FEATURE

Sustaining Namāēw (Lake Sturgeon): Partner-led climate adaptation for Indigenous fisheries in the Laurentian Great Lakes

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Artwork by Moira Villard. Full description available in Figure 1.

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ABSTRACT

Namāēw (Menominee; Lake Sturgeon *Acipenser fulvescens*) have long supported Indigenous culture and food sovereignty but have declined by over 80% in the Laurentian Great Lakes, exacerbating their sensitivity to climate change. Following interest from Indigenous leaders, we initiated a partnership-driven effort to (1) assess climate effects and (2) develop potential adaptation options for Namāēw using a participatory, transdisciplinary approach that combines multiple ways of knowing. Through a literature review and nine semistructured conversations with officials from Indigenous Nations and organizations in the Great Lakes, we identified central themes including access, culture, and fish persistence. Other concerns included habitat, food web shifts, and water quality. Prominent adaptation themes involved population assessments, stocking, regulations, habitat restoration, interagency coordination, and cultural advocacy. These findings underscore the importance of partnership-driven research to support Indigenous fisheries through knowledge coproduction and equitable adaptation. Our approach provides a model to inform stewardship planning for fisheries that are facing global change.

INTRODUCTION

Climate change and Indigenous fisheries

> "Indigenous peoples receive deep knowledge from the environment … how will we learn when things change?"—study participant, Lake Superior

Globally, inland fisheries are critically important for food security and supporting the livelihoods of > 500 million people (Funge-Smith, 2018; Nyboer et al., 2022). Inland fisheries also have immense cultural importance, especially among Indigenous communities, where fishes are viewed as relatives rather than resources (Shultz et al., 2022). However, climate change continues to exacerbate the current challenges that are faced by fish relatives. Climate-induced modification of environments, including changes in streamflow, water temperature, salinity, extreme events, and habitat connectivity can shift fish physiology, disrupt spawning cues, cause fish extinctions and invasions, and alter the community structure of fish (Paukert et al., 2021). Therefore, understanding how a changing climate may affect inland fisheries is critical to developing feasible and effective strategies to support these relationships (Shultz et al., 2022).

Indigenous fisheries are especially vulnerable to the effects of climate change given the place-based nature of communities and relationships (Whyte, 2018). Globally, approximately 400 million Indigenous peoples interact with and steward the planet's biodiversity (Garnett et al., 2018). Climate change is expected to continue to disproportionately affect Indigenous communities because geographically defined boundaries of reservations and ceded territories may limit the communities' ability to follow shifts that occur (Stults et al., 2016). Therefore, climate change has the potential to disrupt culturally important beings, Indigenous food systems, economies, mental and physical health, and culture, highlighting the urgent need to develop Indigenous-driven adaptation strategies (Cunsolo Willox et al., 2013; Kenote, 2020; Lynn et al., 2013; Wyllie de Echeverria & Thornton, 2019).

The seventh-generation philosophy, embraced by many Indigenous Nations in North America, emphasizes the importance of considering the effects of today's actions on future generations (Shultz et al., 2022). Among the Ojibwe people, who are part of the Anishinaabe Confederacy alongside the Odawa and Potawatomi in the Laurentian Great Lakes region (hereafter Great Lakes), this principle guides hunting, fishing, and gathering practices, with a focus on sustaining life and well-being for seven generations ahead (Box 1; Loew, 2014). Anishinaabeg (Ojibwe, Odawa, Potawatomi) are encouraged to make deliberate and thoughtful choices to ensure the preservation and vitality of the natural world for future generations, a concept that is captured in the term Minobimaadiziwin, meaning "the good way of life" (Shultz et al., 2022). One being that many Indigenous Nations of the Great Lakes have a strong cultural, spiritual, and subsistence relationship with is Namāēw (Menominee spelling; Name, Ojibwe; Nmè, Potawatomi; Box 1) or Lake Sturgeon *Acipenser fulvescens*. For many, including the Menominee Indian Tribe of Wisconsin and the Little River Band of Ottawa Indians, Namāēw form a foundational component of Indigenous history and culture, where Namāēw serve as a source of food, an indicator species for environmental change, and a clan identity (Figure 1; Hannibal-Paci, 1998; Runstrom et al., 2002).

Following European colonization in the late 1800s to the early 1900s, Namāēw experienced approximately 90% declines in abundance (Box 1; Bruch et al., 2016; Stults et al., 2016). Despite the closure of commercial and recreational fisheries due to extensive overharvest throughout the 20th century, Namāēw failed to rebound due to two primary factors: habitat fragmentation and their life history requirements (Box 1; Stults et al., 2016). First, the construction of dams has fragmented habitat to prevent access to spawning and rearing areas, reducing natural reproduction (Baker, 2006). Second, Namāēw are late-maturing (mean age at maturity for males = 15 years, for females = 20 years; Stults et al., 2016) and may spawn intermittently (once every 2–6 years; Baker, 2006). Therefore, recruitment is low, even when populations are large and considered healthy, and may not be able to compensate for high adult mortality. The history of decline, persistent effects of habitat fragmentation and degradation, and life history characteristics make Namāēw more sensitive to additional disturbance such as climate change. For some Tribes, the disappearance of Namāēw correlated with the disappearance of Sturgeon Clan families from their ancestral lands, where very few Sturgeon Clan remain in the Great Lakes (Box 1; Little Traverse Bay Bands of Odawa Indians, personal communication). Given the great cultural and subsistence importance of Namāēw, it is critical to understand how climate change may affect their ability to persist in the future and which strategies may be most effective at supporting Indigenous fisheries adaptation.

Climate adaptation and partnership

> "We are running from fire to fire—currently they are small fires, and we're trying to figure out why fires are starting, but we understand that fires are going to start more often"—*study participant, Lake Huron*

Box 1. Namè-ogimaa giigonh (sturgeon—king of the fish) by Eddie Benton-Banai (2008). Excerpt from *Anishinaabe Almanac: Living through the seasons* (Benton-Banai, 2008). Eddie Benton-Banai writes of the importance and history of Lake Sturgeon for Indigenous peoples of the Laurentian Great Lakes region. Note: authors received permission from the original publisher to reprint this text.

"*May wizhaw*, long ago, there was a time when the water was free flowing, without dams or disturbance on every lake, river and stream. During that time, the water was clean, beautiful and sweet to the taste. It was then that the beautiful *Namè*, or sturgeon, was considered the Chief of the Fish Clans for the Ojibwe Anishinaabe people, particularly throughout Wisconsin, Minnesota and Ontario. The sturgeon was also called "Ogimah" ("the king of all freshwater fish"). This name helps to explain the relationship that Anishinaabe people have for their ancient and sacred relatives.

Progress and the encroachment of civilization have brought many dams, which block and change the natural movement of the waters. This fact has also altered the migrations of many spawning fish, including that of the *Namè*.

Each year in the early spring, when booming sounds were made by the melting and cracking of thick ice on the lakes, the Anishinaabe people knew that the water would soon "turn itself over." It was during this time, from the murky dark waters, that *Namè* would soon begin to move around, becoming visible in the shallow spring waters. During the migration upriver, *Namè* could be seen, swimming side by side, in numbers so great that the rivers looked like a solid purple, blue and black mass from bank to bank. Elders say that the sound of their movement was like a murmur, rippling across the water onto the land and through trees like a lullaby in the Anishinaabe way.

When the ice began to break up, the sturgeon would ram their backs and bellies on the underside of the ice chunks as it began floating freely through the water. Some of the younger and braver Anishinaabe would jump onto an ice chunk in order to get a ride as it was being pushed along on the back of a big *Namè*. In that time of long ago, etched in the memories of Anishinaabe elders, the magnificent sturgeon *Namè* was playful with the human beings. My father, *Awke waynzee Jingo Gezhik*, also known as Joe Benton, and others of the Lac Courte Oreilles Reserve of Wisconsin recalled riding on the back of a sturgeon. "That's how big they were on the Namekagon and Flambeau Rivers, at one time…, "he would say sadly. Today, there are no longer many sturgeon in these rivers.

