Spatial units to support restoration of Bloater *Coregonus hoyi*, Lake Whitefish *Coregonus clupeaformis*, Cisco *Coregonus artedi*, and Round Whitefish *Prosopium cylindraceum* in Lake Ontario



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Version 2026.1 30 October 2026

Citation: Egan, J.P., M.M. Woodruff, A.S. Ackiss, & A.M. Muir. 2026. Spatial units to support restoration of Bloater *Coregonus hoyi*, Lake Whitefish *Coregonus clupeaformis*, Cisco *Coregonus artedi*, and Round Whitefish *Prosopium cylindraceum* in Lake Ontario. Available from: https://www.greatlakesciscoes.org

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ABSTRACT

At the request of the Lake Ontario Committee, we delineated spatial units for Bloater, Lake Whitefish, Cisco, and Round Whitefish in Lake Ontario. Spatial units correspond to the reproductive habitat used by extirpated (unoccupied spatial units) and extant (occupied spatial units) populations. We delineated spatial units using a Council of Lake Committees-endorsed method in which data are synthesized for evaluation by a panel with expertise on the focal organisms and ecosystems. By examining catch, survey, observational, telemetry, reproductive status, demography, fish marking, genetic, and modeled probability of occurrence data, an expert panel determined that there are extant populations of Cisco, Lake Whitefish, and Round Whitefish in Lake Ontario, but no extant Bloater populations. Therefore, the experts delineated two occupied Cisco spatial units and one unoccupied Cisco spatial unit, three occupied Lake Whitefish spatial units and one unoccupied Lake Whitefish spatial unit, one occupied Round Whitefish spatial unit and one unoccupied Round Whitefish spatial unit, and one unoccupied Bloater spatial unit. The expert panel also identified key areas of research that can be investigated to further inform the conservation or restoration of Bloater, Lake Whitefish, Cisco, and Round Whitefish in Lake Ontario. The delineated spatial units will inform follow-on threats assessments and population viability analyses that together provide fishery managers science-based planning tools for coregonine restoration and conservation in Lake Ontario.

1. BACKGROUND

On August 21, 2023, the Lake Ontario Committee requested application of the Great Lakes Coregonine Restoration Framework (Bunnell et al. 2023) planning steps to Lake Ontario Bloater *Coregonus hoyi*, Lake Whitefish *Coregonus clupeaformis*, Cisco *Coregonus artedi*, and Round Whitefish *Prosopium cylindraceum* to inform restoration and conservation. This report summarizes the results of the first planning step - spatial unit delineation. Spatial units are comprised of reproductive habitat that was historically used (unoccupied spatial units) or is currently used (occupied spatial units) by populations or subpopulations of focal organisms. Spatial units provide a foundation for downstream planning, modeling, and restoration activities within the Coregonine Restoration Framework. We delineated spatial units for Bloater (assessment dates: 6 and 8 August 2024), Lake Whitefish (assessment dates: 8-9 October 2024), Cisco (assessment dates: 10-11 October 2024), and Round Whitefish (assessment dates: 16 June and 30 July 2025). To delineate spatial units, we used a Council of Lake Committees-endorsed method that involves synthesis of relevant knowledge followed by an expert elicitation process to objectively evaluate Western scientific evidence for spatial unit criteria in a repeatable manner (Ackiss et al. 2023). Indigenous Knowledge can also be used to delineate spatial units. Indigenous Knowledges were not available at the time of this assessment, but can be used to delineate spatial units for Lake Ontario coregonines in the future to inform conservation and restoration. This report provides: (1) a synthesis of data used for the spatial unit assessment, (2) the results of the assessment, (3) maps depicting delineated spatial units, and (4) rationale for decisions made by the expert panel.

2. METHODS

2.1 Overview of spatial unit delineation approach

The Lake Ontario Committee defined Lake Ontario and its tributaries as the assessment area. Lake Ontario tributaries were only eligible for inclusion in spatial units if they contained reproductive habitat used by populations of focal species with ranges that include at least a portion of Lake Ontario (i.e., resident tributary populations that did not enter Lake Ontario were not included in this assessment). Regions adjacent to the assessment area were also not considered. For example, testing for reproductive isolation between organisms in Lake Ontario and Lake Erie was outside the scope of this work. To delineate spatial units within the defined assessment area, we assembled an expert panel and synthesized relevant information. Then, during virtual workshops, the panel formulated and assessed spatial unit hypotheses using their knowledge, the data synthesis, and a structured scoring process involving a knowledge hierarchy consisting of criteria for unit delineation, lines of evidence, and data types (Hemming et al. 2018; Ackiss et al. 2023; Appendix 1). When experts assessed spatial unit hypotheses, they considered whether there was sufficient evidence to support delineating at least the number of spatial units hypothesized. If a spatial unit hypothesis was accepted, experts decided whether or not testing a more complex hypothesis (i.e., with more spatial units) was warranted.

2.2 Expert panel and assessment facilitators

An expert panel representing a range of Western Science expertise and institutions was assembled for each spatial unit assessment (Table 1). Assessments were facilitated by Josh Egan (Great Lakes Fishery Commission (GLFC)), Monica Woodruff (GLFC), Amanda Ackiss (U.S. Geological Survey (USGS)), Renee Renauer-Bova (GLFC), Katie Anweiler (USGS), and Bo Bunnell (USGS).

Table 1. Expert panelists by name, affiliation, and the species they assessed (shaded cells). USGS = U.S. Geological Survey, OMNR = Ontario Ministry of Natural Resources, NYSDEC = New York State Department of Environmental Conservation, MDNR = Michigan Department of Natural Resources, SUNY Oswego = State University of New York Oswego, and DFO = Fisheries and Oceans Canada.

Panelist	Affiliation	Species assessed			
		Bloater	Lake Whitefish	Cisco	Round Whitefish
Amanda Ackiss	USGS		■	■	■
Taylor Brown	Cornell University	■	■	■	■
Sarah Beech	OMNR		■	■	■
Cory Brant	USGS				■
Bo Bunnell	USGS	■	■	■	■
Michael Connerton	NYSDEC	■			■
Alex Gatch	USGS	■	■	■	
Jeremy Holden	OMNR	■	■	■	■
Lisa Holst	NYSDEC				■
Tim Johnson	OMNR		■	■	■
Katelyn King	MDNR		■	■	■
Christopher Legard	NYSDEC	■			■
Nick Mandrak	University of Toronto	■	■	■	
Brian O'Malley	USGS	■	■	■	■
Tom Pratt	DFO	■	■	■	
Nicholas Sard	SUNY Oswego	■			■
Brian Weidel	USGS	■			■

2.3 Data synthesis

Facilitators compiled a catalog of references relevant to the spatial unit assessment with input from the expert panel. The CORHIST database (Brant et al. 2024) is an update of the review of historical accounts of Lake Ontario Bloater spawning by Goodyear et al. (1982) containing additional information and georeferenced data. Georeferences for spawning occurrence data were obtained from CORHIST when available and both CORHIST and the original sources of spawning data were cited in these situations. Scientists and fishery managers shared personal observations and unpublished data with the expert panel which are cited as personal communications (personal communications described in Appendix 2 Table 1). Summarized information from all sources informed spatial unit delineations made by the expert panel.

2.4 Formulating spatial unit hypotheses

For each focal species the expert panel generated spatial unit hypotheses based on a synthesis of occurrence, spawning, and reproductive habitat suitability information, following Ackiss et al. (2023). The expert panel assigned areas containing reproductive habitat for which there was evidence of contemporary occupancy to occupied spatial unit hypotheses and any remaining

reproductive habitat for which there was evidence for historical occupancy to unoccupied spatial unit hypotheses. All information in the data synthesis was used to place spatial unit boundaries, but georeferenced spawning and possible spawning data and reproductive habitat suitability models were particularly important in informing this process. When drawing spatial unit boundaries, the expert panel sought to strike a balance between including relevant reproductive habitat in hypothesized spatial units, while avoiding being overly inclusive and exaggerating historical or contemporary occupancy. Additionally, the expert panel considered the limited resolution of data when drawing spatial unit boundaries. For both occupied and unoccupied space, the expert panel drafted multi spatial unit hypotheses if there was evidence of multiple stocks/populations.

2.5 Criteria for testing spatial unit hypotheses

Both occupied and unoccupied spatial unit hypotheses were formulated by expert panelists for Lake Whitefish, Cisco, and Round Whitefish. Bloater is considered extirpated from Lake Ontario. While ongoing restoration actions are underway, there is not yet confirmed evidence of natural reproduction. Therefore, only an unoccupied spatial unit hypothesis was generated for Bloater.

Unoccupied units - Two criteria must be met to delineate a single unoccupied spatial unit: (1) historical occupancy of the assessment area by focal organisms and (2) lack of contemporary occupancy of the assessment area by the focal organisms. An additional criterion of reproductive isolation must be met to delineate multiple unoccupied spatial units within the assessment area, but does not need to be tested to delineate a single unoccupied spatial unit. Reproductive isolation between organisms within the assessment area relative to adjacent areas is not evaluated (Ackiss et al. 2023). Criteria and lines of evidence are defined in Appendix 3 Table 1 and data types are defined in Appendix 3 Table 3.

Occupied units – A single criterion must be met to delineate a single occupied spatial unit: contemporary occupancy. This unit may be informally assessed if there is strong evidence for contemporary occupancy. To delineate multiple occupied spatial units within the assessment area, one of two additional criteria must be met to delineate an occupied spatial unit: (1) some degree of reproductive isolation between organisms within the hypothesized spatial units and/or (2) evidence that the organisms within the hypothesized spatial units represent distinct components of the focal species' evolutionary legacy. Criteria and lines of evidence are defined in Appendix 3 Table 2 and data types are defined in Appendix 3 Table 3.

2.6 Determining support for spatial unit criteria

During workshops, experts used the estimate-talk-estimate expert-elicitation approach (Hemming et al. 2018; Ackiss et al. 2023) to individually assign scores to each data type, have a panel discussion about anonymized scores, and then assign final second-round scores by either leaving their first-round scores the same or changing them based on the discussion. Data type scores reflected the level of support panelists thought each data type provided for a line of evidence (data deficient = no score, no support = 0, low support = 1, moderate support = 2, and

high support = 3). Individual scores from the second round of scoring were averaged to determine the collective level of support each data type provided for a line of evidence (step 7 in Appendix 1). Predetermined weights from Ackiss et al. (2023) were then applied to the average scores for each data type to generate final weighted average data type scores. Data type weights are based on their relevance, strength, and reliability in the context of the line of evidence in question. Data type weights are shown in Tables 2, 3, 6, 7, 10, 11, 14, 15, 18, 19, 22, 23, and 26. Ackiss et al. (2023) provided an in-depth explanation of data type weights selected for spatial unit delineation. For each line of evidence, a single categorical "rank" was assigned by averaging the weighted average data type scores, then rounding this number to the nearest rank. For example, a line of evidence score of 2.5 would be rounded to 3 (i.e., rank = high support). Data deficiencies were also tracked. If the majority of panelists identify a data type as data deficient, this data type does not receive an average data type score or contribute to line of evidence scoring/ranking. A criterion is met if at least one line of evidence is assigned a moderate or high level of support.

3. RESULTS AND DISCUSSION

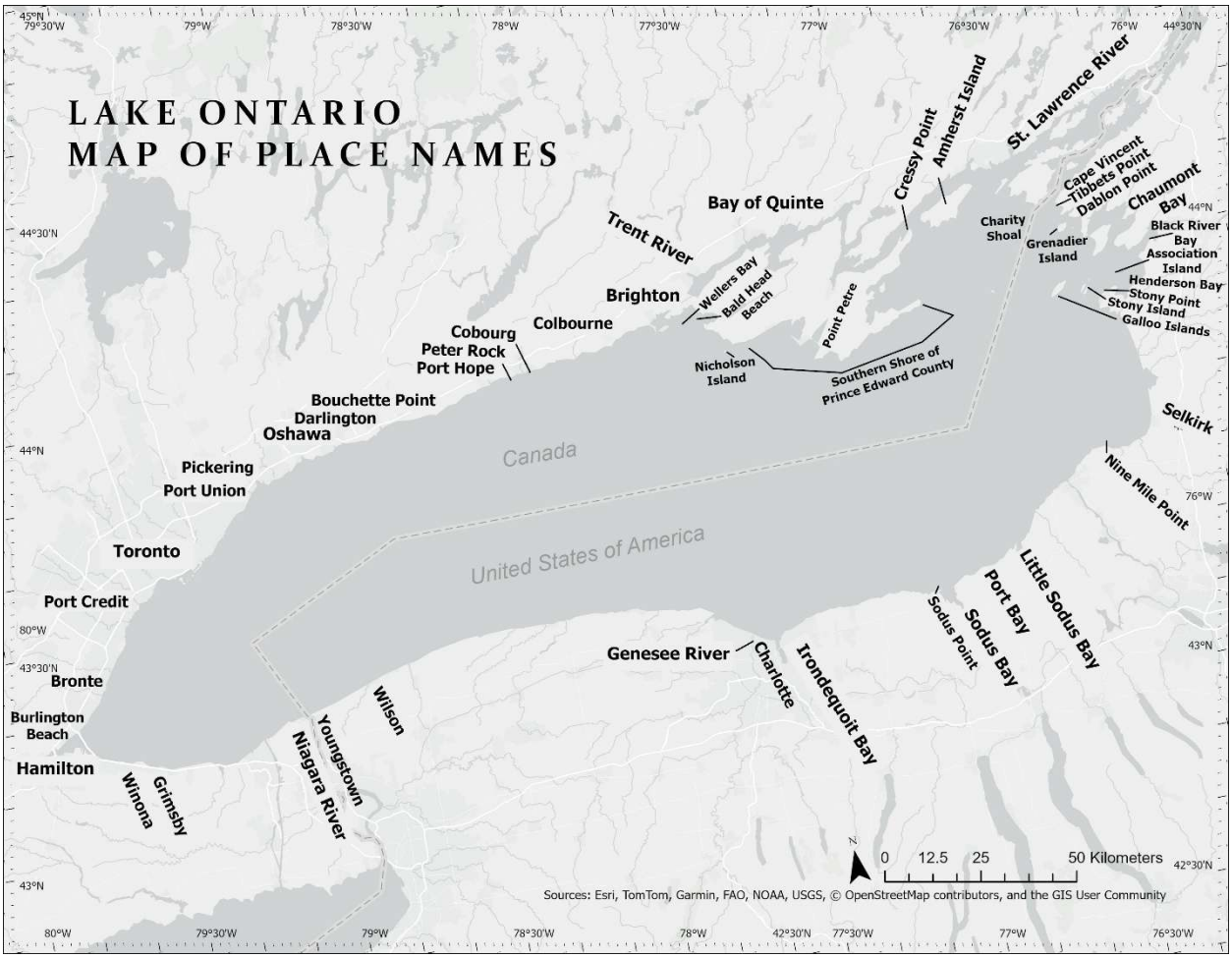


Figure 1. Map of Lake Ontario with place names referenced in this report.

3.1 Bloater

The expert panel assessed a hypothesis for one unoccupied Bloater spatial unit. The expert panel did not identify evidence of Lake Ontario Bloater using reproductive habitat in Lake Ontario tributaries. Thus, no tributaries were included in the hypothesized Bloater spatial unit. The "historical period" for this assessment was designated as 1983 and earlier and the "contemporary period" was designated as 2000 and later. These time periods were based on several major ecosystem changes, including declines in Bloater abundance (the last Bloater thought to be the product of natural reproduction in Lake Ontario was sampled in 1983), increases in zebra mussel *Dreissena polymorpha* and quagga mussel *Dreissena bugensis* abundances, declines in *Diporeia* spp. abundance, and declines in the abundances of other coregonines, such as Lake Whitefish (Griffiths et al. 1991; Mills et al. 1993; Owens et al. 2003; Owens and Dittman 2003; Mills et al. 2005; GLFC 2022; Karatayev et al. 2022).

3.1.1 Unoccupied Bloater spatial unit

3.1.1.1 Unoccupied Bloater spatial unit data synthesis

Facilitators compiled a catalog of 17 references relevant to the unoccupied spatial unit assessment (Tables 2-3) and obtained 32 georeferenced historical spawning observations (direct observations of spawning or mature individuals) and one georeferenced historical possible spawning observation (observations indicative of spawning, such as aggregations of fish during the Bloater spawning season (November-March; Koelz 1929), but spawning/mature fish not directly observed) from CORHIST (Figure 2; Appendix 4 Table 1; Brant et al. 2024).

Table 2. Bloater *Coregonus hoyi* "historically viable population" criterion references (n = 16) organized by line of evidence and data type. Data type weights are shown before references in parentheses: + = weight of one applied to data type and ++ = weight of two applied to data type. Weights are not applied when data types are scored as data deficient. Gray shaded cells indicate the data type was not applicable to assess the line of evidence. Data deficient means that no data of a particular type were available at the time of assessment. See Appendix 4 Table 1 for additional information associated with cataloged Royal Ontario Museum (ROM) and University of Michigan Museum of Zoology (UMMZ) specimens referenced in this table. In some instances, multiple museum catalogue numbers were associated with a single sampling event. In these cases, the sampling event was counted as a single reference.

Data type	Line of evidence		
	Non-ephemeral presence	Reproduction	Genetic / genomic
Harvest	(+) Smith (1894); Pritchard (1931)		
Survey	(++) Koelz (1929); Stone (1947); Wells (1969); O'Gorman et al. (1989); UMMZ 212360 (1983)/Owens et al. (2003)		
Modeled probability of occurrence	(+) K. King (personal communication, 2024a)		
Demography		(+) Pritchard (1931); Stone (1947)	
Reproductive status		(++) Koelz (1929); Pritchard (1931); Stone (1947)	
Observation	(+) Smith (1894); ROM I001795 (1925); ROM I001802, ROM I001804, ROM I001805, ROM I001807 - ROM I001811 (1925); Koelz (1926); ROM I002312 (1926); UMMZ 59603 (1926); ROM I002407, ROM I002411, ROM I002425, ROM I002428, ROM I002431 - ROM I002443 (1926); Koelz (1929); Pritchard (1931); Brant et al. (2024)	(+) Koelz (1926)	
Genetic / genomic			(++) Data deficient
Telemetry	(++) Data deficient		
Conventional marking	(+) Data deficient		
Microchemistry	(+) Data deficient		

Table 3. Bloater *Coregonus hoyi* "lack of contemporary occupancy" criterion references (n = 10) organized by line of evidence and data type. Data type weights are shown before references in parentheses: + = weight of one applied to data type and ++ = weight of two applied to data type. Weights are not applied when data types are scored as data deficient. Gray shaded cells indicate the data type was not applicable to assess the line of evidence. Data deficient means that no data of a particular type were available at the time of assessment. OMNR = Ontario Ministry of Natural Resources.

