A and B found no significant difference in the ages of females, but there was a difference in the estimation of males. Additionally, in both ager groups, the K values for the female von Bertalanffy curves in this study were lower than that of males. However, the $L_{inf}$ was higher in females of both groups than in males. This could possibly suggest that, in Lake Michigan, female cisco grow more slowly than males, but achieve a higher maximum average length.

There were several possible sources of error that could have affected the results. Determining ages from otoliths is subjective, due to possible errors from any step in the processing of the thin sections to reader ability to distinguish annual rings from other marks. Extracting otoliths from the vestibular labyrinth with tweezers might break the otoliths at an angle, forcing the thin sections to be cut along an oblique axis and skew the perception of the annuli. Embedding the otoliths in epoxy might yield air bubbles in the mold or force the otoliths to be embedded at an angle. Other errors can destroy the sample. Sectioning might result in thin slices that are unusable, or sections lost in the blade lubricant bath. Trying to attach the thin sections with super glue is also precarious, as too much super glue can make the section opaque and therefore unreadable. Additionally, polishing too hard may detach the thin sections from the slide or render them almost transparent.

To account for the subjectivity in aging we had two groups of agers. We found that the ages from the two groups differed significantly and propose that the estimates generated by the more experienced readers should be considered for further use of our results.

## Conclusion

Recommendations for future protocols include gathering larger number of samples so that data can be used to evaluate annual or regional differences as cisco populations increase in abundance. For now, we have a baseline of an age-length relationship in various subgroups of cisco in Lake Michigan. The standard operating procedures and Ogle's R code for the VBGM fit perfected and used through this project (see Appendix E, R code from Ogle 2013) will guide LTBB in its future endeavors to investigate population dynamics of cisco in Lake Michigan.

# Chapter 5: Larval Coregonid Diets and Zooplankton Community Composition in Northeastern Lake Michigan

by Jillian Mayer


## Abstract

Lake Michigan is facing a food web crisis of too many predators, insufficient prey biomass, and low primary and secondary productivity. Restoring native forage fishes may be a management solution to the trophic imbalance, but questions remain about the Lake's ability to support larger numbers of planktivores given its oligotrophic state. Cisco (*Coregonus artedi*) were once abundant forage fish in Lake Michigan, but populations have declined in the last century. This study documents the contemporary spring (April-June) diets of larval cisco and also lake whitefish (*Coregonus clupeaformis*) which co-occur with cisco in northeastern Lake Michigan within the 1836 Treaty of Washington D.C. waters. We also analyzed the spring potential prey community for the larvae, composed of zooplankton and macroinvertebrates, to determine the breadth and density of food available to larval fish. Nine sites were sampled for larvae and pelagic prey in 2017, one site in 2016, and four sites in 2015. Most cisco larvae in the samples were concentrated in Grand Traverse Bay, where the only remnant cisco adult population has been documented. Few cisco larvae (fewer than 25% of larvae caught) were found at other sites. Pelagic prey (zooplankton and macroinvertebrates) were low, never reaching more than 4.73 organisms/L and hovering near 1 organism/L overall. Diets and the environment were dominated by adult Calanoid and Cyclopoid copepods, and occasionally nauplii and copepodites. The diets of cisco and lake whitefish larvae overlapped, but lake whitefish appeared to eat a wider breadth of prey taxa than cisco do. We used Chesson's α (1983) index of selectivity and determined that individual adult copepods tended to be selected while other prey taxa tended to be absent or 'avoided' in diets, likely because they composed a small amount of prey biomass and were rarely encountered. Studies are recommended to analyze summer zooplankton densities and larval diets in northeastern Lake Michigan, as other Great Lakes studies suggest that zooplankton densities increase dramatically and may aid larval survival despite low spring densities in the northeastern nearshore.


## Introduction

Lake Michigan is facing an unbalanced food web of too many predators (mostly reintroduced lake trout, *Salvelinus namaycush*, and exotic Chinook salmon, *Oncorhynchus tshawytscha*) and too few forage fishes. Simultaneously, invasive *Dreissenid* mussels and lower anthropogenic nutrient inputs are creating increasingly oligotrophic conditions in the lake (Evans et al. 2011; Vanderploeg et al. 2010), which lowers primary production (Vanderploeg et al. 2012). Due to decreased productivity, predation by planktivores, selective filtering by mussels, and predation by the introduced predatory cladoceran, *Bythotrephes longimanus*, zooplankton densities have decreased across the lake (Pothoven and Fahnenstiel 2014; Tuchman and Barbiero 2004) and shifted to be dominated by calanoid copepods (Vanderploeg et al. 2012). As a result, biomass of planktivorous fish is also decreasing (Vanderploeg et al. 2012). Restoring native planktivores such as cisco (*Coregonus artedi*) may be a management solution to the predator-prey imbalance, but questions remain regarding the potential that native forage fish restoration can reach due to lake conditions.

Cisco was once one of the most abundant forage fish in Lake Michigan, served as prey for the lake's top piscivores, and supported a large commercial fishery (Smith 1968; Smith 1972). Due to overharvesting, invasive species, and habitat degradation, cisco populations plummeted in the mid-1900s (Figure 16) and have yet to recover in Lake Michigan. However, a remnant population in Grand Traverse Bay is showing signs of recovery as the lake may be experiencing conditions more favorable for cisco: fewer predators, decreased fishing pressure, and fewer planktivore competitors (Stockwell et al. 2009). Several tribal, state, and federal agencies are interested in exploring options to restore cisco populations in Lake Michigan. However, among other things, the lack of baseline information on contemporary cisco ecology in Lake Michigan and disagreement in management priorities is impeding consensus about how to proceed.

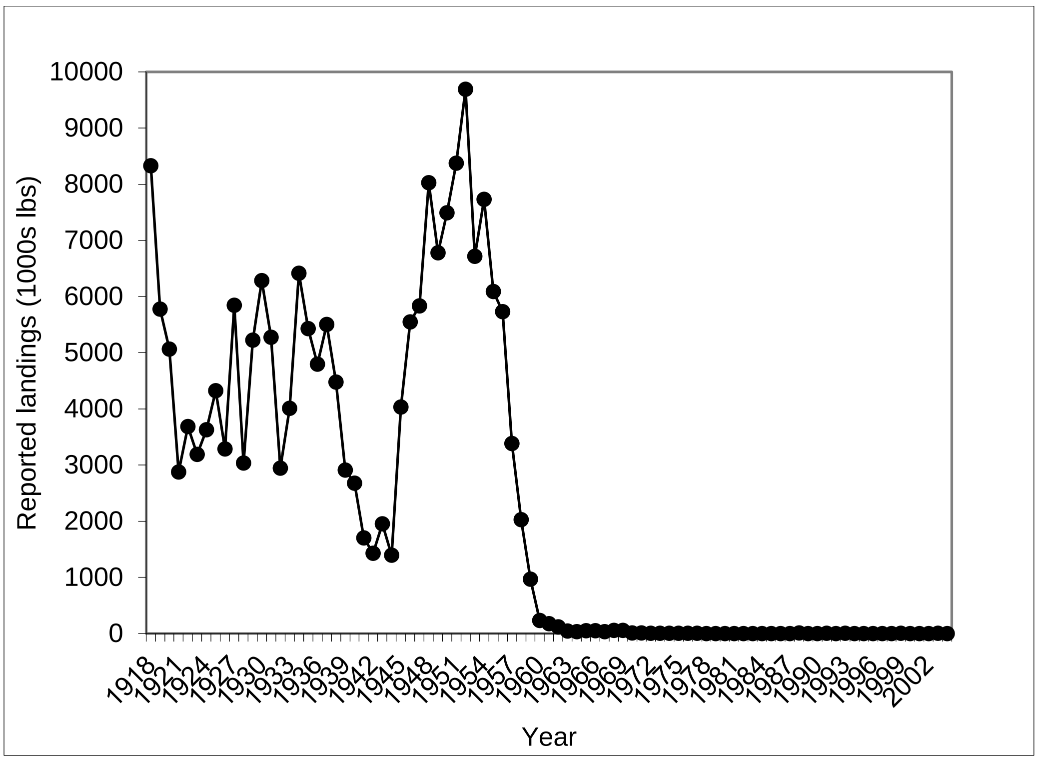


*Figure 16: Commercial landings of cisco in Lake Michigan, 1918-2007 (Baldwin et al. 2009)*

Early life survival is essential to ultimate recruitment and population stability for all fish species, including cisco (Myers 2015). In the Laurentian Great Lakes, cisco spawn between November and December over mud, sand, or gravel in shallow (1-3m) water (Auer 1982). Little is known about the larval feeding ecology of cisco in northern Lake Michigan, but there is research on larval development in Lake Superior where cisco stocks have rebounded (Myers 2015A; Rook et al. 2013). Larval cisco exhaust their yolk sac between 12.8 and 13.8 mm total length, or approximately 30 days after hatching in early spring, usually around April (Oyadomari 2005; Auer 1982). Larval coregonids like cisco primarily consume copepods, including adults and smaller nauplii and copepodites, in the spring (Davis and Todd 1998; Claramunt et al. 2010; Johnson et al. 2009; Selgeby et al. 1994). Nevertheless, there are no specific studies to document cisco feeding ecology in northeastern Lake Michigan where stocks have increased in recent years (unpublished data, Randall Claramunt, Michigan Department of Natural Resources, and Kevin

Donner, Little Traverse Bay Bands of Odawa Indians). As noted in the Lakewide Assessment Plan for Lake Michigan Cisco (2016) adult cisco now consume fish prey in addition to invertebrates and zooplankton. In addition, the contemporary distribution of cisco larvae is largely unknown. This study adds to the growing body of knowledge about Lake Michigan larval cisco feeding ecology and distribution, which can help inform management and restoration priorities.

Lake whitefish (*Coregonus clupeaformis*) are one of the most financially lucrative and abundant forage fish in Lake Michigan, and often, at the larval stage, co-occur with cisco at nearshore areas. Like cisco, lake whitefish spawn from November to December in shallow nearshore areas, and emerge around April (Auer 1982). They lose their yolk sac around 14 mm total length (Auer 1982). Like cisco, larval lake whitefish eat largely copepods (Claramunt et al. 2009). Some studies suggest that larval lake whitefish and cisco are competitors (Davis and Todd 1998), which may be driving commercial fishers' resistance to investing resources into cisco restoration.

In this study, we sampled for larval cisco and potential prey in northeastern Lake Michigan in 2017, in addition to analyzing samples collected in 2015 and 2016 by biologists at the Little Traverse Bay Bands of Odawa Indians Natural Resources Department. Though we attempted to only sample and process cisco for diet content analyses, we inevitable caught lake whitefish larvae due to the species' overlapping distribution. Larvae of these two species cannot be distinguished by physical characteristics alone and species identification required genetic analysis. Due to time constraints, we processed the gut samples before genetic testing confirmed the species. Thus, given the current interest in understanding the feeding interaction and potential competition between the two species, we report on distribution and feeding ecology of larval cisco and lake whitefish.

## Materials and Methods

### Larval and Zooplankton Sampling

Larval coregonids and potential available prey were sampled at nearshore areas in northeastern Lake Michigan (Figure 17). What we labelled as "zooplankton samples" corresponds to everything caught in a zooplankton net, which was considered as available prey. Sampling in 2015 had been conducted between April 27 and June 5, and in 2016 on April 28. During 2017, we sampled between April 1 and June 1. In 2015, samples were collected at Grand Traverse Bay, Charlevoix, Little Traverse Bay, and Cross Village, in 2016 only at Charlevoix, and in 2017 at nine areas: Ludington, Manistee, Grand Traverse Bay, Charlevoix, Little Traverse Bay, Beaver Island, Cross Village, St. Ignace, and Naubinway (Figure 17). These areas were chosen because they lie within 1 km of known, suspected, or historical cisco spawning sites. Within each area, sampling was conducted at 1-5 distinct sites and sometimes sites were repeated to obtain more larvae for diet analysis (Table 9). At each site on each day, we towed for zooplankton and larvae with hand-towed nets. In 2017, sampling was conducted from south to north throughout the spring to compensate for temperature gradients.

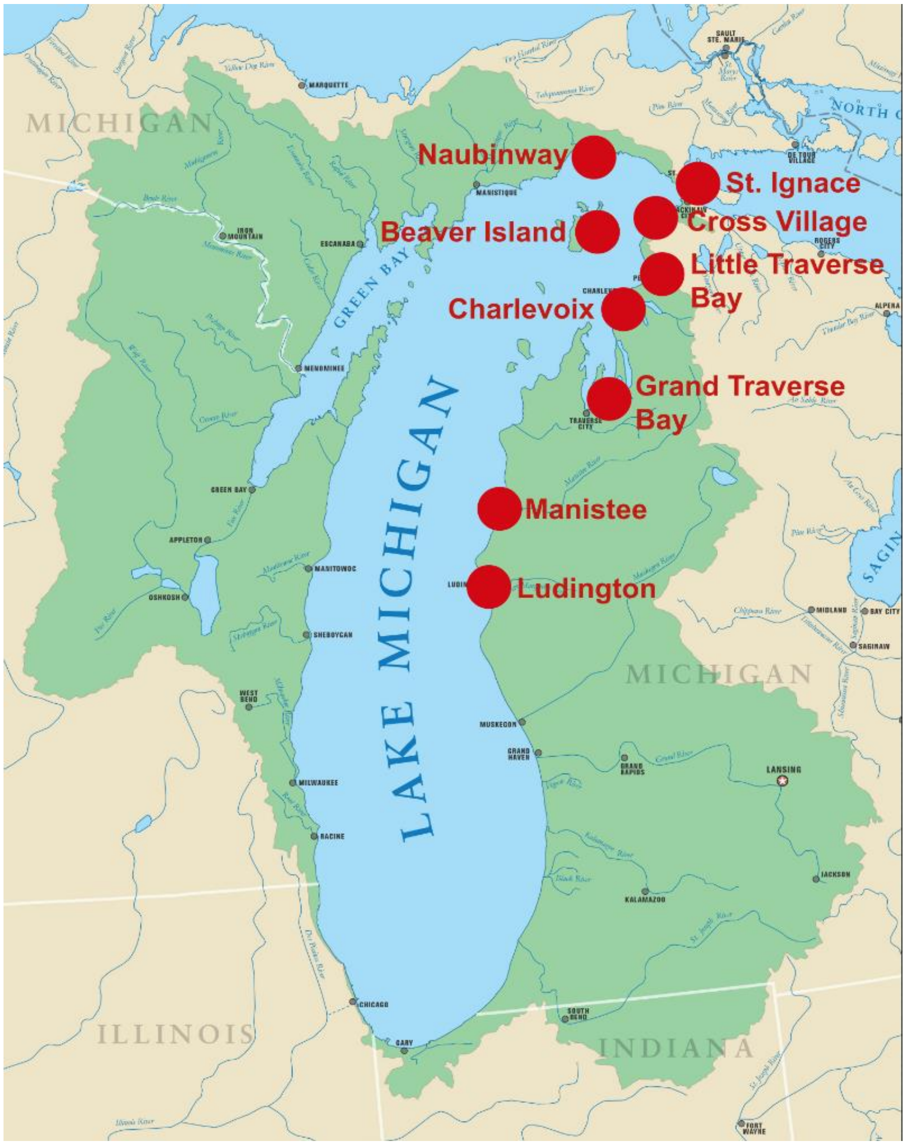


*Figure 17: Sampling areas for this study. In each area, samples were taken at 1-5 sites (Table 10). Sites were chosen for ease of access. At each site on a given day, larvae and zooplankton were sampled. In 2017, samples were collected in all areas. In 2016, sampling was conducted on in Charlevoix and in 2015 in Grand Traverse Bay, Charlevoix, Little Traverse Bay, and Cross Village.*