Today many rivers and waterways have been blocked and dammed up for the sake of industry and development. In many ways we are much too "civilized," and for that, the land, the waters and our animal relatives pay the highest price. The sight, the sound, the murmur, and lullaby made by *Namè* may never be heard by us, or our grandchildren.

But hope is alive and well. When people show care for the water, through tobacco offerings and prayers, we help to strengthen the spirit of the water and the creatures that live there, including *Namè*, the beautiful sturgeon. Hope is alive!"

Understanding climate adaptation approaches for Indigenous fisheries (e.g., Namāēw) fills a critical knowledge gap to support access to rights and lifeways in a changing world. Specifically, past research on climate change adaptation for Indigenous fisheries is limited (especially for culturally-important species; GLIFWC Climate Change Team, 2023), many habitats are vulnerable to climate disruptions (Embke et al., 2023), and reliant Indigenous communities are closely tied to specific locations (Stults et al., 2016). As the climate shifts, this presents an opportunity to develop solutions that address social and ecological change.

To integrate climate adaptation into Namāēw stewardship, it is critical to understand the needs of the Indigenous communities that are the most reliant on Namāēw for cultural, spiritual, and nutritional sovereignty to provide relevant information for decision making (Stults et al., 2016). Following interest expressed by Indigenous leaders in the Great Lakes, we initiated a partnership-driven effort that focused on Namāēw to (1) assess climate change effects and (2) codevelop potential adaptation options. We used a participatory, transdisciplinary approach to combine multiple ways of knowing (Meadow et al., 2015; Reid et al., 2021). We used a literature review along with nine semistructured conversations with officials from Indigenous Nations and organizations in the Great Lakes. Here, we present a synthesis of the partnership-driven process that we used in this work as well as potential climate effects and adaptation options for Namāēw that we identified through conversations. Our approach and findings can be used to inform future collaborations and stewardship planning.

METHODS

> "Will [Namāēw] swim 25 million years from now? They go back farther than that, how will they last into the future?"—study participant, Lake Superior

Study area—Laurentian Great Lakes region

Namāēw are the only sturgeon that are native to the Great Lakes and have a wide geographical range (Bruch et al., 2016). Namāēw make expansive (e.g., >100 km) migrations to spawn throughout their long lifetimes; thus, these beings connect habitats, food webs, and peoples across a wide spatial extent. However, climate change is expected to disproportionately affect many of these relations among Namāēw and Indigenous communities because of the geographically limited boundaries of the reservations and ceded territories, which may limit communities' ability to follow beings' shifts because certain traditional fishing rights are limited to sovereign lands (Stults et al., 2016). Therefore, we focus on the Great Lakes because it supports the largest native Namāēw populations and is a critical

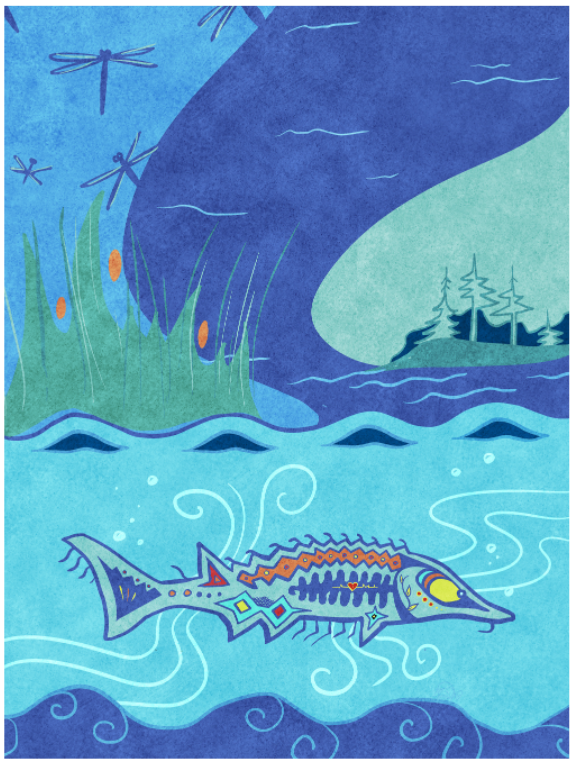

Figure 1. Artwork by Moira Villard, a multidisciplinary artist with a mixed Indigenous and settler heritage. Moira grew up on the Fond Du Lac Reservation in Minnesota and is a Fond Du Lac direct descendant. Concerning this piece, Moira shared, "Like many kids, I grew up fascinated by dinosaurs and prehistoric beings; while other little girls would say their favorite animals were kittens or bears or rabbits, my favorite animals were always ancient relics that carried the weight of deep time. When I lived on the Fond du Lac Reservation, I was surrounded by fascinating plant and animal relatives of all kinds and naturally grew fond of fish and insects. The sturgeon in particular became a fascination; they are living dinosaurs—gentle, ancient, and enduring. To me, they symbolize life that predates and persists beyond human time. It serves as a reminder of the resilience of the natural world and the interconnectedness of all life. Through my work, I seek to honor these connections and explore the ways ancient beings like Namewag inspire us to consider our place within the vast timeline of existence."

area for many Indigenous communities who are still present on ancestral homelands and maintain hunting and fishing rights in ceded territories (Figure 2).

Research process

This study was highly collaborative and partnership driven, involving a core team (authors one through five) that aided in setting a standardized approach (Meadow et al., 2015). The core team consisted of individuals from the College of Menominee Nation, Great Lakes Indian Fish and Wildlife Commission, and the U.S. Geological Survey Midwest Climate Adaptation Science Center and was established to span expertise in ethical Tribal engagement, climate adaptation, fisheries science, and qualitative research methods. The core team was responsible for developing research processes, identifying research questions, facilitating and analyzing semistructured conversations, and supporting data and knowledge sovereignty for the participants (Meadow et al., 2015). Following the conversation synthesis, all the participants were invited to review the identified themes and contribute to the study synthesis through coauthorship. The core team structured the project along four guidelines: (1) ground all understanding on individuals' experiences and relationships, (2) coproduce the research with Indigenous participants, (3) accommodate a flexible timeline and structure to meet participants' capacities, and (4) support data and knowledge sovereignty (Figure 3). Prior to starting the project, we established a data-sharing agreement that outlined data sharing, collection, and protection expectations using FAIR (Findable, Accessible, Interoperable, Reusable) and CARE (Collective benefit, Authority to control, Responsibility, Ethics) principles (Carroll et al., 2021). This study qualified for an exemption from Institutional Review Board oversight in accordance with institutional and regulatory criteria. No personally identifiable information was collected so that the identity of participants was protected, and all participants contributed through their professional capacities.

Literature review

To understand the potential climate effects on Namāēw and inform the template analysis (see "Conversation analysis"; Brooks et al., 2015), we conducted a literature review in January 2023. We used Publish or Perish (Harzing, 2007), a tool that retrieves and analyzes academic publications, to initiate searches in Google Scholar and organize the search findings for analysis. The years were set to range 2000–2022. The following search string was entered into the "keywords" field and returned the following number of peer-reviewed articles:

> "lake sturgeon" AND ("climate change" OR "global warming") AND ("temperature" OR "precipitation" OR "drought" OR "extreme weather events")—997 papers

We conducted a review of the top 150 most relevant and the top 50 most cited papers following the same process. We first read through the article titles and abstracts and excluded articles that were not related to effects of climate change or stewardship strategies for Namāēw in the region. We conducted full-text reviews of all the articles with relevant titles and abstracts.