Data type	Line of evidence	
	Absence of target organisms	Genetic / genomic
Harvest	(+) OMNR (2023)	
Survey	(++) O'Gorman et al. (1989); Owens et al. (2003); Brown et al. (2022); Weidel et al. (2022); Weidel et al. (2022b); O'Malley et al. (2022); Weidel et al. (2023)	
Modeled probability of occurrence	(+) K. King (personal communication, 2024a)	
Observation	(+) Data deficient	
Genetic / genomic		(++) Weidel et al. (2022); A. Ackiss (personal communication, 2024a)
Telemetry	(++) Data deficient	
Conventional marking	(+) Weidel et al. (2022)	
Microchemistry	(+) Data deficient	

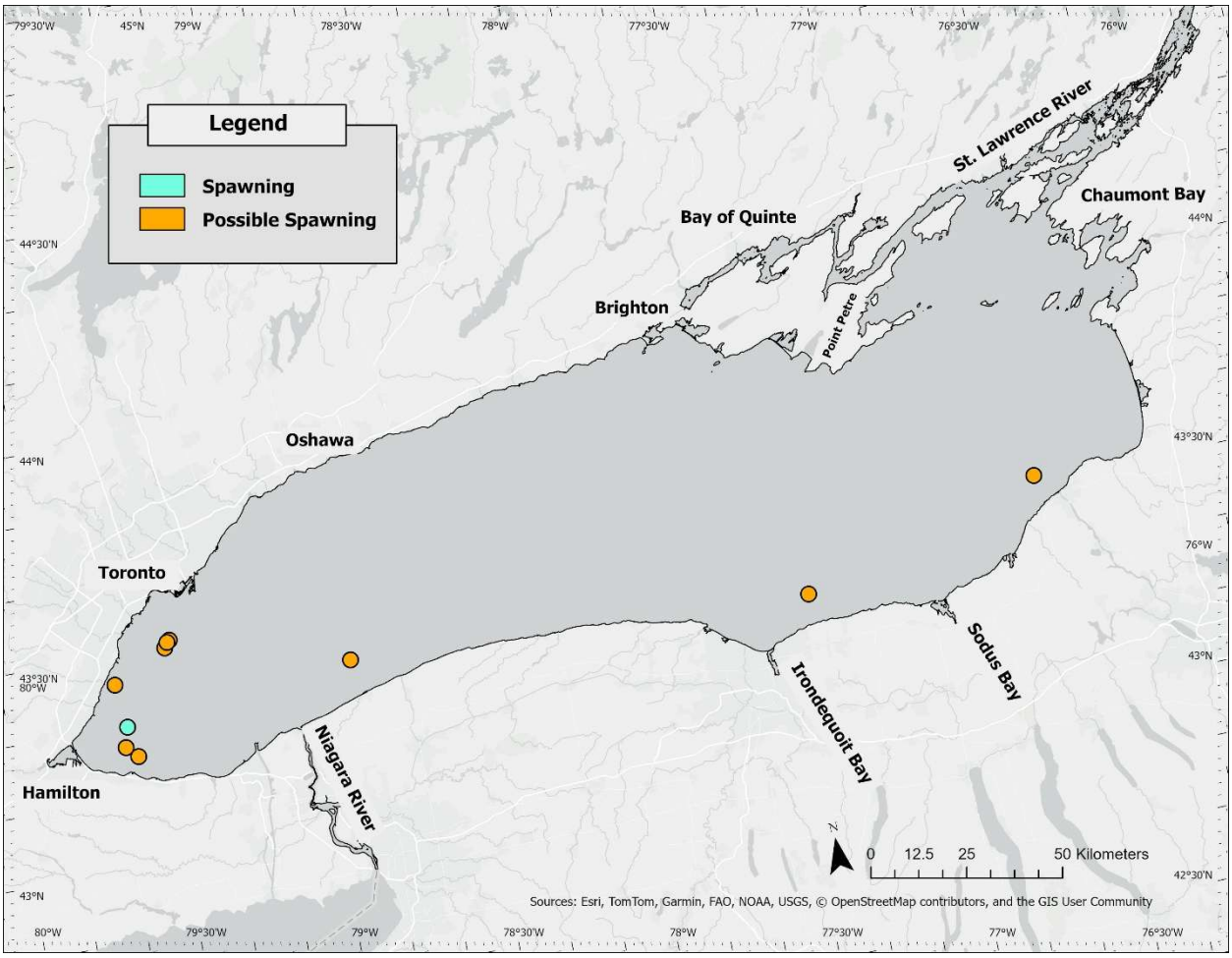


Figure 2. Map of Lake Ontario with historical Bloater *Coregonus hoyi* spawning and possible spawning observations (Appendix 4 Table 1). "Spawning" observations (n = 1) are direct observations of spawning, mature individuals, or spawning grounds and "possible spawning" observations (n = 9) are observations suggestive of spawning (e.g., aggregations of fish during the spawning season) but not direct observations of spawning/mature fish. In this figure, there are cases in which points showing the locations of observations overlap, obscuring the true number of observations.

3.1.1.2 Description of hypothesized unoccupied Bloater spatial unit

The expert panel generated a hypothesis to formally assess containing one unoccupied Bloater spatial unit encompassing all areas in Lake Ontario with modeled historically suitable reproductive habitat (K. King, personal communication, 2024a; Figure 3). The panel restricted the hypothesized unoccupied spatial unit to depths of 30-150 meters because spawning data (Koelz 1929; Stone 1947; Brant et al. 2024), their expert knowledge, and a reproductive habitat suitability model (K. King, personal communication, 2024a) indicated that historical spawning of Bloater outside this depth range was unlikely in Lake Ontario.

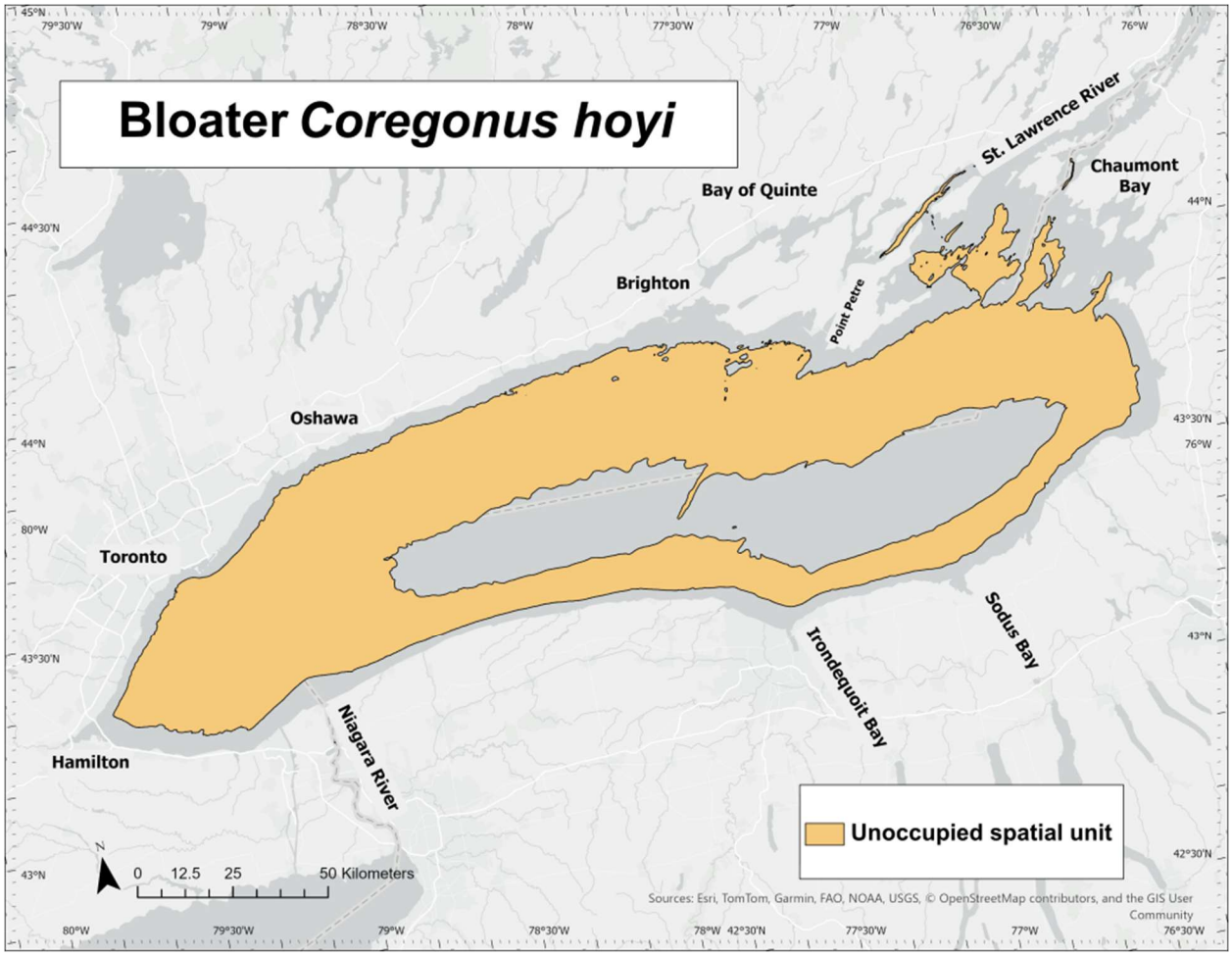


Figure 3. Map of Lake Ontario with color demarcating the location of the single unoccupied Bloater *Coregonus hoyi* spatial unit. Space not assigned to the spatial unit is demarcated via gray shading. Space may not have been assigned to the spatial unit because either it historically did not contain Bloater reproductive habitat or there was no evidence of historical occupancy of Bloater regardless of reproductive habitat suitability. See Section 2.2 for an explanation of the requirements for occupancy criteria.

3.1.1.3 Unoccupied Bloater spatial unit assessment results and discussion

Both criteria for delineating the hypothesized unoccupied Bloater spatial unit hypothesis were met: "historically viable population" (Table 4) and "lack of contemporary occupancy" (Table 5).

Historically viable population criterion (historical presence of a naturally reproducing (sub)population over an extended period of time): The historically viable population criterion received **high support** from the non-ephemeral presence line of evidence and **moderate support** from the reproduction line of evidence (Table 4). The genetic/genomic line of evidence was **data deficient**. Given that only one line of evidence was required to achieve at least a moderate level of support, the historically viable population criterion was met.

LINES OF EVIDENCE

Non-ephemeral presence

The harvest, survey, and observation data types provided **high support** for the non-ephemeral presence line of evidence and the modeled probability of occurrence data type provided **low support**. The telemetry, conventional marking, and microchemistry data types were **data deficient.**

Harvest data (high support) – Bloater harvest data spanned the period of 1892-1928 (Smith 1894; Pritchard 1931). Smith (1894) positively identified two Bloater caught by commercial fishers at an unspecified location within Lake Ontario in 1892. Pritchard (1931) identified Bloater caught by commercial fishers from 1925-1928 during February, March, and November and remarked that Bloater comprised approximately 93% of "deepwater coregonine" catches during this time. Although harvest records were limited, the expert panel scored the harvest data type as high support for the non-ephemeral presence line of evidence due to the historical harvest of Bloater during multiple time periods at several locations within the hypothesized unoccupied spatial unit and the positive identification of Bloater by multiple prominent scientists.

Survey data (high support) – Koelz (1929) conducted coregonine surveys in 1921 and 1923 and concluded that Bloater occurred throughout much of Lake Ontario. O'Gorman et al. (1989) surveyed the U.S. waters of Lake Ontario using bottom trawls and gill nets between May and October 1972 and caught one or two Bloater (discrepancy in report regarding number of Bloater caught). Stone (1947) conducted a gillnet survey in New York waters and caught 2,231 Bloater from June to November 1942. Wells (1969) conducted a gillnet survey in New York waters and caught ten Bloater in September 1964. Owens et al. (2003) surveyed the U.S. waters of Lake Ontario in several locations with bottom trawls and gill nets annually during the period of 1978-1998 and with gillnets during the period of 1994-1998 and collected a single Bloater in 1983. The expert panel concluded that survey data provided evidence of widespread historical occurrence of Bloater over a long time period and scored the survey data type as high support for the non-ephemeral presence line of evidence.

Modeled probability of occurrence data (low support) – K. King (personal communication, 2024a) generated two maximum entropy (Elith et al. 2011) historical reproductive habitat suitability models using historical georeferenced Bloater spawning records from both Lake Michigan and Lake Ontario data (spawning records time range:

1860-1983; Brant et al. 2024). K. King used both Lake Michigan and Lake Ontario data because there were insufficient data to generate models that only used Lake Ontario data. One model was generated for all of Lake Ontario except the Bay of Quinte and a second model was generated just for the Bay of Quinte. Lake Ontario modeling included mean circulation magnitude [meters/second] as a potential variable, but Bay of Quinte modeling considered fetch [meters] instead because circulation data were unavailable for this portion of the lake. Both models also considered seven additional variables: bathymetry [meters], historical substrate [categorical variable with 14 substrate categories], predicted reefs [predicted reef suitability from 0-1], coefficient of variation of ice duration [days], mean ice duration [days], distance to wetlands [kilometers], and bottom slope [degrees]. Four environmental variables with the most predictive power were selected for both final models: bathymetry, historical substrate, predicted reefs, and circulation/fetch. The expert panel determined that the models indicated the historical presence of suitable reproductive habitat for Bloater in Lake Ontario. The expert panel also noted that reproductive habitat suitability models that necessarily used data from both Lake Michigan and Lake Ontario may be less accurate than a robust model based entirely on Lake Ontario Data. Therefore, the expert panel assigned the modeled probability of occurrence data type a score of low support for the non-ephemeral presence line of evidence.

Observational data (high support) – Observations of Bloater in Lake Ontario during the late-1800s to the 1920s were common (Smith 1894; Koelz 1926; Koelz 1929; Pritchard 1931; Brant et al. 2024) and multiple reports that Bloater were very abundant in the late-1800s (Smith 1894; Koelz 1926; Pritchard 1931). Many observations suggested that Bloater started declining in abundance during the early 1900s and persisted at least until the mid-1900s (Koelz 1926; Brant et al. 2024). Based on the numerous, consistent observations of Bloater over many years in Lake Ontario, the expert panel assigned a score of high support to the observational data type for the non-ephemeral presence line of evidence.

Reproduction

The reproductive status data type provided **high support** for the reproduction line of evidence, the demography data type provided **moderate support**, and the observation data type provided **low support**.

Demography data (moderate support) – Multiple age classes were identified in samples of Lake Ontario Bloater collected during the period of 1925-1942 (Pritchard 1931; Stone 1947). Pritchard (1931) identified age classes 1 - 6 at Port Credit and Bronte, ON, CAN between 1925-1928. Stone (1947) aged 440 Bloater captured during the period of June - November 1942 in New York waters and identified age classes 3 - 13. The expert panel determined the limited demographic data available indicated the presence of several Bloater age classes, indicative of successful reproduction over a period of many years, and therefore assigned the demography data type a score of moderate support for the reproduction line of evidence.

Reproductive status data (high support) – Koelz (1929) collected a male Bloater with nuptial tubercles in November 1917 near Winona and collected a spent female near Port Credit in March 1926. Additionally, Pritchard (1931) identified mature Bloater in western Lake Ontario around Port Credit and Bronte in February, March, and November 1925-1928. CORHIST (Brant et al., 2024) contained records of Bloater that were mature or nearly mature and of adult-sized individuals collected during the reproductive period, primarily in western Lake Ontario off Port Credit and Hamilton. Stone (1947) noted that most of the 2,200 Bloater they collected in New York waters along southern Lake Ontario during 1942 were mature. Due to the substantial evidence of Bloater reproduction from several time periods and locations, the expert panel assigned a score of high support to the reproductive status data type for the reproduction line of evidence.

Observation data (low support) – Koelz (1926) putatively identified spawning coregonines collected off Burlington Beach during the period of ~1860-1900 in the fall as Bloater. Due to the dearth of observational data and uncertainty about whether Koelz (1926) correctly identified the fish he observed as Bloater, the expert panelists assigned a score of low support to the observation data type for the reproduction line of evidence.

Table 4. Results describing how the "historically viable population" criterion was met for the hypothesized unoccupied Bloater *Coregonus hoyi* spatial unit. Unweighted "data type scores" are the average scores for each data type prior to weighting and SD is the standard deviation of data type scores among individual expert panelists. "Line of evidence ranks" show the overall support a line of evidence provided for the spatial unit criterion (gray = data deficient, yellow = low support, orange = moderate support, red = high support). Ranks were calculated by weighting, then averaging associated data type scores. "-" indicates data deficiency.

Line of evidence	Data type	Data type score	SD	Line of evidence rank
Non-ephemeral presence	Harvest	2.8	0.40	High (2.60)
	Survey	3.0	0.00	
	Modeled prob of occurrence	1.2	0.75	
	Observational	2.7	0.47	
	Telemetry	-	-	
	Tagging/marking	-	-	
	Microchemistry	-	-	
Reproduction	Demography	2.2	0.42	Moderate (2.30)
	Reproductive Status	2.5	0.53	
	Observation	1.2	0.44	
Genetic / genomic	Genetic / genomic	-	-	Data Deficient

Lack of contemporary occupancy criterion (focal organisms are entirely absent from the focal area or only ephemerally present): The lack of contemporary occupancy criterion received **moderate support** from the contemporary absence and genetic/genomic lines of evidence (Table 5). Given that one line of evidence was required to achieve at least a moderate level of support to meet this criterion, the lack of contemporary occupancy criterion was met.

LINES OF EVIDENCE

Contemporary absence

The survey data type provided **high support,** the conventional tagging/marking data type provided **moderate support**, and the harvest data type provided **low support** for the contemporary absence line of evidence. The modeled probability of occurrence, observation, telemetry, and microchemistry data types were **data deficient.**

Harvest data (low support) – No harvest of Bloater has been reported during the contemporary period, despite consistent commercial fishing, primarily in Canadian waters (OMNR 2023). The expert panel contributed substantial knowledge related to commercial fisheries in Lake Ontario and determined that current commercial fisheries primarily do not operate with mesh sizes or at the depths likely to catch Bloater. Therefore, the expert panel assigned the harvest data type a score of low support for the contemporary absence line of evidence.

Survey data (high support) – General fish surveys have been conducted throughout much of Lake Ontario during the period of 1962-present. Despite substantial survey effort, only 13 Bloater were captured during the contemporary period, all of which were stocked (O'Gorman et al. 1989; Owens et al. 2003; Brown et al. 2022; Weidel et al. 2022; Weidel et al. 2022b; O'Malley et al. 2022; Weidel et al. 2023). The last Bloater of Lake Ontario (wild) origin was captured during the historical period in 1983 (Owens et al. 2003). Expert panelists agreed that extensive survey effort capable of catching Bloater during the contemporary period has occurred; yet, this work yielded no Lake Ontario origin bloater. Therefore, the expert panel assigned the survey data type a score of high support for the contemporary absence line of evidence.