*Table 9: Sampling location and date. Areas are listed south to north. At each site on each date, larvae and zooplankton samples were taken.*

| Sampling Area | Sample Site (Public Name if Available) | Latitude | Longitude | Date/Year |
|---|---|---|---|---|
| **Ludington** | Pentwater | 43.7827 | 86.4418 | 4/1/17 |
| | Ludington 1 | 43.85663 | 86.411 | 4/1/17 |
| | Dam Beach | 44.90244 | 85.4144 | 4/8/17 |
| **Manistee** | Captain Johns State Park | 44.36193 | 86.2548 | 4/1/17 |
| | Manistee A4 | 44.24521 | 86.34547 | 4/1/17 |
| **Grand Traverse Bay** | Elk Rapids Day Park | 44.8874 | 85.42422 | 4/27/15, 5/18/15, 4/8/17 |
| | Acme | 44.23997 | 85.46187 | 4/8/17 |
| | Wilcox Nature Preserve | 44.90198 | 85.41365 | 4/8/17 |
| **Charlevoix** | Fisherman's Island State Park | 45.28607 | 85.34391 | 4/27/15, 5/5/15, 5/11/15, 4/28/16, 5/9/17 |
| | Charlevoix 1 | 45.28576 | 85.34481 | 4/15/17 |
| | Charlevoix 2 | 45.31915 | 85.26488 | 4/15/17 |
| | Charlevoix 3 | 45.30261 | 85.2594 | 5/9/17 |
| **Little Traverse Bay** | Petoskey State Park | 45.40739 | 84.91274 | 5/6/15, 5/29/15, 4/15/17, 4/29/17, 5/9/17, 5/17/17 |
| **Beaver Island** | Cable's Bay | 45.59291 | 85.51978 | 5/6/17 |
| | Central Michigan University Biological Station | 45.68567 | 85.50527 | 5/6/17 |
| | Dunegal's Bay | 45.74464 | 85.5638 | 5/7/17 |
| | Iron Ore Bay | 45.57925 | 85.58426 | 5/6/17 |
| | Lookout Point | 45.74813 | 85.49905 | 5/7/17 |
| **Cross Village** | Big Stone Bay | 45.7506 | 84.8913 | 5/1/15, 5/5/15, 5/15/15, 5/20/15, 6/5/15, 4/16/17, 4/29/17, 5/17/17 |
| | Sturgeon Bay | 45.68318 | 84.97528 | 4/16/17, 5/17/17, 5/18/17 |
| | Cross Village | 45.6339 | 85.0105 | 5/17/17, 5/18/18 |
| **St. Ignace** | St. Ignace 1 | 45.85693 | 84.72931 | 5/26/17 |
| | St. Ignace 2 | 45.86084 | 84.86269 | 6/1/17 |
| **Naubinway** | Naubinway 1 | 46.07349 | 85.37756 | 5/26/17 |

Zooplankton samples were collected using a hand-towed cylindrical-conical zooplankton net (63µm mesh, 0.33m mouth diameter). The net was towed for 30m horizontally in 0.5-1m of water. A total of 2570 L was sampled for zooplankton per site and date (Table 10). Zooplankton samples were placed in 95% ethanol and stored for processing.

Larvae were collected using a hand-towed neuston net (1000μm mesh, 1m x 2m mouth). The net was towed for 20m in 0.5-1m of water, for a total of 40,000 L of water sampled per site and date (Table 9). The larvae captured in this 20m tow determined the larval density at the site on that date (Table 10). If there were insufficient (<20) larvae in this tow, we towed for up to 200 additional meters at the same site/date to obtain more larvae for diet analyses. The larvae captured in these longer secondary tows were used for diet content analyses but not for larval densities at the site.

Coregonid larvae were identified according to the Auer (1982) key. However, distinguishing between cisco and lake whitefish at the larval stage using physical characteristics is impractical. We tried to separate cisco and Lake whitefish larvae during sampling based on their species-specific response to light. Preliminary experiments with cisco and lake whitefish larvae conducted at the Little Traverse Bay Bands of Odawa Indians' (LTBB) Fisheries Enhancement Facility (hatchery) suggested that larval lake whitefish tend to move away from light and cisco move towards it. Accordingly, in an effort to select cisco during sampling, we covered a plastic basin ("light-box") with an opaque covering which had a hole carved out of one end (Figure 18). A flashlight was placed over this hole, thus creating a light gradient in the basin. Larvae were left in the basin for 30 minutes to allow them to sort themselves. Then, we placed a wooden partition in the middle of the light-box (Figure 18). Larvae on the 'light' side of the light-box were placed in 95% ethanol and transported to the LTBB laboratory. The larvae from the dark side of the light-box were also placed in ethanol but not analyzed for diets. In the lab, we used the Auer (1982) key to try to further select cisco from the larvae from the 'light' side of the light-box. These twice-selected-for larvae were processed for diet analyses.

*Figure 18: Light-box used to separate coregonid larvae into cisco and lake whitefish. This light-box with larvae inside was left covered for 30 minutes for larvae to sort themselves along a light gradient. After the allotted time, the wooden partition was placed in the middle of the light-box (shown). Larvae on the light side of the box were processed for gut contents. Photo by Jillian Mayer.*

## Stomach and Intestinal Content Processing

Larval stomachs and entire intestinal tracts ("guts") were processed at the LTBB hatchery in Harbor Springs, Michigan and at the USGS Great Lakes Science Center (GLSC) in Ann Arbor, Michigan, between August 2017 and March 2018. Up to 40 larvae per site and sampling date were randomly selected for gut content processing. We stopped opening larvae collected a given site and date when we believed we had an accurate picture of the diet contents at that site on that date: when the relative composition and number of diet contents in individual larvae did not appear to be changing with additional larvae processed. Larvae were removed from the ethanol solution one at a time, measured to the nearest 0.01μm, and guts were removed under a microscope (Figure 19). The following microscopes were used: Nikon SMZ1000 (LTBB) and Nikon SMZ800 (USGS GLSC). The following software programs were used to take photographs and measurements: QCapture Pro 7 (LTBB) and Image-Pro Premier (USGS GLSC). Magnifications from 1x to 7x were used.

All stomach contents were identified and classified using the Balcer et al. (1984) zooplankton key and online searches. Contents were enumerated and classified into the following categories: Calanoida (copepod), Cyclopoida (copepod), Harpacticoida (copepod), copepedites and nauplii, Rotifera, Ostracoda, Chrironomidae adults, Chironomidae larvae, Cladocera, Hydracarina, *Gammarus* spp., *Ephemeroptera* spp. larvae, *Odonata* spp. larvae, Thrips, and Other. The presence or absence of a yolk sac was also recorded for some larvae in 2017.

After processing, larvae were sent for species determination using genetic techniques. Genetic testing was unavailable or inconclusive for some 2017 samples. When this was the case, we assigned the species based on available information on species composition at that area. For example, as samples with genetic information indicated that 100% of the larvae in Cross Village in 2017 were lake whitefish, we assumed that unidentified larvae in that area were also lake whitefish.

*Figure 19: Coregonid larvae under microscope before gut processing. Photo by Jillian Mayer.*

## Zooplankton Sample Processing

Zooplankton samples were processed at the LTBB hatchery and USGS GLSC using the same microscopes as above. Organisms were enumerated and identified into the same categories as for stomach contents. Each sample was strained through a 200µm (LTBB) or 63µm (USGS GLSC) sieve (difference due to available equipment) to remove ethanol. The sample was then diluted with water to a measured volume of 200-1000mL. Subsamples were taken using a Hensen-Stempel pipette and placed into a Bogorov zooplankton counting chamber (Figure 20). Up to 25% of each zooplankton sample was analyzed to provide a representative sample of the available prey community. Up to 20 individuals from each taxa were measured (total length) to the nearest 0.01µm, and all organisms with a head present were enumerated (Figures 22, 23, 24).

We calculated the total number of organisms of each taxon in a zooplankton sample, as well as the total number of organisms of all taxa combined, according to methods in Dettmers et al. (2003). The total number of organisms of each taxa, and then all taxon combined, was calculated by dividing the number of organisms counted in the sub-sample by the proportion of the sample volume processed. Potential prey (all organisms of all taxa found in zooplankton sample) densities were calculated by multiplying the total number of organisms in a sample (on a given site and date) by the volume of water filtered by the zooplankton net: 2570 L. This produced the density of potential prey items per liter of lake water, at that site and date. Veligers were excluded from counts of potential prey because when they were present, they were too numerous to count and were never found in diets. Nematodes were also excluded because they were misidentified at the beginning of laboratory work, were extremely rare, and were never found in diets.

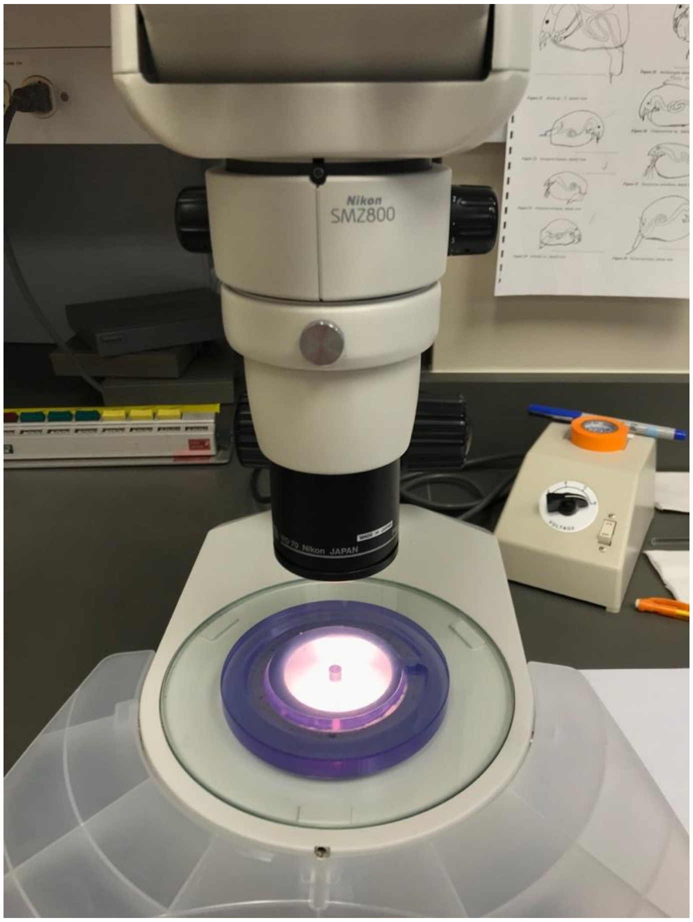


*Figure 20: 5mL zooplankton sub-sample in Bogorov counting chamber, ready for processing at USGS GLSC. Photo by Kayla Musil.*

## Diet Selectivity

Diet selectivity was calculated using the Chesson's α index of selectivity assuming no food depletion (Chesson 1983; Figure 21).

$$\hat{\alpha}_i = \frac{r_i / n_i}{\sum_{j=1}^{m} r_j / n_j}, \quad i = 1, \ldots, m$$

*Figure 21: Chesson's (1983) alpha index of selectivity assuming no food depletion in the environment.*

In Chesson's (1983) index (Figure 21), $r_i$ is the proportion of items of food type *i* in the diet, $n_i$ is the proportion of items of food type *i* in the environment, and m is the number of prey categories in the environment. Diet selectivity was calculated using relative proportions of prey taxa in guts and zooplankton samples. When taxa appeared in diets but not in the environment, they were excluded from selectivity calculations per suggestions by Steve Pothoven (personal communication, April 2017) and Jason Smith (personal communication, April 2017). Chesson's α ranges from 0 (complete avoidance) to 1 (complete preference). Where α/m, there is no preference for the food type, as it is found in equal numbers in diets and the water column. If $\alpha > 1/m$, larvae are selecting for that prey type. If $\alpha < 1/m$, larvae are avoiding the prey type.

To determine diet selectivity at each area by species, the diets of all larvae of one species in an area in one year were combined. For example, the diet contents of all cisco found in Grand Traverse Bay in 2017 were combined to establish the relative composition of prey taxa among all cisco guts at that area in 2017. We performed an analogous process to determine the potential prey community at an area in a given year: all potential prey individuals from different sites and dates (within one area and year) were combined to establish the relative composition of prey taxa in the environment (at one area and year). With the relative composition of prey in the larval guts and environment within each area each year, we calculated Chesson's α.

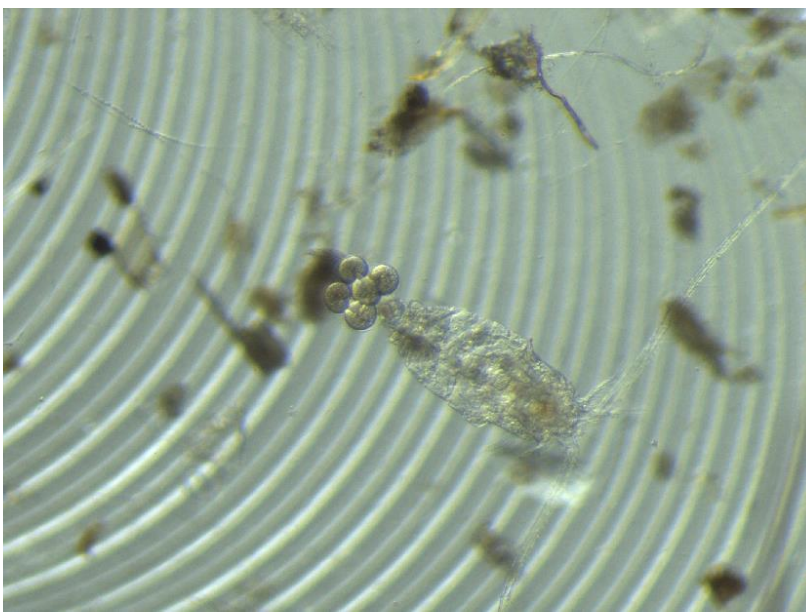


*Figure 22: Female calanoid copepod seen under microscope, from zooplankton sample. Taken by Jillian Mayer.*

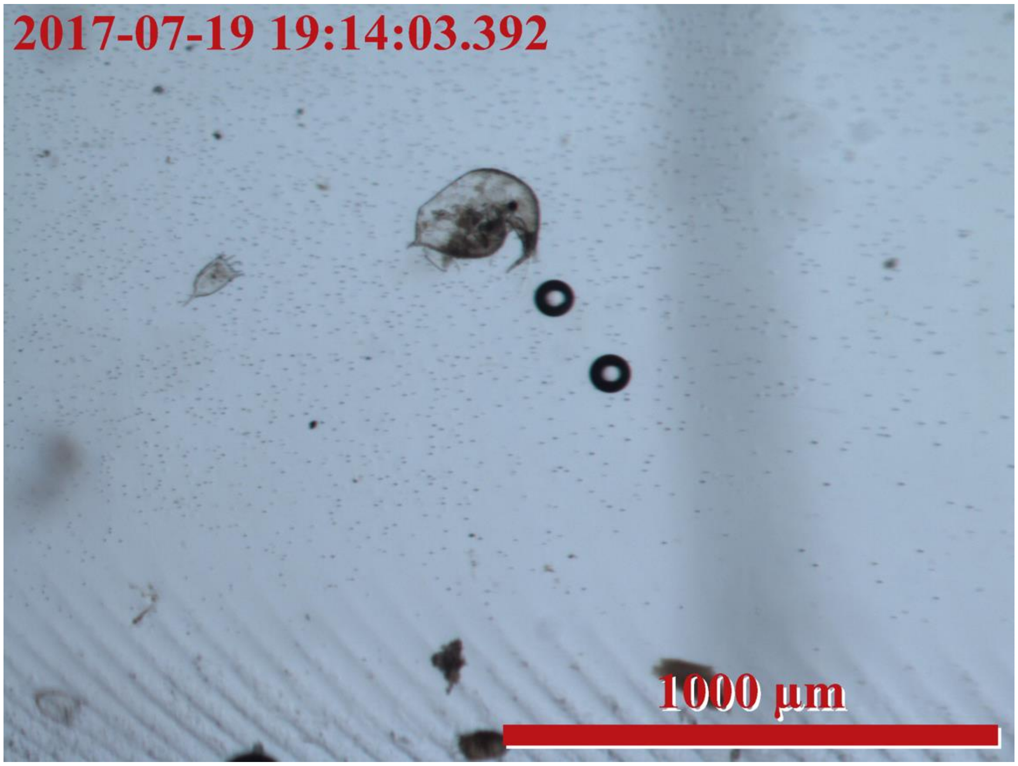


*Figure 23: Cladoceran (top middle) and rotifers (top left) under microscope, from zooplankton sample. Taken by Jillian Mayer.*

*Figure 24: Adult Chironomidae under microscope, from zooplankton sample. Taken by Jillian Mayer.*

## Results

### Larval Densities

Total coregonid larval densities in 2015 samples by site varied between 0.0001 larvae/L in Little Traverse Bay to 0.0034 larvae/L in Grand Traverse Bay (Table 2). Overall, the southernmost site sampled (Grand Traverse Bay) had the most larvae, the two middle-latitude sites (Charlevoix and Little Traverse Bay) had the lowest larval densities, and density increased in the north (Cross Village) though not to densities present at Grand Traverse Bay (Table 11).