Our initial literature search was conducted in English, which may have caused us to miss relevant research that was published in another language. For example, information that is published in Anishinaabe, such as GLIFWC Climate Change Team (2023) titled "Aanji-bimaadiziimagak o'ow aki," which provides extensive information on Namāēw climate vulnerability, did not come up in the literature search. So, we reviewed reports, project overview documents, and additional peer-reviewed literature that were sent to us by partners and collaborators in addition to our formal literature search. From these sources, we synthesized information about the effects of climate change on Namāēw to develop thematic questions to structure our conversations (see online Supplementary Material, Appendix I). The discussion themes included ongoing

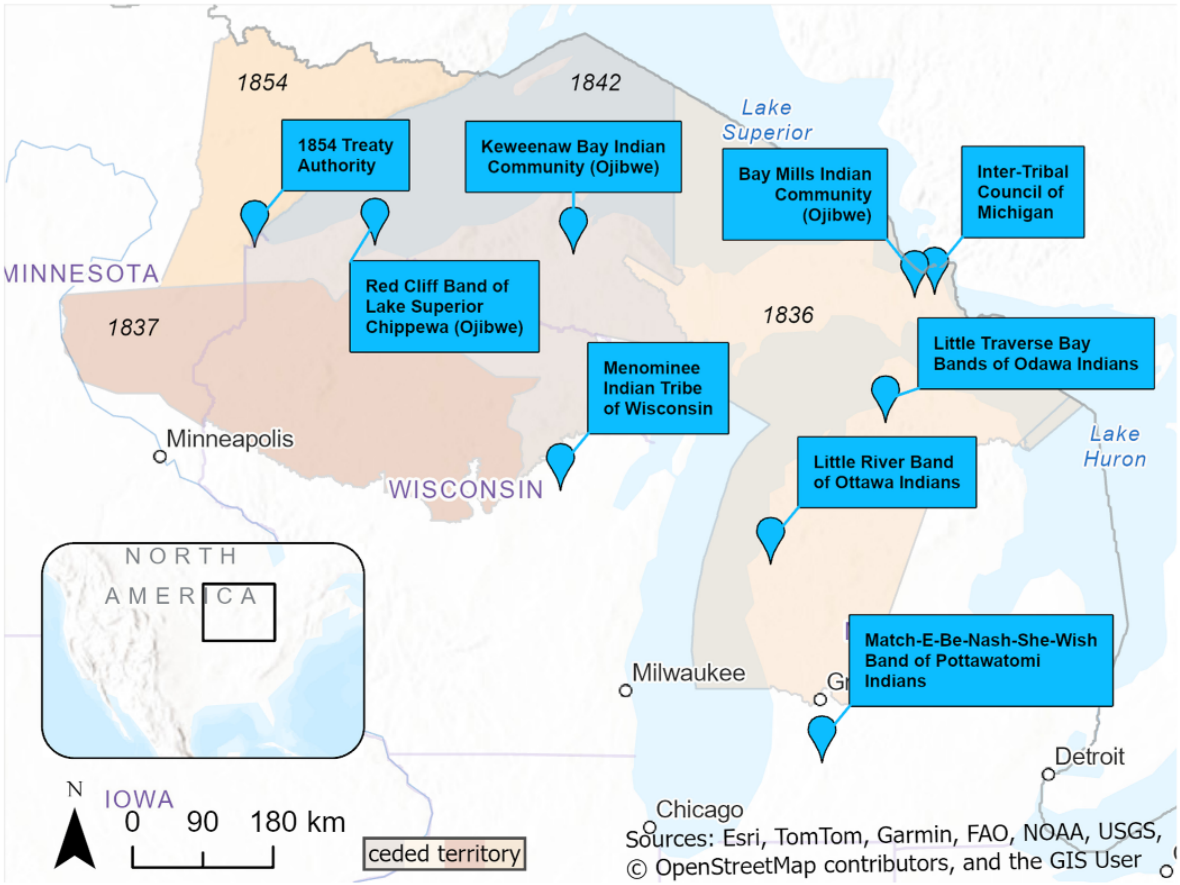

Figure 2. Map of the Laurentian Great Lakes region indicating the approximate locations of the participants' affiliations. The shaded areas represent ceded territories, annotated with the year corresponding to each treaty that established these territories.

concerns and management strategies as well as future climate effects that are related to Namāēw (see online Supplementary Material, Appendix I).

Conversations

We conducted nine semistructured conversations with officials from Indigenous Nations or organizations. In the Great Lakes (Minnesota, Wisconsin, Michigan, Iowa), there are 36 federally recognized Tribes (https://www.bia.gov/regional-offices/midwest-region). To select conversation participants (i.e., an Indigenous Nation or organization), the participants met a series of criteria: the Tribe held a cultural connection to Namāēw (e.g., Namāēw clan), the organization was an intertribal agency that is responsible for supporting multiple Tribes, and the representative held experience related to Namāēw through their professional capacity (Figure 2). The participants' roles included biologists, environmental specialists, natural resource directors, and Tribal Historic Preservation Officers. The semistructured conversations were organized around several themes to begin the discussions (see online Supplementary Material, Appendix I), and they were conducted between 2022 and 2023 for approximately 1.5 h each. The first author was present for all the conversations, and at least one other core team member (usually 3–4 members) was also present for each conversation. The conversation notes were completed by a minimum of two core team members to document the conversation verbatim as best as possible regardless of the question asked and then discussed for agreement. We acknowledge that we may have missed certain themes given the use of conversation notes. However given the sensitivity of Indigenous data and knowledge sovereignty and sharing of cultural information, we did not record all the conversations because consent was not provided for audio recordings. However, consent was provided for a subset of conversations ($n = 2$), which we used to assess the accuracy of our notes for the unrecorded conversations. We compared the themes that were present in the conversation transcripts and notes and found there were minimal (<2 lower order themes) differences between the transcripts and notes, so we used conversation notes for the thematic analysis.

We analyzed the notes by using template analysis (see Conversation review; King, 2004). We acknowledge that these conversations do not correspond to all the perspectives of Indigenous Nations or organizations in the Great Lakes, nor do they capture a complete view of all the climate concerns

Figure 3. Diagram showing the approach that was developed for this project, where a core team was responsible for developing the research processes, identifying the research questions, facilitating and analyzing the semistructured conversations, and maintaining data and knowledge sovereignty for the participants. Following the conversation synthesis, all participants were invited to review the identified themes and contribute to the study synthesis through coauthorship, forming a working group. The project was structured along four central guidelines: (1) ground all understanding in the participants' experiences and relationships, (2) coproduce the research with the participants, (3) accommodate a flexible timeline and structure to meet the participants' capacities, and (4) support data and knowledge sovereignty.

and possible adaptation options. However, the participants presented a range of representative concerns and adaptation needs in these areas, which we synthesize to aid future research prioritization, coordination, and adaptation implementation.

Conversation review

We used the template analysis to review the semistructured conversations for dominant themes that were associated with concerns and adaptation options (King, 2004). This method of thematic analysis prioritizes hierarchical coding for examining textual data (Brooks et al., 2015). Unlike other thematic analytical methods such as content analysis, template analysis does not require that the researchers predetermine a fixed sequence of hierarchical coding levels (Brooks et al., 2015). We began by developing an initial coding template, using a priori themes that we gleaned from the literature review on climate effects on Namāēw (see Literature review). This template was then applied to the conversation notes and refined to capture the themes (Brooks et al., 2015). The template was then applied to notes from individual conversations (see online Supplementary Material, Figure S1). The first author coded all the conversations, and at least one additional core team member coded each conversation. Differences in codes and themes were discussed until a consensus was reached. We then calculated the frequency of themes as the presence of a theme in a given conversation divided by the total number of conversations ($n = 9$).

Participant organizations and Nations spanned the geographies of focus including the watersheds of Lake Huron ($n = 2$), Lake Michigan ($n = 4$), and Lake Superior ($n = 3$). Therefore, we analyzed the concerns and adaptation options across the participants' focal geographies to understand how their responses were related to their locations.

