Sub-Indicator: Aquatic Habitat Connectivity

Overall Assessment

Status: Fair

10-Year Trend (2014-2023): Improving

Long-term Trend (1950-2023): Improving

Rationale: Due to anthropogenic impacts, only about 33% of the tributaries that were historically connected to the Great Lakes remain accessible to migratory fishes (Figure 1). The least amount of connectivity is on Lake Michigan (19%) and the most is on Lake Superior (53%). This lake to river connectivity is limited by thousands of dams, and within-river disconnectedness is also due to hundreds of thousands of road-stream crossings. Upstream of lowermost dams (Figure 2), aquatic connectivity is slowly improving in Great Lakes tributaries through the replacement of problematic culverts and the removal of dams that no longer serve their intended purpose but improving lake to river connectivity is challenging due to the need to limit the expansion of invasive Sea Lamprey populations. Efforts to prioritize barrier removals are ongoing, and agencies in each lake basin have identified barriers that are a priority to remove (Figure 3), as well as those that serve as critical blocking structures for the invasive sea lamprey (Figure 4).

Lake-by-Lake Assessment

Lake Superior

Status: Fair

10-Year Trend (2014-2023): Improving

Long-term Trend (1950-2023): Improving

Rationale: Migratory fish can access 54% of tributaries that were historically connected, but expanding lake to river connectivity is challenging due to Sea Lamprey concerns and economic, social, and political factors. Ongoing efforts to restore in-river connectivity continue to be successful and are improving conditions for native fishes, including Brook Trout. In the near future, the replacement of a perched culvert on the Sucker River near Grand Marais, Michigan with an adjustable sea lamprey blocking structure further upstream is expected to provide up to an additional 145km of habitat for native species. Aging and decaying dams continue to be a concern, specifically the AuTrain River Dam which is in poor condition and has been abandoned by its previous owners.

Lake Michigan

Status: Poor

10-Year Trend (2014-2023): Improving

Long-term Trend (1950-2023): Improving

Rationale: Lake to river connectivity is extremely limited in Lake Michigan. Aquatic organisms can access only 19% of historically connected tributaries (Figure 1), but in-river connectivity improvements continue. Replacing perched culverts in Michigan's White River has allowed access to an additional 10km of stream. An experimental selective fish passage facility is under construction at the Union Street Dam on the Boardman River (FishPass – GLFC). This

facility is intended to research selective fish passage solutions that block sea lamprey but pass desirable fish at lowermost dams (Figure 2).

Lake Huron

Status: Fair

10-Year Trend (2014-2023): Improving

Long-term Trend (1950-2023): Improving

Rationale: Lake Huron tributaries accessible to migratory fishes remains at 30% of what was historically connected. In-river connectivity has continued to improve in a number of watersheds including the Carp Lake River, where efforts continue to replace nine undersized culverts for the benefit of native fish species and the federally endangered Hungerford's Crawling Water Beetle. Additionally, a private dam was removed on the West Branch of the Tittabawassee River to restore connectivity to 6.2 miles of stream (Huron Pines).

Lake Erie

Status: Fair

10-Year Trend (2014-2023): Improving

Long-term Trend (1950-2023): Improving

Rationale: Approximately 33% of historically connected Lake Erie tributaries remain accessible to migratory fishes (Figure 1), but efforts to improve in-river connectivity continue. The Brightwood Lake Dam on Ohio's Grand River was removed in 2022 and stream restoration efforts continue there. The Peninsular Paper Dam on the Huron River is one of a number of ongoing dam removal projects in Lake Erie tributaries and is likely to be removed by 2026.

Lake Ontario

Status: Fair

10-Year Trend (2014-2023): Improving

Long-term Trend (1950-2023): Improving

Rationale: Migratory fish are able to access 39% of tributaries that were historically connected to Lake Ontario (Figure 1). Connectivity is being re-established between Lake Ontario and the Don River in Toronto (Toronto and Region Conservation Authority). A dam there is being removed as part of a waterfront revitalization effort. In-river connectivity efforts continue in a number of places, including Cortland County where four fish barriers are being removed to reopen six miles of river for the benefit of Brook Trout (Cortland County Soil and Water Conservation District).

Status Assessment Definitions

Good: >75% aquatic habitat connectivity (by river and stream length) compared to historical conditions. The state of aquatic habitat connectivity and access to spawning habitat is likely sufficient to maintain migratory fish populations.

Fair: 25% to 75% aquatic habitat connectivity (by river and stream length) compared to historical conditions. The state of aquatic habitat connectivity is stressed in some locations and access to spawning habitat is likely limiting populations of some migratory fish species.