In 2017, total larval coregonid densities varied between 0.0001 larvae/L at nine sites (Acme, Wilcox Nature Preserve, Fisherman's Island, Charlevoix 3, Cable's Bay, CMUBS, Iron Ore Bay, Big Stone Bay, and St. Ignace 1) and 0.0085 at Manistee A4 (Table 10). Overall, larval densities were highest in the southernmost areas, Ludington and Manistee, and remained lower than 0.0005 larvae/L on average at the remaining six areas (Table 10). Between 2015 and 2017, average larval density decreased at all areas except Little Traverse Bay, where average density increased (Table 10).

*Table 10: Number of larvae collected by 20 m tow (#/Tow) and number of tows ()conducted by site, Larval densities( #/L)and number of larvae (Total #) collected for 2017 and 2015. Larval densities were calculated by dividing the number of larvae at each sample by the volume of water sampled, (2570L).*

| | | 2017 | | | | 2015 | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Area** | **Site** | **#/Tow** | **#/L** | **Total #** | **#/L** | **#/Tow** | **#/L** | **Total #** | **#/L** |
| **Ludington** | Dam Beach | 17(1) | 0.0004 | 108 | 0.0012 ± 0.0015 | | | | |
| | Ludington 1 | 118(1) | 0.003 | 232 | | | | | |
| | Pentwater | 9(1) | 0.0002 | 79 | | | | | |
| **Manistee** | Captain Johns State Park | 42(1) | 0.0011 | 108 | 0.0048 ± 0.0053 | | | | |
| | Manistee A4 | 34(1) | 0.0085 | 651 | | | | | |
| **Grand Traverse Bay** | Acme | 3(1) | 0.0001 | 135 | 0.0001± 0.0001 | - | - | - | 0.0034± 0.0047 |
| | Elk Rapids Day Park | 0(1) | 0 | 54 | | 272(2) | 0.0068± 0.0047 | 272 | |
| | Wilcox Nature Preserve | 4(1) | 0.0001 | 57 | | - | - | - | |
| **Charlevoix** | Fisherman's Island | 4(1) | 0.0001 | 62 | 0.0001± 0.0002 | 20(3) | 0.0002± 0.001 | 20 | 0.0002± 0.0001 |
| | Charlevoix 1 | 0(1) | 0 | 0 | | - | - | - | |
| | Charlevoix 2 | 0(1) | 0 | 3 | | - | - | - | |
| | Charlevoix 3 | 2(1) | 0.0001 | 6 | | - | - | - | |
| **Little Traverse Bay** | Petoskey State Park | 72(4) | 0.0005 ± 0.0008 | 164 | 0.0005± 0.0008 | 11(2) | 0.0001± 0.0002 | 11 | 0.0001± 0.0002 |
| **Beaver Island** | Cable's Bay | 3(1) | 0.0001 | 52 | 0.0001± 0.0001 | | | | |
| | CMUBS | 5(1) | 0.0001 | 68 | | | | | |
| | Dunegal's Bay | 0(1) | 0 | 16 | | | | | |
| | Iron Ore Bay | 2(1) | 0.0001 | 56 | | | | | |
| | Lookout Point | 12(1) | 0.0003 | 90 | | | | | |

*Table 10 (Cont): Number of larvae collected by 20 m tow (#/Tow) and number of tows ()conducted by site, Larval densities( #/L)and number of larvae (Total #) collected for 2017 and 2015. Larval densities were calculated by dividing the number of larvae at each sample by the volume of water sampled, (2570L).*

| | | **2017** | | | | **2015** | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Area** | **Site** | **#/Tow** | **#/L** | **Total #** | **#/L** | **#/Tow** | **#/L** | **Total #** | **#/L** |
| **Cross Village** | Big Stone Bay | 6(3) | 0.0001± >0.0008 | 35 | 0.0006± 0.005 | 127(5) | 0.0006 | 127 | 0.0015± 0.0012 |
| | Cross Village | 63(2) | 0.0008± 0.001 | 123 | | - | - | - | |
| | Sturgeon Bay | 123(3) | 0.001± 0.0016 | 252 | | 95(1) | 0.0024 | 95 | |
| **St. Ignace** | St. Ignace 1 | 5(1) | 0.0001 | 10 | 0.0001± 0.0001 | | | | |
| | St. Ignace 2 | 0(1) | 0 | 9 | | | | | |
| **Naubinway** | Naubinway | 4(1) | 0.0001 | 175 | 0.0001 | | | | |

## Larval Distributions

In 2015, cisco larvae were found in all areas sampled except in Cross Village (Figure 25). The highest representation of cisco among the 67 larvae for which species identification was available was found in Grand Traverse Bay (77%) and total composition decreased with northward latitude. Though the general trend shows decreasing representation of cisco with increasing latitude (Figure 25) representation nevertheless varied among sites and dates (Table 10) within areas. In Grand Traverse Bay, cisco representation varied between 66% and 80%; at Charlevoix representation varied between 0% and 50%; at Little Traverse Bay representation varied between 0% and 50%; and in Cross Village 0% of larvae were cisco. In 2016, 60% of the 5 larvae collected at Charlevoix were cisco (Figure 26). In 2017, 187 larvae were identified to the species level. In 2017, as in 2015, cisco comprised the majority of larvae caught at Grand Traverse Bay (67%; Figure 27). At all other areas, cisco larvae comprised less than one-quarter of larvae caught (Ludington and Beaver Island) or were absent (Manistee, Charlevoix, Little Traverse Bay, Cross Village, Naubinway). Like in 2015, 2017 species composition varied among sites and dates within areas: at Ludington, cisco representation varied between 0% and 100%; at Grand Traverse Bay representation varied between 40% and 90%; at Beaver Island representation varied between 0% and 0.06%; at other areas no cisco were ever found.

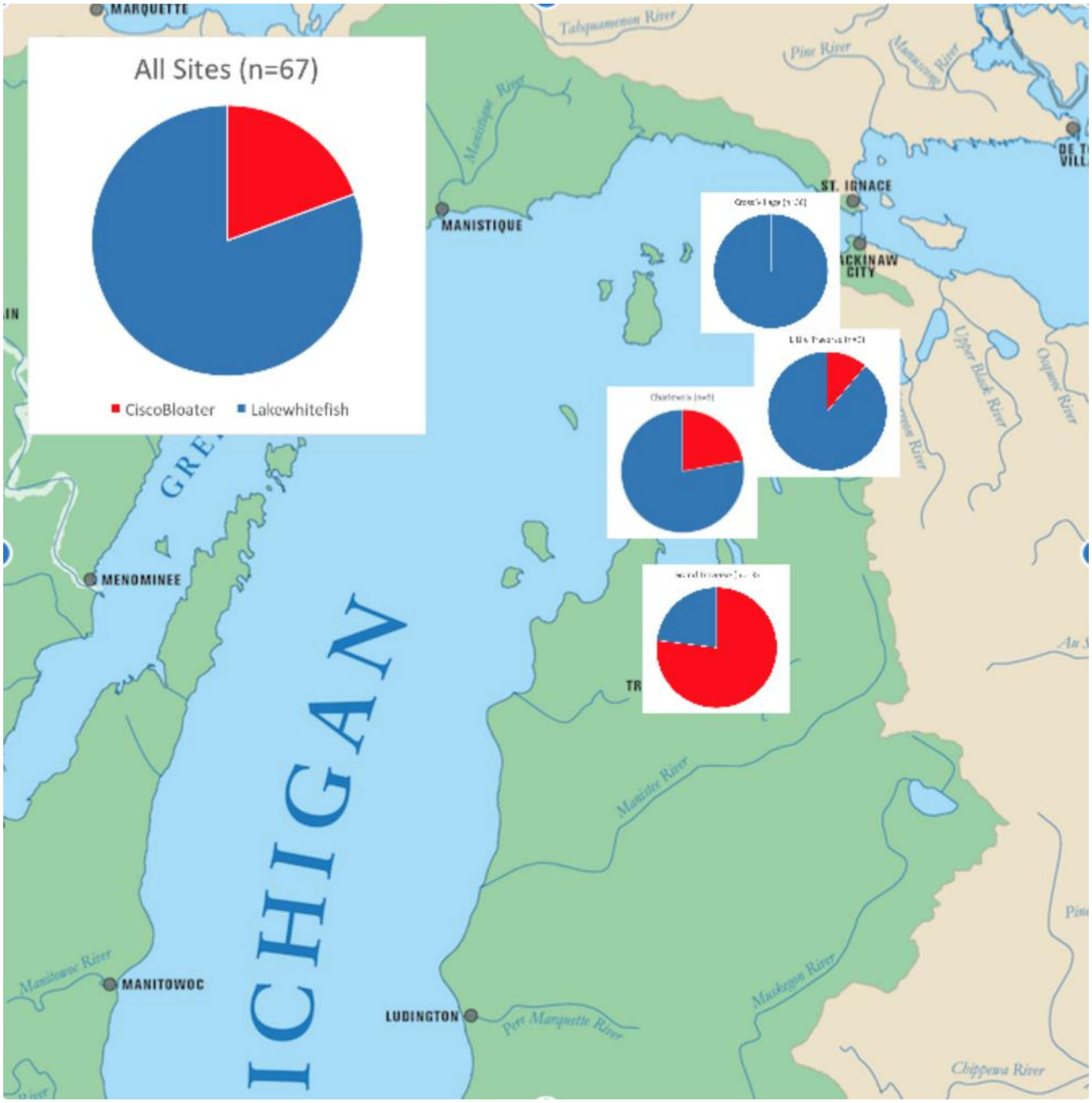


*Figure 25: Larval composition in 2015 coregonid samples (n=67 larvae) at Grand Traverse Bay, Charlevoix, Little Traverse Bay, and Cross Village. Red = cisco larvae in each area; blue = lake whitefish larvae.*

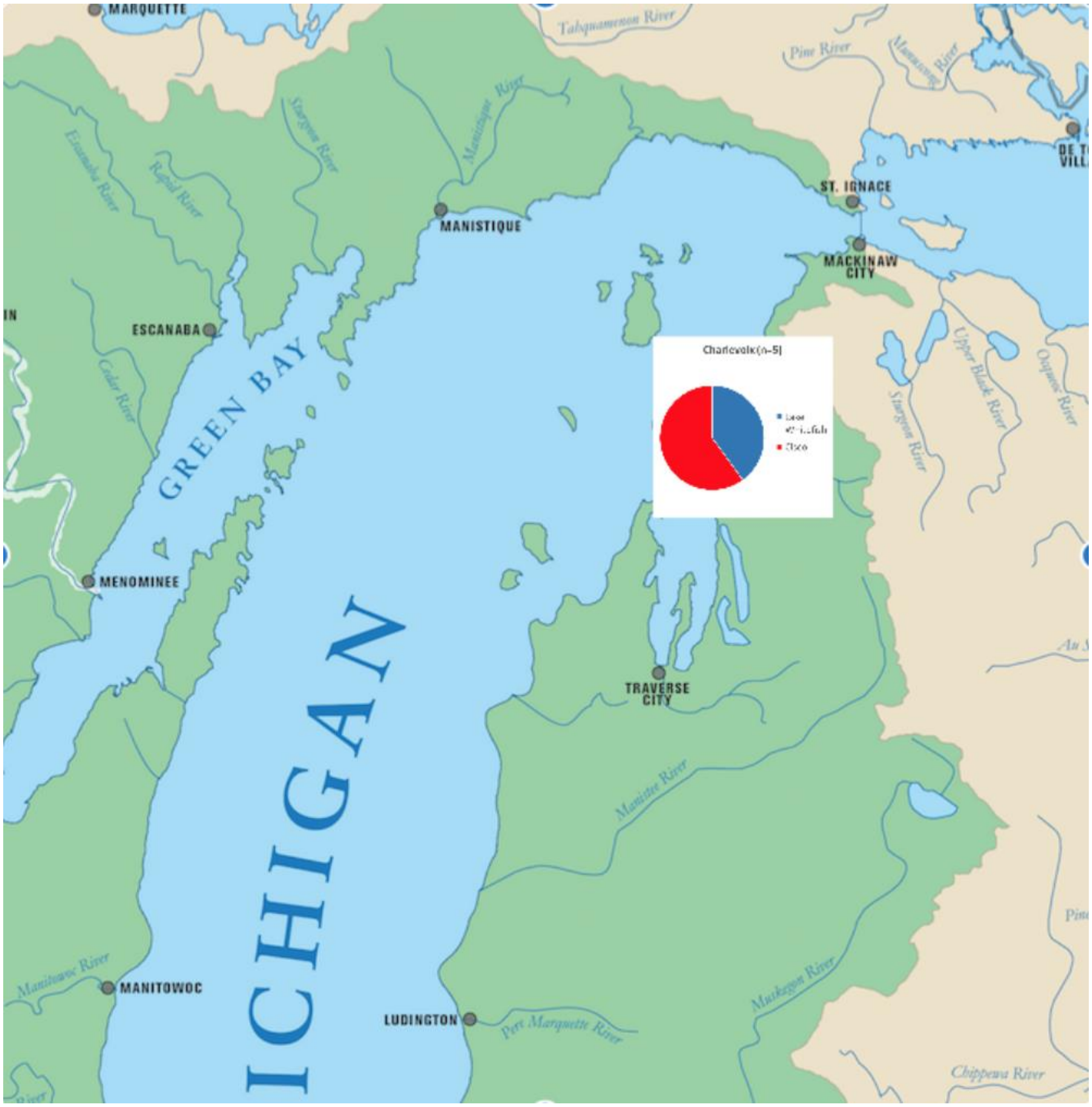



*Figure 26: Larval composition in 2016 coregonid sampling at Charlevoix (n=5 larvae). Red = cisco larvae; blue = lake whitefish larvae.*