Conventional tagging/marking data (moderate support) – Expert panelists shared knowledge about mark-recapture efforts for stocked Bloater marked with calcein in Lake Ontario. To date, only stocked Bloater have been captured, which the expert panelists thought was indicative of a lack of wild spawning/recruitment; therefore, they assigned the tagging/marking data type a score of moderate support for the contemporary absence line of evidence.

Genetic/genomic

The genetic/genomic data type provided **moderate support** for the genetic/genomic line of evidence.

Genetic/genomic data (moderate support) – Twelve bloater captured in Lake Ontario during the 2020s were genotyped and all individuals had Lake Michigan genotypes, indicating the fish were likely of hatchery origin (Weidel et al. 2022; A. Ackiss, personal communication, 2024a). The expert panel acknowledged that available genetic data could not conclusively determine whether the genotyped fish were of hatchery origin, but they thought this was highly likely, given that the Bloater broodstock population used for Lake Ontario stocking was of Lake Michigan origin. Thus, the expert panel thought genetic data provided some evidence that there are currently very few if any Bloater with Lake Ontario genotypes in Lake Ontario and assigned the genetic/genomic data type a score of moderate support for the genetic/genomic line of evidence.

Table 5. Results describing how the "lack of contemporary occupancy" unoccupied spatial unit criterion was met for the hypothesized unoccupied Bloater *Coregonus hoyi* spatial unit. Unweighted "data type scores" show the average scores for each data type prior to weighting and SD is the standard deviation of data type scores among individual expert panelists. "Line of evidence ranks" show the overall support a line of evidence provided for the spatial unit criterion (gray = data deficient, yellow = low support, orange = moderate support, red = high support). Ranks were calculated by weighting, then averaging associated data type scores. "-" indicates data deficiency.

Line of evidence	Data type	Data type score	SD	Line of evidence rank
Absence	Harvest	1.2	0.41	Moderate (2.3)
	Survey	3.0	0.00	
	Modeled probability of occurrence	-	-	
	Observational	-	-	
	Telemetry	-	-	
	Conventional marking	1.8	0.67	
	Microchemistry	-	-	
Genetic / genomic	Genetic / genomic	1.8	0.44	Moderate (2.0)

3.1.2 Conclusions

3.1.2.1 Delineated spatial units

This assessment determined that the criteria were met for the hypothesized unoccupied Bloater spatial unit (Figure 4). Therefore, **one unoccupied spatial unit was delineated for Lake Ontario Bloater** (Figure 3). This spatial unit should be viewed as the most complex hypothesis for historical Bloater population structure that was supported by the data available for this assessment. If new data become available, future assessments can revise the Lake Ontario Bloater spatial unit. Furthermore, Indigenous Knowledge may also delineate spatial units for Lake Ontario Bloater in the future, which may or may not be congruent with the spatial unit delineated herein using Western Science.

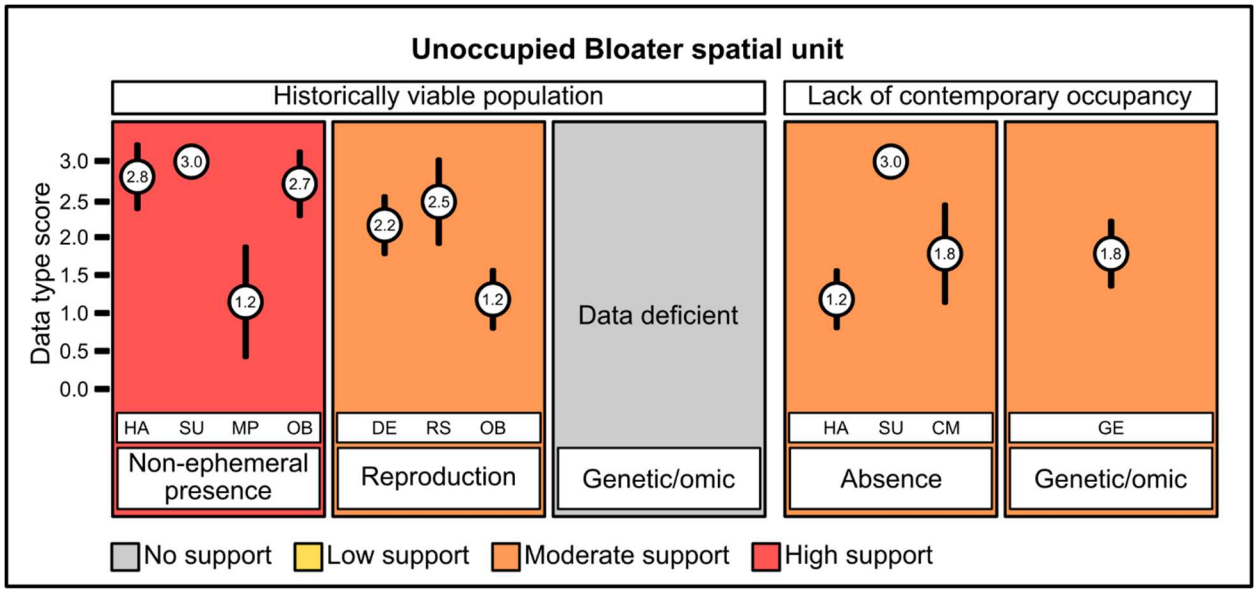


Figure 4. Summary of spatial unit assessment results for Lake Ontario Bloater *Coregonus hoyi*. The "historically viable population" and "lack of contemporary occupancy" criteria were assessed for a one unoccupied unit hypothesis. Circles show the average "data type scores" for each data type prior to weighting and vertical black bars show the standard deviation (SD) of data type scores among individual expert panelists. Data type codes: HA = harvest, SU = survey, MP = modeled probability of occurrence, OB = observation, DE = demography, RS = reproductive status, MT = marking/tagging, and GE = genetic/genomic. Data deficient data types are not shown (See Tables 4 and 5). The color of each line of evidence box corresponds to the "line of evidence rank," which shows the overall support a line of evidence provides for the spatial unit criterion (see legend). Ranks were calculated by weighting, then averaging associated data type scores.

3.1.2.2 Key knowledge gaps

The expert panel identified three key knowledge gaps that inhibited Bloater spatial unit delineation. Knowledge gaps were associated with spawning behavior, movement, and resource use (see also data poor and data deficient data types in Tables 2 and 3 that highlight additional knowledge gaps):

1. When and where did Bloater historically spawn in Lake Ontario? The habitats used by Bloater for reproduction and embryogenesis and the timing of spawning are poorly understood.

2. Where (i.e., depths and areas) did Bloater historically move throughout their life history in Lake Ontario and were historical movement patterns conducive to reproductive isolation/population structuring?

3. Historically, was there adaptive phenotypic diversity/local adaptation within Lake Ontario Bloater?

3.2 Lake Whitefish

The expert panel formulated and formally assessed a Lake Whitefish spatial unit hypothesis containing three occupied spatial units and one unoccupied spatial unit. The expert panel identified evidence of Lake Ontario Lake Whitefish using reproductive habitat in three Lake Ontario tributaries: the Trent River (Christie 1967), Genesee River (Smith et al. 1891), and Niagara River (Brant et al. 2024). Thus, the lower reaches of these tributaries were included in the hypothesized unoccupied Lake Whitefish spatial units (see Section 3.2.1.2 for additional details). The "historical period" for this assessment was designated as prior to 1970 and the "contemporary period" was designated as 2000 and after. These time periods were based on several major ecosystem changes that occurred between 1970-1999 including very low Lake Whitefish abundance, increases in zebra and quagga mussel abundances, and declines in *Diporeia* abundance (Griffiths et al. 1991; Mills et al. 1993; Owens and Dittman 2003; Mills et al. 2005; GLFC 2022; Karatayev et al. 2022).

3.2.1 Unoccupied Lake Whitefish spatial unit

3.2.1.1 Unoccupied Lake Whitefish spatial unit data synthesis

Facilitators compiled a catalog of 82 references (Tables 6 and 7) and obtained 39 georeferenced historical spawning observations (direct observations of spawning or mature individuals on spawning grounds) and 6 georeferenced historical possible spawning observations (observations indicative of spawning but spawning/mature fish not directly observed) from CORHIST (Figure 5; Appendix 4 Table 2; Brant et al. 2024) to facilitate assessment of the hypothesized unoccupied Lake Whitefish spatial unit.

Table 6. Lake Whitefish *Coregonus clupeaformis* "historical occupancy" criterion references (n = 61) organized by line of evidence and data type. Data type weights are shown before references in parentheses: + = weight of one applied to data type and ++ = weight of two applied to data type. Weights are not applied when data types are scored as data deficient. Gray shaded cells indicate the data type was not applicable to assess the line of evidence. Data deficient means that no data of a particular type were available at the time of assessment. GLFC = Great Lakes Fishery Commission; OMNR = Ontario Ministry of Natural Resources.

Data type	Line of evidence		
	Non-ephemeral presence	Reproduction	Genetic / genomic
Harvest	(+) Rathbun et al. (1897); Department of Marine and Fisheries (1904); Green (1908); Pritchard (1931); Holmes and Whillans (1984); OMNR (2002); GLFC (2022)		
Survey	(++) Koelz (1929); Wells (1969)		
Modeled probability of occurrence	(+) K. King (personal communication, 2024b)		
Demography		(+) Data deficient	
Reproductive status		(++) Koelz (1929)	
Observation	(+) Kerr and Kerr (1860-1898); Smith et al. (1891); Rathbun et al. (1897); Dymond et al. (1929); Pritchard (1931); Christie (1967); Goodyear et al. (1982); Brant et al. (2024)	(+) Kerr and Kerr (1860-1898); Smith et al. (1891); Smith (1892); Bean (1903); Harris (1906); Dymond et al. (1929); Koelz (1929); Hart (1930); Pritchard (1931b); Ontario Game and Fisheries Department (1943); Christie (1967); Balesic (1979c); Whillans (1977); Goodyear et al. (1982); Brant et al. (2024)	
Genetic / genomic			(++) Data deficient
Telemetry	(++) Data deficient		
Conventional marking	(+) Data deficient		
Microchemistry	(+) Data deficient		

Table 7. Lake Whitefish *Coregonus clupeaformis* "no contemporary occupancy" criterion references (n = 13) organized by line of evidence and data type. Data type weights are shown before references in parentheses: + = weight of one applied to data type and ++ = weight of two applied to data type. Weights are not applied when data types are scored as data deficient. Gray shaded cells indicate the data type was not applicable to assess the line of evidence. Data deficient means that no data of a particular type were available at the time of assessment. GLFC = Great Lakes Fishery Commission; OMNR = Ontario Ministry of Natural Resources.

Data type	Line of evidence	
	Absence of target organisms	Genetic / genomic
Harvest	(+) OMNR (2002); GLFC 2022	
Survey	(++) Hoyle et al. 2011; Brown et al. (2022); Weidel et al. (2023); OMNR (2024); O'Malley et al. (2024); O'Malley et al. (2024b); B. O'Malley (personal communication, 2024a); B. Weidel (personal communication, 2024)	
Modeled probability of occurrence	(+) K. King (personal communication, 2024b)	
Observation	(+) Salvesen (2015); Gatch et al. (2021)	
Genetic / genomic		(++) Data deficient
Telemetry	(++) Beech et al. (2024)	
Conventional marking	(+) Data deficient	
Microchemistry	(+) Data deficient	

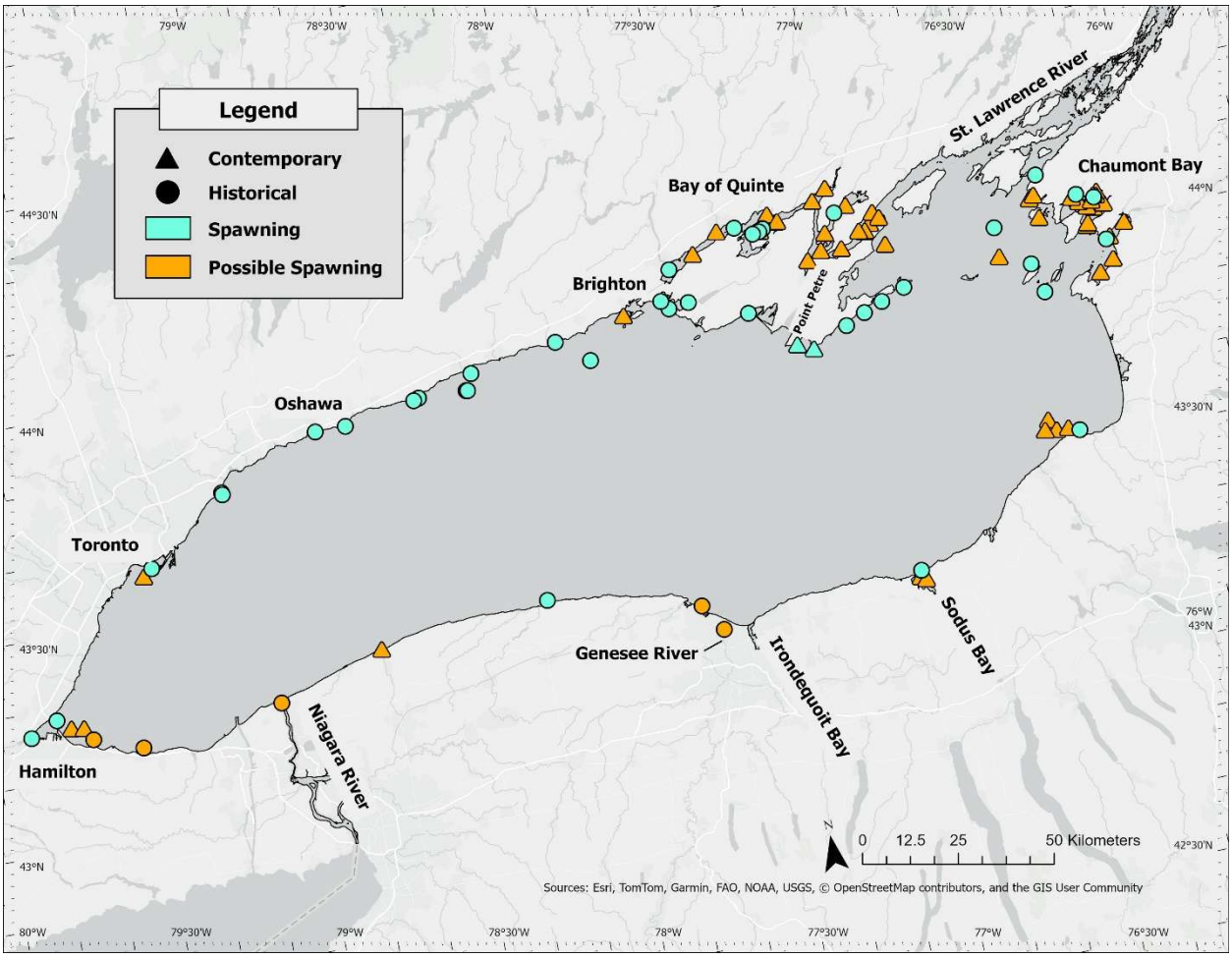


Figure 5. Map of Lake Ontario with georeferenced Lake Whitefish *Coregonus clupeaformis* historical and contemporary spawning and possible spawning observations (Appendix 4 Table 2). "Spawning" observations (n = 43) are direct observations of spawning, mature individuals, or spawning grounds and "possible spawning" observations (n = 58) are observations suggestive of spawning (e.g., aggregations of fish during the spawning season) but not direct observations of spawning/mature fish. In this figure, there are cases in which points showing the locations of observations overlap, obscuring the true number of observations.

3.2.1.2 Description of hypothesized unoccupied Lake Whitefish spatial unit

The expert panel generated a Lake Whitefish hypothesis to formally assess containing one unoccupied spatial unit including historical Lake Whitefish reproductive habitat along most of Lake Ontario's shoreline with the exception of the Bay of Quinte, Chaumont Bay area, and southern shore of Prince Edward County (Figure 6). Additionally, observational data suggested that Lake Whitefish historically spawned in the Trent River (Christie 1967), Genesee River (Smith et al. 1891), and Niagara River (Brant et al. 2024). Therefore, the lower reaches of each of the rivers were included in the hypothesized unoccupied spatial unit, but were not given hard upstream boundaries due to insufficient knowledge about where Lake Whitefish historically spawned in these rivers. The expert panel restricted the unoccupied spatial unit to

depths < 20 meters because they did not find evidence for historical spawning of Lake Whitefish in Lake Ontario at depths outside that range. The expert panel determined that there were insufficient data to test for reproductive isolation among Lake Whitefish within different regions of the unoccupied spatial unit, so hypotheses containing multiple unoccupied spatial units were not tested.

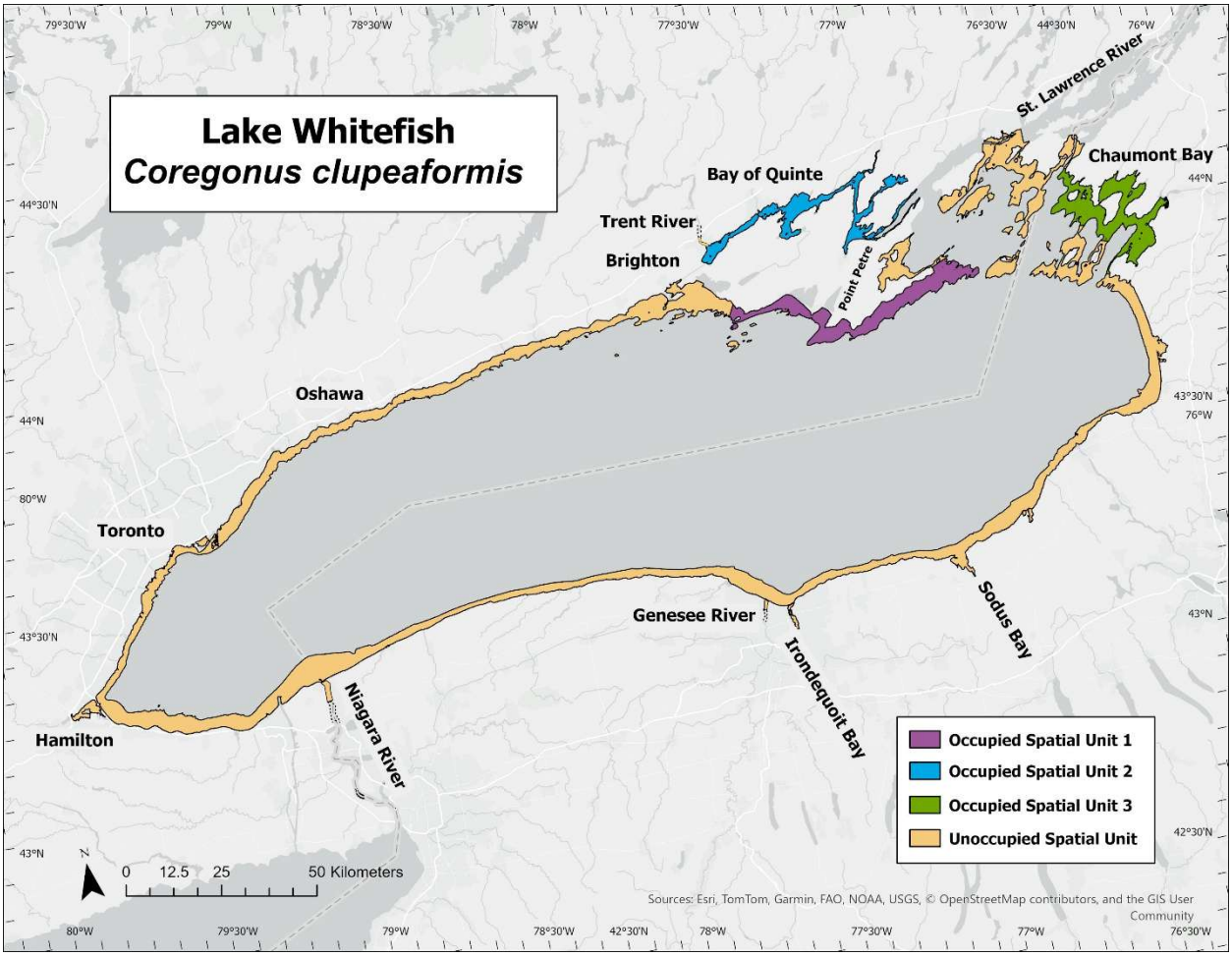


Figure 6. Map of Lake Ontario with colors demarcating the locations of the three occupied Lake Whitefish spatial units and single unoccupied Lake Whitefish *Coregonus clupeaformis* spatial unit. Space not assigned to any spatial units is demarcated via gray shading. Space may not have been assigned to a spatial unit because either it did not contain Lake Whitefish reproductive habitat (neither historically or contemporarily) or there was no evidence of historical or contemporary occupancy of Lake Whitefish regardless of reproductive habitat suitability. See section 2.2 for an explanation of the requirements for occupancy criteria.