Poor: < 25% aquatic habitat connectivity (by river and stream length). The state of aquatic habitat connectivity severely impaired and access to spawning habitat is likely limiting populations of many migratory fish species

Undetermined: Data are not available or are insufficient to assess condition of the ecosystem components.

Trend Assessment Definitions

Improving: Increase in the amount of riverine habitat connected to the Great Lakes based on an assessment of new mitigation projects and new barriers.

Unchanging: No measurable change in the amount of aquatic connectivity.

No Trend: Data are available for a 10-year or longer period, but the trend is not statistically Improving or Deteriorating due to high variability in the data.

Deteriorating: Decrease in the amount of riverine habitat connected to the Great Lakes based on an assessment of new mitigation projects and new barriers.

Undetermined: Information on barrier mitigation does not indicate a clear overall trend or data are not available to report on a trend.

Endpoints and/or Targets

1. Percent of rivers/streams connected to the Great Lakes compared to historical conditions. Overall objective to increase connectivity, with a focus on priority barriers, while managing for invasive species.
2. Progress in mitigating priority barriers (Table 1, Figure 3).
3. Examples of key initiatives to improve aquatic habitat connectivity.

Sub-Indicator Purpose

The purpose of this sub-indicator is to track the amount of accessible tributary habitat for migratory Great Lakes fishes by lake, to summarize key initiatives to improve the connectivity of aquatic habitat with a focus on priority sites; and highlight some of the issues related to barrier mitigation.

Ecosystem Objective

This sub-indicator supports work towards General Objective #5 of the 2012 Great Lakes Water Quality Agreement which states that the Waters of the Great Lakes should “support healthy and productive wetlands and other habitats to sustain resilient populations of native species.” The objective is to increase aquatic habitat connectivity in a manner that enhances native fish populations while supporting the control of invasive species.

Methods

This sub-indicator measures tributary connectivity as the percent of total stream length that is currently connected to the Great Lakes compared to historical conditions and has been calculated for the entire Great Lakes basin and each lake (Khoury et al., 2018, USGS 2023). Connectedness serves as a representation of available habitat for

migratory fishes. Results for this sub-indicator have been drawn from an analysis on barriers that is available for the Great Lakes basin and case studies on barrier removal projects. Barrier data can be viewed and downloaded via the Great Lakes Aquatic Habitat Framework (GLAHF), which also notes those lowermost barriers important to sea lamprey control and allows stream tracing up- and downstream of the dams using the NHDPlus HR hydrography dataset (USGS 2023). Status thresholds on aquatic habitat connectivity have been developed for the Biodiversity Conservation Strategies for each lake (Franks Taylor et al., 2010; Lake Ontario Biodiversity Conservation Strategy Working Group, 2009; Lake Superior Lakewide Action and Management Plan, 2013; Pearsall et al., 2012a; Pearsall et al., 2012b).

Discussion

Over the last century, thousands of dams were built in the Great Lakes basin to aid in logging operations, hydropower production, mills, industry, irrigation, recreation, and beautification. Many of those dams no longer serve their intended purpose, but their presence continues to impact fish communities by limiting access of fishes to spawning and nursery habitats, restricting nutrient flows and warming water, and altering riparian and coastal processes (Childress et. al, 2014; Jansson et. al, 2007; Walter et al. 2021). Presently, dams and roads serve as critical infrastructure for power generation, flood control, transportation, and control of invasive species (Hrodey et al. 2021). Over the last few decades, very few new dams have been built. Instead, a heavy investment in infrastructure, especially in the US, has led to the removal of dams that no longer serve their intended purpose, and replacement of culverts that act as barriers. Much of this work is focused on in-watershed connectivity as lowermost barriers (Figure 2) restricting sea lamprey access to tributaries are retained.