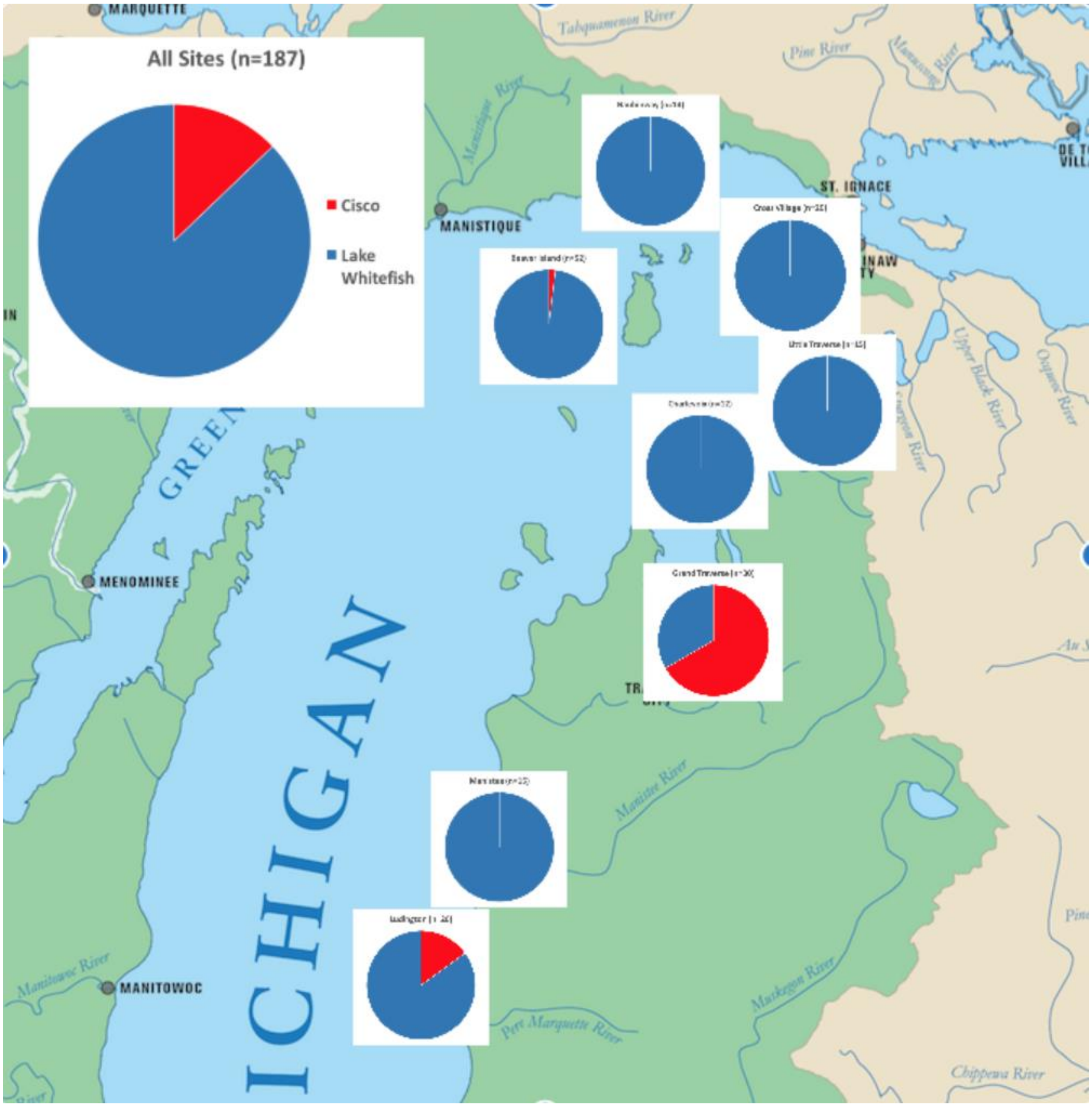



*Figure 27: Larval composition in 2017 coregonid sampling (n=187 larvae) at, Ludington, Manistee, Grand Traverse Bay, Charlevoix, Little Traverse Bay, Beaver Island, Cross Village, St. Ignace, and Naubinway. Red = cisco larvae in each area; blue = lake whitefish larvae.*

## Larval Lengths and Gut Contents

In 2015, cisco larvae ranged from 9mm to 18mm (total length) and lake whitefish larvae ranged from 12mm to 24mm. At areas where cisco and lake whitefish were both present (Grand Traverse Bay, Charlevoix, and Little Traverse Bay), cisco were, on average, smaller than lake whitefish (Table 12), but these differences were never significant between the two species at a given area ($p>0.05$ at all sites). Compared to lake whitefish, cisco overall contained fewer gut contents, and were more likely to have empty guts (Table 12). Cisco were found with up to 12 prey in guts, while lake whitefish were found with up to 43. Only at Little Traverse Bay did cisco guts contain more prey than lake whitefish. Differences between average gut contents were significant at Charlevoix ($p<0.05$).

In 2016 at Charlevoix, cisco larvae ranged from 17mm to 20mm, and lake whitefish ranged from 15mm to 16mm (Table 13). Overall, lake whitefish were larger. No larvae were found with empty guts. Cisco were found with 20-26 gut contents, and lake whitefish were found with 20-33 gut contents (Table 13) Overall, lake whitefish contained more gut contents. Neither differences in average length nor average number of gut contents between species were significant ($p>0.05$ for both).

In 2017, cisco larvae ranged from 12mm to 19mm and lake whitefish ranged from 7mm to 21mm. Overall, cisco were smaller than lake whitefish (Table 14) The only area at which cisco were larger than lake whitefish was at Beaver Island, but only one cisco larvae was caught (1.92% of larvae from area). Differences in size were not significant at any area. Cisco contained up to 15 items, while lake whitefish contained up to 136. Overall, more cisco had empty guts than lake whitefish (Table 14). Differences in the number of gut contents was not significant at any area ($p>0.05$ for all areas).

*Table 12: Coregonid larval composition in 2015 sample in % of total sample with species genetic identification, mean length of larvae selected for stomach content analysis (± standard deviation), and mean number of items in gut contents (± standard deviation).*

| | **Cisco** | | | | **Lake Whitefish** | | | |
|---|---|---|---|---|---|---|---|---|
| **Area** | **N** | **Length (mm)** | **Gut Contents (N prey)** | **Empty Guts (% )** | **N** | **Length (mm)** | **Gut Contents (N prey)** | **Empty Guts (%)** |
| **Grand Traverse Bay** | 10 | 13.3 ± 1.3 | 1.9 ± 1.2 | 10 | 3 | 15.3 ± 12.42 | 7.7 ±12.4 | 33 |
| **Charlevoix** | 2 | 10.5 ± 2.12 | 0.5 ± 0.7 | 50 | 7 | 15.4 ± 1.3 | 9.1 ± 5.1 | 14.3 |
| **Little Traverse Bay** | 1 | 15 | 12 | 0 | 8 | 18 ± 1.6 | 5.5 ± 3.6 | 12.5 |
| **Cross Village** | 0 | - | - | - | 36 | 16.9 ± 2.9 | 11 ± 10.6 | 5.6 |
| **All Sites** | 13 | 13 ± 2.2 | 2.2 ± 2.5 | 15.4 | 54 | 16.8 ± 2.7 | 9.8 ± 9.4 | 9.3 |

*Table 13: Coregonid larval composition in 2016 sample in % of total sample with species genetic identification, mean length of larvae selected for stomach content analysis (± standard deviation), and mean number of items in gut contents (± standard deviation)*

| | Cisco | | | | Lake Whitefish | | | |
|---|---|---|---|---|---|---|---|---|
| **Area** | **N** | **Avg Length (mm)** | **Avg Gut Contents** | **% Empty Guts** | **N** | **Avg Length (mm)** | **Avg Gut Contents** | **% Empty Guts** |
| **Charlevoix** | 3 | 18.3 ± 1.5 | 24 ± 3.5 | 0 | 2 | 15.5 ± 0.7 | 26.5 ± 9.1 | 0 |

*Table 14: Coregonid larval composition in 2017 sample in % of total sample with species genetic identification, mean length of larvae selected for stomach content analysis (± standard deviation), and mean number of items in gut contents (± standard deviation).*

| | Cisco | | | | Lake Whitefish | | | |
|---|---|---|---|---|---|---|---|---|
| **Site** | **N** | **Avg Length (mm)** | **Avg Gut Contents** | **% Empty Guts** | **N** | **Avg Length (mm)** | **Avg Gut Contents** | **% Empty Guts** |
| **Ludington** | 3 | 14.3 ± 2.4 | 0 | 100 | 17 | 15.5 ± 0.87 | 1.8 ± 2.8 | 37.5 |
| **Manistee** | 0 | - | - | - | 15 | 15.2 ± 0.64 | 3.9 ± 3.1 | 6.7 |
| **Grand Traverse Bay** | 20 | 14 ± 1.4 | 4.9 ± 3.5 | 10 | 10 | 14.4 ± 1.2 | 4.7 ± 3.7 | 10 |
| **Charlevoix** | 0 | - | - | - | 12 | 18.4 ± 1.8 | 14.3 ± 5.8 | 0 |
| **Little Traverse Bay** | 0 | - | - | - | 15 | 15.7 ± 3.5 | 12 ± 9.1 | 0 |
| **Cross Village** | 0 | - | - | - | 29 | No data available | 20.9 ± 8.1 | 0 |
| **Beaver Island** | 1 | 18.8 | 15 | 0 | 52 | 17.7 ± 1.2 | 9.8 ± 7.8 | 6.8 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Naubinway** | 0 | - | - | - | 14 | No data available | 63.5 ± 39.7 | 0 |
| **All Sites** | 24 | 14.21 ± 1.8 | 4.71 ± 4.2 | 20.83 | 163 | 16.60 ± 2.1 | 15.96 ± 21.7 | 7.1 |

## Pelagic Prey Densities

Most organisms found in the zooplankton samples, whether or not they were zooplankton organisms, were considered potential prey for larval coregonids. Veligers (numerous) and nematodes (rare) not enumerated or included in density calculations. Average prey densities ranged across areas, and generally showed high variability among sites and dates within each sampling area (Figure 28). In 2015, prey densities were slightly higher in the mid-latitudes (Charlevoix, Little Traverse Bay) compared to lower latitudes (Grand Traverse Bay), and ranged from 0.1 prey/L to 0.93 prey/L (Figure 28). In 2016, density in Charlevoix was lower than that in both 2015 and 2017. In 2017, densities ranged from 0.03 prey/L(Charlevoix) to 4.73 prey/L (Ludington) and were lower than in previous years (Figure 28). Densities tended to increase towards the north, except for at Ludington where the highest densities were found.

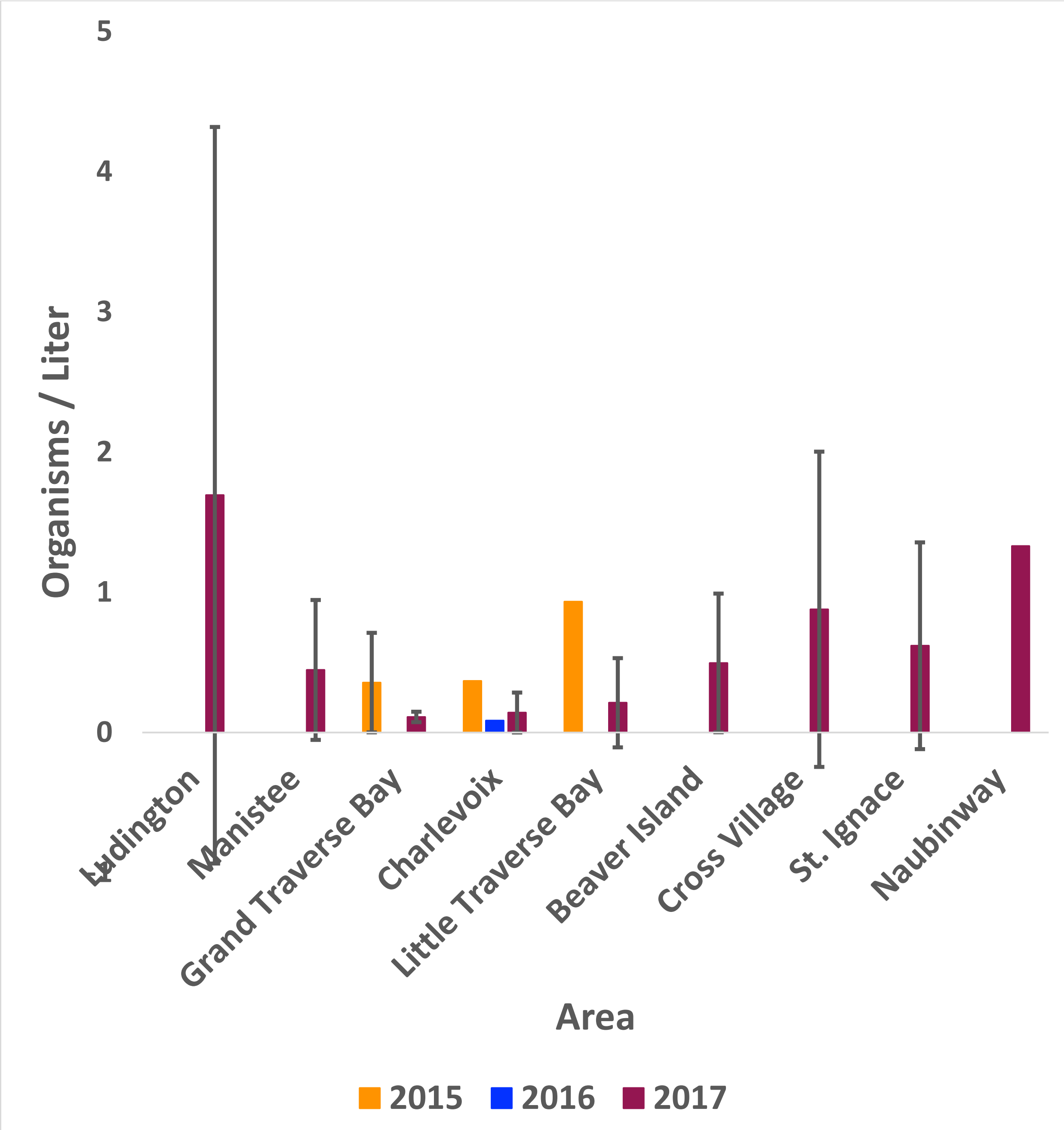



Figure 28: *Average pelagic prey densities by area in 2015, 2016, and 2017 samples, south (Ludington) to north (Naubinway). Error bars indicate one standard deviation of the mean.*

## Diet Contents and Selectivity

The presence or absence of egg yolk sacs was recorded for 20 cisco and 81 lake whitefish from 2017 (Figure 29). Cisco over 16.4mm had no yolk sac present. The average size of cisco with yolk sac was 13.72mm and those without a yolk sac was 14.62 mm. There was no significant difference in the sizes of cisco with and without yolk sacs ($T=2.1$, $p>0.05$).