3.2.1.3 Unoccupied Lake Whitefish spatial unit assessment results and discussion

<u>Both criteria for delineating the hypothesized unoccupied Lake Whitefish spatial unit were met</u>: "historically viable population" (Table 8) and "lack of contemporary occupancy" (Table 9).

Historically viable population criterion (historical presence of a naturally reproducing (sub)population over an extended period of time): One line of evidence must achieve at least a moderate level of support for the historical occupancy criterion to be met. This requirement was satisfied by the non-ephemeral presence and reproduction lines of evidence, which both received **moderate support** (Table 8). The genetic/genomic line of evidence was **data deficient**.

LINES OF EVIDENCE

Non-ephemeral presence

Harvest and observation data types provided **high support** and the survey and modeled probability of occurrence data types provided **low support** for the non-ephemeral presence line of evidence. The telemetry, conventional marking, and microchemistry data types were **data deficient.**

Harvest data (high support) – We found Lake Whitefish harvest data from as early as the 1850s throughout large portions of Lake Ontario (Department of Marine and Fisheries (1904); Rathbun et al. 1897; Green 1908; Pritchard 1931; Holmes and Whillans 1984; OMNR 2002). Here we summarize particularly notable reports of Lake Whitefish harvest. See OMNR (2002) and GLFC (2022) for comprehensive time-series Lake Whitefish commercial harvest data. Rathbun et al. (1897) reported harvest of 45,380 pounds of Lake Whitefish in U.S. waters in 1893 and harvest of 126,650 pounds in Canadian waters in 1895. Department of Marine and Fisheries (1904) reported harvest of 86,400 Lake Whitefish in the Burlington Beach area in 1856. Additional harvest was prosecuted between 1871-1976 near Hamilton Harbor (Holmes and Whillans 1984). Large Lake Whitefish catches were reported near Cape Vincent and the Duck Islands (Green 1908). Expert panelists agreed that there was substantial evidence of Lake Whitefish harvest from the 1850s to the end of the "historical period" in 1970 and assigned the harvest data type a score of high support for the non-ephemeral line of evidence.

Survey data (moderate support) – Koelz (1929) surveyed the U.S. and Canadian waters of Lake Ontario (except the southern shoreline) for coregonines in 1921 and 1923 and caught a total of 39 Lake Whitefish. In September 1964, Wells (1969) surveyed U.S. waters along the southern shore of Lake Ontario using gillnets and bottom trawls and caught no Lake Whitefish. Expert panelists acknowledged the catches made by Koelz (1929) in the 1920s, but found the quantity of historical survey data to be limited. The panel also observed that the survey conducted by Wells (1964) occurred after a dramatic decline in Lake Whitefish abundance began to occur in the 1920s (OMNR 2002). The expert panel assigned the survey data type a score of low support for the non-ephemeral line of evidence.

Modeled probability of occurrence data (low support) – K. King (personal communication, 2024b) generated a maximum entropy (Elith et al. 2011) historical

reproductive habitat suitability model using georeferenced historical Lake Ontario Lake Whitefish spawning records from CORHIST (spawning occurrence data range: 1925-1995; Brant et al. 2024). Ten environmental variables were considered for modeling: bathymetry [meters], predicted reefs [predicted reef suitability from 0-1], fetch [meters], distance to rivers [kilometers], distance to wetlands [kilometers], mean circulation magnitude [meters/second], mean bottom slope [degrees], historical substrate [categorical variable with 14 substrate categories], mean ice duration [days], and coefficient of variation of ice duration [days]. Three environmental variables with the most predictive power were selected for the final model: mean ice duration, predicted reefs, and fetch. King et al.'s (personal communication, 2024b) model predicted that suitable reproductive habitat for Lake Whitefish was historically distributed along much of the Lake Ontario shoreline. The expert panel determined that the reproductive habitat suitability model predicted the historical presence of suitable reproductive habitat for Lake Whitefish, but did not provide direct evidence for the non-ephemeral historical presence of Lake Whitefish within the hypothesized unoccupied spatial unit. Therefore, the expert panel assigned the modeled probability of occurrence data type a score of low support for the non-ephemeral presence line of evidence.

Observational data (high support) – We found several observations of Lake Whitefish from the 1850s through the 1950s in both the western and southern regions of the hypothesized unoccupied spatial unit (Kerr and Kerr 1860-1898; Smith et al. 1891; Rathbun et al. 1897; Dymond et al. 1929; Pritchard 1931; Christie 1967; Goodyear et al. 1982). From 1856-1898, Lake Whitefish were observed in the western region of the hypothesized unoccupied unit near Grimsby, Winona, Burlington Bay, and Burlington Beach (Kerr and Kerr 1860-1898; Pritchard 1931). By the 1920s, Dymond et al. (1929) reported that Lake Whitefish were scarce, but still present in western Lake Ontario. In the southern and eastern regions of the hypothesized unoccupied unit, Rathbun et al. (1897) observed that Lake Whitefish were "caught most abundantly in Jefferson, Monroe, and Oswego counties." There are historical observations of Lake Whitefish in the Trent River (Christie 1967), Genesee River (Smith et al. 1891), and Niagara River (Brant et al. 2024). The expert panel assigned the observation data type a score of high support for the non-ephemeral presence line of evidence because of the abundance of historical Lake Whitefish observations throughout the hypothesized unoccupied spatial unit.

Reproduction

The observation data type provided **high support** and the reproductive status data type provided **low support** for the reproduction line of evidence. The demography data type was **data deficient.**

Reproductive status data (low support) – Koelz (1929) was the only source of historical reproductive status data applicable to the hypothesized unoccupied spatial unit. Koelz (1929) collected Lake Whitefish near Port Hope, Ontario, CAN on November 21, 1917 that were "nearly ready to spawn." Due to the very limited quantity of reproductive

status data, the expert panel assigned the reproductive status data type a score of low support for the reproduction line of evidence.

Observational data (high support) –Lake Whitefish reproduction in the hypothesized unoccupied spatial unit was observed from the 1860s through the 1960s (Kerr and Kerr 1860-1898; Smith et al. 1891; Smith 1892; Dymond et al. 1929; Hart 1930; Pritchard 1931b; Ontario Game and Fisheries Department 1943; Christie 1967; Whillans 1977; Balesic 1979c; Goodyear et al. 1982). In the western region of the hypothesized unoccupied spatial unit, large groups of spawning Lake Whitefish were reported from the 1860s until the 1930s near Burlington Bay, Toronto Island, and Port Union (Kerr and Kerr 1860-1898; Whillans 1977). Important historical Lake Whitefish spawning grounds were also documented near Bouchette Point and Colborne (Balesic 1979c; Goodyear et al. 1982) and in the northeast region of the hypothesized unoccupied spatial unit around Charity Shoal, Stony Island, and the Galloo Islands (Smith et al. 1891; Smith 1892). Historically, fewer spawning grounds were observed in the southern portion of the hypothesized unoccupied spatial unit, but were reported to exist near Oak Orchard, Sodus Point, and Nine Mile Point (Smith 1892; Koelz 1929). The expert panel assigned the observation data type a score of high support for the reproduction line of evidence due to the numerous reports of Lake Whitefish spawning throughout the hypothesized unoccupied spatial unit over a protracted period of time.

Table 8. Results describing how the "historically viable population" unoccupied spatial unit criterion was met for the hypothesized unoccupied Lake Whitefish *Coregonus clupeaformis* spatial unit. Unweighted "data type scores" show the average scores for each data type prior to weighting and SD is the standard deviation of data type scores among individual expert panelists. "Line of evidence ranks" show the overall support a line of evidence provided for the spatial unit criterion (gray = data deficient, yellow = low support, orange = moderate support, red = high support). Ranks were calculated by weighting, then averaging associated data type scores. "-" indicates data deficiency.

Line of evidence	Data type	Data type score	SD	Line of evidence rank
Non-ephemeral presence	Harvest	3.00	0.00	Moderate (2.00)
	Survey	1.00	0.76	
	Modeled probability of occurrence	0.70	0.82	
	Observational	2.80	0.40	
	Telemetry	-	-	
	Tagging/marking	-	-	
	Microchemistry	-	-	
Reproduction	Demography	-	-	Moderate (1.70)
	Reproductive Status	1.30	0.50	
	Observation	3.00	0.00	
Genetic / genomic	Genetic / genomic	-	-	Data Deficient

Lack of contemporary occupancy criterion (focal organisms are entirely absent from the focal area or only ephemerally present): The lack of contemporary occupancy criterion received moderate support from the contemporary absence line of evidence (Table 9). The genetic/genomic line of evidence was data deficient. Only one line of evidence was required to achieve at least a moderate level of support to meet this criterion, thus the lack of contemporary occupancy criterion was met.

LINES OF EVIDENCE

Contemporary absence

The survey data type provided **high support** for the contemporary absence line of evidence while the harvest data type provided **moderate support,** and the modeled probability of occurrence and observation data types provided **low support**. The telemetry, conventional marking, and microchemistry data types were **data deficient.**

Harvest data (moderate support) – The only reported contemporary Lake Whitefish harvest in the hypothesized unoccupied spatial units occurred in 2001 (7,208 pounds; OMNR 2002; GLFC 2022). There were no active fishing licenses in much of this region at the time of the spatial unit assessment (S. Beech, personal communication, 2024a). Some expert panelists thought that commercial fishermen choosing not to fish in most of the hypothesized unoccupied spatial unit was evidence of low Lake Whitefish abundance. The expert panel scored the harvest data type as providing moderate support for the contemporary absence line of evidence.

Survey data (high support) – For this line of evidence, the expert panel considered both surveys that targeted Lake Whitefish and general fish surveys that did not specifically target Lake Whitefish, but could have captured them. Contemporary surveys captured approximately 50 juvenile and adult Lake Whitefish in the hypothesized unoccupied spatial unit between 2000-2024 (Weidel et al. 2023; O'Malley et al. 2024; O'Malley et al. 2024b; B. O'Malley, personal communication, 2024a; B. Weidel, personal communication, 2024). Approximately half of these catches occurred during the Lake Whitefish spawning season (October-December; B. O'Malley, personal communication, 2024a; B. Weidel, personal communication, 2024). Additionally, Brown et al. (2022) caught 58 Lake Whitefish larvae during April and May 2018 in the western, southern, and southeastern regions of the hypothesized unoccupied spatial unit. Experts determined that although Lake Whitefish larvae were sporadically captured by surveys in the hypothesized unoccupied spatial unit, these data were insufficient to demonstrate the non-ephemeral presence of Lake Whitefish. Therefore, the expert panel scored the survey data type as high support for the contemporary absence line of evidence.

Modeled probability of occurrence (low support) – K. King (personal communication, 2024b) generated a maximum entropy (Elith et al. 2011) contemporary reproductive habitat suitability model using georeferenced contemporary Lake Whitefish spawning

records from CORHIST (spawning occurrence data range: 2000 – present; Brant et al., 2024). Ten environmental variables were considered for contemporary maximum entropy modeling (see modeled probability of occurrence section above for full list) and two variables with the most predictive power were selected for the final model: mean ice duration for the contemporary period and probability of reefs. King et al.'s (personal communication, 2024b) final model predicted that suitable reproductive habitat for Lake Whitefish currently primarily occurs in the Bay of Quinte, Chaumont Bay, and the beginning of the St. Lawrence River. The model also predicted the presence of some moderately suitable reproductive habitat in the Brighton and Toronto areas. The expert panel determined that the reproductive habitat suitability model generally predicted the existence of reproductive habitat where Lake Whitefish have been collected during the contemporary period (2000 - present) and the absence of reproductive habitat where Lake Whitefish have not been detected, providing indirect evidence of the contemporary absence of Lake Whitefish throughout the hypothesized unoccupied unit in the northern, western, and southern parts of the lake. The expert panel assigned the modeled probability of occurrence data type a score of low support for the contemporary absence line of evidence.

Observation data (low support) – In 2010 and 2011, 53 embryos were collected in the lower Niagara River and one was identified as a Lake Whitefish (Salvesen 2015; Gatch et al. 2021). The expert panel agreed that this observation indicated ephemeral presence of Lake Whitefish, but due to the limited quantity of observational data available, the expert panel assigned a score of low support to the observational data type for the contemporary absence line of evidence.

Table 9. Results describing how the "lack of contemporary occupancy" unoccupied spatial unit criterion was met for the hypothesized unoccupied Lake Whitefish *Coregonus clupeaformis* spatial unit. Unweighted "data type scores" show the average scores for each data type prior to weighting and SD is the standard deviation of data type scores among individual expert panelists. "Line of evidence ranks" show the overall support a line of evidence provided for the spatial unit criterion (gray = data deficient, yellow = low support, orange = moderate support, red = high support). Ranks were calculated by weighting, then averaging associated data type scores. "-" indicates data deficiency.

Line of evidence	Data type	Data type score	SD	Line of evidence rank
Absence	Harvest	1.90	0.32	Moderate (1.83)
	Survey	2.60	0.50	
	Modeled probability of occurrence	0.80	0.44	
	Observational	1.40	0.52	
	Telemetry	-	-	
	Conventional marking	-	-	
	Microchemistry	-	-	
Genetic / genomic	Genetic / genomic	-	-	Data Deficient

3.2.2 Occupied Lake Whitefish spatial units

3.2.2.1 Occupied Lake Whitefish spatial unit data synthesis

Facilitators compiled a catalog of 35 references (Tables 10 and 11), four georeferenced contemporary spawning observations (direct observations of spawning or mature individuals or spawning grounds), and 52 georeferenced contemporary possible spawning observations (observations indicative of spawning but spawning/mature fish not directly observed) from CORHIST (Figure 5; Brant et al. 2024) to facilitate assessment of hypothesized occupied Lake Whitefish spatial units.

Table 10. Lake Whitefish *Coregonus clupeaformis* "contemporary reproductive isolation" criterion references (n = 32) organized by line of evidence and data type. Data type weights are shown before references in parentheses: + = weight of one applied to data type and ++ = weight of two applied to data type. Weights are not applied when data types are scored as data deficient. Gray shaded cells indicate the data type was not applicable to assess the line of evidence. Data deficient means that no data of a particular type were available at the time of assessment. OMNR = Ontario Ministry of Natural Resources.

Data type	Line of evidence		
	Limited movement or migration	**Reproductive differences**	**Genetic / genomic divergence**
Harvest		(+) OMNR (2002); Beech (2023); S. Beech (personal communication, 2024a); J. Holden (personal communication, 2024); T. Johnson (personal communication, 2024)	
Survey		(++) Data deficient	
Demography		(+) OMNR (2001-2024)	
Reproductive status		(++) S. Beech (personal communication, 2024c)	
Observation	(++) Data deficient	(++) Data deficient	
Genetic / genomic			(++) Bernard et al. (2009); Jared Homola (personal communication, 2024)
Telemetry	(++) Hoyle et al. (2011); Brown et al. (2022); Weidel et al. (2023); Beech et al. (2024); S. Beech (personal communication, 2024b); O'Malley et al. (2024); Hlina et al. (2025)	(++) Beech et al. (2024)	
Conventional marking	(+) Data deficient		
Microchemistry	(+) Data deficient		

Table 11. Lake Whitefish *Coregonus clupeaformis* "distinct component of evolutionary legacy" criterion references (n = 3) organized by line of evidence and data type. Data type weights are shown before references in parentheses: + = weight of one applied to data type and ++ = weight of two applied to data type. Weights are not applied when data types are scored as data deficient. Gray shaded cells indicate the data type was not applicable to assess the line of evidence. Data deficient means that no data of a particular type were available at the time of assessment.

Data type	Line of evidence	
	Life history variation	Local adaptation / adaptive diversity
Survey	(++) Data deficient	
Reproductive status	(+) Data deficient	
Observation	(+) S. Beech (personal communication, 2024b)	
Genetic / genomic		(++) Data deficient
Telemetry	(++) Beech et al. (2024)	
Conventional marking	(+) Data deficient	
Ontogeny	(++) Data deficient	
Phenotypic		(++) O'Malley (personal communication, 2024b)
Resource partitioning		(++) Data deficient

3.2.2.2 Description of occupied Lake Whitefish spatial unit hypothesis

The expert panel generated a Lake Whitefish spatial unit hypothesis to formally assess containing three occupied spatial units (Figure 6). *Occupied spatial unit 1* extends along the shoreline from the Scotch Bonnet/Nicholson Island area (43.944149, -77.515043) to southern Point Traverse in Prince Edward County (43.950052, -76.784071). The boundaries of *occupied spatial unit 2* encompass the Trent River below Lock 1 (44.075817, -77.599363) and the Bay of Quinte to the tip of Cressy Point (44.113494, -76.847011). *Occupied spatial unit 3* contains the Chaumont Bay area from Stony Point in the Henderson region (43.843258, -76.296703) and north to Tibbets Point (44.101062, -76.370430).

3.2.2.3 Occupied Lake Whitefish spatial unit assessment results and discussion

Both criteria for delineating the three occupied Lake Whitefish spatial unit hypothesis were met: "contemporary reproductive isolation" (Table 12) and "distinct component of evolutionary legacy" (Table 13).