Aquatic connectivity provides chemically and physically unobstructed routes to fulfill life history requirements of aquatic species, including access to intact refugia and opportunities for genetic exchange. Barriers threaten the diversity and abundance of native Great Lakes fishes by restricting or eliminating connectivity between the lakes and critical spawning, nursery, and overwintering habitats (Januchowski-Hartley et al., 2013) and compromise production and harvests. Two-thirds of the river and stream habitats that were historically connected to the Great Lakes are now inaccessible to migratory fishes (Figure 1). This loss of tributary habitat has resulted in significant declines in native fish populations in the Great Lakes, such as Lake Herring, Yellow Perch, Walleye, River Redhorse, Black Redhorse, Eastern Sand Darter, and Channel Darter (Great Lakes Fishery Commission 2007b; Bredin 2002). Specifically, barriers were a contributing factor to the near elimination of Atlantic Salmon in Lake Ontario, and continue to be described as the single greatest impediment to population recovery (Nieland et al. 2013). Similarly, dramatic decline and local extirpation of Great Lakes Lake Sturgeon populations are attributed to the construction of barriers during the late 1880s, and barrier persistence continues to hinder rehabilitation efforts (Auer 1996; Peterson et al. 2007). For most fishes, traditional passage facilities will not completely mitigate the impact of stream fragmentation, as the hydraulic conditions don't typically match with the behavior and physiology of targeted species (Mallen-Cooper and Brand, 2007). For example, salmonids can pass through the fishway at the Flat Rock Dam on the Huron River but it remains a barrier for Walleye (Leonardi & Thomas, 2000). In addition to impacting the fishes that migrate from the Great Lakes into tributaries, many stream-dwelling species of fish (e.g. Brook Trout) suffer discontinuity in their ranges because of barriers.

Increased aquatic connectivity would benefit fish passage and general ecosystem function, however, barriers can also provide benefit, including blocking Sea Lamprey and other harmful invasive species, isolating native from non-native salmonids, stopping disease transfer, and holding back contaminated sediments (Fausch et al., 2009; Kirk et al., 2019). Barriers block invasive Sea Lamprey from spawning in more than 54,000 km of riverine habitat, keeping the basin-wide infestation controllable through lampricide applications (Hrodey et al., 2021, Figure 4). The risk of increased Sea Lamprey production prohibits removal of lowermost barriers (Figure 2) to Great Lakes migration at

this time (Walter et al. 2021), but efforts to find alternative solutions for fish passage at lowermost barriers are ongoing, specifically at the experimental bi-directional selective fish passage facility (FishPass) in Traverse City, MI (Zielinski and Freiburger 2021).

This sub-indicator on aquatic habitat connectivity primarily focusses on the connectivity of the Great Lakes to its tributaries for fishes. While natural barriers to fish migration, such as rapids and waterfalls, are not the same as dams as they do not disrupt the flow and temperatures of tributaries, they still are a barrier to the upstream migration of many fishes. However, their presence has not resulted in decline in the diversity and abundance of Great Lakes fishes from historical conditions, therefore these watersheds have been removed from the analysis. As a result, tributaries that were naturally not connected to the Great Lakes have been excluded. Both lakes Huron and Ontario have significant portions of their watersheds that have natural barriers (e.g. Moon River Falls on the Moon River in Georgian Bay). While aquatic connectivity is showing a positive Improving trend in all the Great Lakes, genuine change in status is expected to take decades of continued efforts. These gains will come through both the mitigation of priority barriers (Table 1, Figure 3) and the cumulative impact of the thousands of smaller scale projects such as inventories and culvert replacements that are happening throughout the basin.

Evaluating aquatic habitat connectivity and prioritizing projects to increase it are complex matters. Changing environmental conditions and aging infrastructure are resulting in the failure of dams and culverts. Some dams and barriers impede the movement of some fish species but not others. Many dams and reservoirs have been in place for over a century and there are strong social pressures to maintain them. Conversely, the expense of maintaining structures such that they are not at risk of failure continues to increase and even large hydropower producers are considering the decommissioning and removal of long-standing dams (Consumers Energy 2022). Removing dams can be complicated by contaminated sediments or endangered species that require careful consideration and planning (Milt et al. 2018; Pratt et al. 2009). Dams and barriers have also been identified as both an opportunity to control the spread of aquatic invasive species, and as a potential source of aquatic invasive species due to releases of bait fish in impoundments and by acting as ‘stepping stones’ for aquatic invasive species (Anas & Mandrak, 2021; Comte et al., 2021; Johnson et al., 2008). Impoundments can also change fish assemblages in adjacent river habitats through the proliferation of habitat generalists species and declines in fluvial specialists.

Linkages

Linkages to other sub-indicators in the indicator suite include:

- Changes in Physical Conditions – Increasing frequency and magnitude of storm events is expected to continue to put pressure on aging infrastructure. This increases the urgency to thoroughly inspect dams and identify under-sized culverts at road-stream crossings. Upgrading this infrastructure provides opportunity to mitigate barriers to fish migration during replacement. Policy around dam inspections and maintenance continues to become more rigorous, especially in Michigan after the May 2020 failure of the privately-owned Edenville and Sanford Dam failures, and that rigor along with a greater public understanding of the risks of failure is starting to change the social pressures of retaining dams in some communities. Evaluating the many trade-offs (ecological, but also economical and sociopolitical) of dam repair, modification, or removal is an urgent need so that resources are applied for maximum benefit (Walter et al. 2021).
- Aquatic Invasive Species – There are many examples across the Great Lakes where the first barrier is protecting native stream assemblages from competition and physical disturbance of substrates from invasive species and non-native salmonids (Bredin 2002; Fausch et al., 2009). Hence, decisions about

removal of dams and barriers must balance competing interests and goals, which may not always be explicit.