RESULTS

> "We are experiencing a rollercoaster of temperatures and snowmelt"—study participant, Lake Michigan

Literature review: Climate change impacts

Adult Namāēw inhabit a range of environments in the Great Lakes, from high-gradient streams to nearshore areas and deep rivers and lakes (Moore et al., 2021). However, climate change is anticipated to disrupt these habitats by increasing temperatures and precipitation while decreasing ice cover and snowmelt (Lyons & Stewart, 2014). Higher temperatures and reduced ice cover are expected to elevate water temperatures, leading to increased hypoxia and algal blooms, which can affect mortality and prey availability in Namāēw (Embke et al., 2023). Changes in precipitation and snowfall patterns may alter streamflow, runoff, and lake levels and decrease egg and larval survival and the availability of nursery habitat (Lyons & Stewart, 2014; Moore et al., 2021). These changes are likely to influence spawning timing and duration. Climate change could disrupt various aspects of Namāēw's life such as spawning patterns, egg survival, larval growth, juvenile feeding, and adult movement (Embke et al., 2023). However, it remains unclear how regional patterns may affect Namāēw and Indigenous communities as well as which adaptation options may be most desirable.

Conversation themes

Concerns and adaptation themes

For all the themes, we organized the expressed concerns and adaptation options around their relationship with Namāēw, which led to three higher-order themes: the relationship between Namāēw and the environment (concern $n = 15$; adaptation $n = 7$), the relationship between Namāēw and nonhuman beings (concern $n = 13$; adaptation $n = 8$), and the relationship between Namāēw and humans (concern $n = 7$; adaptation $n = 5$; Figure 4; see online Supplementary Material, Figure S1). When the participants focused on concerns, a total of 34 lower-order themes and 10 intermediate-order themes emerged (Figure 4A). The most prominent themes included concerns around access, culture, and population persistence, as these themes were present in every conversation (Figure 5). Habitat-related concerns were prevalent (e.g., water temperature increases, water quality declines, spawning habitat declines; Figure 4A). For adaptation options, we identified 20 lower-order themes and eight intermediate-order themes (Figure 4B). The dominant adaptation themes clustered around population assessments, habitat restoration, and costewardship/coordination (Figures 4B and 5). All the themes that were related to the relationship between Namāēw and nonhuman beings (e.g., fisheries assessments,

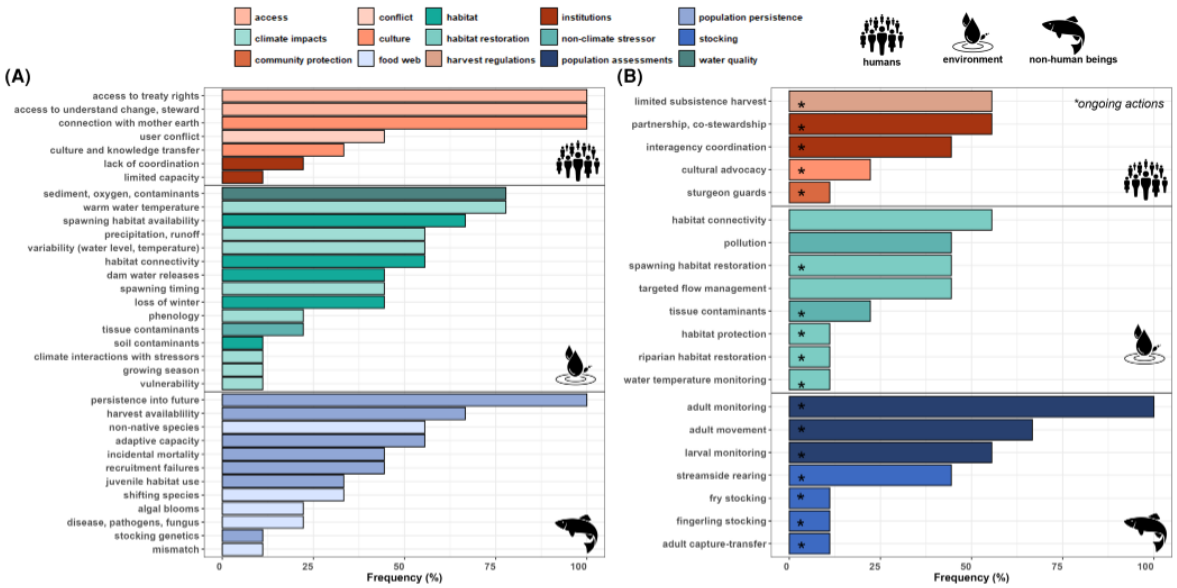

Figure 4. Frequency (%) of concerns (A) and adaptation options (B) expressed during conversations. The lower order themes are shown on the *y*-axis, color indicates the intermediate-order themes (legend at the top), and the highest order themes are labeled on the right. We oriented the highest order themes around their relationship with Namāēw (Lake Sturgeon), leading to three categories that focus on the relationship between Namāēw and (1) humans, (2) the environment, and (3) nonhuman beings. For the adaptation options, themes with an asterisk (*) indicate ongoing actions, and open columns indicate actions of interest for future implementation.

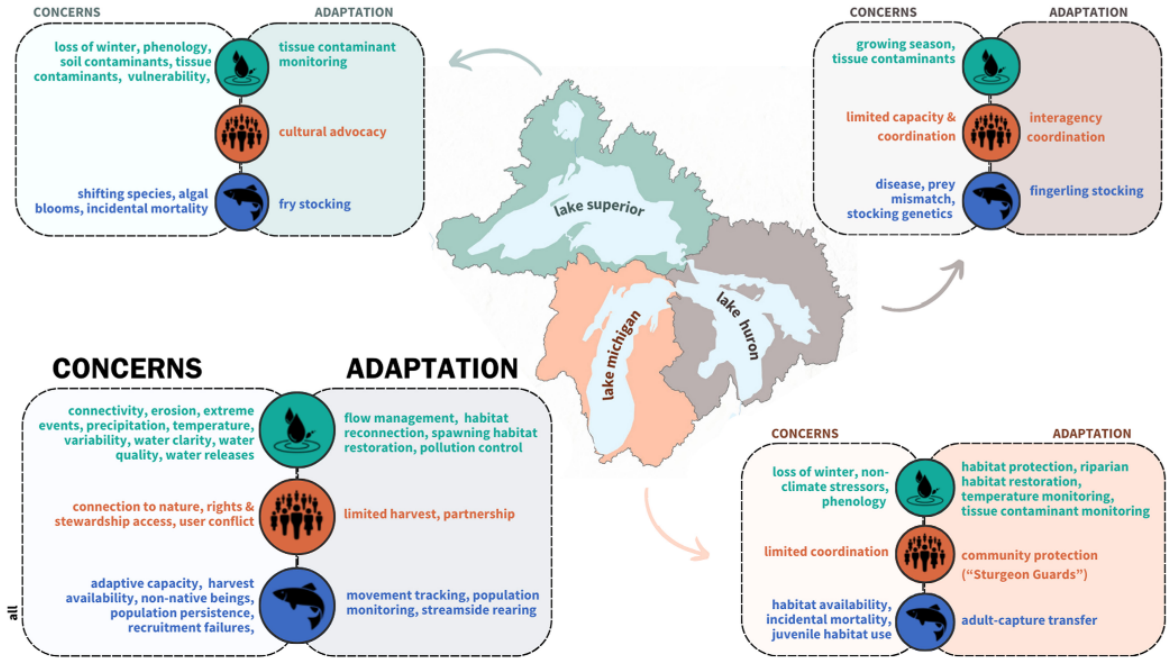

Figure 5. Concerns and adaptation options discussed with officials from Tribal Nations and organizations focused on water bodies and Namāēw (Lake Sturgeon) in the Lake Superior, Lake Michigan, and Lake Huron watersheds. The shared lower order themes of concerns (left boxes) and adaptation options (right boxes) are shown in the bottom left box ("all"), and geographically unique lower order themes are illustrated in the boxes that correspond to each watershed. Color and organization correspond to highest order themes including the relationship between Namāēw and the environment; humans; and nonhuman beings.

stocking) and humans (e.g., partnership) were ongoing efforts (Figure 5B). However, many themes that were related to the relationship between Namāēw and the environment (lower-order adaptation themes $n = 7$) were expressed as not yet in progress but something of interest (Figure 4B).