Contemporary reproductive isolation criterion (contemporary reproductive isolation between hypothesized spatial units): Reproductive isolation need not be absolute. The contemporary reproductive isolation criterion received **moderate support** from the movement and migration line of evidence and **low support** from the reproductive differences and genetic/genomic divergence lines of evidence (Table 12). Given that only one line of evidence was required to achieve at least a moderate level of support, this criterion was met.

LINES OF EVIDENCE

Movement and migration

The telemetry data type provided **moderate support** for the movement and migration line of evidence and the conventional marking, microchemistry, and observation data types were **data deficient**.

Telemetry data (moderate support) – There are three major areas where contemporary Lake Whitefish spawning appears to occur: (1) the Bay of Quinte, (2) along the Lake Ontario shoreline in Prince Edward County, and (3) Chaumont Bay (Hoyle et al. 2011; Brown et al. 2022; Weidel et al. 2023; Beech et al. 2024; O'Malley et al. 2024a; Hlina et al. 2025). Beech et al. (2024) used acoustic telemetry to monitor the movement of Lake Whitefish collected in the Bay of Quinte and Lake Whitefish collected in Prince Edward County. Beech et al. (2024) found that during the study period (2016-2024), Lake Whitefish collected in each area exhibited distinct movement patterns and limited mixing outside the spawning season and spawning site fidelity and no mixing during the reproductive period. Additionally, two individuals from the Bay of Quinte spawning group entered the lower reaches of the Trent River (S. Beech, personal communication, 2024b). No Lake Whitefish were collected in Chaumont Bay for this study, but the expert panel found that telemetry data showing that Lake Whitefish from the Bay of Quinte and Prince Edward County spawning groups exhibited site fidelity and did not enter Chaumont Bay during the spawning season provided some evidence that all three spawning groups likely exhibit distinct movement patterns. Therefore, the expert panel assigned a score of moderate support to the telemetry data type for the movement and migration line of evidence.

Reproductive differences

The harvest data type provided **moderate support** for the reproductive differences line of evidence, while the demography and reproductive status data types provided **low support**. The telemetry, observation, and survey data types were **data deficient**.

Harvest data (moderate support) – Commercial fisheries for Lake Whitefish occur within hypothesized occupied spatial units 1 (Prince Edward County area) and 2 (Bay of Quinte; OMNR 2023; S. Beech, T. Johnson, and J. Holden, personal communication, 2024). Hypothesized occupied spatial unit 3 (Chaumont Bay) is not currently commercially fished (OMNR 2023; S. Beech, T. Johnson, and J. Holden, personal communications, 2024). Commercial fisheries generally target Lake Whitefish when they aggregate for spawning, with fishing in the Bay of Quinte typically occurring in October and November and Prince Edward County in November (OMNR 2002; Beech 2023). The expert panel reasoned that these inter-spatial unit differences in harvest timing indicated differences in reproductive timing between hypothesized occupied spatial units 1 and 2, but provided no insight regarding hypothesized occupied spatial unit 3. Therefore, the expert panel assigned a score of moderate support to the harvest data type for the reproductive differences line of evidence.

Demography data (low support) – During the contemporary period, the Ontario Ministry of Natural Resources (OMNR 2001-2024) quantified multiple demographic attributes of Lake Whitefish captured in hypothesized occupied spatial units 1 and 2, but not hypothesized spatial unit 3: population age structure via otoliths (data range: 2000-2023), length at age (2003-2023), and weight at age (2003-2023). Qualitative observation of these data indicated to the expert panel that there were only very minor differences between hypothesized spatial units 1 and 2 in all three demographic traits assessed. Therefore, the expert panel assigned a score of low support to the demography data type for the reproductive differences line of evidence.

Reproductive status data (low support) – The Ontario Ministry of Natural Resources (OMNR 2006-2015) and S. Beech (personal communication, 2024c), reported gonadal somatic and visceral fat indices for Lake Ontario Lake Whitefish for the periods 2005-2014 and 2021-2023, respectively. Qualitative comparison of these indices between hypothesized spatial units 1 and 2 by the expert panel did not reveal major differences. Gonadal somatic and visceral fat indices were not available for hypothesized spatial unit 3. Consequently, the expert panel assigned a score of low support to the reproductive status data type for the reproductive differences line of evidence.

Genetic/Genomic divergence

The genetic/genomic data type provided **low support** to the genetic/genomic divergence line of evidence.

Genetic/genomic data (moderate support) – Bernard et al. (2009) used microsatellite markers to assess the genetic distinctiveness of Lake Whitefish spawning aggregations from Prince Edward County (hypothesized occupied spatial unit 1), Bay of Quinte (hypothesized occupied spatial unit 2), and Chaumont Bay (hypothesized occupied spatial unit 3). Bernard et al. (2009) found that Chaumont Bay Lake Whitefish were distinct from Bay of Quinte and Prince Edward County fish, but that Bay of Quinte and Prince Edward County fish were not distinct from each other. Additionally, J. Homola (personal communication, 2024) used a RAD capture dataset (5211 SNPs after filtering) to characterize genetic variation in Lake Whitefish from eastern Lake Ontario (11 fish from Chaumont Bay and six fish from the Bay of Quinte) and did not identify genetic differences indicative of more than one population/spawning stock. Therefore, the expert panel assigned a score of low support to the genetic/genomic data type for the genetic/genomic divergence line of evidence.

Table 12. Results describing how the "contemporary reproductive isolation" criterion was met for the three hypothesized occupied Lake Whitefish *Coregonus clupeaformis* spatial units. Unweighted "data type scores" show the average scores for each data type prior to weighting and SD is the standard deviation of data type scores among individual expert panelists. "Line of evidence ranks" show the overall support a line of evidence provided for the spatial unit criterion (gray = data deficient, yellow = low support, orange = moderate support, red = high support). Ranks were calculated by weighting, then averaging associated data type scores. "-" indicates data deficiency.

Line of evidence	Data type	Data type score	SD	Line of evidence rank
Movement and migration	Telemetry	1.91	0.54	Moderate (1.9)
	Conventional marking	-	-	
	Microchemistry	-	-	
	Observation	-	-	
Differences in reproduction	Harvest	1.50	0.69	Low (0.7)
	Telemetry	-	-	
	Observation	-	-	
	Survey	-	-	
	Demography	0.82	0.60	
	Reproductive status	0.27	0.47	
Genetic / genomic divergence	Genetic / genomic	0.64	0.50	Low (0.6)

Distinct component of evolutionary legacy criterion (organisms in hypothesized spatial units represent distinct components of evolutionary history): The distinct component of evolutionary legacy criterion received **moderate support** from the life history variation line of evidence and **no support** from the local adaptation/adaptive diversity line of evidence (Table 13). Given that only one line of evidence was required to achieve at least a moderate level of support, this criterion was met.

LINES OF EVIDENCE

Life history variation

The telemetry data type provided **moderate support** for the life history variation line of evidence, and the observation data type provided **low support**. The conventional marking, survey, reproductive status, and ontogeny data types were **data deficient**.

Telemetry data (moderate support) – Beech et al. (2024) tagged 57 Lake Whitefish with acoustic transmitters collected in the Bay of Quinte (hypothesized occupied spatial unit 2) and along the southern shore of Prince Edward County (hypothesized occupied spatial unit 1) between 2016-2018. Beech et al. discovered that Lake Whitefish in the Bay of Quinte and Prince Edward County exhibited distinct movement patterns and minimal overlap outside of the spawning season (spawning migrations considered by the "contemporary reproductive isolation" criterion). The expert panel agreed that these data suggested life history differences between hypothesized units 1 and 2, but acknowledged the lack of data for hypothesized unit 3. Therefore, the expert panel

assigned a score of moderate support to the telemetry data type for the life history variation line of evidence.

Observational data (low support) – S. Beech (personal communication, 2024b) observed two Lake Whitefish entering the Trent River during the fall, potentially to spawn. Adfluvial spawning behavior has not been documented in the other two hypothesized occupied spatial units, indicating that Lake Whitefish in hypothesized occupied spatial unit 2 may exhibit distinct life history variation. However, use of rivers by Lake Whitefish has not been rigorously investigated in any of the hypothesized spatial units. Consequently, the expert panel assigned a score of low support to the telemetry data type for the life history variation line of evidence.

Local adaptation/adaptive diversity

The phenotypic data type provided **no support** for the local adaptation/adaptive diversity line of evidence, and the genetic/genomic and resource partitioning data types were **data deficient**.

Phenotypic data (no support) – O'Malley (personal communication, 2024b) quantified gill raker number on the first gill arches of Lake Whitefish during spawning season between 2018-2019 from commercial harvests and surveys in all three hypothesized spatial units. Gill raker counts in all three units primarily ranged from 25-30 and qualitative observation of gill raker counts by the expert panel did not suggest that there were differences between the occupied spatial units. The expert panel assigned a score of no support to the phenotypic data type for the local adaptation/adaptive diversity line of evidence.

Table 13. Results describing how the "distinct component of evolutionary legacy" criterion was met for the three hypothesized Lake Whitefish *Coregonus clupeaformis* spatial units. Unweighted "data type scores" show the average scores for each data type prior to weighting and SD is the standard deviation of data type scores among individual expert panelists. "Line of evidence ranks" show the overall support a line of evidence provided for the spatial unit criterion (gray = data deficient, yellow = low support, orange = moderate support, red = high support). Ranks were calculated by weighting, then averaging associated data type scores. "-" indicates data deficiency.

Line of evidence	Data type	Data type score	SD	Line of evidence rank
Life history variation	Telemetry	1.64	0.50	Moderate (1.70)
	Conventional marking	-	-	
	Survey	-	-	
	Observation	1.27	0.47	
	Reproductive status	-	-	
	Ontogeny	-	-	
Local adaptation / adaptive diversity	Genetic / genomic	-	-	None (0.00)
	Phenotypic	0.00	0.00	
	Resource partitioning	-	-	

3.2.3 Conclusions

3.2.3.1 Delineated spatial units

The criteria were met to delineate the single hypothesized unoccupied spatial unit and the three hypothesized occupied spatial units (Figure 7). Therefore, **one unoccupied and three occupied spatial units were delineated for Lake Ontario Lake Whitefish** (Figure 6). These spatial units should be viewed as the most complex hypotheses for historical and contemporary Lake Ontario Lake Whitefish population structure supported by the data available for this assessment. If new data become available, future assessments can revise Lake Ontario Lake Whitefish spatial units. Furthermore, Indigenous Knowledge may also delineate spatial units for Lake Ontario Lake Whitefish in the future, which may or may not be congruent with the spatial units delineated herein using Western Science.

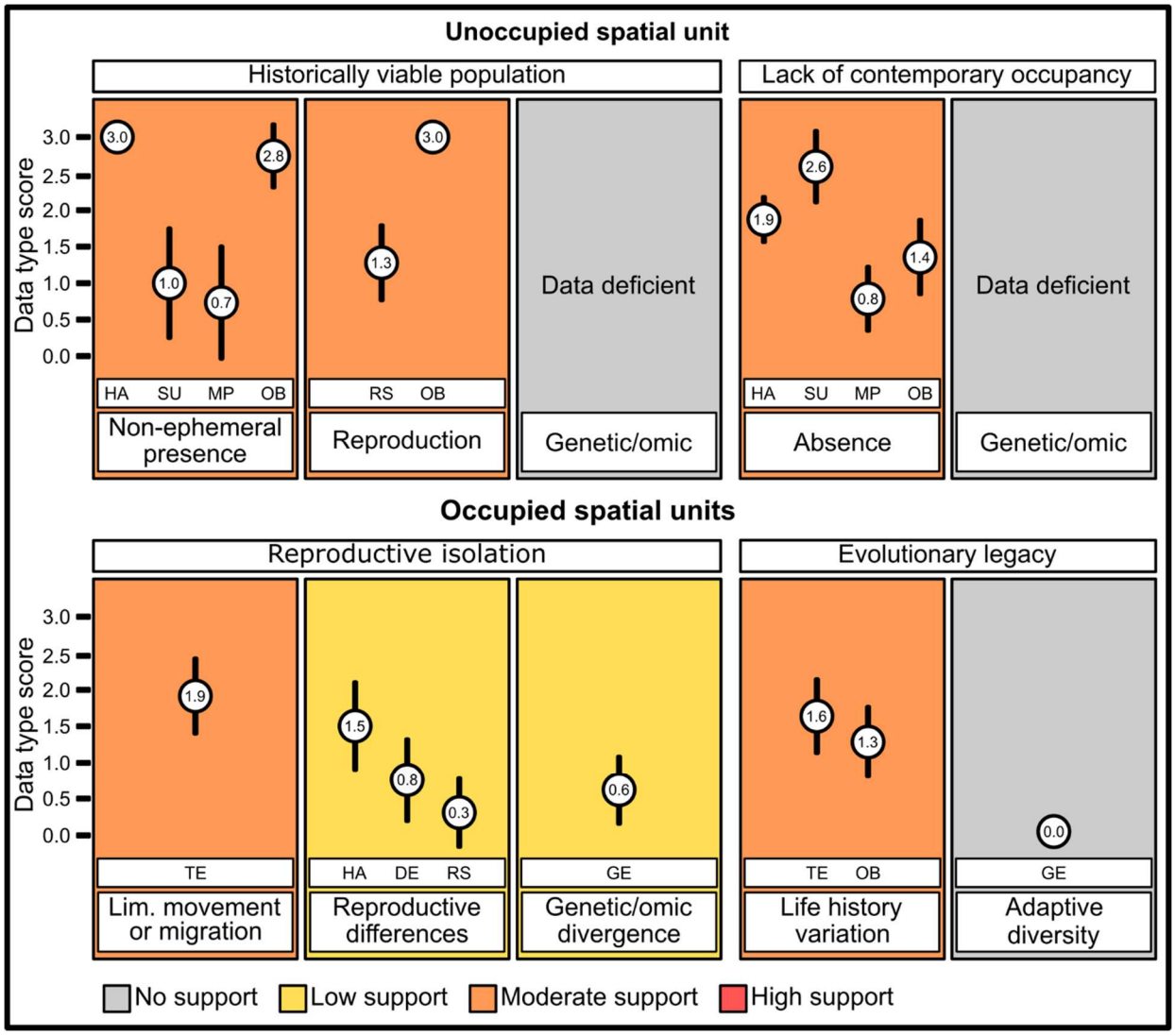


Figure 7. Summary of Lake Whitefish *Coregonus clupeaformis* spatial unit assessment results. The "historically viable population" and "lack of contemporary occupancy" criteria were assessed for the single unoccupied spatial unit hypothesis. The "contemporary reproductive isolation" and "distinct component of evolutionary legacy" criteria were assessed for the three occupied spatial unit hypothesis. Circles show the average "data type scores" for each data type prior to weighting and vertical black bars show the standard deviation (SD) of data type scores among individual expert panelists. Data type codes: HA = harvest, SU = survey, MP = modeled probability of occurrence, OB = observation, DE = demography, RS = reproductive status, MT = marking/tagging, TE = telemetry, and GE = genetic/genomic. Data deficient data types are not shown (See Tables 8-13). The color of each line of evidence box corresponds to the "line of evidence rank," which shows the overall support a line of evidence provides for the spatial unit criterion (see legend). Ranks were calculated by weighting, then averaging associated data type scores.

3.2.3.2 Key knowledge gaps

The expert panel identified four key knowledge gaps that inhibited delineation of Lake Whitefish spatial units in Lake Ontario (see also data poor and data deficient data types in Tables 8-13 that highlight additional knowledge gaps):

1. What was the historical Lake Whitefish population structure in Lake Ontario?

2. To what extent do Lake Whitefish spawn in rivers in the Lake Ontario basin? The expert panel noted that further investigation of the use of the Trent River by Lake Whitefish may be a helpful starting point for research on this topic.

3. How do the movement patterns of Lake Whitefish that spawn in Chaumont Bay (occupied spatial unit 3) compare to Lake Whitefish associated with occupied spatial units 1 (southern shore of Prince Edward County) and 2 (Bay of Bay of Quinte)?

4. To what extent are there heritable phenotypic differences between Lake Whitefish in the delineated occupied spatial units?

3.3 Cisco

The expert panel formulated a Cisco spatial unit hypothesis consisting of two occupied spatial units and one unoccupied spatial unit to formally assess. The expert panel identified evidence of Lake Ontario Cisco using reproductive habitat in the Genesee River (Smith et al. 1891). Additionally, a reproductive habitat suitability model indicated that, historically, Cisco reproductive habitat existed in the lower reaches of the Niagara River that contiguous with modeled reproductive habitat along the lakeshore. Historical Cisco occurrence data were associated with reproductive habitat along the lakeshore very near the Niagara River mouth. Thus, the lower reaches of both the Genesee River and Niagara River were included in the hypothesized unoccupied Cisco spatial unit, but were not given hard upper boundaries due to insufficient data (see section 3.3.1.2 for additional details). The “historical period” for this assessment was designated as 1970 and earlier and the contemporary period included 2000 and after. These time periods were based on several major ecosystem changes that occurred between 1970-1999 including low Cisco and Lake Whitefish abundances and increases in zebra and quagga mussel abundances (Griffiths et al. 1991; Mills et al. 1993; Owens and Dittman 2003; Mills et al. 2005; GLFC 2022; Karatayev et al. 2022).

3.3.1 Unoccupied Cisco spatial unit

3.3.1.1 Unoccupied Cisco spatial unit data synthesis

Facilitators compiled a catalog of 71 references (Tables 14 and 15) and 47 georeferenced historical spawning observations (direct observations of spawning or mature individuals or spawning grounds) and 8 georeferenced historical possible spawning observations (observations indicative of spawning but spawning/mature fish not directly observed) from

CORHIST (Figure 8; Appendix 4 Table 3; Brant et al. 2024) to facilitate assessment of the hypothesized unoccupied Cisco spatial unit.

Table 14. Cisco *Coregonus artedi* "historically viable population" criterion references (n = 63) organized by line of evidence and data type. Data type weights are shown before references in parentheses: + = weight of one applied to data type and ++ = weight of two applied to data type. Weights are not applied when data types are scored as data deficient. Cells filled with gray indicate the data type was not applicable for the line of evidence.

Data type	Line of evidence		
	Non-ephemeral presence	**Reproduction**	**Genetic / genomic**
Harvest	(+) Pritchard (1928); Christie (1973); Holmes and Whillans (1984); Weidel et al. (2021)		
Survey	(++) Koelz (1929); Stone (1947); Wells (1969)		
Modeled probability of occurrence	(+) K. King (personal communication, 2024c)		
Demography		(+) Stone (1938)	
Reproductive status		(++) Pritchard (1928); Fry (1937); Goodyear et al. (1982)	
Observation	(+) Kerr and Kerr (1860-1898); Smith et al. (1891); Koelz (1926); Dymond et al. (1929); Koelz (1929)	(+) Rathbun et al. (1897); Kerr and Kerr (1860-1898); Bean (1903); Koelz (1929); Ontario Game and Fisheries Department (1911, 1915, 1916); State of New York (1925); Dymond et al. (1929); Pritchard (1931b); Goodyear et al. (1982)	
Genetic / genomic			(++) Data deficient
Telemetry	(++) Data deficient		
Conventional marking	(+) Data deficient		
Microchemistry	(+) Data deficient		

Table 15. Cisco *Coregonus artedi* "lack of contemporary occupancy" criterion references (n = 10) organized by line of evidence and data type. Data type weights are shown before references in parentheses: + = weight of one applied to data type and ++ = weight of two applied to data type. Weights are not applied when data types are scored as data deficient. Cells filled with gray indicate the data type was not applicable for the line of evidence.