The largest size of lake whitefish with a yolk sac was 17.78mm, and the average size of lake whitefish yolk sac larvae was 14.83mm (Figure 29). The average size of lake whitefish without yolk sac was 17.40mm, and there was a significant difference in the size of yolk sac and no-yolk sac larvae ($T=2.03$, $p<0.05$).

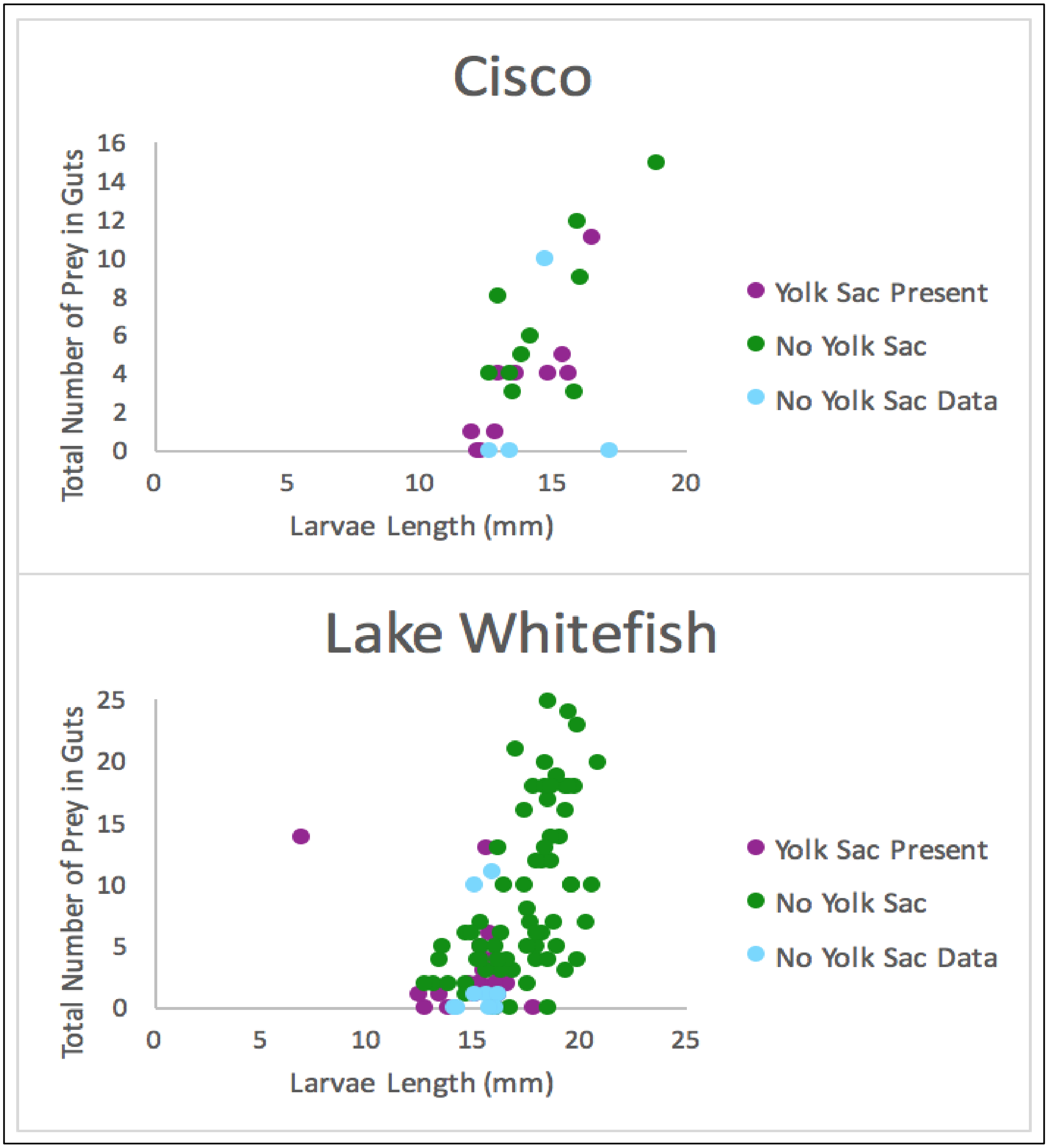



*Figure 29: Larval lengths (mm) and number of diet contents by species and yolk sac stage in 2017.*

In 2015, the diets of both cisco and lake whitefish consisted largely of adult Calanoid and Cyclopoid copepods (Figure 30) even when those items were not the most numerous in the pelagic water column (as in Charlevoix and Little Traverse Bay). The pelagic prey community was dominated by adult copepods (Calanoids, Cyclopoids, and Harpacticoids) and sub-adult copepods (nauplii and copepodites). Using Chesson's α index of selectivity, we determined that lake whitefish larvae showed positive selection for Calanoids, Cyclopoids, and Harpacticoids at Little Traverse Bay, but negative selectivity for these taxa at Grand Traverse Bay (Figure 33). Where Chironomidae larvae were present, lake whitefish larvae always showed positive selectivity for them (Figure 33).

In 2016 at Charlevoix, the diets of cisco and lake whitefish were comprised entirely of adult Calanoid and Cyclopoid copepods (Figure 31). The available prey community was roughly 50% adult Calanoids and Cyclopoid, and 50% nauplii and copepodites. This prey composition is much different than in 2015, which was dominated by Chironomidae larvae and Hydracarina (Figure 30). Lake whitefish showed strong positive selectivity for cyclopoid copepods, but slight positive selectivity for Calanoids (Figure 34). Cisco showed weak positive selectivity for both Calanoid and Cyclopoid copepods Figure 34). All prey items found in diets were present in the zooplankton sample.

In 2017, diets and prey community at all sites were dominated by adult Calanoid and Cyclopoid copepods (Figure 32). The only notable departure was the diets of lake whitefish at Naubinway, which consumed almost 40% cladocera, despite there being few cladocera in the environment (Naubinway's available prey community was dominated by nauplii and copepodites; Figure 32. At all sites except for Ludington and Naubinway, both cisco and lake whitefish positively selected for Calanoids and Cyclopoids (Figure 35). Cisco negatively selected for all other prey taxa (Figure 35). Lake whitefish also positively selected for Harpacticoids at Ludington and Cross Village, Chironomidae larvae at Beaver Island, Cross Village, and Naubinway, and cladocera at Cross Village and Naubinway (Figure 35). Lake whitefish negatively selected for most other prey taxa. As with the 2015 samples, some prey taxa were found in diets but not in zooplankton samples, so were excluded from selectivity analyses. Those taxa were: Chironomidae larvae at Charlevoix, Harpacticoids and "other" at Grand Traverse Bay, and Chironomidae larvae at Manistee, and Calanoids, Chironomidae adults, and "other" at Naubinway.

There are a few notable trends in these diet comparisons. First, while both larvae of both species consumed mostly copepods, lake whitefish larvae tended to eat a wider breadth of prey than cisco did. Second, benthic Chironomidae larvae was eaten by both species, however lake whitefish ate Chironomidae larvae with greater frequency. When available prey communities were not dominated by adult copepods, they tended to be comprised of nauplii and copepodites (see Grand Traverse 2015 [Figure 30], Little Traverse 2015 [Figure 30], Charlevoix 2016 [Figure 31], Grand Traverse 2017 [Figure 32], and Naubinway 2017 [Figure 32]).

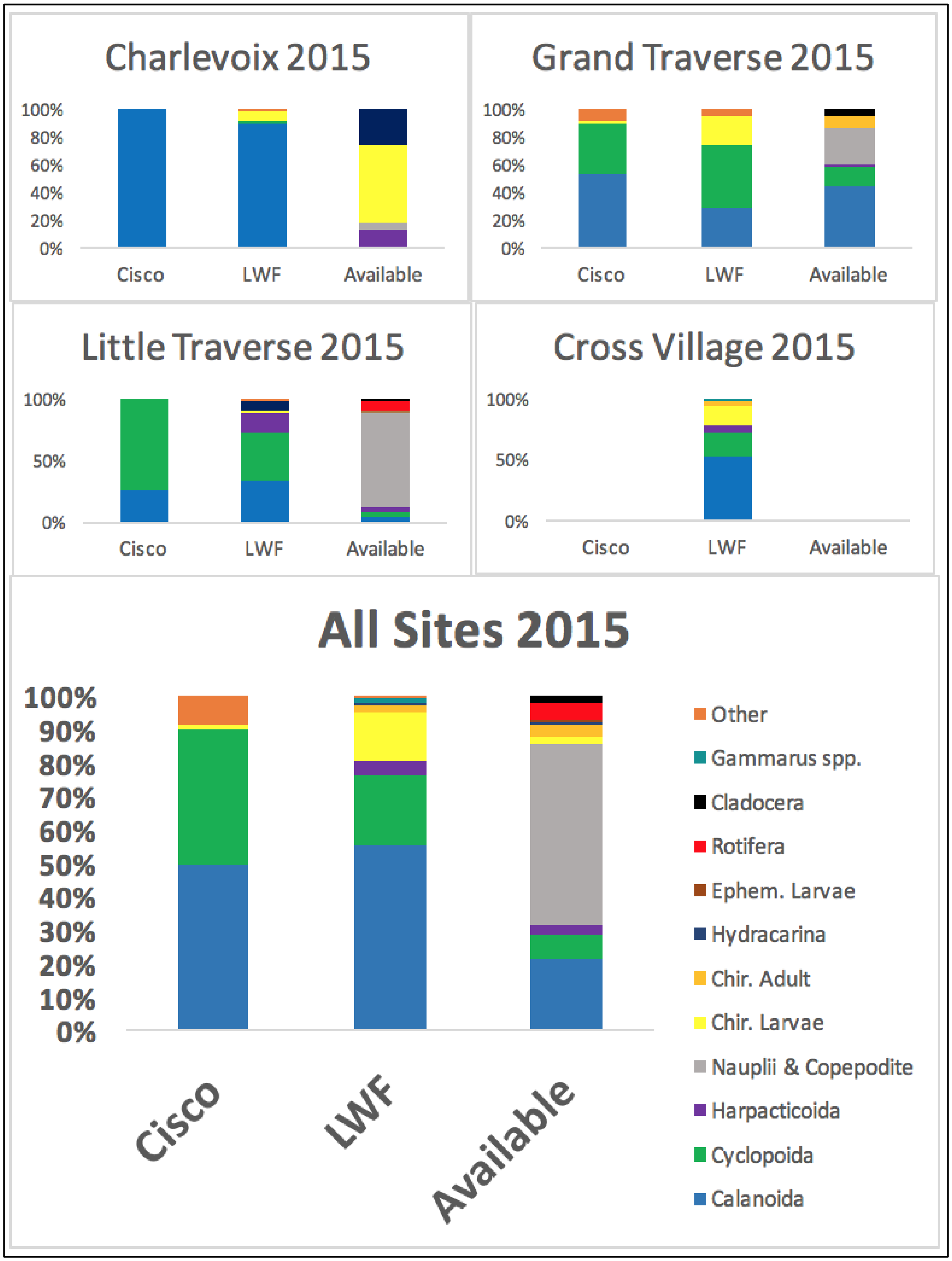



*Figure 30: Diet composition of cisco and lake whitefish larvae and pelagic prey availability by item in 2015 samples. The left-most columns represent the diet composition, by number of organisms, of all larval cisco processed at each area (Charlevoix, Grand Traverse Bay, Little Traverse Bay, and Cross Village), or all areas ("All Sites 2015") in 2015. The middle columns represent that for lake whitefish larvae. The rightmost columns represent the community composition of available prey in the water column.*

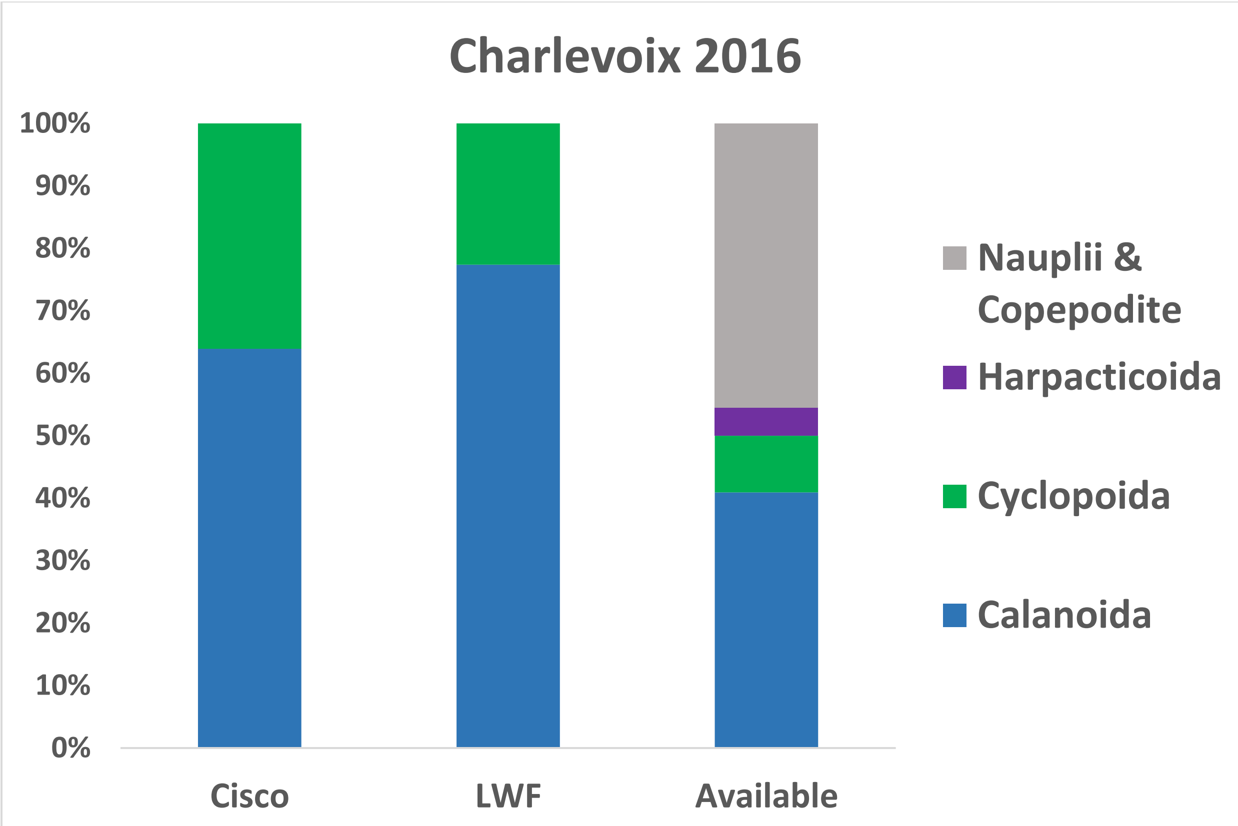



*Figure 31: Total diet composition and pelagic prey availability by item in 2016 at the one area sampled, Charlevoix. The left-most column represents the diet composition, by number of organisms, of all larval cisco processed. The middle column represents that for lake whitefish larvae. The rightmost column represents the community composition of available prey in the water column.*