Themes across geographies

We were interested in understanding how the variation in the concerns and adaptation needs that were expressed by participants could reflect their different geographical contexts. The participants spanned geographic foci that were dispersed across the watersheds of three Laurentian Great Lakes: Lake Huron, Lake Michigan, and Lake Superior. For concerns that were related to the relationship between Namāēw and the environment, all participants regardless of geography were concerned about several climate-related effects (e.g., water temperature, variability, habitat availability, precipitation and runoff, water quality) as well as habitat-related concerns (e.g., connectivity, water releases, spawning timing). The environmental concerns were more similar for participants who focused on the two Northern, less developed watersheds of Lake Huron and Lake Superior, whereas the participants who focused on the Lake Michigan basin were more concerned about climate interactions with other stressors (Figure 5; see online Supplementary Material, Figure S2). Specifically, the participants who focused on Lake Huron were less concerned about phenology and loss of water than were those who focused on Lake Michigan and Lake Superior but were more concerned about changes in the growing season (Figure 5; see online Supplementary Material, Figure S2). The participants who focused on Lake Superior expressed unique concerns including the overall vulnerability of Namāēw as well as other environmental pollutants (e.g., soil contaminants).

Concerning the relationship of Namāēw with nonhuman beings, all the participants were concerned with recruitment failures, population persistence, nonnative beings, harvest availability of Namāēw, and potential adaptive capacity (Figure 5; see online Supplementary Material, Figure S2). The participants who focused on Lake Superior and Lake Michigan expressed concerns that were similar versus those who focused on Lake Huron, where they were more concerned about shifting species compositions, juvenile habitat availability, and incidental mortality. The participants who focused on Lake Huron were more concerned about stocking genetics, potential mismatches between Namāēw and prey availability, and disease spread (Figure 5). However, participants who focused on Lake Huron and Lake Superior were more concerned about algal blooms than were participants who focused on Lake Michigan. For concerns that were related to the relationship of Namāēw with humans, all the participants were concerned about the connection with Mother Earth, access to exercise treaty rights and steward, and user (e.g., fisher) conflict. The participants who focused on Lake Huron were more concerned about limited capacity than were those who focused on Lake Superior and Lake Michigan, whereas participants who focused on Lake Huron and Lake Michigan were concerned about the lack of coordination (Figure 5).

The adaptation discussions were variable across geographies (Figure 5; see online Supplementary Material, Figure S2). For environmental adaptation, all the participants focused on several actions that are related to dams, including targeted flow management, spawning habitat restoration, and habitat connectivity. Pollution control was also a prominent adaptation need regardless of location. The participants who focused on Lake Superior and Lake Huron were monitoring fish tissue contamination, whereas those who focused on Lake Michigan were more interested in habitat-related adaptation (e.g., riparian habitat restoration, water temperature monitoring, habitat protection). For nonhuman beings' adaptation, all the participants were focused on population monitoring (e.g., larval and adult monitoring and movement tracking) and supplementation through streamside rearing (Figure 5; see online Supplementary Material, Figure S2). Related to supplementation via stocking, all the participants were currently stocking Namāēw, but the age of stocked individuals varied, with some participants who focused on Lake Michigan using adult capture–transfer, participants who focused on Lake Huron stocking fingerlings, and participants who focused on Lake Superior stocking fry. For adaptation that is related to the relationship of Namāēw and humans, all the participants emphasized partnership/costewardship as well as limited subsistence harvest as critical actions (Figure 5; see online Supplementary Material, Figure S2). However, the participants who focused on Lake Huron and Lake Michigan highlighted the need for improved interagency coordination, whereas those who focused on Lake Michigan and Lake Superior emphasized cultural advocacy. Uniquely, participants who focused on Lake Michigan described community protection through "Sturgeon Guards" as an ongoing adaptation measure.

DISCUSSION

> "Water is a vessel … providing a home for Namāēw … if the vessel becomes unstable, we're done."—*study participant, Lake Superior*

In the Laurentian Great Lakes, climate change is likely to increase water temperatures, precipitation, and variability and reduce ice cover and snowmelt (Embke et al., 2023). The effects of climate change on Namāēw likely include changes in spawning patterns, egg survival, larval growth, juvenile feeding, and adult movement (Embke et al., 2023). From conversations with Indigenous officials, certain concerns and adaptation options, such as access and population monitoring, were prominent across all the conversations. However, many of the themes were variable across conversations and geographies. For example, the participants who focused on Lake Michigan were more concerned about climate interactions with other stressors than were those who focused on the less developed basins of Lake Superior and Lake Huron (Figure 5). Lake Michigan is farther south, and its watershed is more urbanized and agricultural than those of Lakes Superior and Huron (Environment and Climate Change Canada and the U.S. Environmental Protection Agency, 2022). Consequently, participants who focused on Lake Michigan discussed how climate stressors may interact with pollution, habitat fragmentation, and habitat-related adaptation needs. All geographies were using some form of population supplementation, but the age of the stocked individuals varied across geographies (Figure 5). Older individuals were stocked in the

more southerly Lake Huron and Lake Michigan than in Lake Superior, where participants described a reliance on stocking fry. Lake Superior is more northernly and less developed than the other Great Lakes, so this stocking variability may suggest a possible interaction between latitudinal warming, land use, and habitat fragmentation that affects stocking efficacy.

Overall, our results emphasize the individuality of each Indigenous Nation and organization, where each may have their own specific needs and priorities depending on many factors including their geography, culture, and capacity. Recognizing this individuality when developing adaptation strategies is critical to support feasible outcomes and satisfy community needs.

The most prominent concerns across all the conversations focused on access to and the persistence of the fish population. Access is a multifaceted issue, and the participants mentioned concerns about the effects of climate on access in two ways: (1) exercising treaty rights and (2) effectively stewarding populations. Treaties in the Great Lakes secure many rights for Tribes on reservations as well as on ceded territory lands, including access to fishing, hunting, and water (Shultz et al., 2022). Certain Namāēw populations currently support cultural harvest for annual feasts (e.g., Red Cliff Band of Lake Superior Chippewa, Menominee Indian Tribe of Wisconsin). Climate changes that reduce the ability of Namāēw to support cultural and subsistence harvest and the exercise of treaty rights was a substantial concern. For the Tribes where harvest was no longer supported, access to exercise treaty rights and the connection to Mother Earth was of concern, where many mentioned the inherent right of Namāēw as a relative, to return to their ancestral homelands (J. M. Holtgren & Auer, 2016). From a more logistical perspective, there was concern that climate effects, such as more variable water levels, would inhibit the ability of practitioners to access critical locations for monitoring and stewardship actions and harm the safety of beings.

Ongoing versus potential adaptation strategies varied substantially. Many ongoing actions were related to biological monitoring (e.g., adult movement tracking, stocking), whereas potential actions were focused on habitat restoration or protection (e.g., riparian restoration, floodplain reconnection) and interagency coordination. Given the widespread nature of certain biological monitoring information, there may be opportunities to synthesize across geographies to fill identified information needs, such as quantifying juvenile habitat use (see Future directions). For actions of interest that focus on habitat restoration, these avenues present areas for further assessment to determine the feasibility of implementation. Of note, several social actions that concerned costewardship and cultural advocacy were emphasized by the participants as highly effective when implemented. Although current adaptation strategies predominantly involve biological levers, there is great potential for habitat restoration efforts and collaborative social actions, highlighting the need for ongoing dialogue and exploration of innovative approaches to address the multifaceted challenges that are posed by climate change.