Data type	Line of evidence	
	Absence of target organisms	Genetic / genomic
Harvest	(+) Christie (1973)	
Survey	(++) OMNR (2014); Patrick et al. (2020); Weidel et al. (2021); Brown et al. (2022); Weidel et al. (2023); O'Malley et al. (2024b); B. O'Malley, (personal communication, 2024a); B. Weidel (personal communication, 2024)	
Modeled probability of occurrence	(+): K. King (personal communication, 2024c)	
Observation	(+) Data deficient	
Genetic / genomic		(++) Data deficient
Telemetry	(++) Gatch et al. (2023)	
Conventional marking	(+) Data deficient	
Microchemistry	(+) Data deficient	

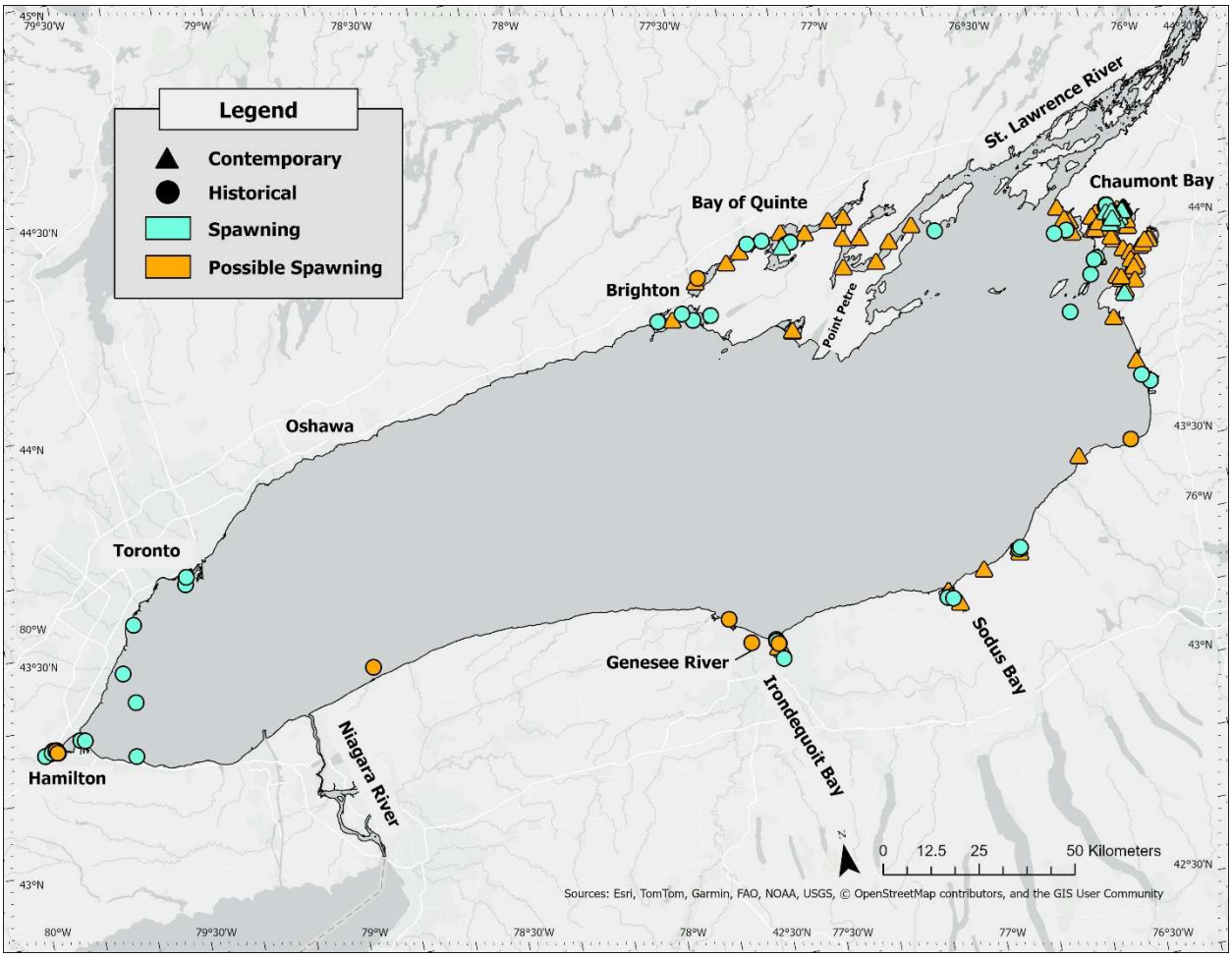


Figure 8. Map of Lake Ontario with georeferenced Cisco *Coregonus artedi* historical and contemporary spawning and possible spawning observations (Appendix 4 Table 3). "Spawning" observations (n = 73) are direct observations of spawning, mature individuals, or spawning grounds and "possible spawning" observations (n = 81) are observations suggestive of spawning (e.g., aggregations of fish during the spawning season) but not direct observations of spawning/mature fish. In this figure, there are cases in which points showing the locations of observations overlap, obscuring the true number of observations.

3.3.1.2 Description of hypothesized unoccupied Cisco spatial unit

The expert panel generated a Cisco spatial unit hypothesis containing one unoccupied spatial unit to formally assess. The hypothesized unoccupied Cisco spatial unit encompasses areas that historically contained Cisco reproductive habitat, which was inferred to occur along much of the Lake Ontario shoreline outside of the hypothesized occupied spatial units described herein (Figure 9). Additionally, there was evidence that Cisco historically spawned in the Genesee River (Smith et al. 1891). Therefore, the lower reaches of the Genesee River were included in the hypothesized unoccupied spatial unit, but the expert panel did not designate a hard upstream boundary due to insufficient knowledge about where Cisco historically spawned in this river. Additionally, a reproductive habitat suitability model indicated that, historically, Cisco

reproductive habitat existed in the lower reaches of the Niagara River. This habitat was contiguous with predicted historical reproductive habitat along the Lakeshore (K. King, personal communication, 2024a). Therefore, the lower reaches of the Niagara River were also included in the hypothesized unoccupied spatial unit, but no hard upstream boundary was assigned. The hypothesized unoccupied spatial unit was restricted to depths <55 meters because evidence suggests it was unlikely that Lake Ontario Cisco spawned below these depths (Koelz 1929; George et al. 2017; Paufve et al. 2022; Gatch et al. 2023; K. King, personal communication, 2024a). The area north of Amherst Island was excluded from this spatial unit because there is no evidence of historical spawning in this area. The expert panel determined that there were insufficient data to test for reproductive isolation among different areas within the hypothesized unoccupied spatial unit, so multiple unoccupied spatial units were not considered.

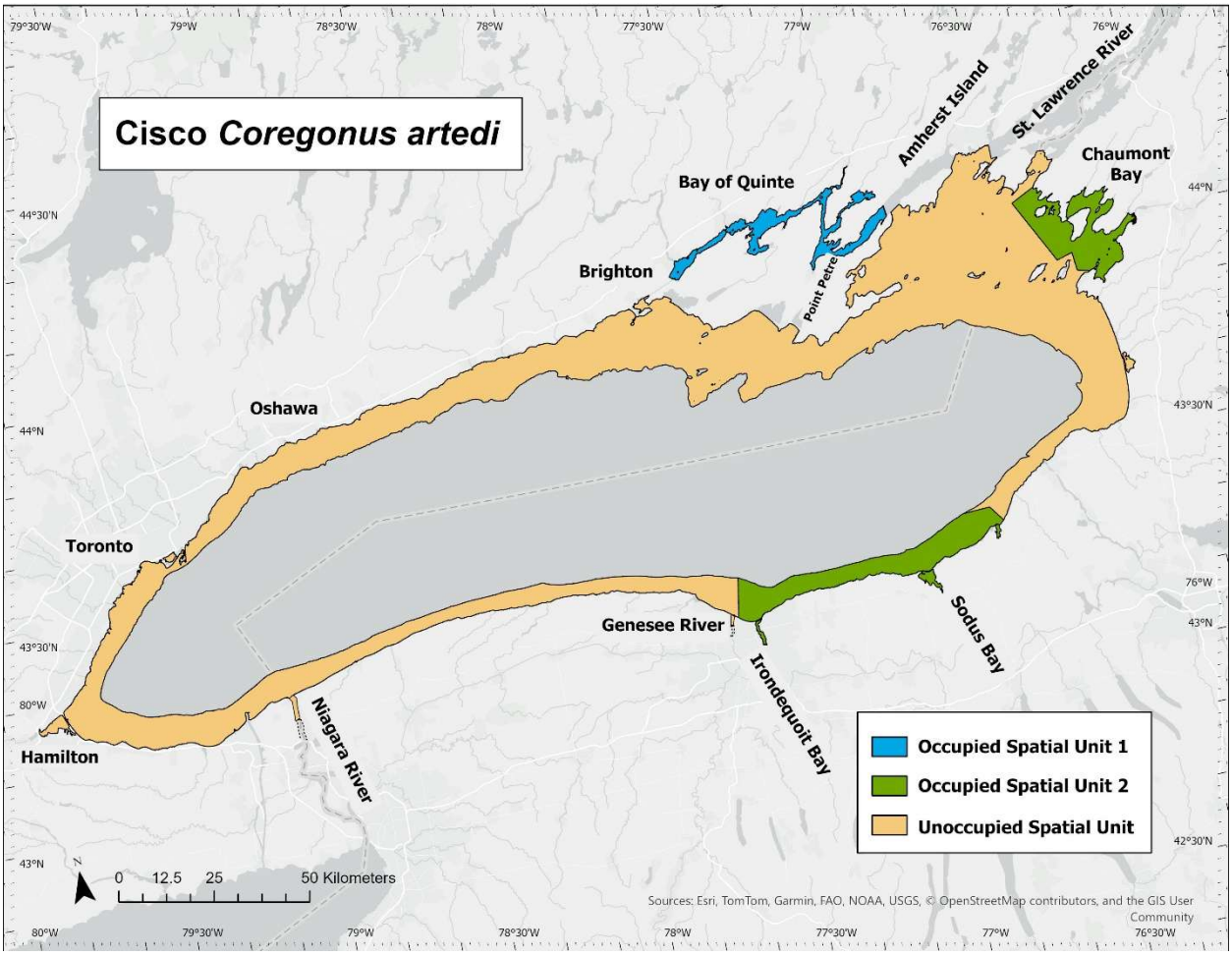


Figure 9. Map of Lake Ontario with colors demarcating the locations of the two occupied and one unoccupied Cisco *Coregonus artedi* spatial units. Occupied spatial unit 2 is comprised of two disjunct areas. Space not assigned to any spatial units is demarcated via gray shading. Space may not have been assigned to a spatial unit because either it did not contain Cisco reproductive habitat (neither historically or contemporarily) or there was no evidence of historical or contemporary occupancy of Cisco regardless of reproductive habitat suitability. See section 2.2 for an explanation of the requirements for occupancy criteria.

3.3.1.3 Unoccupied Cisco spatial unit assessment results and discussion

<u>Both criteria for delineating the hypothesized unoccupied Cisco spatial unit were met</u>: "historically viable population" (Table 16) and "lack of contemporary occupancy" (Table 17).

Historically viable population criterion (historical presence of a naturally reproducing (sub)population over an extended period of time): One line of evidence must achieve at least a moderate level of support for the historically viable population criterion to be met. This requirement was satisfied by the non-ephemeral presence and reproduction lines of evidence, which both received a **moderate level** of support (Table 16). The genetic/genomic line of evidence was **data deficient**.

LINES OF EVIDENCE

Non-ephemeral presence

The harvest data type provided **high support** for the non-ephemeral presence line of evidence, and the survey, modeled probability of occurrence, and observation data types provided **moderate support**. The telemetry, conventional marking, and microchemistry data types were **data deficient.**

Harvest data (high support) – For the historically viable population criterion, the expert panel focused on historical data (1970 and earlier). Annual Cisco harvest in Lake Ontario was reported consistently from the 1870s through 1970 throughout much of west, central, and eastern Lake Ontario (Holmes and Whillans 1984; Pritchard 1928; Christie 1973; Weidel et al. 2021; GLFC 2022). Expert panelists agreed that there was considerable evidence of historical Cisco harvests in Lake Ontario and assigned a score of high support to the harvest data type for the non-ephemeral presence line of evidence.

Survey data (moderate support) – Koelz (1929) surveyed the U.S. and Canadian waters of Lake Ontario for coregonines in the early 1920s and collected Cisco in several locations, including in the vicinities of Winona, Port Credit, and the Kingston Basin, Ontario, CAN and Wilson, Charlotte, and Selkirk. Stone (1947) surveyed New York waters using gillnets and caught 146 Cisco between June and November of 1942, near Oswego, Wilson, Youngstown, Cape Vincent, Sodus Point, Charlotte, and Selkirk. In September 1964, Wells (1969) surveyed New York waters using gillnets and bottom trawls and caught two Cisco near Rochester. The expert panel observed that survey data from the spawning season were lacking. The expert panel assigned the survey data type a score of moderate support for the non-ephemeral line of evidence.

Modeled probability of occurrence data (moderate support) – K. King (personal communication, 2024c) generated a maximum entropy (Elith et al. 2011) historical reproductive habitat suitability model using georeferenced historical Lake Ontario Cisco spawning records from CORHIST (spawning occurrence data range: 1925-1995; Brant et al., 2024). Ten environmental variables were considered for historical maximum entropy modeling: bathymetry [meters], predicted reefs [predicted reef suitability from 0-1], fetch [meters], distance to rivers [kilometers], distance to wetlands [kilometers], mean circulation magnitude [meters/second], mean bottom slope [degrees], historical substrate [categorical variable with 14 substrate categories], mean ice duration [days],

and coefficient of variation of ice duration [days]. Three environmental variables with the most predictive power were selected for the final model: mean ice duration, predicted reefs, and historical substrate. King et al.'s (personal communication, 2024c) model predicted that suitable reproductive habitat for Cisco was historically distributed along much of the Lake Ontario shoreline, with the largest expanses of highly suitable habitat occurring in the Bay of Quinte, Chaumont Bay, and the beginning of the St. Lawrence River. The expert panel believed the model may overestimate reproductive habitat suitability in some areas (e.g., the beginning of the St. Lawrence River), but thought the model appeared to perform well based on their knowledge of Lake Ontario Cisco. The expert panel determined that the reproductive habitat suitability model provided indirect evidence of a historically viable Cisco population throughout the hypothesized unoccupied spatial unit and assigned the modeled probability of occurrence data type a score of moderate support for the non-ephemeral presence line of evidence.

Observational data (moderate support) – Many observations of Cisco were made from the 1860s through the 1930s in the hypothesized unoccupied spatial unit (Kerr and Kerr 1860-1898; Koelz 1926; Koelz 1929; Dymond et al. 1929), including an observation of Cisco in the Genesee River during the Cisco spawning period (Smith et al. 1891). The expert panel agreed that multiple sources supported the non-ephemeral presence throughout the hypothesized unoccupied space but also recognized a paucity of observations during spawning season. Therefore, the expert panel assigned a score of moderate support for the non-ephemeral presence line of evidence.

Reproduction

The observation data type provided **high support** for the reproduction line of evidence, and the reproductive status data type provided **moderate support**. The demography data type was **data deficient.**

Reproductive status data (moderate support) – Mature Cisco were documented during spawning season in the 1920s in western Lake Ontario near Port Credit and Toronto (Pritchard 1928; Goodyear et al. 1982). Fry (1937) collected Cisco in eastern Lake Ontario off Amherst Island during spawning season and noted that "22% were spent, 21% were partly spent, and 32% were ripe." The expert panel agreed that a small amount of qualitative data provided evidence of Cisco reproduction in the hypothesized unoccupied spatial unit and assigned the reproductive status data type a score of moderate support for the reproduction line of evidence.

Observational data (high support) – Large numbers of spawning Cisco were observed in western Lake Ontario near Winona and Burlington Bay (Kerr and Kerr 1860-1898; Koelz 1929; Ontario Game and Fisheries Department 1911, 1915, 1916; Whillans 1977; Goodyear et al. 1982). Cisco spawning was observed near Stony Island during the 1890s (Rathbun et al. 1897) and near Brighton off Wellers Bay and Bald Head Beach in the 1970s (Goodyear et al. 1982). The expert panel assigned the observation data type a

score of high support for the reproduction line of evidence because several sources reported Cisco spawning at various locations throughout the hypothesized unoccupied spatial unit.

Table 16. Results describing how the "historically viable population" criterion was met for the hypothesized unoccupied Cisco *Coregonus artedi* spatial unit. Unweighted "data type scores" show the average scores for each data type prior to weighting and SD is the standard deviation of data type scores among individual expert panelists. "Line of evidence ranks" show the overall support a line of evidence provided for the spatial unit criterion (gray = data deficient, yellow = low support, orange = moderate support, red = high support). Ranks were calculated by weighting, then averaging associated data type scores. "-" indicates data deficiency.

Line of evidence	Data type	Data type score	SD	Line of evidence rank
Non-ephemeral presence	Harvest	2.91	0.30	Moderate (2.20)
	Survey	2.10	0.70	
	Modeled probability of occurrence	1.73	0.65	
	Observational	2.36	0.67	
	Telemetry	-	-	
	Tagging/marking	-	-	
	Microchemistry	-	-	
Reproduction	Demography	-	-	Moderate (1.80)
	Reproductive Status	1.70	0.67	
	Observation	2.80	0.42	
Genetic / genomic	Genetic / genomic	-	-	Data Deficient

Lack of contemporary occupancy criterion (focal organisms entirely absent or only ephemerally present): The lack of contemporary occupancy criterion received **moderate support** from the contemporary absence line of evidence (Table 17). The genetic/genomic line of evidence was **data deficient**. One line of evidence was required to achieve at least a moderate level of support to meet this criterion, thus the lack of contemporary occupancy criterion was met.