- Lake Sturgeon – Loss of aquatic connectivity has contributed to the decline of the species (Auer 1996; Peterson et al., 2007).
- Lake Trout – Removed barriers that result in more parasitic Sea Lamprey would likely cause declines in numbers of Lake Trout and slow progress towards restoration. However, Lake Trout were also a historic migrant into river systems and loss of connectivity contributed to the loss of most riverine Lake Trout spawning runs (Loftus 1958, Khoury 2018).
- Sea Lamprey – Dams and barriers serve as the most successful tool in controlling invasive Sea Lamprey, by restricting access to spawning and larval habitat. By managing Sea Lamprey through barriers, non-target species such as native lampreys, are not impacted by lampricide treatments. Failure or removal of dams that block spawning sea lamprey is considered the greatest risk to successful sea lamprey control (Burkett et al., 2021; DFO and USFWS 2023).
- Walleye – Loss of aquatic connectivity has contributed to the decline of some populations (MacDougall et al., 2007; Schmidt et al., 2020).
- Water Quality in Tributaries – Barrier removal could improve water quality by restoring natural flow patterns and helping to reduce stream temperatures (Brown et al. 2024).
- Precipitation Amounts – An increase in extreme rainfall events may encourage replacement of aging infrastructure, including culverts. Infrastructure adaption projects could potentially improve aquatic habitat connectivity at road-stream crossings (Neeson et. al 2015).

This sub-indicator also links directly to the other sub-indicators in the Habitats and Species indicator.

Citizen Science, Traditional Ecological Knowledge (TEK), and other Bodies of Knowledge

There are several excellent examples from around the Great Lakes of citizen science being used to help confirm potential barriers to aquatic habitat connectivity. These programs typically engage volunteers to visit road-stream crossings and collect data to identify if the crossing represents a barrier, such as a perched culvert. Volunteers use standardized protocols to collect this data (e.g. U.S. Forest Service et. al 2011). The impacts of these projects can be difficult to measure, but are significant (see Data Limitations).

Efforts to incorporate indigenous knowledge and perspectives into aquatic connectivity decision making continues through tribal involvement in the Great Lakes Fishery Commission's Joint Strategic Plan process (GLFC 2007a), as well as through Sea Lamprey control planning for barriers on specific tributaries (Mattes & Kitson, 2021).

Assessing Data Quality

Data Characteristics	Agree	Neutral or Unknown	Disagree	Not Applicable
Data are documented, validated, or quality-assured by a recognized agency or organization	X			

Data are from a known, reliable and respected generator of data and are traceable to original sources	X			
Geographic coverage and scale of data are appropriate to the Great Lakes Basin	X			
Data obtained from sources within the U.S. are comparable to those from Canada	X			
Uncertainty and variability in the data are documented and within acceptable limits for this sub-indicator report	X			
Data used in assessment are openly available and accessible	Yes	Sources include: https://hub.glahf.org/ https://fishwerks.discovery.wisc.edu/ https://aquaticbarriers.ca/en		

Notes on Accessing Data

Transfer of the Great Lakes Aquatic Habitat Framework from its historical location to a new web-based data hub is ongoing in the fall of 2024 and is expected to be complete by spring 2025. The site is at times not accessible as these changes are made.

Data Limitations

Dam and barrier inventories continue to be conducted across the basin, but some dams remain undocumented. Some watersheds are better sampled than others, potentially resulting in data bias (Khoury et al. 2018). Spatial analysis of connectivity can be challenging if dam coordinates do not intersect with the hydrology layer, so efforts within the Aquatic Landscape Ecology Laboratory at Michigan State University are ongoing to clean up those intersections for an improved analysis. Additionally, road stream crossings need to be ground-truthed to assess their actual impact on connectivity. Recently, the Canadian Wildlife Federation launched the Canadian Aquatic Barriers Database (https://aquaticbarriers.ca/en) and the US Fish and Wildlife Service has incorporated Great Lakes region barrier data into the National Aquatic Barrier Database Tool (aquaticbarriers.org). Both of these datasets relied heavily on the dam dataset in the Great Lakes Aquatic Habitat Framework.