Adaptation opportunities

> "Will we see a shift in the behavior of such a long-lived fish, or will the change outpace the ability of [Namāēw] to adapt?"—study participant, Lake Michigan

We identified many adaptation options for potential future implementation that could address the main concerns that were voiced by participants. Some adaptation options were already implemented by the participants, whereas others were identified as potential areas for future action. These strategies include reducing pollution, habitat restoration, habitat reconnection, and targeted flow management. Additionally, a primary cross-cutting adaptation option that we identified was the need for costewardship between Indigenous agencies and other stewardship agencies. Some of these options (e.g., costewardship) were in use, but all of them were strategies of interest.

Reducing pollution

The Great Lakes is a hub for many industries, including mining, refinement, agriculture, and shipping, sometimes leading to point- and non-point-source pollution (Environment and Climate Change Canada and the U.S. Environmental Protection Agency, 2022). Although efforts to improve pollution, especially point-source pollution, have expanded in past decades, industrial pollution is of concern given potential adverse interactions with climate effects. Increasing development, agricultural expansion, and road salt may interact with climate drivers (e.g., temperature and precipitation) to affect the runoff of contaminants and sediment into water bodies (Burn & Whitfield, 2023). Therefore, actions that reduce pollution, such as regulations and policy initiatives in combination with local habitat restoration (see more below) may work to limit contaminants (Stults et al., 2016).

Habitat restoration and connectivity

Various forms of habitat restoration were discussed during the conversations. For Namāēw, many identified the critical role that habitat plays in population success (Bruch et al., 2016). This emphasis has led to a focus on identifying and supporting spawning habitat for many parts of the Great Lakes. Spawning habitat restoration has commonly occurred through rock/cobble additions to supplement a spawning location (Landsman et al., 2011). In a different approach to protect spawning grounds, the Menominee Indian Tribe of Wisconsin used cultural advocacy and community protection through the "Sturgeon Guards" program (Figure 5).

Nature-based solutions were discussed, including habitat protection and restoration strategies that are directed at increasing resilience to the effects of climate change (e.g., increased runoff; Seddon et al., 2021). Nature-based solutions (e.g., flood-resistant native vegetation, ponds) can offer long-term, multipurpose solutions that are more resilient to increased water level variability while supporting biodiversity and mitigating against future change (Seddon et al., 2021). Some of the nature-based solutions that the participants discussed included riparian restoration, forest protection, and wetland restoration. Given the importance of certain habitat types for life-history stages (e.g., nearshore wetlands for juveniles), considering habitat restoration for wetland areas could be beneficial, as they also protect against fluctuating water levels (Abdel-Fattah & Krantzberg, 2014).

Habitat connectivity was a prominent concern that arose during conversations, as many areas are currently fragmented by dams that prevent access to spawning and nursery habitats

(Baker, 2006). Providing fish passage or barrier removals, when possible, has been shown to successfully restore Namāēw populations in some areas (Aadland, 2015). Additionally, providing reconnected habitat can allow Namāēw access to more suitable habitats (e.g., temperature, flow; Lyons & Stewart, 2014). Reconnecting aquatic habitats has myriad benefits for biodiversity and climate resilience.

Targeted flow management

Seasonal flow variability is critical to Namāēw's life cycle because rising water levels and temperatures in the spring (April–June) trigger spawning migrations (Bruch et al., 2016; Moore et al., 2021). However, climate change is likely to change the seasonality of precipitation, leading to increased and earlier spring flows and altered spawning (Embke et al., 2023). For areas that are operating with regulated flows (e.g., reservoirs, dammed rivers), targeted flow regimes may support species' biodiversity needs (Sabo et al., 2017) and increase their resilience to hydrologic variability (e.g., adapt to increased droughts and floods). Regulated flows may be optimized to pulse flows during critical times to maintain suitable thermal regimes or access to critical habitat (e.g., spawning; Stults et al., 2016).

Multijurisdictional coordination and costewardship

> "It is critical to recognize Tribes as costewards."—study participant, Lake Michigan

We recognize there are many challenges to adaptation given that the range and migrations of Namāēw span many habitats and geographies. For beings who span multiple jurisdictions, national/political boundaries can limit the recognition and management of transboundary climate change effects (Ward et al., 2023). In the Great Lakes, many governments, agencies, and industries have jurisdiction, sometimes with competing interests. The multijurisdictional nature of Namāēw may present challenges for stewardship given the need for interagency coordination, especially when the effects are experienced over long distances and time scales (Bouska et al., 2023). Additionally, ecologically important issues can be difficult to observe by people who do not have intimate knowledge of an ecosystem or long-term perspectives to serve as a baseline, emphasizing the need for the inclusion of multiple ways of knowing (Baird et al., 2021). The transboundary nature of the Great Lakes has the potential to interact with Indigenous concerns that are centered on access, where the decisions that people make in one part of the range of Namāēw have the potential to affect Indigenous access in another area. To reconcile interjurisdictional challenges to adaptation, some have used a portfolio approach to coordinate across boundaries and balance needs across varying scales, representing a critical adaptation opportunity that was expressed by many of the participants (Figure 4B; Bouska et al., 2023; Ward et al., 2023).

Despite multijurisdictional challenges, there are several cases of Namāēw costewardship between Indigenous Nations and agencies (e.g., J. M. Holtgren & Auer, 2016; Runstrom et al., 2002). For example, the Little River Band of Odawa Indians and Menominee Indian Tribe of Wisconsin have worked with state and federal agencies to support Namāēw (M. Holtgren et al., 2016; Runstrom et al., 2002). Furthermore, multiple participants mentioned the importance of recognizing Indigenous Nations as costewards of Namāēw as well as the widespread traditional ecological knowledge that is available to support costewardship (for example, GLIFWC Climate Change Team, 2023). However, partnerships with Indigenous communities require specific ethical considerations, where they are built on trust, are community-based and participatory, and ensure knowledge sovereignty to ensure equitable outcomes (Kenote, 2020). Costewardship that combines multiple ways of knowing, such as traditional ecological knowledge and Western science, can fill knowledge gaps and lead to a more comprehensive understanding of adaptation planning while supporting Indigenous sovereignty (Kenote, 2020; Reid et al., 2021).

Participatory, coproduction approach

Building resilience and adapting to changing climate conditions is a process rather than an outcome (Stults et al., 2016). Through this work, we developed a participatory process to identify areas of future collaboration and costewardship (Meadow et al., 2015). Although this project was focused on Namāēw, the approach that we developed that was grounded in combining multiple ways of knowing can be expanded to other adaptation initiatives (Djenontin & Meadow, 2018). We structured this work around four central guidelines: (1) ground all understanding in individuals' experiences and relationships, (2) coproduce research with Indigenous participants, (3) accommodate a flexible timeline and structure to meet the participants' capacities, and (4) support data and knowledge sovereignty (Figure 3). Moreover, all the participants were offered the opportunity to assume an authorship role if desired and those who did not seek this role were approached throughout the project for feedback and recommendations on all products. To ensure open and transparent communication, we asked all the participants their preferred way for their organizations and Indigenous Nations to discuss the project findings. Thus, in addition to this article, we developed several additional communications, including presentations to Indigenous leadership and a handout that was featured in an intertribal organization newsletter. We sought for this work to be a continuous conversation, where participants and collaborators can build on the knowledge shared to work toward reciprocally beneficial outcomes (Meadow et al., 2015). The approach that we used for this work, focused on reciprocity, respect, and sovereignty, lays a path for other initiatives to coproduce equitable outcomes.