LINES OF EVIDENCE

Contemporary absence

The survey and modeled probability of occurrence data types provided **moderate support** for the contemporary absence line of evidence while the harvest data type provided **low support**. The observation, telemetry, conventional marking, and microchemistry data types were **data deficient.**

Harvest data (low support) – During the late 1800s and early 1900s, Cisco were harvested in many locations in Lake Ontario, but contemporary Cisco harvest is restricted to the northeast portion of the lake (Pritchard 1928; Christie 1973; Holmes

and Whillans 1984; Weidel et al. 2021; GLFC 2022, OMNR 2022, OMNR 2023, OMNR 2024). Experts commented that a lack of contemporary harvest effort using gear types efficient at capturing Cisco in other areas of Lake Ontario made the assessment of the data type difficult (the lack of harvest would be more compelling if there was also substantial fishing effort with relevant gear types). However, the panel also expressed that fishers would likely target Cisco in other areas if they were abundant. The expert panel assigned the harvest data type a score of low support for the non-ephemeral line of evidence.

Survey data (moderate support) – The expert panel considered both surveys that targeted Cisco and more general fish surveys that did not specifically target Cisco, but used gears to which Cisco were vulnerable. In U.S. waters, the catch per unit effort (CPUE) of juvenile and adult Cisco reported by long-term gillnet and trawl surveys (much of the sampling occurred outside the Cisco spawning season) between 2000-2020 was less than 0.1 (number ha^{-1}) across most of the hypothesized unoccupied unit (Weidel et al. 2021; Weidel et al. 2023; O'Malley et al. 2024b; B. Weidel, personal communication, 2024). No Cisco were captured by these surveys during the spawning season (November and December). A fall (October through December) gillnet survey of New York embayments conducted from 2018 to 2022 captured 352 Cisco during 124 sampling events. Most sampling occurred within hypothesized occupied spatial unit 2 and all Cisco were captured within hypothesized occupied spatial unit 2 (B. O'Malley, personal communication, 2024a). Brown et al. (2022) conducted a larval fish survey and captured 2,350+ coregonine larvae (>94% were Cisco) from April to May, predominantly within embayments in the hypothesized occupied spatial units, but a small number were also collected along the southern shore in the hypothesized unoccupied spatial unit. Patrick et al. (2020) identified eggs and larvae in water pumped from Lake Ontario at the Darlington Nuclear Generating Station from December 2015 to November 2016, but did not identify any Cisco. The expert panel scored the survey data type as moderate support for the contemporary absence line of evidence because there was a large quantity of survey data, but much of it was collected outside the Cisco spawning season.

Modeled probability of occurrence (moderate support) – K. King (personal communication, 2024c) generated a maximum entropy (Elith et al. 2011) contemporary reproductive habitat suitability model using georeferenced contemporary Cisco spawning records from CORHIST (spawning occurrence data range: 2000-2024; Brant et al., 2024). Ten environmental variables were considered for contemporary maximum entropy modeling (see modeled probability of occurrence section above for full list) and two variables with the most predictive power were selected for the final model: mean ice duration for the contemporary period and reefs. Small embayments could not be included in the reproductive habitat suitability model because environmental data were unavailable, something that the expert panel highlighted could be improved in the future. King et al.'s final model predicted that suitable reproductive habitat for Cisco is currently primarily in the Bay of Quinte and Chaumont Bay. The expert panel thought the reproductive habitat suitability model provided indirect evidence for the

contemporary absence of Cisco in some portions of the hypothesized unoccupied spatial unit and therefore the expert panel assigned the modeled probability of occurrence data type a score of moderate support for the contemporary absence line of evidence.

Table 17. Results describing how the "lack of contemporary occupancy" criterion was met for the hypothesized unoccupied Cisco *Coregonus artedi* spatial unit. Unweighted "data type scores" show the average scores for each data type prior to weighting and SD is the standard deviation of data type scores among individual expert panelists. "Line of evidence ranks" show the overall support a line of evidence provided for the spatial unit criterion (gray = data deficient, yellow = low support, orange = moderate support, red = high support). Ranks were calculated by weighting, then averaging associated data type scores. "-" indicates data deficiency.

Line of evidence	Data type	Data type score	SD	Line of evidence rank
Absence	Harvest	1.00	0.00	Moderate (1.80)
	Survey	1.91	0.30	
	Modeled prob of occurrence	1.56	0.73	
	Observational	-	-	
	Telemetry	-	-	
	Conventional marking	-	-	
	Microchemistry	-	-	
Genetic / genomic	Genetic / genomic	-	-	Data Deficient

3.3.2 Occupied Cisco spatial unit

3.3.2.1 Occupied Cisco spatial unit data synthesis

Facilitators compiled a catalog of 11 references (Tables 18 and 19) and 26 georeferenced spawning observations (direct observations of spawning or mature individuals or spawning grounds) and 81 georeferenced possible spawning observations (observations indicative of spawning but spawning/mature fish not directly observed; Figure 8) from CORHIST (Figure 8; Appendix 4 Table 3; Brant et al., 2024) to facilitate assessment of the hypothesized occupied Cisco spatial units.

Table 18. Cisco *Coregonus artedi* "contemporary reproductive isolation" criterion references (n = 9) organized by line of evidence and data type. Data type weights are shown before references in parentheses: + = weight of one applied to data type and ++ = weight of two applied to data type. Weights are not applied when data types are scored as data deficient. Cells filled with gray indicate the data type was not applicable for the line of evidence.

Data type	Line of evidence		
	Limited movement or migration	**Reproductive differences**	**Genetic / genomic divergence**
Harvest		(+) Data deficient	
Survey		(++) Data deficient	
Demography		(+) Data deficient	
Reproductive status		(++) S. Beech (personal communication, 2024e); B. O'Malley (personal communication, 2024c)	
Observation	(++) Data deficient	(++) Data deficient	
Genetic / genomic			(++) George (2019); Stott et al. (2022); A. Ackiss, (personal communication, 2024b)
Telemetry	(++) Gatch et al. (2023); S. Beech (personal communication, 2024d)	(++) Gatch et al. (2023); S. Beech (personal communication, 2024e)	
Conventional marking	(+) Data deficient		
Microchemistry	(+) Data deficient		

Table 19. Cisco *Coregonus artedi* "distinct component of evolutionary legacy" criterion references (n = 2) organized by line of evidence and data type. Data type weights are shown before references in parentheses: + = weight of one applied to data type and ++ = weight of two applied to data type. Weights are not applied when data types are scored as data deficient. Cells filled with gray indicate the data type was not applicable for the line of evidence.

Data type	Line of evidence	
	Life history variation	**Local adaptation/adaptive diversity**
Survey	(++) Data deficient	
Reproductive status	(+) Data deficient	
Observation	(+) Data deficient	
Genetic / genomic		(++) Data deficient
Telemetry	(++) Data deficient	
Conventional marking	(+) Data deficient	
Ontogeny	(++) Data deficient	
Phenotypic		(++) Eshenroder et al. (2016); B. O'Malley, (personal communication, 2024d)
Resource partitioning		(++) Data deficient

3.3.2.2 Description of occupied Cisco spatial unit hypothesis

The expert panel generated an occupied Cisco spatial unit hypothesis containing two spatial units to formally assess (Figure 9): *Hypothesized occupied spatial unit 1* contains the Bay of Quinte down to the tip of Cressy Point (44.113711, -76.848965); *Hypothesized occupied spatial unit 2* is comprised of two disjunct areas. The first area contains Chaumont Bay (44.041720, -76.204232) and adjacent waters (Stony Point area starting at Association Island (43.903993, -76.212999), Henderson Bay (43.897482, -76.174403), Black River Bay (43.972111, -76.106371), and north to Tibbets Point (44.101699, -76.372437) area, including the waters surrounding Dablon Point (44.072307, -76.361936), Fox Island (44.043461, -76.323191), and Grenadier Island (44.055963, -76.352911). The second area is comprised of four bays along the southern shoreline of Lake Ontario: Little Sodus Bay (43.343471, -76.707320), Port Bay (43.305389, -76.836877), Sodus Bay (43.272839, -76.962967), and Irondequoit Bay (43.237218, -77.536262). The expert panel determined that there were insufficient data to test for reproductive isolation between the two disjunct areas comprising hypothesized occupied spatial unit 2 or determine if these areas comprised distinct components of evolutionary legacy. Therefore, a hypothesis in which these two areas constituted separate occupied spatial units was not tested. Occupied spatial units were restricted to depths <55 meters because evidence suggested it was unlikely that Lake Ontario Cisco spawned below these depths.

3.3.2.3 Occupied Cisco spatial unit assessment results and discussion

One of two criteria to delineate two occupied Cisco spatial unit hypotheses was met (at least one criterion must be met to delineate occupied units): "contemporary reproductive isolation" (Table 20). The "distinct component of evolutionary legacy" criterion was not met (Table 21).

Contemporary reproductive isolation criterion (some degree of reproductive isolation between hypothesized spatial units): The contemporary reproductive isolation criterion received moderate support from the movement and migration line of evidence and no support from the reproductive differences and genetic/genomic divergence lines of evidence (Table 20). Given that only one line of evidence was required to achieve at least a moderate level of support, this criterion was met.

LINES OF EVIDENCE

Movement and migration

The telemetry data type provided **moderate support** for the movement and migration line of evidence and the conventional marking, microchemistry, and observation data types were **data deficient**.

Telemetry data (moderate support) – Gatch et al. (2023) used acoustic telemetry to monitor 76 Cisco collected from spawning aggregations in Chaumont Bay from 2016 - 2021. Tagged females did not survive multiple spawning seasons, but 23 males survived until a second spawning season and all exhibited spawning site fidelity, returning to

Chaumont Bay during the spawning season (Gatch et al. 2023). Additionally, two Cisco from Bay of Quinte spawning aggregations were observed using acoustic telemetry during the period of 2018-2019 and were found to stay in the Kingston Basin throughout most of the year and return to the upper Bay of Quinte during spawning season (S. Beech, personal communication, 2024d). The experts determined that the few telemetry data available demonstrated spawning site fidelity in Bay of Quinte and Chaumont Bay Cisco and assigned a score of moderate support to the telemetry data type for the movement and migration line of evidence.

Reproductive differences

The reproductive status data type provided **no support** for the reproductive differences line of evidence. The harvest, telemetry, observation, survey, and demography data types were **data deficient**.

Reproductive status data (no support) – The expert panel qualitatively compared gonadal somatic indices between Cisco collected in the Bay of Quinte and Chaumont Bay during 2022-2023 (B. O'Malley, personal communication, 2024c; S. Beech, personal communication, 2024e). The expert panel did not observe major differences in gonadal somatic indices between the hypothesized occupied spatial units and assigned a score of no support to the reproductive status data type for the reproductive differences line of evidence.

Genetic/genomic divergence

The genetic/genomic data type provided **no support** to the genetic/genomic divergence line of evidence.

Genetic/genomic data (no support) – George (2019) and Stott et al. (2022) used microsatellite markers to characterize the stock structure of Cisco collected during the spawning season in Chaumont Bay and the Bay of Quinte and neither study found evidence for any genetically distinct stocks. Using RADseq data, A. Ackiss (personal communication, 2024b) also did not find that Cisco collected from the Bay of Quinte and Chaumont Bay during spawning season were genetically distinct. The expert panel assigned a score of no support to the genetic/genomic data type for the genetic/genomic divergence line of evidence.

Table 20. Results describing how the "contemporary reproductive isolation" criterion was met for the two hypothesized occupied Cisco *Coregonus artedi* spatial units. Unweighted "data type scores" show the average scores for each data type prior to weighting and SD is the standard deviation of data type scores among individual expert panelists. "Line of evidence ranks" show the overall support a line of evidence provided for the spatial unit criterion (gray = data deficient, yellow = low support, orange = moderate support, red = high support). Ranks were calculated by weighting, then averaging associated data type scores. "-" indicates data deficiency.

Line of evidence	Data type	Data type score	SD	Line of evidence rank
Movement and migration	Telemetry	1.80	0.40	Moderate (1.80)
	Conventional marking	-	-	
	Microchemistry	-	-	
	Observation	-	-	
Differences in reproduction	Harvest	-	-	None (0.00)
	Telemetry	-	-	
	Observation	-	-	
	Survey	-	-	
	Demography	-	-	
	Reproductive status	0.00	0.00	
Genetic / genomic divergence	Genetic / genomic	0.00	0.00	None (0.00)

Distinct component of the evolutionary legacy criterion (organisms in hypothesized spatial units represent distinct components of evolutionary history): The distinct component of evolutionary legacy criterion received **no support** from the local adaptation/adaptive diversity line of evidence, and the life history variation line of evidence was **data deficient** (Table 21). One line of evidence was required to achieve at least a moderate level of support. Thus, this criterion was not met.

LINES OF EVIDENCE

Local adaptation/adaptive diversity

The phenotypic data type provided **no support** for the local adaptation/adaptive diversity line of evidence, and the genetic/genomic and resource partitioning data types were **data deficient**.

Phenotypic data (no support) – The expert panel qualitatively compared gill raker counts (first gill arch) between Cisco collected in the Bay of Quinte Cisco (O'Malley, personal communication, 2024d) and Chaumont Bay Cisco (Eshenroder et al. 2016; O'Malley, personal communication, 2024d) and no differences were observed (means were approximately equal). Therefore, the expert panel assigned a score of **no support** to the phenotypic data type for the local adaptation/adaptive diversity line of evidence.

Table 21. Results describing how the "distinct component of evolutionary legacy" criterion was not met for the two hypothesized occupied Cisco *Coregonus artedi* spatial units. Unweighted "data type scores" show the average scores for each data type prior to weighting and SD is the standard deviation of data type scores among individual expert panelists. "Line of evidence ranks" show the overall support a line of evidence provided for the spatial unit criterion (gray = data deficient, yellow = low support, orange = moderate support, red = high support). Ranks were calculated by weighting, then averaging associated data type scores. "-" indicates data deficiency.

Line of evidence	Data type	Data type score	SD	Line of evidence rank
Life history variation	Telemetry	-	-	Data deficient
	Conventional marking	-	-	
	Survey	-	-	
	Observation	-	-	
	Reproductive status	-	-	
	Ontogeny	-	-	
Local adaptation / adaptive diversity	Genetic / genomic	-	-	None (0.00)
	Phenotypic	0.00	0.00	
	Resource partitioning	-	-	

3.3.3 Conclusions

3.3.3.1 Delineated spatial units

This assessment determined that the criteria were met for the hypothesis of one-unoccupied and two-occupied Cisco spatial units in Lake Ontario (Figure 10). Therefore, **one unoccupied and two occupied spatial units were delineated for Lake Ontario Cisco** (Figure 9). These spatial units should be viewed as the most complex hypotheses for historical and contemporary Lake Ontario Cisco population structure that were supported by the data available for this assessment. If new data become available, future assessments can revise Lake Ontario Cisco spatial units. Furthermore, Indigenous Knowledge may also delineate spatial units for Lake Ontario Cisco in the future, which may or may not be congruent with the spatial units delineated using Western Science.

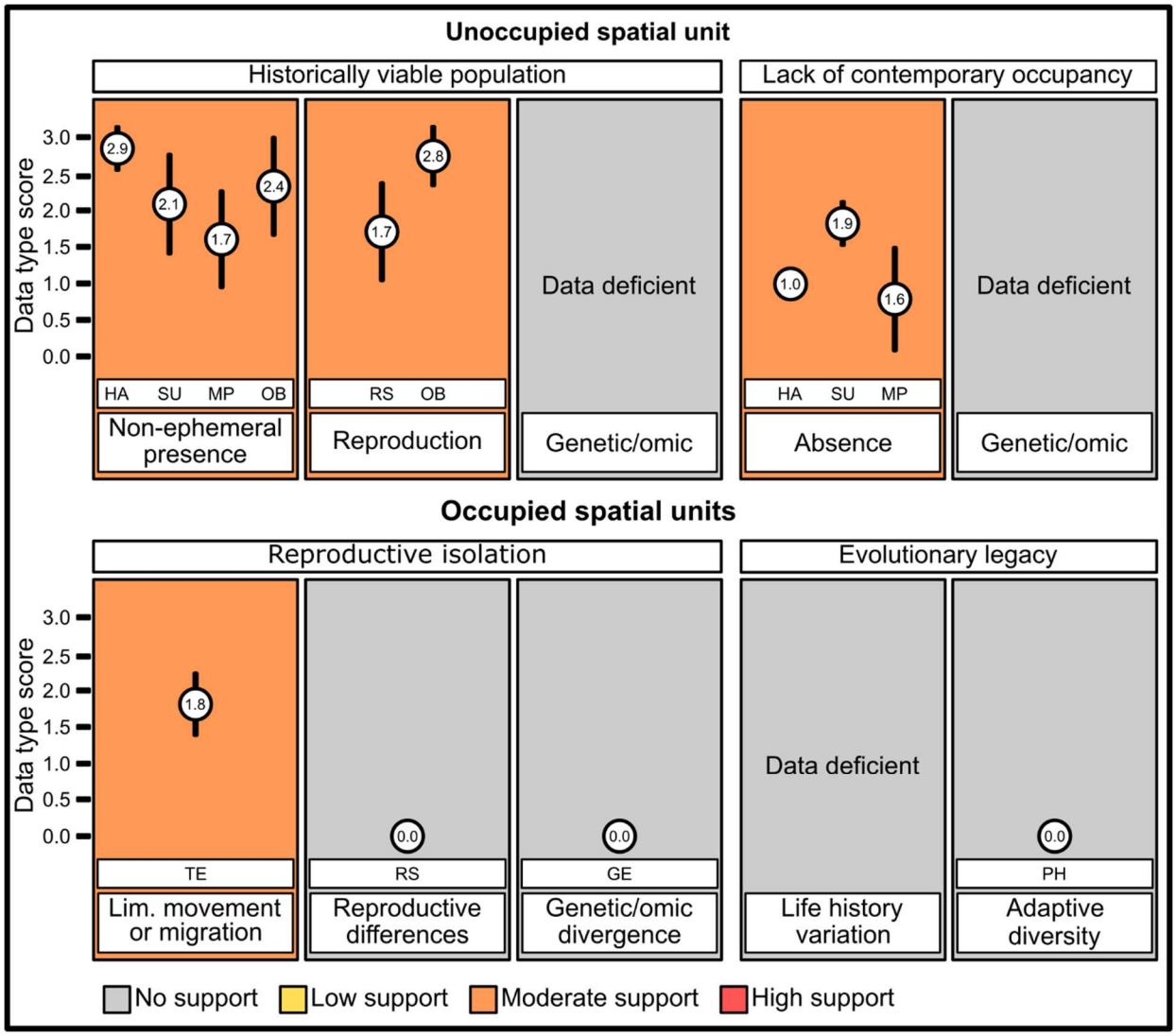


Figure 10. Summary of spatial unit assessment results for Lake Ontario Cisco *Coregonus artedi*. The "historically viable population" and "lack of contemporary occupancy" criteria were assessed for a single unoccupied spatial unit hypothesis. The "contemporary reproductive isolation" and "distinct component of evolutionary legacy" criteria were assessed for a two occupied spatial unit hypothesis. Circles show the average "data type scores" for each data type prior to weighting and vertical black bars show the standard deviation (SD) of data type scores among individual expert panelists. Data type codes: HA = harvest, SU = survey, MP = modeled probability of occurrence, OB = observation, DE = demography, RS = reproductive status, TE = telemetry, PH = phenotypic, and GE = genetic/genomic. Data deficient data types are not shown (See Tables 16-17 and 20-21). The color of each line of evidence box corresponds to the "line of evidence rank," which shows the overall support a line of evidence provides for the spatial unit criterion (see legend). Ranks are calculated by weighting, then averaging associated data type scores.