This sub-indicator does not measure lateral hydrological connectivity (LHC) (Liu and Wang 2018), which is the connectivity between aquatic ecosystems and adjacent habitats such as floodplains. A decrease in LHC can result from flow regulation on rivers and physical structures and have an impact on fish communities. In the context of the Great Lakes LHC could include access to spawning habitat in floodplains along rivers that are connected to the Great Lakes, and aquatic habitat connectivity to coastal marshes. Data to measure LHC has not been adequately developed throughout the Great Lakes. Land cover and dams may provide a proxy, although connectivity between rivers and streams and their floodplains in sub-watersheds dominated by natural cover could be impacted by water level regulation from upstream dams. Connectivity of the Great Lakes to coastal marshes has also not been analyzed and mapped.

This sub-indicator does not fully measure all the smaller scale changes to connectivity that are occurring around the basin. While the many active smaller scale projects around the basin are difficult to fully report on, their impact is significant, and likely exceeds the impact of larger single barrier removal projects. For example, in just the last five years, Huron Pines in Michigan has improved over 90 road/stream crossings, removed 5 dams and reconnected over 720 km of river.

Additional Information

Examples of barrier removal projects were based on a search of Great Lakes Restoration Initiative (GLRI) projects database (search terms: 'connectivity', 'culvert', 'dam', 'passage' and 'tributary'). For Canadian projects a web search was conducted using these same terms, plus Great Lake name.

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Table 1. Priority rivers and barriers for sea lamprey control (Great Lakes Fishery Commission 2023).

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Figure 2. Great Lakes tributary connectivity and lowermost barriers as of April 2024. Fully connected watersheds (blue) and disconnected watersheds (red) based on barriers in the inventory of the Great Lakes Aquatic Habitat Framework (www.glahf.org).

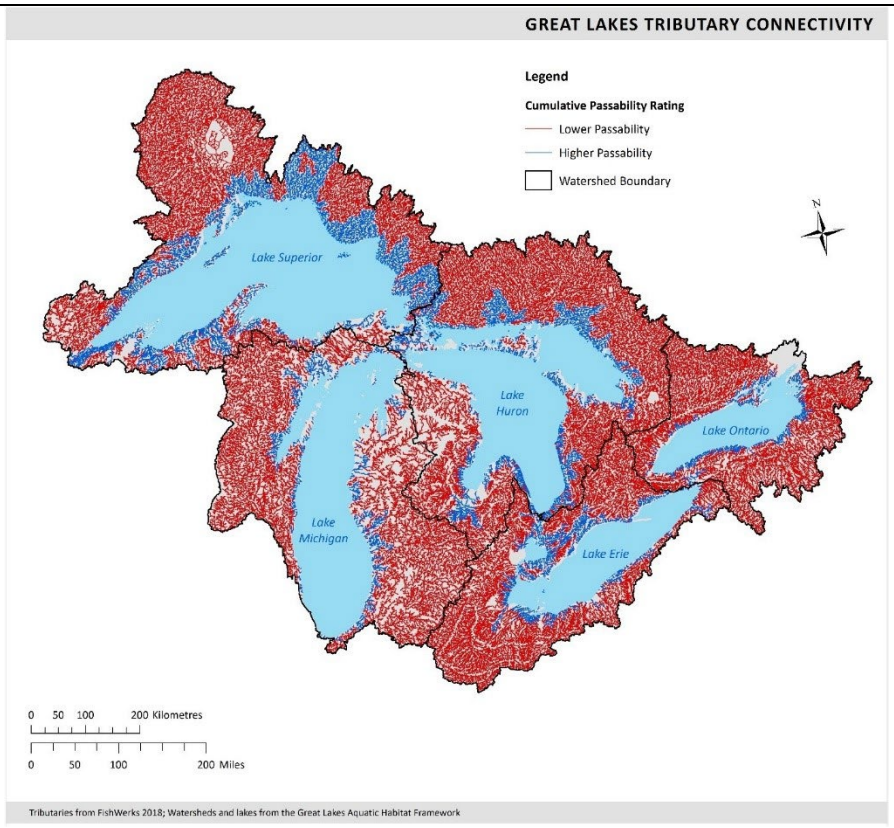
Figure 3. Priority rivers and barriers (Great Lakes Fisheries Commission, 2021).

Figure 4. Priority barriers for Sea Lamprey control (DFO & USFWS, 2021).