Future directions

> "This is just the beginning … of dealing with tremendous change on Earth … we don't know what will happen, but it's coming"—study participant, Lake Huron

In addition to highlighting concerns and potential adaptation strategies, we identified several information needs to link climate effects to potential ecological and social responses of Namāēw fisheries. First, a deeper understanding of the potential adaptive capacity of Namāēw across spatial and temporal scales is needed. Lower latitude populations spawn at higher temperatures, but whether higher latitude populations can adapt to spawning at these elevated temperatures is unclear,

especially given the rapid pace of climate change (Baril et al., 2018). Additionally, understanding how the effects of climate change on one life stage, such as a loss of juveniles or larvae in a given spawning year, influence the overall population trajectories is crucial. Related to stage-specific warming effects, diseases that are linked to climate warming may vary across life stages and warrant further examination (Embke et al., 2023). Research examining the effects of shifting spawning timing and duration on population dynamics and prey availability would be beneficial, as changing water levels and reduced ice cover will alter future wetland conditions, which are vital for the various life stages of Namāēw. Finally, it would be beneficial to understand the efficacy and feasibility of the proposed adaptation strategies across geographies and Indigenous communities prior to implementing them. The concerns and adaptation approaches that were expressed in the conversations were variable across geographies and Indigenous communities, emphasizing that approaches may need to go beyond a one-size-fits-all approach to ensure that social and ecological needs are met.

Engaging Indigenous Nations and rightsholders through all parts of adaptation planning and decision-making process not only enhances the relevance and acceptance of stewardship initiatives, but also recognizes traditional knowledge and local expertise (Reid et al., 2021). However, we acknowledge that the knowledge shared in this work does not correspond to all perspectives of Indigenous Nations or organizations in the Great Lakes, nor does it capture a complete view of all the climate concerns and possible adaptation options. Rather, we seek to provide this work as a starting point to initiate conversations for research priorities, collaborations, and implementation.

Recognizing the interconnectedness of ecosystems and the diverse perspectives of rightsholders and stakeholders is essential for the effective stewardship and adaptation of inland fisheries including Namāēw. Despite some extensive stewardship actions, incorporating climate effects and adaptation into plans for Namāēw has been limited, as multiple participants discussed challenges such as limited capacity and localized data hindering this integration. By incorporating climate considerations and embracing a participatory approach, we can develop more comprehensive and effective adaptation efforts that are better equipped to meet future challenges.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *Fisheries* online.

DATA AVAILABILITY

The data supporting the findings of this study are not publicly available to respect and uphold Indigenous knowledge sovereignty. Access to these data is restricted as they contain information that is culturally sensitive and protected under agreements with the relevant Indigenous communities. Sharing or use of these data is governed by the principles of Indigenous Data Sovereignty and the CARE Principles for Indigenous Data Governance, which prioritize collective benefit, authority to control, responsibility, and ethics.

Requests for access to the data may be considered on a case-by-case basis and require approval from the appropriate Tribal governance body. Those interested should contact the corresponding author, who will facilitate communication with the relevant Tribal Nation/organization representatives. Any data sharing will be subject to community protocols, free, prior, and informed consent, and may require a formal agreement outlining the terms of use and benefit sharing.

ETHICS STATEMENT

This study qualified for an exemption from Institutional Review Board oversight in accordance with institutional and regulatory criteria.

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CONFLICTS OF INTEREST

None declared.

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REFERENCES

Aadland, L. (2015). *Barrier effects on native fishes of Minnesota*. Minnesota Department of Natural Resources.

Abdel-Fattah, S., & Krantzberg, G. (2014). A review: Building the resilience of Great Lakes beneficial uses to climate change. *Sustainability of Water Quality and Ecology*, *3–4*, 3–13. https://doi.org/10.1016/j.swaqe.2014.11.006

Baird, I. G., Silvano, R. A. M., Parlee, B., Poesch, M., Maclean, B., Napoleon, A., Lepine, M., & Hallwass, G. (2021). The downstream impacts of hydropower dams and indigenous and local knowledge: Examples from the peace—Athabasca, Mekong, and Amazon. *Environmental Management*, *67*, 682–696. https://doi.org/10.1007/s00267-020-01418-x

Baker, E. A. (2006). *Lake Sturgeon distribution and status in Michigan, 1996–2005* (Fisheries Technical Report 2006-417). Michigan Department of Natural Resources.

Baril, A.-M., Buszkiewicz, J. T., Biron, P. M., Phelps, Q. E., & Grant, J. W. A. (2018). Lake Sturgeon (*Acipenser fulvescens*) spawning habitat: A quantitative review. *Canadian Journal of Fisheries and Aquatic*

Sciences: Journal Canadien Des Sciences Halieutiques Et Aquatiques, *75*, 925–933. https://doi.org/10.1139/cjfas-2017-0100

Benton-Banai, E. (2008). *Anishinaabe almanac: Living through the seasons*. Kenjgewin Teg Educational Institute.

Bouska, K. L., Healy, B. D., Moore, M. J., Dunn, C. G., Spurgeon, J. J., & Paukert, C. P. (2023). Diverse portfolios: Investing in tributaries for restoration of large river fishes in the Anthropocene. *Frontiers in Environmental Science*, *11*, Article 1151315. https://doi.org/10.3389/fenvs.2023.1151315

Brooks, J., McCluskey, S., Turley, E., & King, N. (2015). The utility of template analysis in qualitative psychology research. *Qualitative Research in Psychology*, *12*, 202–222. https://doi.org/10.1080/14780887.2014.955224

Bruch, R. M., Haxton, T. J., Koenigs, R., Welsh, A., & Kerr, S. J. (2016). Status of Lake Sturgeon (*Acipenser fulvescens* Rafinesque 1817) in North America. *Zeitschrift Fur Angewandte Ichthyologie = Journal of Applied Ichthyology*, *32*, 162–190. https://doi.org/10.1111/jai.13240

Burn, D. H., & Whitfield, P. H. (2023). Climate related changes to flood regimes show an increasing rainfall influence. *Journal of Hydrology*, *617*, Article 129075. https://doi.org/10.1016/j.jhydrol.2023.129075

Carroll, S. R., Herczog, E., Hudson, M., Russell, K., & Stall, S. (2021). Operationalizing the CARE and FAIR principles for Indigenous data futures. *Scientific Data*, *8*, Article 108. https://doi.org/10.1038/s41597-021-00892-0

Cunsolo Willox, A., Harper, S. L., Ford, J. D., Edge, V. L., Landman, K., Houle, K., Blake, S., & Wolfrey, C. (2013). Climate change and mental health: An exploratory case study from Rigolet, Nunatsiavut, Canada. *Climatic Change*, *121*, 255–270. https://doi.org/10.1007/s10584-013-0875-4

Djenontin, I. N. S., & Meadow, A. M. (2018). The art of co-production of knowledge in environmental sciences and management: Lessons from international practice. *Environmental Management*, *61*, 885–903. https://doi.org/10.1007/s00267-018-1028-3

Embke, H. S., Nikiel, C. A., & Lyons, M. P. (2023). Potential effects of climate change on *Acipenser fulvescens* (Lake Sturgeon). In *Effects of climate change on fish and wildlife species in the United States* (Open file report No. 2021-1104-E). U.S. Geological Survey. https://doi.org/10.3133/ofr20211104E

Environment and Climate Change Canada and the U.S. Environmental Protection Agency. (2022). *State of the Great Lakes 2022 technical report*. (Cat No. En161-3/1E-PDF. EPA 905-R22-004). https://binational.net/wp-content/uploads/2022/07/State-of-the-Great-Lakes-2022-Report.pdf

Funge-Smith, S. (2018). *Review of the state of the world fishery resources: Inland fisheries*. Food and Agricultural Organization of the United Nations.

Garnett, S. T., Burgess, N. D., Fa, J. E., Fernández-Llamazares, Á., Molnár, Z., Robinson, C. J., Watson, J. E. M., Zander, K. K., Austin, B., Brondizio, E. S., Collier, N. F., Duncan, T., Ellis, E., Geyle, H., Jackson, M. V., Jonas, H., Malmer, P., McGowan, B., Sivongxay, A., & Leiper, I. (2018). A spatial overview of the global importance of Indigenous lands for conservation. *Nature Sustainability*, *1*, 369–374. https://doi.org/10.1038/s41893-018-0100-6

GLIFWC Climate Change Team. (2023). *Aanji-bimaadiziimagak o'ow aki*. Great Lakes Indian Fish and Wildlife Commission.