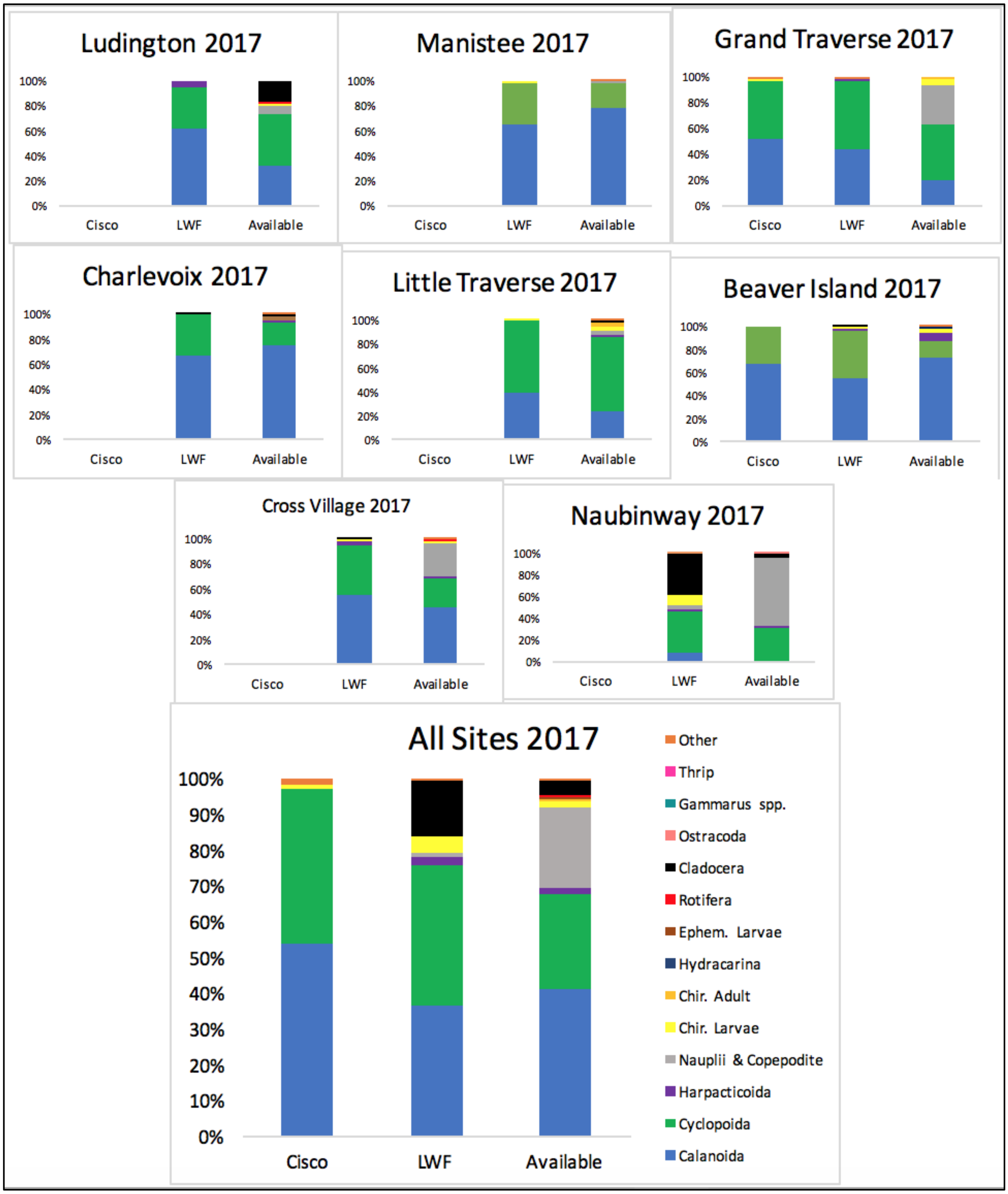



*Figure 32: Total diet composition and pelagic prey availability by item in 2017. The left-most columns represent the diet composition, by number of organisms, of all larval cisco processed at each area, or all areas ("All Sites 2017") in 2015. The middle columns represent that for lake whitefish larvae. The rightmost columns represent the community composition of available prey in the water column.*

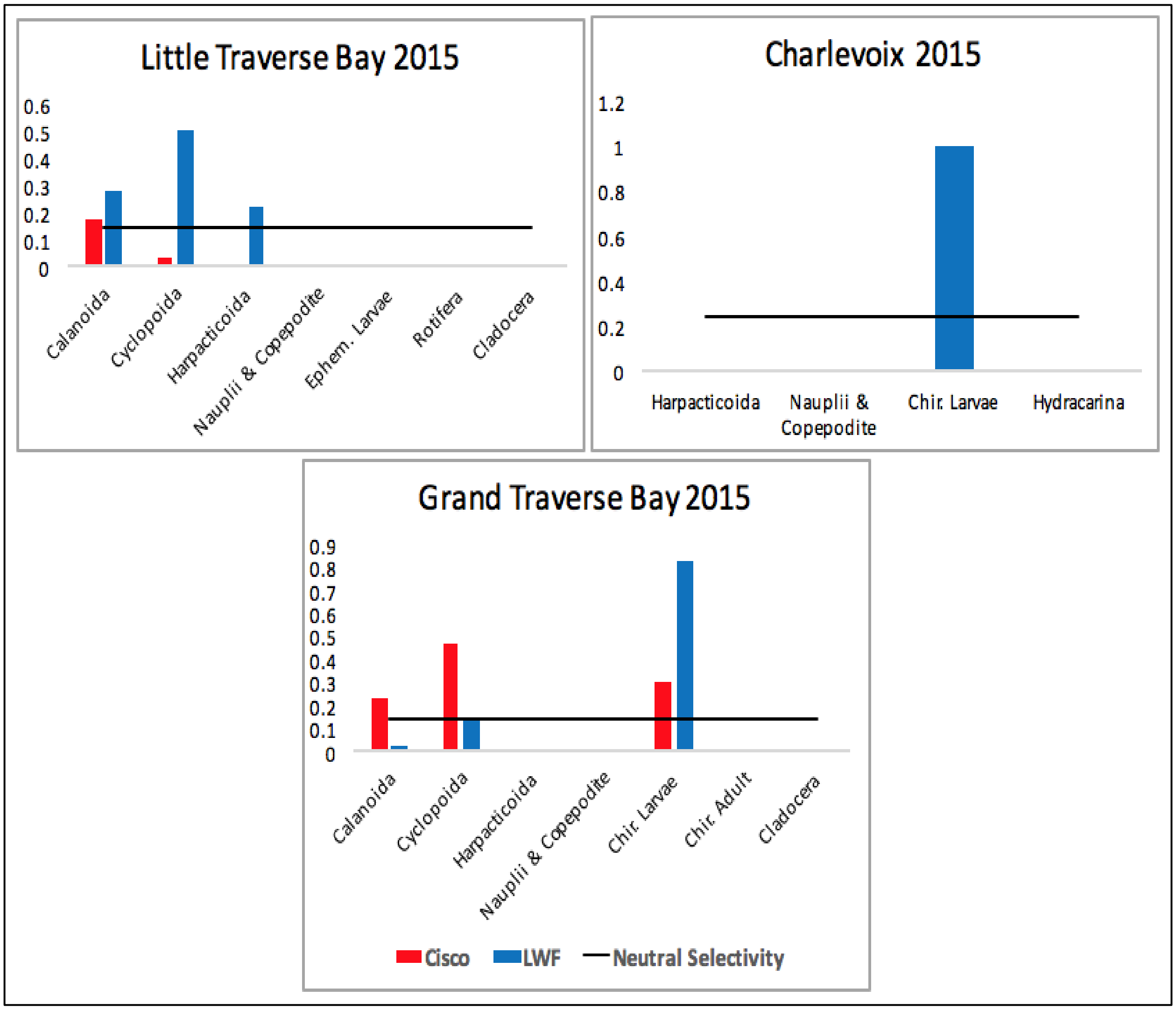



*Figure 33: Chesson's α selectivity values for areas with larvae and prey samples in 2015. Within each area, all larvae were combined to derive the above values. The x-axis lists all the prey taxa that were present in the environment. If a value is above the line of "neutral selectivity," the larvae positively selected for the prey taxa; if a value lies below this line, larvae selected against the taxa.*

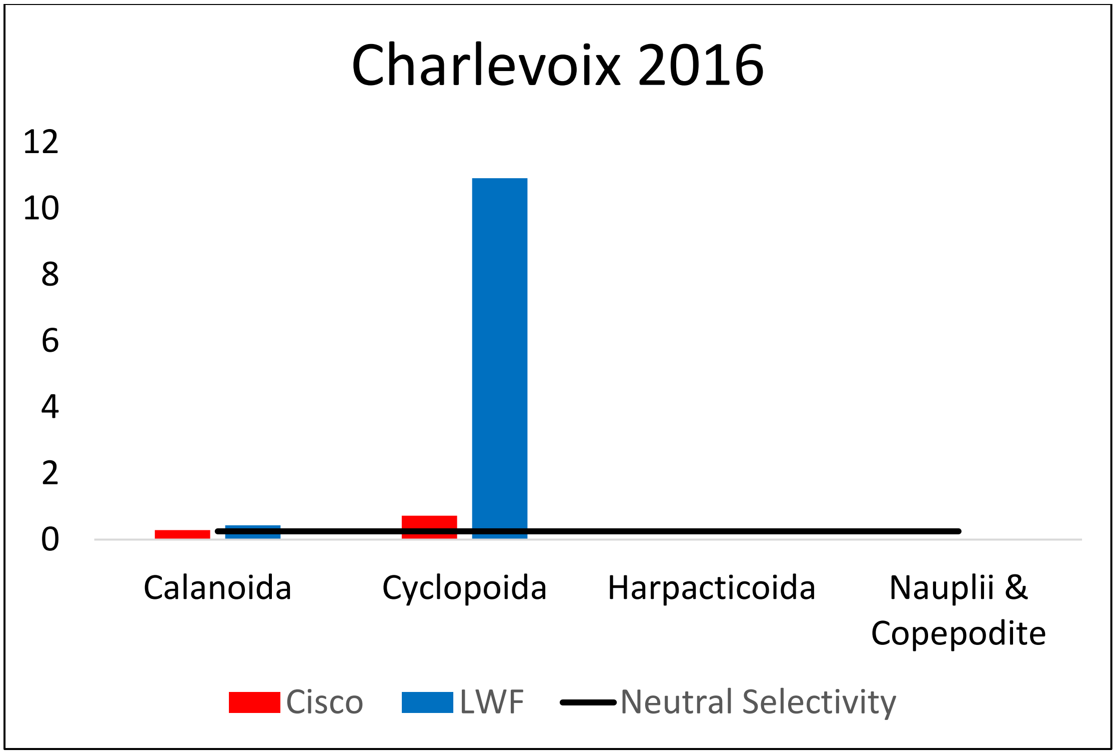



*Figure 34: Chesson's α selectivity values for Charlevoix in 2016. All larvae were combined to derive the above values. The x-axis lists all the prey taxa that were present in the environment. If a value is above the line of "neutral selectivity," the larvae positively selected for the prey taxa; if a value lies below this line, larvae selected against the taxa.*

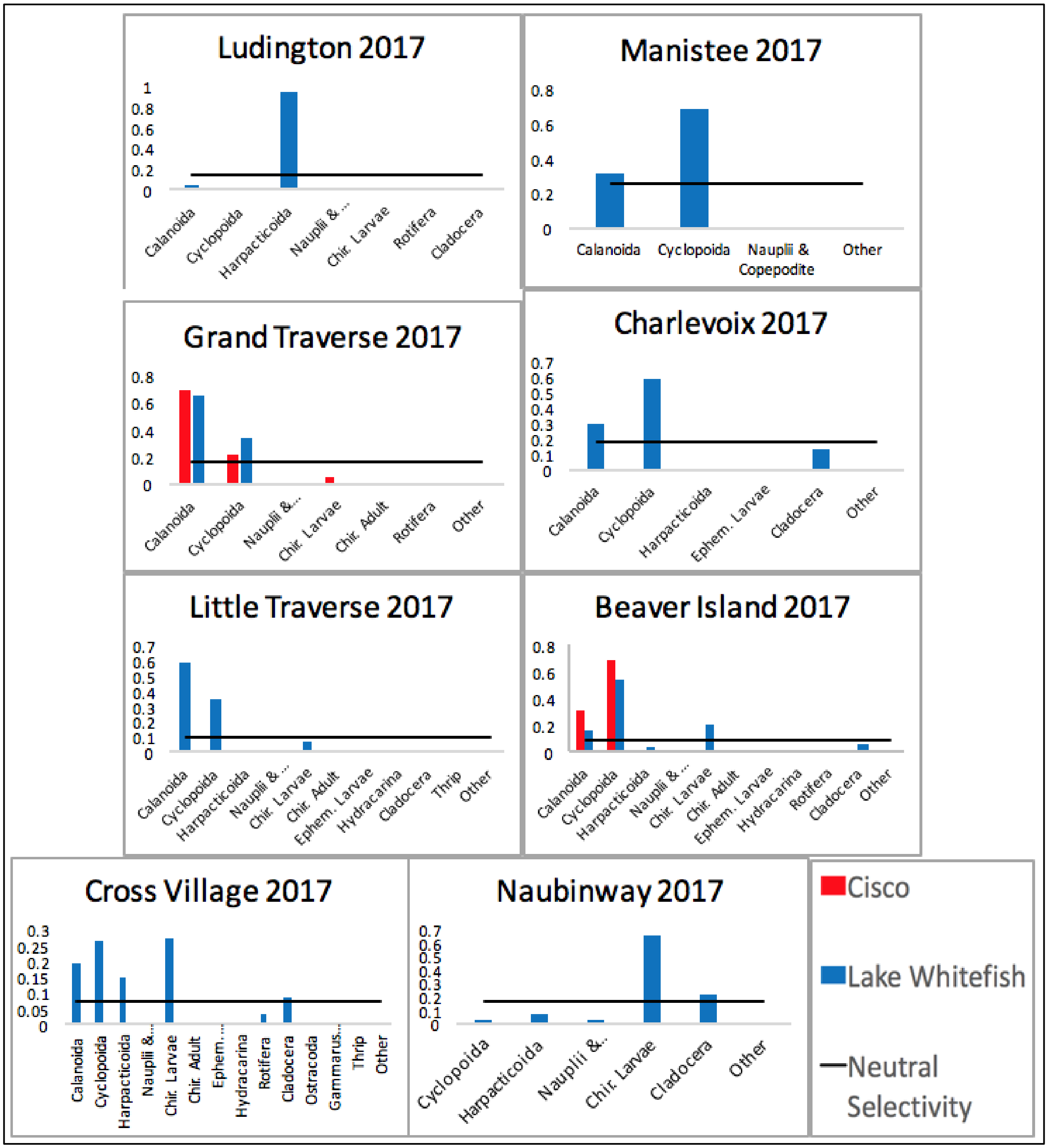



*Figure 35: Chesson's α selectivity values for areas with larvae and prey samples in 2017. Within each area, all larvae were combined to derive the above values. The x-axis lists all the prey taxa that were present in the environment. If a value is above the line of "neutral selectivity," the larvae positively selected for the prey taxa; if a value lies below this line, larvae selected against the taxa.*

## Discussion

Cisco larvae were found mostly in Grand Traverse Bay (Figures 25, 26, 27), where the only sizable population of cisco exists (unpublished data, Randall Claramunt, Michigan Department of Natural Resources, and Kevin Donner, Little Traverse Bay Bands of Odawa

Indians). There were few larval cisco in our samples in other areas. Nevertheless, our methods were not designed to estimate cisco larval density but rather to collect cisco for diet analysis. We did not find evidence that the higher larval cisco densities correlated with higher prey densities, as Grand Traverse Bay had some of the lowest prey densities each year but the largest representation of cisco. It is conceivable that cisco themselves are responsible for the low prey density in Grand Traverse Bay.