Table 1. Priority rivers and barriers believed to impede achievement of Fish Community Objectives in each Great Lake, as identified by the Council of Lake Committees. A full list of environmental priorities can be found at https://www.glfc.org/pubs/lake_committees/common_docs/Combined%20Lake%20Committee%20Environmental%20Priorities%202021.pdf.

Lake	State/Province	Priority River	Dam	Current Fish Passage
Superior	ON	Montreal	Andrews Generating Station	None
Superior	MN, WI	St. Louis	Fond du Lac Dam	None (Schram et al. 1999)
Superior	ON	Michipicoten	Michipicoten River Dam	None
Michigan	WI	Peshtigo	Peshtigo Dam	None (Daugherty et al. 2009)
Michigan	WI	Oconto	Stiles Dam	None (Daugherty et al. 2009)
Huron	MI	Saginaw (Tittabawassee)	Dow Rock Ramp	Fish ladder installed in 1971 (Schrouder et al. 2009)
Huron	ON	Saugeen	Denny's Dam	None
Erie	MI	Black	Wingford Dam	None
Erie	MI	Huron	Flat Rock Dam	Fish ladder installed in 1997 (Leonardi & Thomas 2000)
Erie	ON	Grand	Dunnville Dam	Fishway (Bunt et al. 2000)
Ontario	ON	Cobourg Brook	Pratt Dam	Fishway (Pratt et al. 2009)
Ontario	ON	Credit	Streetsville Dam Norval Dam	Fish ladders https://www.riverwatcherdaily.is/Migration

A)



B)

Figure 1. A) Dams and barriers in the Great Lakes basin (University of Wisconsin, 2018), and B) Watersheds that were historically disconnected from the Great Lake due to natural barriers (Khoury et al., 2018). *This figure is from 2022 SOGL Aquatic Habitat Connectivity Report and the information in this figure is still substantially correct as of 2025.*