Hannibal-Paci, C. (1998). Historical representations of Lake Sturgeon by native and non-native artists. *The Canadian Journal of Native Studies*, *XVIII*, 203–232. https://cjns.brandonu.ca/wp-content/uploads/18-2-cjnsv18no2_pg203-232.pdf

Harzing, A. W. (2007). *Publish or perish [Computer software]*. https://harzing.com/resources/publish-or-perish

Holtgren, J. M., & Auer, N. A. (2016). Re-envisioning state and tribal collaboration in fishery assessment and restoration. *Fisheries*, *41*, 244–257. https://doi.org/10.1080/03632415.2016.1162159

Holtgren, M., Ogren, S., & Whyte, K. (2016). *Renewing relatives: Nmé stewardship in a shared watershed*. Tales of Hope and Caution in Environmental Justice. A website for the Mellon Humanities for the Environment initiative. Retrieved January 15, 2023, from https://bit.ly/44YSwnF

Kenote, T. R. (2020). *Indigenous phenology: An interdisciplinary case study on indigenous phenological knowledge on the Menominee Nation forest [Doctoral dissertation]*. University of Minnesota. http://login.ezproxy.lib.umn.edu/login?url=https://www.proquest.com/dissertations-theses/indigenous-phenology-interdisciplinary-case-study/docview/2437446147/se-2

King, N. (2004). Using templates in the thematic analysis of text. In C. Cassell & G. Symon (Eds.), *Essential guide to qualitative methods in organizational research* (pp. 256–270). SAGE. https://doi.org/10.4135/9781446280119.n21

Landsman, S. J., Nguyen, V. M., Gutowsky, L. F. G., Gobin, J., Cook, K. V., Binder, T. R., Lower, N., McLaughlin, R. L., & Cooke, S. J. (2011). Fish movement and migration studies in the Laurentian Great Lakes: Research trends and knowledge gaps. *Journal of Great Lakes Research*, *37*, 365–379. https://doi.org/10.1016/j.jglr.2011.03.003

Loew, P. (Ed.). (2014). *Seventh generation earth ethics: Native voices of Wisconsin*. Wisconsin Historical Society Press.

Lynn, K., Daigle, J., Hoffman, J., Lake, F., Michelle, N., Ranco, D., Viles, C., Voggesser, G., & Williams, P. (2013). The impacts of climate change on tribal traditional foods. *Climatic Change*, *120*, 545–556. https://doi.org/10.1007/s10584-013-0736-1

Lyons, J., & Stewart, J. S. (2014). Predicted effects of future climate warming on thermal habitat suitability for Lake Sturgeon (*Acipenser fulvescens*, Rafinesque, 1817) in rivers in Wisconsin, USA. *Zeitschrift Fur Angewandte Ichthyologie = Journal of Applied Ichthyology*, *30*, 1508–1513. https://doi.org/10.1111/jai.12543

Meadow, A. M., Ferguson, D. B., Guido, Z., Horangic, A., Owen, G., & Wall, T. (2015). Moving toward the deliberate coproduction of climate science knowledge. *Weather, Climate, and Society (Print)*, *7*, 179–191. https://doi.org/10.1175/WCAS-D-14-00050.1

Moore, M. J., Paukert, C. P., & Moore, T. L. (2021). Effects of latitude, season, and temperature on Lake Sturgeon movement. *North American Journal of Fisheries Management*, *41*, 916–928. https://doi.org/10.1002/nafm.10416

Nyboer, E. A., Embke, H. S., Robertson, A. M., Arlinghaus, R., Bower, S., Baigun, C., Beard, D., Cooke, S. J., Cowx, I. G., Koehn, J. D., Lyach, R., Milardi, M., Potts, W., & Lynch, A. J. (2022). Overturning stereotypes: The fuzzy boundary between recreational and subsistence inland fisheries. *Fish and Fisheries*, *23*, 1282–1298. https://doi.org/10.1111/faf.12688

Paukert, C., Olden, J. D., Lynch, A. J., Breshears, D. D., Chambers, R. C., Chu, C., Daly, M., Dibble, K. L., Falke, J., Issak, D., Jacobson, P., Jensen, O. P., & Munroe, D. (2021). Climate change effects on North American fish and fisheries to inform adaptation strategies. *Fisheries*, *46*, 449–464. https://doi.org/10.1002/fsh.10668

Reid, A. J., Eckert, L. E., Lane, J., Young, N., Hinch, S. G., Darimont, C. T., Cooke, S. J., Ban, N. C., & Marshall, A. (2021). "Two-eyed seeing": An Indigenous framework to transform fisheries research and management. *Fish and Fisheries*, *22*, 243–261. https://doi.org/10.1111/faf.12516

Runstrom, A., Bruch, R. M., Reiter, D., & Cox, D. (2002). Lake Sturgeon (*Acipenser fulvescens*) on the Menominee Indian Reservation: An effort toward co-management and population restoration. *Zeitschrift Fur Angewandte Ichthyologie = Journal of Applied Ichthyology*, *18*, 481–485. https://doi.org/10.1046/j.1439-0426.2002.00426.x

Sabo, J. L., Ruhi, A., Holtgrieve, G. W., Elliott, V., Arias, M. E., Ngor, P. B., Räsänen, T. A., & Nam, S. (2017). Designing river flows to improve food security futures in the lower Mekong basin. *Science*, *358*, Article eaao1053. https://doi.org/10.1126/science.aao1053

Seddon, N., Smith, A., Smith, P., Key, I., Chausson, A., Girardin, C., House, J., Srivastava, S., & Turner, B. (2021). Getting the message right on nature-based solutions to climate change. *Global Change Biology*, *27*, 1518–1546. https://doi.org/10.1111/gcb.15513

Shultz, A., Luehring, M., Ray, A., Rose, J. D., Croll, R., Gilbert, J., Price, M., Graveen, J., & Chapman, L. (2022). Case study: Applying the resist–accept–direct framework to an Ojibwe Tribe's relationship with the natural world. *Fisheries Management and Ecology*, *29*, 392–408. https://doi.org/10.1111/fme.12568

Stults, M., Petersen, S., Bell, J., Baule, W., Nasser, E., Gibbons, E., & Fougerat, M. (2016). *Climate change vulnerability assessment and adaptation plan—1854 Ceded Territory including the Bois Forte, Fond du Lac, and Grand Portage Reservations: Duluth, Minn.* 1854 Treaty Authority. https://www.1854treatyauthority.org/images/ClimateAdaptationPlan_Final-July_2016-optimized(1).pdf

Tribal Adaptation Menu Team. (2019). *Dibaginjigaadeg Anishinaabe Ezhitwaad: A tribal climate adaptation menu*. Great Lakes Indian Fish and Wildlife Commission.

Ward, N. K., Lynch, A. J., Beever, E. A., Booker, J., Bouska, K. L., Embke, H., Houser, J. N., Kocik, J. F., Kocik, J., Lawrence, D. J., Lemon, M. G., Limpinsel, D., Magee, M. R., Maitland, B. M., McKenna, O., Meier, A., Morton, J. M., Muehlbauer, J. D., Newman, R., … Wilkening, J. L. (2023). Reimagining large river management using the Resist–Accept–Direct (RAD) framework in the Upper Mississippi River. *Ecological Processes*, *12*, Article 48. https://doi.org/10.1186/s13717-023-00460-x

Whyte, K. P. (2018). Indigenous science (fiction) for the Anthropocene: Ancestral dystopias and fantasies of climate change crises. *Environment and Planning: E, Nature and Space*, *1*, 224–242. https://doi.org/10.1177/2514848618777621

Wyllie De Echeverria, V. R., & Thornton, T. F. (2019). Using traditional ecological knowledge to understand and adapt to climate and biodiversity change on the Pacific coast of North America. *Ambio*, *48*, 1447–1469. https://doi.org/10.1007/s13280-019-01218-6