This is the first study to document early spring zooplankton (prey) abundances in northeastern Lake Michigan, which hovered near one organism per liter across areas and years and were never higher than 4.73 prey/liter. Densities were lower than any published data about contemporary Lake Michigan zooplankton densities, although results cannot be compared directly to other studies because they were conducted offshore and during summer. Tuchman and Barbiero (2004) found that between 1983 and 1999, annual main basin summer (August 1 – September 4) zooplankton densities averaged 21.5 zooplankton per liter. In 1998, spring zooplankton numbers in main-basin Lake Michigan hovered around 6 organisms/L (Barbiero et al. 2001). In 2001, summer zooplankton densities in southern Lake Michigan hovered around 1-10 zooplankton per liter (Hook et al. 2011). In other systems, good larval recruitment requires 50-100 zooplankton per liter (Li and Matthias 1982; Welker et al. 1994), and larvae generally improve their growth rates and survivability with higher zooplankton abundances and wider prey diversity (Seljeset et al. 2010).

Barbiero et al. (2001) note that a greater abundance of zooplankton and a greater diversity of taxa were found in Lake Michigan's main basin during summer 1998, as compared to spring. Preliminary data from an unpublished study by this author suggests that prey densities increase more than 50-fold in July in near-shore northeastern Lake Michigan. Summer prey density may be sufficient to support larval coregonid recruitment, even given the extremely low spring densities shown in this study. With changing weather patterns and shifting zooplankton community structure, larval coregonids may be falling victim to spatio-temporal mismatch. Since there is no obvious correlation between prey densities and larval abundance as predicted by Claramunt et al. (2009), larvae may not be emerging during times with sufficient food. Cisco and lake whitefish were previously believed to absorb their egg yolk sac by 14mm (Auer 1982; Oyadomari 2005). We found that both cisco and lake whitefish often retained their yolk sacs past this threshold (Figure 29). It is conceivable that larval coregonids are maintaining their yolk sacs until longer lengths in northeastern Lake Michigan because early spring prey densities are so low. Future studies should test the plasticity of this trait in larval coregonids.

The pelagic water column was frequently dominated by Calanoid and Cyclopoid copepods. This is in agreement with the findings of Tuchman and Barbiero (2004) who document how the introduction of *Bythotrephes longimanus*, a predatory cladoceran, changed the Lake Michigan zooplankton communities in the mid-1980s. Due to predation and competition by *B. longimanus*, cladoceran abundances decreased while copepods remained largely unaffected, and overall species richness of the zooplankton community decreased. We found negligible numbers of cladocera in the water column except for the northernmost site, Naubinway, at the end of May 2017. The dominance of copepods in the Lake Michigan zooplankton community is well documented (Vanderploeg et al. 2012; Barbiero et al. 2009; Barbiero et al. 2001; Dettmers et al. 2003), and supported in this study.

Calanoid and cyclopoid copepods dominated larval diets, similar to other studies of cisco and lake whitefish diets (Davis and Todd 1998; Johnson et al. 2009; Jacobson 1982). Adult copepods were usually positively selected for, especially among cisco. Many taxa that were rare in the water column were often negatively selected against in diets, probably because they were so rarely encountered and comprised a small amount of the available prey biomass. When diets were not dominated by adult copepods, nauplii and copepodites were often numberous. Nauplii and copepodites are smaller than adult copepods, and thus have smaller biomass. Without converting the numbers of individual prey items in diets and the water column, we can nevertheless hypothesize that the larvae are eating not just what is abundant numerically, but what comprises the majority of biomass at most areas: adult copepods.

Notably, lake whitefish tended to have a greater diversity of prey taxa in their guts. Chironomidae larvae, a benthic macroinvertebrate, occasionally appeared in cisco diets but was always negatively selected. Chironomidae larvae were often positively selected for by lake whitefish, indicating that larval lake whitefish may be more benthic feeders than larval cisco are. Studies have noted that gape size and gill raker number are important determinants of feeding preferences in coregonids (Kahilainen et al. 2011), and may account for the differences in diets.

Future studies of coregonid diets in northeastern Lake Michigan should consider differential digestion rates of prey. Sutela and Hussko (2000) showed that different zooplankton taxa are digested at different rates in coregonid guts, and recommend either analyzing only foreguts for diet contents or multiplying taxa by prey-specific coefficients to eliminate bias associated with entire gut analysis. The authors do note that since larval coregonids lack a morphological and functional stomach, the disparate pattern of digestion may be smaller in larvae than in adult planktivores.

Our results do not fully support studies that have suggested that lake whitefish larvae may be competitively dominant when they co-occur with cisco larvae (Davis and Todd 1998). From our results, it is clear that cisco and lake whitefish have similar diets. At all sites except Beaver Island (n=1 larvae) lake whitefish were, on average, larger than cisco but these differences were rarely statistically significant (Tables 12, 13, 14). On the other hand, across most areas and years, cisco were more likely to have empty guts than lake whitefish (Tables 12, 13, 14). We do not find the evidence convincing that lake whitefish are negatively affecting cisco larvae at the areas where they co-occur. Given the low and variable larval and prey densities over a large area, it seems more likely lack of prey overall is having a larger effect on both species' larvae than competition is.

This study provides support for concerns that coregonids may experience sub-optimal conditions for larval survival in northeastern Lake Michigan due to oligotrophic conditions in spring. Although the remnant Grand Traverse Bay cisco population is experiencing a recovery, lake whitefish populations in northeastern Lake Michigan are experiencing a decline. We observed low zooplankton densities in our samples and a predominance of adult copepods, as expected following studies of decreasing productivity and changing zooplankton communities in Lake Michigan (Tuchman and Barbiero 2004; Barbiero et al. 2001). However, Dettmers et al. (2003) found evidence that low zooplankton density was more influential than changing zooplankton community composition for failing yellow perch (*Perca flavescens*) in sourthern Lake Michigan. In addition, other studies document how copepods are the preferred prey of larval coregonids in both inland lakes (Davis and Todd 1998; Johnson et al. 2009; Jacobson 1982) and the Great Lakes. Still, we can assume that larval coregonids are being affected by the oligotrophication of Lake Michigan. Larval coregonids face other threats including climate change change (Collingsworth et al. 2017) and predation (Myers et al. 2015; Krueger and Hrabik 2005). We recommend continued monitoring of prey densities and coregonid feeding ecology in northeastern Lake Michigan.

# Chapter 6: Final Thoughts

This project is among the first to document the contemporary status and ecology of cisco in northeastern Lake Michigan. It is also the first to document the perspectives of LTBB citizens regarding Lake Michigan management, utilization of natural resources, and cisco restoration.

We found that the majority of LTBB citizens we interviewed want native fish restored to abundances that elders can remember (within the past 60 years), and possibly to pre-contact abundances. They also drew direct connections between their community's health and fisheries management, water and land pollution (often including Enbridge Line 5 pipelines), access to Lake Michigan due to privatization of lakefront property, and the revitalization of language and culture. Clearly, there are many factors that influence citizens' relationship to their Treaty land and waters. Education about natural resources and cultural traditions was stressed. In Chapter 2, we list direct recommendations to the LTBB NRD based on our findings.

Our hydroacoustic study (Chapter 3) established a baseline abundance of cisco in Little Traverse Bay: 1.93 cisco/hectare. It also created standard operating procedures (Appendix D) for the LTBB NRD to continue monitoring cisco populations. This study also demonstrates the LTBB NRD's capacity to contribute to lake-wide hydroacoustic efforts. Several non-tribal agencies already run yearly hydroacoustic assessments of Lake Michigan fish communities, but there is a need for more data collected from a variety of players. The LTBB NRD can now add to the efforts of USGS, USFW, and MDNR, and managers can have a more complete picture of fish communities.

Chapter 4 lays the groundwork for an age-at-length model for cisco in northern Lake Michigan. What is clear is that there is a diversity of ages within the population(s) of cisco in northern Lake Michigan, despite low cisco abundances. With repeated sampling, a more complete picture of growth and maturation for cisco can be derived. Understanding life history traits and reproductive habits for cisco in the much-altered northeastern Lake Michigan will aid managers in determining priorities for the species.

Results from larval diet content and pelagic prey analyses (Chapter 5) indicate that zooplanktonic (and macroinvertebrate prey) densities may be too low to support good coregonid recruitment. We found that larval cisco are concentrated where the only recovered/recovering adult population exists – Grand Traverse Bay – and that cisco tend to be more selective in their diets than lake whitefish.

Overall, we cannot recommend a specific restoration intervention, but encourage managers to consider that the cisco population in northeastern Lake Michigan is low but potentially stable. Perhaps intervention is unnecessary given lake conditions and population structure. We continue to advocate for the treaty rights of LTBB to be respected and elevated.

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# Appendices

# Appendix A: Letter Sent by LTBB NRD as Interview Invitation

# Appendix B: Guideline for semi-structured interviews

Study ID: HUM00131077   IRB: Health Sciences and Behavioral Sciences   Date Approved: 5/31/2017

Aanii!!!

The Natural Resources Department is initiating an effort to better understand how LTBB citizens value resources in the Great Lakes. The goal is to examine perspectives on the conditions of Lake Michigan, lake herring, and lake whitefish to guide ongoing research and restoration efforts through the LTBB Natural Resource Department. To accomplish this goal, we are excited to partner with April Richards, Albany Jacobson Eckert, and Jillian Mayer from the University of Michigan *School of Natural Resources and the Environment* whom will be conducting interviews and analyzing data as part of their graduate research.

This is an opportunity to have your voice heard! By participating in this initiative, you will help to better guide NRD operations, inform aspects of the upcoming Great Lakes Consent Decree renegotiation, and generally influence how and why we protect, manage, and preserve Great Lakes resources. Your participation will also be valuable for providing a general understanding of tribal perspectives and may influence restoration efforts in Lake Michigan.

Interviews will be informal and take 30 minutes to one hour depending on your responses. We simply hope to capture your thoughts and perspectives on the current conditions and your observations of Lake Michigan, utilization of lake resources, and your opinion on restoration strategies. We will take voice recordings, with your permission, for our own records. Your responses to the questions will be kept confidential, avoiding personal identifiers during analysis and the write up of our findings.

We invite all tribal citizens, leaders, elders, fishermen, descendants, and others interested in the conditions of Lake Michigan.

If you are willing to participate please respond email April Richards (aprilrr@umich.edu) and we will coordinate a time to conduct the interview. You may also contact us via phone at 231-242-16XX. If you have any questions, please do not hesitate to ask.

Miigwetch!

Kevin Donner, Great Lakes Fisheries Program Manager

April Richards

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*University of Michigan*
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Albany Jacobson Eckert

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Jillian Mayer

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**Title of interview project:** Perspectives on Cisco Restoration in Lake Michigan

*Note:* All interviewees will be asked a variation of these questions in a semi-structured interview format with some follow-up questions for clarification and additional questions directed at fishermen and tribal leaders. Numbered questions are the primary questions. Lettered sub-questions are suggestions for clarification or to elicit more of a response.

*Project goals:* The goal of this interview is to examine the perspectives of tribal members/ leaders/fishermen on the current conditions and restoration efforts at Lake Michigan. First, I will ask a few questions about your background and interactions with the lake. Then I will ask your opinion about the conditions of the lake and changes to it. And lastly I will ask for your opinion on some restoration strategies.

**Questions for LTBB citizens**

Questions were organized within seven categories:

**Category 1. Interviewee's Background and Tribal Relationships and Perspectives**

1. Let's begin by you telling me a little bit about yourself.
2. Describe your average day at Lake Michigan?
    a. What types of activities do you engage in at the lake? Do you fish, hunt or gather?
        i. How long have you fished/hunted/gathered at Lake Michigan?
3. Can you tell me about your tribal affiliation or relationship?
4. How would you describe the tribe's relationship to Lake Michigan?
    a. How has this relationship changed over time?
    b. What do you think has caused this change or impacted this relationship?

**Category 2. Perspectives on current lake conditions and fishery management**

5. How would you describe the current conditions of the lake?
    a. What changes in the conditions of the lake have you noticed or become aware of recently?
    b. What do you think caused these changes?
6. Have changing conditions in Lake Michigan changed your relationship with the Lake?
7. Have changes to the conditions of Lake Michigan impacted the relationship between the tribe and the Lake?
8. How do you think the conditions will change in the future?
    a. Will the conditions improve or get worse?
    b. Are you concerned about climate change in the Great Lakes region?
        i. *If so:* What changes do you expect?
        ii. What about in Lake Michigan?
9. How do you feel about the way fish are managed in Lake Michigan?
    a. How has fisheries management changed over time?

b. Could you expand on how current management strategies have impacted the conditions or quality of the lake?

10. How have changes to lake or fisheries management impacted you?
    a. How has it impacted tribal members or communities?

**Category 3. Utilization of lake resources**

11. What types of lake resources do you use? (Fishing, hunting, gathering, etc.)
    a. What type? How much? How do you get it? What gear do you use?
12. Do members of your family use or eat anything from the lake?
    a. Who? What? How much? How do they get it?
13. How do you process what you harvest?
    a. *f sold:* How do you sell your product (fish, meat, art, etc)?
    b. To who? For how much (per pound)?
14. What would having a tribal processing facility mean for you?

**Category 4. Background on Cisco and personal relationship with the species**

15. Are you familiar with cisco, also known as lake herring?

    *If so*
16. What do you know about them?
    a. How did you learn about them?
17. Do you ever catch cisco?
    a. How much/how often?
    b. Where do you see or catch cisco?
    c. Have you noticed any changes in the location or amount of cisco you have seen in recent years?
18. Do you eat cisco?
19. Are you familiar with Lake Whitefish?
    a. Do you eat whitefish? How often? Where do you get it?
20. Does your community/tribe have any relationship to cisco or lake whitefish?
    a. Did they in the past?
    b. How do you feel about your community/tribe's current relationship to cisco? Whitefish?

**Category 5. Individual Perspectives on Cisco Restoration and perception of community perspectives on cisco restoration**

*Background (if needed):* Currently, there is concern amongst managers about an imbalance in predator and prey populations in Lake Michigan. So for example, there, but not enough pelagic prey fish, like exotic rainbow smelt and alewife, to support the salmon population at recreational fishers desired levels. As these non-native prey fishabundance is declining, managersare looking for options to sustain predator abundance. . One suggested solution is to restore cisco populations to provide alternative prey.

**Individual Perspectives**

21. Are you familiar with cisco restoration efforts in Lake Michigan?
    a. What have you heard?
    b. Where did you learn these efforts?

22. Do you support cisco restoration?
    a. Why/why not?
    b. What factors influence your decision?
    c. What concerns do you have about restoring cisco to Lake Michigan?
    d. What information would change your opinion?

**Perception of Community Perspectives on Cisco Restoration**

23. Do members of your community/tribe care about cisco?
24. Do members of your community/tribe support cisco restoration?
    a. Do you think members of your community/tribe would support cisco restoration?
    b. How would cisco restoration impact your community/tribe?
25. What do community/tribal leaders think about cisco restoration?
    a. Who supports cisco restoration?
    b. Who opposes cisco restoration?