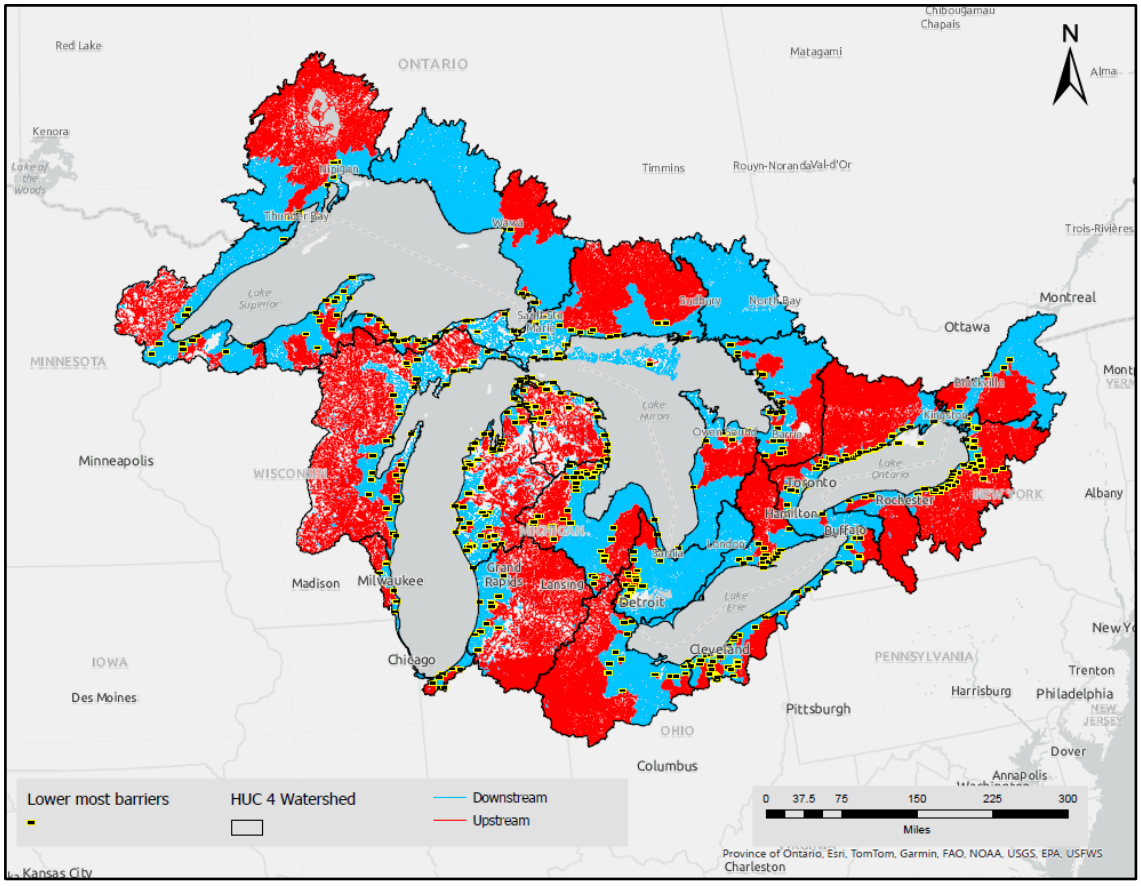


Figure 2. Great Lakes tributary connectivity and lowermost barriers as of April 2024. Fully connected watersheds (blue) and disconnected watersheds (red) based on barriers in the inventory of the Great Lakes Aquatic Habitat Framework (www.glahf.org).

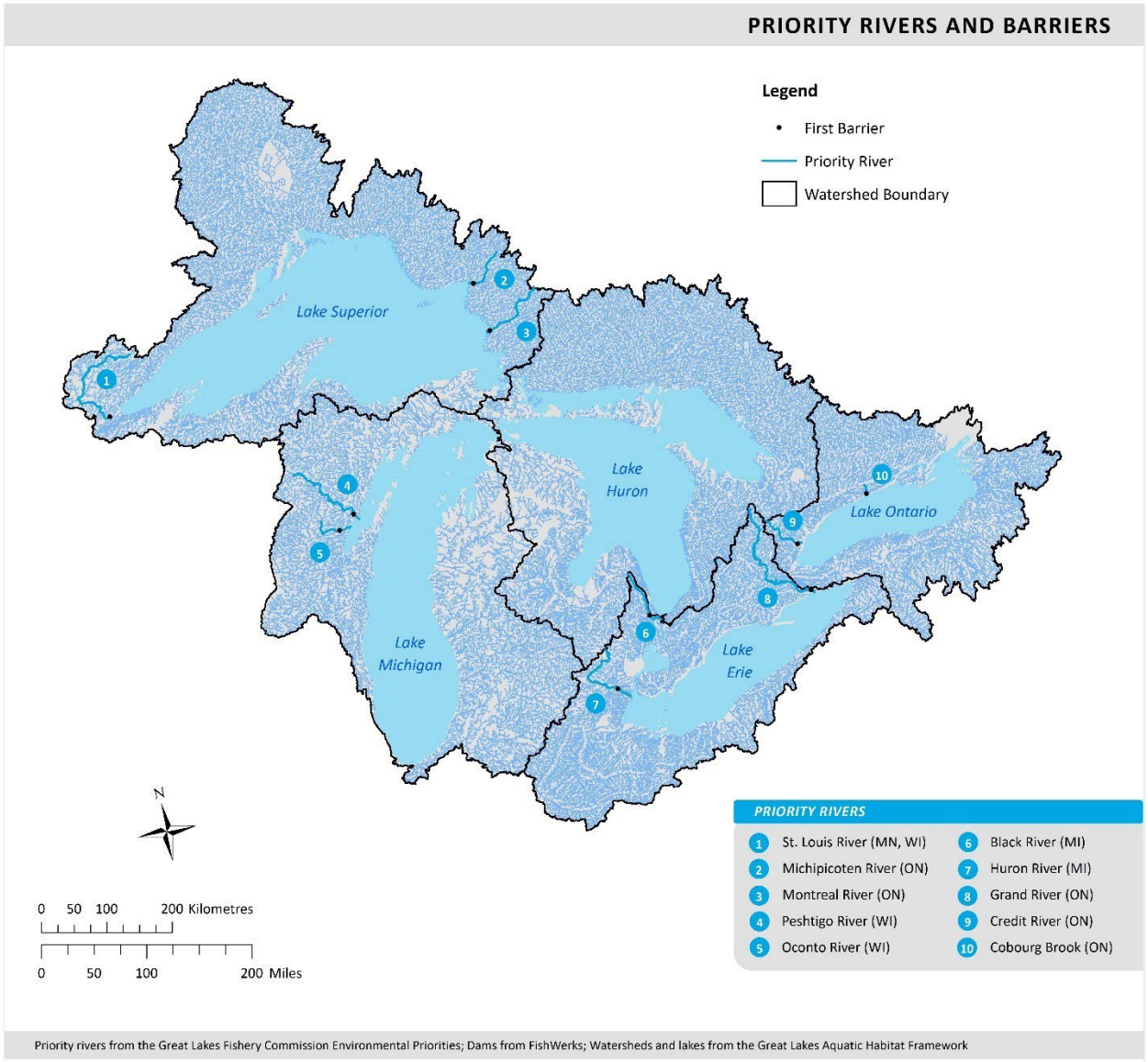


Figure 3. Priority rivers and barriers (Great Lakes Fisheries Commission, 2021). *This figure is from 2022 SOGL Aquatic Habitat Connectivity Report and the information in this figure is still substantially correct as of 2025.*