**Category 6. Perspectives on Restoration Strategies**

Lastly, I am going to ask a series of questions about potential restoration strategies, followed be a short hypothetical exercise.

26. One strategy that has been suggested for restoring the cisco population is allow the remaining populations to grow while improving their capacity to grow through some form of habitat restoration. What are your thoughts on this idea?
    a. What benefits are there to this strategy?
    b. What are your concerns about this strategy?
27. Would you be supportive of cisco restoration if you were unable to harvest cisco while it was being restored- keeping in mind that this could take years?
28. What if a restoration strategy required state agencies to stop stocking nonnative predators, such as salmon, in Lake Michigan?
    a. How does this impact your opinion?
    b. What about this management strategy concerns you?
29. Another strategy that has been discussed is stocking Lake Michigan with cisco with juvenile cisco grown in hatcheries. Would the source of the eggs (from remaining Lake Michigan cisco or Lake Superior cisco) be important for this restoration method?
    a. Do you have any concerns about introducing fish from other lakes, even though it is the same species?
30. Who do you think should lead restoration efforts: states, tribes, or federal agencies?

**Category 7. Final Thoughts on Priorities to improve current lake conditions**

Now I want you to imagine that you are the person who makes the final decision on how to improve the conditions of Lake Michigan and balance predator and prey populations.

31. What do you think should be done to improve the conditions of Lake Michigan?
    a. Why do you think this is the best method?
    b. How possible do you think this strategy is?
    c. What are barriers to its success?

**Additional questions for elders [Category 3]**

1. Did your parent/s fish or gather materials from the lake?
2. What was your parent's relationship to cisco and/or whitefish like?
    a. How has the relationship between the tribe and cisco or lake whitefish changed in your lifetime? Between generations?
3. What is the relationship like between young people today and cisco or lake whitefish?

**Additional questions for leaders [Category 5]**

1. How will intertribal government interactions, or relationships between different tribes, influence a cisco restoration process?
2. What would facilitate some kind of consensus between tribes?

## Appendix C: Pre-Interview Informed Consent Forms for the University of Michigan Institutional Review Board

Study ID: HUM00131077 IRB: Health Sciences and Behavioral Sciences Date Approved: 5/31/2017

Informed Consent Form
University of Michigan: School of Natural Resources and the Environment

Tribal Perspectives on Lake Michigan Ecological Integrity

*Researcher's Name(s) and Contact Information*
You are invited to participate in a research study conducted by April Richards (aprilrr@umich.edu; 319-333-4223), Albany Jacobson Eckert (ajeckert@umich.edu; 703-600-9787) and Jillian Mayer (jbmayer@umich.edu; 941-321-9430), University of Michigan students studying environmental justice and conservation ecology. The purpose of this form is to give you information to help you decide whether or not to participate in this study. You can contact the researchers using the contact information above or contact the faculty advisor for the project, Dr. Sara Adlerstein Gonzalez (adlerste@umich.edu; 734-764-4491). Additionally, we are collaborating with Kevin Donner from the Little Traverse Bay Bands of Odawa Indians Natural Resources Department (kdonner@ltbbodawa-nsn.gov).

*Purpose*
The purpose of this study is to examine perspectives on the condition of Lake Michigan and cisco (lake herring) restoration. Additionally, when available, we will collect local and traditional ecological knowledge that may assist in ecological restoration efforts.

*Participants*
The participants in this research project will include tribal leaders such as elders and chairs of CORA, fishermen and those who utilize lake resources, other tribal members, and some nontribal fishermen. Between 30 and 60 individuals are expected to participate.

*Procedures*
If you agree to participate in this study, you will be asked to do the following: verbally respond to interview questions including tribal relationships, lake conditions, utilization of lake resources, familiarity with cisco and lake whitefish, and potential management strategies. Participants will be interviewed once at a time and place agreed upon between the participant and the researcher. With the permission of the interviewee, interviews will be recorded using a handheld voice recorder. Interviews will last 30 minutes to an hour, but may vary in length depending on the participant's answers.

*Voluntary Nature of the Study*
Participation in this research is completely voluntary. There will be no consequences if you refuse to participate. You can withdraw from the study or refuse to answer any question at any time. Notify the interviewer or contact April Richards (aprilrr@umich.edu; 319-333-4223) should you decide to withdraw from the research study.

*Risks of Participation*

To the best of the researchers' knowledge, there will be no more risk of harm than you would normally experience in daily life. The anticipated risks associated with participation in this research are minimal and participants have the option to decline to answer any question

Informed Consent Form
University of Michigan: School of Natural Resources and the Environment

Tribal Perspectives on Lake Michigan Ecological Integrity

*Researcher's Name(s) and Contact Information*
You are invited to participate in a research study conducted by April Richards (aprilrr@umich.edu; 319-333-4223), Albany Jacobson Eckert (ajeckert@umich.edu; 703-600-9787) and Jillian Mayer (jbmayer@umich.edu; 941-321-9430), University of Michigan students studying environmental justice and conservation ecology. The purpose of this form is to give you information to help you decide whether or not to participate in this study. You can contact the researchers using the contact information above or contact the faculty advisor for the project, Dr. Sara Adlerstein Gonzalez (adlerste@umich.edu; 734-764-4491). Additionally, we are collaborating with Kevin Donner from the Little Traverse Bay Bands of Odawa Indians Natural Resources Department (kdonner@ltbbodawa-nsn.gov).

*Purpose*
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*Participants*
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*Procedures*
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*Risks of Participation*

To the best of the researchers' knowledge, there will be no more risk of harm than you would normally experience in daily life. The anticipated risks associated with participation in this research are minimal and participants have the option to decline to answer any question

*Statement of Consent*
By signing, I am affirming that I have read this information, asked questions and received answers, am at least 18 years old, and consent to participate in this study. I also affirm that I have been given a copy of this information for my records.

_______________________________________________ __________________
Signature of participant Date

_______________________________________________ __________________
Printed name of participant Date

*Consent for voice recording*
By signing, I am agreeing to have this interview voice recorded.

_______________________________________________ __________________
Signature of participant Date

*Person Obtaining Consent:*
I have explained to the participant above the nature, purpose, risks, and benefits of participating in this research project. I have answered any questions that may have been raised and I will provide the participant with a copy of this consent form.

_______________________________________________ __________________
Name of [authorized] person obtaining informed consent Date

**Little Traverse Bay Bands of Odawa Indians**
Department of Archives and Records
7500 Odawa Circle, Harbor Springs, MI 49740
231 / 242-1450

***Oral History Deed of Gift Form Interviewee***

(Revised August 2017)

**Interviewee Information:**

Name______________________________________________________________

Address ____________________________________________________________

City, State, ZIP _____________________________________ Phone ____________

I, ___________________ (name of interviewee), hereby give to the Little Traverse Bay Bands of Odawa Indians' Archives and Records Department as a donation this interview recorded on _______________ (date). With this gift, I hereby transfer to the Little Traverse Bay Bands of Odawa Indians' Archives and Records Department legal title and nonexculsive literary property rights to the interview, including copyright. In so doing, I understand that my interview will be made available for research and may be quoted from, published or broadcast in any medium that the Little Traverse Bay Bands of Odawa Indians' Archives and Records Department shall deem appropriate.

*The materials described above were approved by the Archivist for acceptance as a gift to the Little Traverse Bay Bands of Odawa Indians' Archives and Records Department*

**For LTBB Archives:** __________________________________________________________
Signature and Date

**For the Interviewee:** __________________________________________________________
Signature and Date

Please sign one copy and return it to:

Jordan E. Karlis, Archivist
Little Traverse Bay Bands of Odawa Indians
Department of Archives and Records
7500 Odawa Circle
Harbor Springs, MI 49740

**Little Traverse Bay Bands of Odawa Indians**
Department of Archives and Records
7500 Odawa Circle, Harbor Springs, MI 49740
231 / 242-1450

***Oral History Deed of Gift Form Interviewer***

(Revised August 2017)

**Interviewer Information:**

Name ________________________________________________________________
Address ______________________________________________________________
City, State, ZIP ________________________________________ Phone _____________

I, ____________________ (name of interviewer), who served as an interviewer for the LTBB Archives and Records Department and who conducted an interview(s) with _________________________________________________ (name of interviewee(s)) on or about ________________ (date), do hereby give same to the Little Traverse Bay Bands of Odawa Indians' Archives and Records Department. With this gift, I hereby transfer to the he Little Traverse Bay Bands of Odawa Indians' Archives and Records Department legal title and nonexculsive literary property rights to the interview, including copyright. In so doing, I understand that the interview will be made available for research and may be quoted from, published or broadcast in any medium that the he Little Traverse Bay Bands of Odawa Indians' Archives and Records Department shall deem appropriate.

*The materials described above were approved by the Archivist for acceptance as a gift to the Little Traverse Bay Bands of Odawa Indians' Archives and Records Department*

**For LTBB Archives:** ___________________________________________________________
Signature and Date

**For the Interviewer:** __________________________________________________________
Signature and Date

Please sign one copy and return it to:

Jordan E. Karlis, Archivist
Little Traverse Bay Bands of Odawa Indians
Department of Archives and Records
7500 Odawa Circle
Harbor Springs, MI 49740

## Appendix D: Standard Operating Procedures for Hydroacoustics and Pelagic Trawl Checklists

Note: Working documents with fully outlined procedures will be provided to the NRD.

1.Hydroacoustic Assessment Checklist

□ Black hydroacoustics box, including;

- □ Transducer
- □ GPS
- □ Black cable
- □ Grey box
- □ Blue bag with power cord (connect to generator) and bluetooth cord (connect to computer)

□ Toughbook Laptop and charger

□ Generator

□ Mounting pole

□ YSI for temperature profile

□ Surge protecting power strip

□ Boat pad (to set the transducer on when in transit)

□ Data sheet

□ Small toolkit (razor knife, adjustable wrenches, cable ties, and channel locks)

Suggested:

□ Levels (bullseye and post) for making sure the transducer is flat in the water.

□ Warm clothes/survival suits

□ Sleeping pad

2.Pelagic Trawling Checklist

- Trawling gear
  - Net and bridles
  - Trawl doors
  - Warps
  - Fish boxes (3-5)
  - Ziplock bags and waterproof labels
  - Data sheets

Trawl monitor gear

  - Trawl monitor- with safety net and ropes
  - Trawl monitor charger- plug in after each trawling session
  - Hydrophone- with suspending rope and safety rope
  - Blue hydrophone cord and hydrophone junction box (connects to computer gear)
- Computer gear
  - Computer desk
  - Computer monitor
  - Wireless keyboard and mouse
  - Marport computer base unit/tower
  - Black Marport $M^3$ box
  - Surge protecting power strip
  - Generator
- Small toolkit (razor knife, adjustable wrenches, cable ties, and channel locks)

## Appendix E: Standard operating procedures for otolith preparation for cisco aging

by Albany Jacobson Eckert

There are seven steps for aging cisco using otoliths:
Otolith extraction, (2) Otolith embedding, (3) Otolith sectioning, (4) Otolith mounting, (5). Thin section polishing, (6) Thin section imaging and (7) Annual marks identification and mark counting.

1. Otolith extraction
    a. Materials needed: personal sanitation gear (face mask, gloves, clear eye covering, apron, boots), cutting board, serrated knife, tweezers, small sampling envelopes, pencil
    b. Place the specimen ventral side down on the cutting board.
    c. Using the gills as a visual guide, saw off the head of the specimen.
    d. Using the tweezers, pull out the otoliths from the vestibular labyrinth.
    e. Put the otoliths in the sampling envelope and mark the envelope with the specimen identification.
2. Embedding (putting the otoliths in epoxy or resin molds)
    a. Materials needed: clean sampled otoliths, plastic cup, q-tips, 10 mL syringe, plastic molds
    b. Epoxy prep: Use a 4:1 weight ratio of epoxy to hardener. Do not utilize more than 40 grams of combined resin and hardener so as to avoid a chemical reaction.
    c. Using a q-tip, stir the mixture for at least a minute, or until completely homogenized.
    d. Using the syringe, get 10 mL of the mixture and fill each dip in the mold half way
    e. Leave the molds overnight to cure.
    f. Once the bottom halves are cured, place the otoliths in the molds lengthwise, with the convex side facing up. The otoliths should be placed more toward the tapered ends of the plastic mold, so that the other end of the mold can be adequately gripped by the saw clamps.
    g. Carefully pour the epoxy and hardener mixture over the otoliths to fill the molds. It's better to slightly under-pour than over-pour.
    h. If needed, otoliths can be manipulated with sewing needle-like instruments, and the air bubbles can be ushered out.
    i. Leave to cure overnight.
3. Sectioning (using a double blade saw to slice the embedded otoliths into sagittal transverse sections)
    a. Materials needed: Double-bladed isometric slow-speed saw, tweezers, hex key

    b. Loosen the saw clamp with the hex key and place the mold, tapered side facing the blades. Tighten the clamp. Make sure that the mold is perpendicular to the clamp and that the blades are aimed at the widest part of the otolith. Adjust if needed.
    c. Keep the clamp and mold elevated above the saw as you start it up and accelerate to level 5. The blades need to be only touching the oil in the reservoir before they can start the first cut. This helps with blade lubrication and maintains integrity.
    d. Gently drop the clamp with the mold down so that the blade is cutting through the middle of the otolith.
    e. The blade will automatically stop when it has finished slicing the thin section. Pay attention to where the thin section ends up. Retrieve the thin section from in between the two blades, or it may be at the bottom of the lubricant reservoir.
    f. Dry off the thin section with a Kim-wipe and mount it on the designated microscope slide.
4. Mounting (attaching, via superglue, the sectioned otoliths onto microscope slides)
    a. Materials: Tweezers, superglue, permanent marker pen, microscope slide
    b. Squeeze the superglue bottle so that only one drop comes out onto the slide.
    c. Lower the section onto the drop of glue with tweezers.
    d. Label the slide.
5. Polishing (grinding down the mounted otoliths with sandpaper so the sections can be as transparent as possible)
    a. Materials: Sandpaper (600 to 2000 grain)
    b. Starting with the roughest (lowest) grain, carefully rub sections (mounted on slides) against sandpaper.
    c. Check with a microscope regularly so as to not overpolish and render the slide to transparent and unusable.
6. Imaging (taking microscope images of the otoliths and saving them into a computererized source)
    a. Materials: Microscope, imaging software, mineral oil
    b. Turn on microscope and camera
    c. Set otolith on stand and adjust so that it is in the field of view.
    d. Put a dab of mineral oil on the otolith to enhance image contrast and clarity.
    e. Adjust contrast and lighting when needed.
    f. Capture image in the software and save it with the appropriate label.
7. Aging (counting the annuli using the images and entering ages into a spreadsheet)
    a. Materials: USB or hard drive with captured images, ImageJ software, Excel spreadsheet or similar software
    b. Open the corresponding image in ImageJ software.
    c. Create a new layer for the ring markings.

d. Determine which axis to measure the annuli on (horizontal, vertical, or diagonal from the sulcus).
e. Use the mark tool to count the rings on the new layer. The rings will be noticeable by their marked contrast from the background. Be careful to select the most conspicuous rings, as some rings may be "false annuli" that reflect daily growth.
f. Save the layer and image as one file.
g. Input the ages into the spreadsheet.