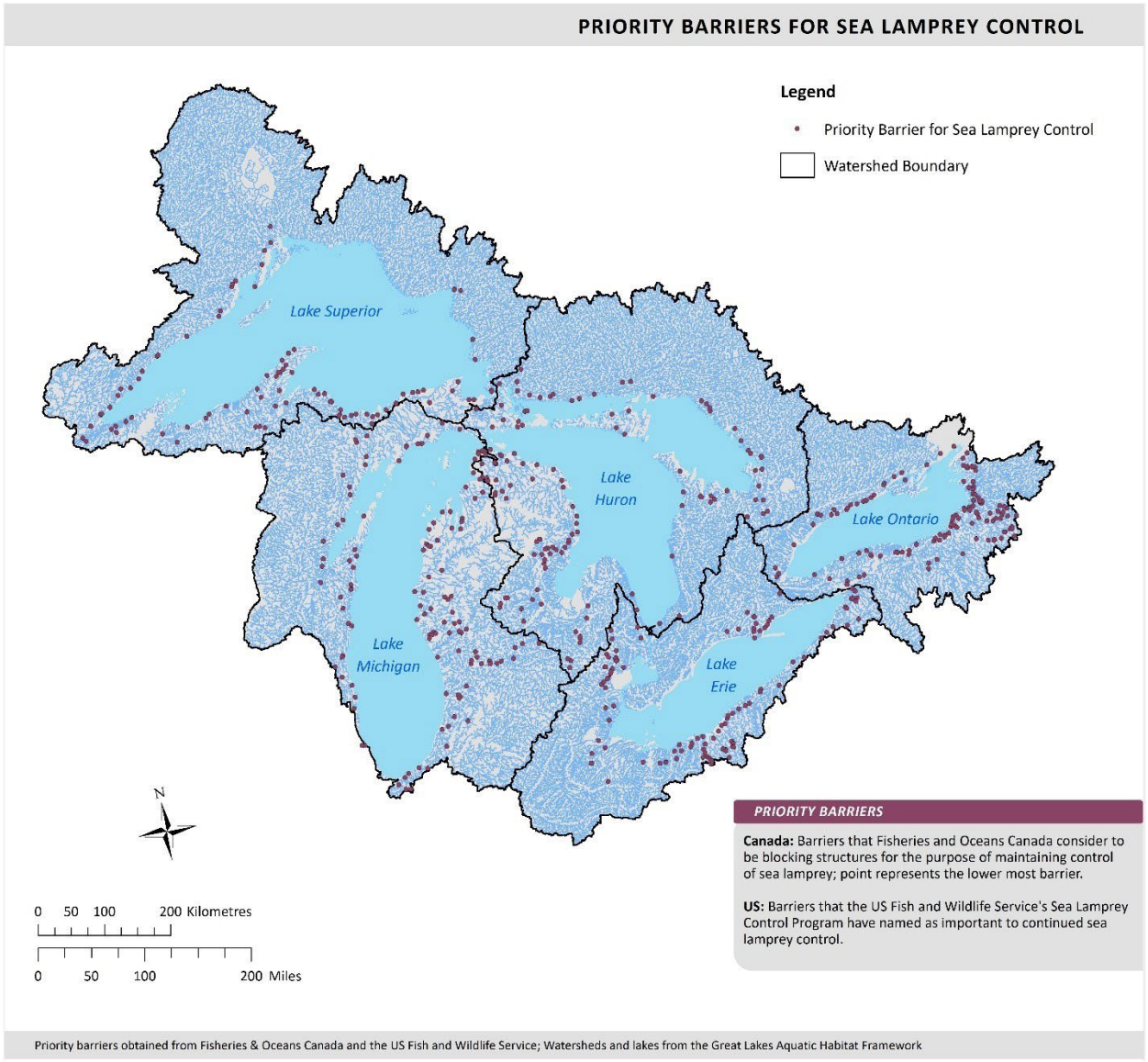


Figure 4. Priority barriers for Sea Lamprey control (DFO & USFWS, 2021). *This figure is from 2022 SOGL Aquatic Habitat Connectivity Report and the information in this figure is still substantially correct as of 2025.*

Last Updated

State of the Great Lakes 2025 Report