3.3.3.2 Key knowledge gaps

The expert panel identified six key knowledge gaps that inhibited Lake Ontario Cisco spatial unit delineation (see also data poor and data deficient data types in Tables 16-17 and 20-21 that highlight additional knowledge gaps):

1. Are there heritable phenotypic differences (e.g., in morphology or life history), particularly resulting from local adaptation, between Cisco in occupied spatial unit 1 versus occupied spatial unit 2?

2. What are the primary contemporary spawning migration routes used by Cisco and how do they vary within and between spatial units?

3. How does movement and habitat use outside the spawning season vary within and between occupied spatial units?

4. How much gene flow occurs between occupied Cisco spatial units and among different areas within occupied spatial units?

5. Do Cisco consistently spawn in bays along the southern shore of Lake Ontario?

6. What was the historical Cisco population structure in Lake Ontario? Koelz (1929) posed several questions related to historical cisco population structure that remain unanswered.

3.4 Round Whitefish

The expert panel formulated a Round Whitefish spatial unit hypothesis consisting of one occupied spatial unit and one unoccupied spatial unit to formally assess. The expert panel did not identify evidence of Lake Ontario Round Whitefish using reproductive habitat in tributaries. Therefore, no tributaries were included in hypothesized spatial units. The historical period included prior to 2000 and the contemporary period included 2000 and after. Due to the limited data available for Round Whitefish, more recent Round Whitefish data (up to the year 2000) were designated as historical relative to the other Lake Ontario coregonines assessed. These time periods were separated based on several major ecosystem changes that occurred during the 1990s and early 2000s including increases in zebra and quagga mussel abundances, and declines in *Diporeia* abundance (Griffiths et al. 1991; Mills et al. 1993; Owens and Dittman 2003; Mills et al. 2005; GLFC 2022; Karatayev et al. 2022).

3.4.1 Unoccupied Round Whitefish spatial unit

3.4.1.1 Unoccupied Round Whitefish spatial unit data synthesis

Facilitators compiled a catalog of 28 references (Tables 22 and 23) and 26 georeferenced historical spawning observations (direct observations of spawning or mature individuals or

spawning grounds) and 47 georeferenced historical possible spawning observations (observations indicative of spawning but spawning/mature fish not directly observed) from CORHIST (Figure 11; Appendix 4 Table 4; Brant et al. 2024) to facilitate assessment of the hypothesized unoccupied Round Whitefish spatial unit.

Table 22. Round Whitefish *Prosopium cylindraceum* "historically viable population" criterion references (n = 19) organized by line of evidence and data type. Data type weights are shown before references in parentheses: + = weight of one applied to data type and ++ = weight of two applied to data type. Weights are not applied when data types are scored as data deficient. Gray shaded cells indicate the data type was not applicable to assess the line of evidence. Data deficient means that no data of a particular type were available at the time of assessment. See Appendix 4 Table 4 for additional information associated with cataloged Royal Ontario Museum (ROM) specimens referenced in this table. OMNR = Ontario Ministry of Natural Resources

Data type	Line of evidence		
	Non-ephemeral presence	Reproduction	Genetic / genomic
Harvest	(+) Dymond et al. (1929); OMNR (1994); OMNR (1995); OMNR (1996); OMNR (1997); S. Beech, (personal communication, 2025a)		
Survey	(++) Koelz (1929); Haymes and Kolenosky (1984); OMNR (1995); OMNR (1996); OMNR (1997); OMNR (1998); OMNR (1999); OMNR (2012); S. Beech (personal communication, 2025b); S. Beech (personal communication, 2025c)		
Modeled probability of occurrence	(+) K. King (personal communication, 2025d)		
Demography		(+) Data deficient	
Reproductive status		(++) Data deficient	
Observation	(+) ROM I001803 (1925); ROM I064634 (1991); Howell (1970); Anderson and Coker (1991); Carlson et al. (2016)	(+) Data deficient	
Genetic / genomic			(++) Data deficient
Telemetry	(++) Data deficient		
Conventional marking	(+) Data deficient		
Microchemistry	(+) Data deficient		

Table 23. Round Whitefish *Prosopium cylindraceum* "lack of contemporary occupancy" criterion references (n = 9) organized by line of evidence and data type. Data type weights are shown before references in parentheses: + = weight of one applied to data type and ++ = weight of two applied to data type. Weights are not applied when data types are scored as data deficient. Gray shaded cells indicate the data type was not applicable to assess the line of evidence. Data deficient means that no data of a particular type were available at the time of assessment. OMNR = Ontario Ministry of Natural Resources.

Data type	Line of evidence	
	Absence of target organisms	Genetic / genomic
Harvest	(+) S. Beech (personal communication, 2025a)	
Survey	(++) OMNR (2012); Hoyle (2015); OMNR (2020); OMNR (2022); S. Beech (personal communication, 2025c)	
Modeled probability of occurrence	(+) K. King (personal communication, 2025d)	
Observation	(+) OMNR (2014); Carlson et al. (2016)	
Genetic / genomic		(++) Data deficient
Telemetry	(++) Data deficient	
Conventional marking	(+) Data deficient	
Microchemistry	(+) Data deficient	

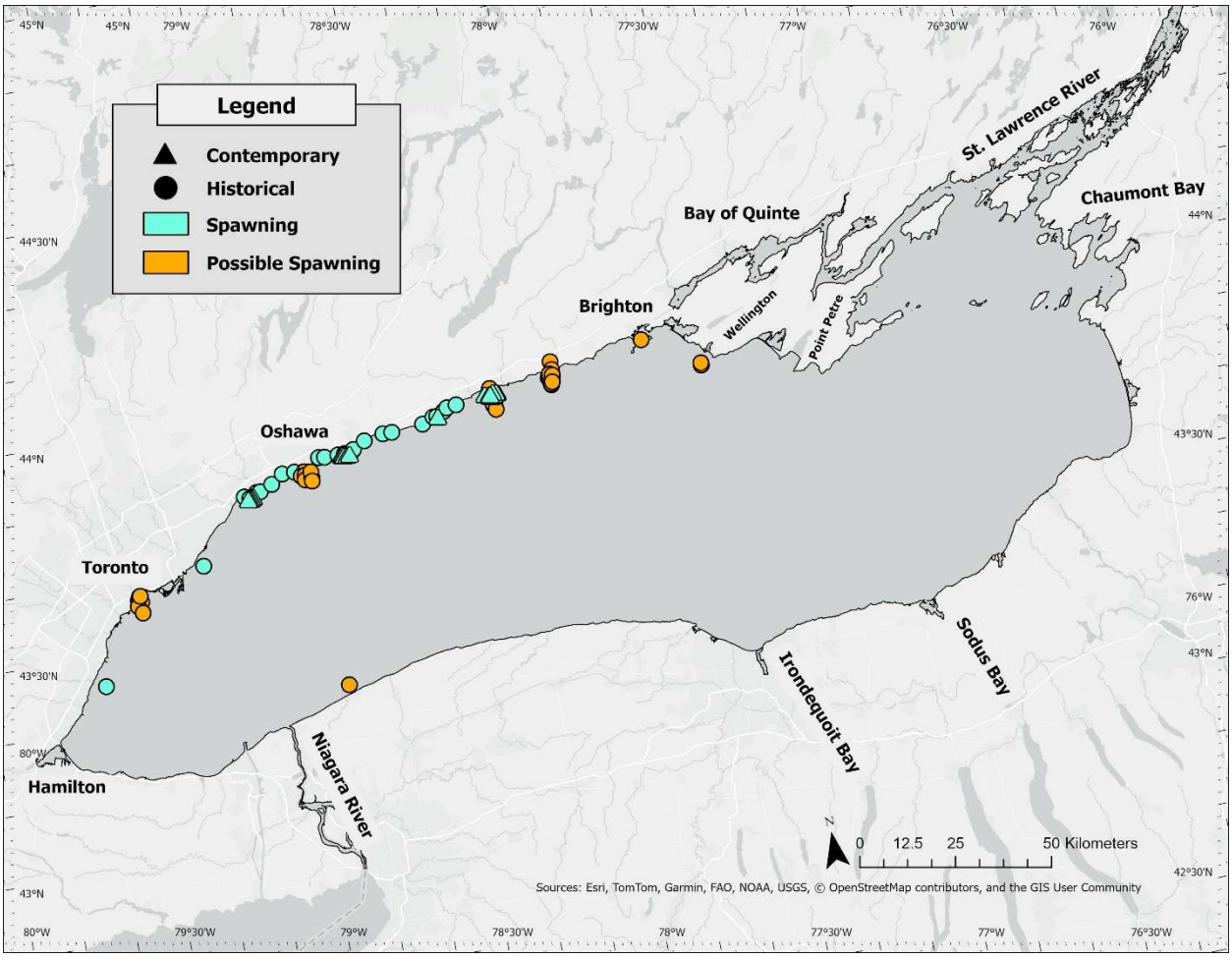


Figure 11. Map of Lake Ontario with georeferenced historical and contemporary Round Whitefish *Prosopium cylindraceum* spawning and possible spawning observations (Appendix 4 Table 4). "Spawning" observations (n = 57) are direct observations of spawning, mature individuals, or spawning grounds and "possible spawning" observations (n = 47) are observations suggestive of spawning (e.g., aggregations of fish during the spawning season) but not direct observations of spawning/mature fish. In this figure, there are cases in which points showing the locations of observations overlap, obscuring the true number of observations.

3.4.1.2 Description of hypothesized unoccupied Round Whitefish spatial unit

The expert panel generated a Round Whitefish spatial unit hypothesis containing one unoccupied spatial unit to formally assess comprised of two regions along the northern Lake Ontario shoreline (Figure 12): (1) from near Toronto, Ontario, CAN (43.655439, -79.261443) to the Grimsby, Ontario, CAN area (43.211524, -79.550440) and (2) from the Brighton area (43.995809, -77.772559) to Petre Point (43.839393, -77.156229). Although spawning east of Wellington was not confirmed, the expert panel conservatively extended the eastern portion of the unoccupied unit to Point Petre because of large commercial harvests that occurred in the Brighton area, without precise locality data, that could have occurred east of Wellington (S. Beech, personal communication, 2025a). Furthermore, a small amount of historically suitable

reproductive habitat was predicted to occur between the Wellington area and Point Petre (K. King, personal communication, 2025). The expert panel determined that there were insufficient data to test for reproductive isolation between the two disjunct areas comprising hypothesized unoccupied spatial unit or determine if these areas comprised distinct components of evolutionary legacy. Therefore, a hypothesis in which these two areas constituted separate unoccupied spatial units was not tested.

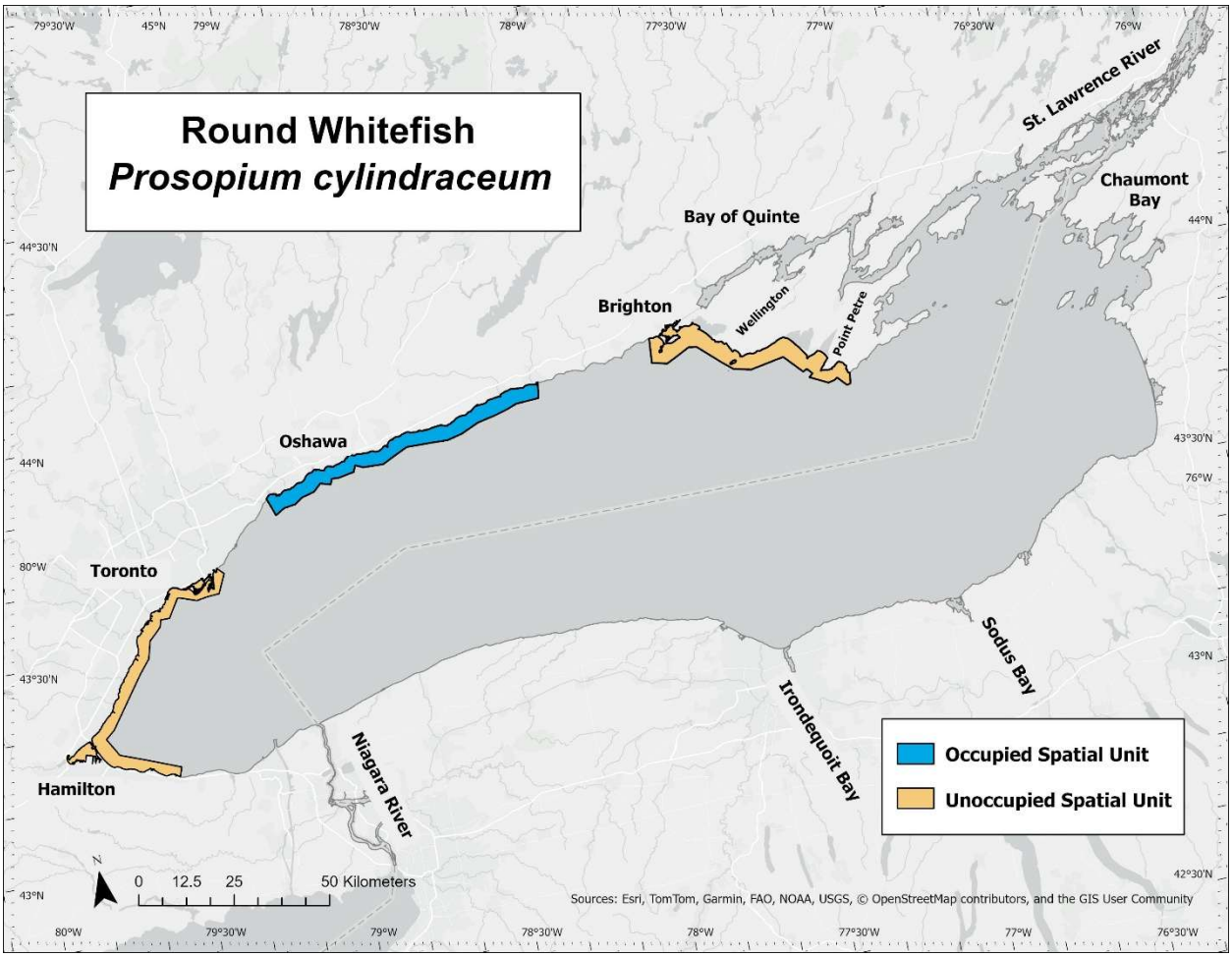


Figure 12. Map of Lake Ontario with colors demarcating the locations of the single unoccupied and single occupied Round Whitefish *Prosopium cylindraceum* spatial units. Space not assigned to any spatial units is demarcated via gray shading. Note: the unoccupied spatial unit 2 is comprised of two disjunct areas. Space may not have been assigned to a spatial unit because either it did not contain Round Whitefish reproductive habitat (neither historically or contemporarily) or there was no evidence of historical or contemporary occupancy of Round Whitefish regardless of reproductive habitat suitability. See section 2.2 for an explanation of the requirements for occupancy criteria.

3.4.1.3 Unoccupied Round Whitefish spatial unit assessment results and discussion

Both criteria for delineating the hypothesized unoccupied Round Whitefish spatial unit hypothesis were met: "historically viable population" (Table 24) and "lack of contemporary occupancy" (Table 25).

Historically viable population criterion (historical presence of a naturally reproducing (sub)population over an extended period of time): One line of evidence must achieve at least a moderate level of support for the historically viable population criterion to be met. This requirement was satisfied by the non-ephemeral presence line of evidence, which received **moderate support** (Table 24). The reproduction and genetic/genomic lines of evidence were **data deficient**.

LINES OF EVIDENCE

Non-ephemeral presence

Harvest, survey, and modeled probability of occurrence data types provided **moderate support** for the non-ephemeral presence line of evidence and the observation data type provided **low support**. The telemetry, conventional marking, and microchemistry data types were **data deficient.**

Harvest data (moderate support) – We found reports of Round Whitefish harvest spanning the period of 1926-1996 in the proximities of Port Credit and Brighton (Dymond et al. 1929; OMNR 1994; OMNR 1995; OMNR 1996; OMNR 1997). Dymond et al. (1929) reported that Round Whitefish were collected near Port Credit from 1926-1928 at depths between 11-38 meters. During the 1990s, an average of 410 pounds of Round Whitefish were caught commercially from October through December 1993-1996 (this period overlaps with the Round Whitefish spawning season of late September through December; Koelz 1929) from the area between Brighton and Nicholson Island (OMNR 1994; OMNR 1995; OMNR 1996; OMNR 1997; S. Beech, personal communication, 2025a). There was limited evidence of harvest in the western region of the hypothesized unoccupied spatial unit. The expert panel assigned a score of moderate support to the harvest data type for the non-ephemeral presence line of evidence.

Survey data (moderate support) – Annual gillnet surveys conducted by OMNR caught ~ 40 Round Whitefish annually from 1994-1998 at depths of 13-28 meters during the summer from offshore of Brighton to near Nicholson Island (OMNR 1995; OMNR 1996; OMNR 1997; OMNR 1998; OMNR 1999). OMNR fall Lake Trout spawning surveys collected Round Whitefish near Port Credit between 1985-1995 in mid- and late-September (S. Beech, personal communication, 2025b). The Lake Ontario Management Unit long-term community index gillnetting program caught Round Whitefish near Brighton every August between 1988-1999 (a total of 241 individuals) at depths of 8.5-28.0 meters and caught one Round Whitefish in June 1990 near Port Credit (S. Beech, personal communication, 2025c). Additionally, Koelz (1929) surveyed Lake Ontario for

coregonines in the 1920s and caught two Round Whitefish near Brighton in June 1922 and one near Winona in November 1921. The expert panel agreed that there were consistent Round Whitefish survey catches in the eastern unoccupied spatial unit segment, but fewer in the western unoccupied spatial unit segment and noted that survey effort was limited throughout much of the hypothesized unoccupied spatial unit. The expert panel assigned the survey data type a score of moderate support for the non-ephemeral line of evidence.

Modeled probability of occurrence data (moderate support) – K. King (personal communication, 2025) generated a maximum entropy (Elith et al. 2011) historical reproductive habitat suitability model using georeferenced historical Lake Ontario Round Whitefish spawning records from CORHIST (spawning occurrence data range: 1925 - 1995; Brant et al., 2024). Ten environmental variables were considered for historical maximum entropy modeling: bathymetry [meters], predicted reefs [predicted reef suitability from 0-1], fetch [meters], distance to rivers [kilometers], distance to wetlands [kilometers], mean circulation magnitude [meters/second], mean bottom slope [degrees], historical substrate [categorical variable with 14 substrate categories], mean ice duration [days], coefficient of variation of ice duration [days], and mean annual upwelling index [days]. Four environmental variables with the most predictive power were selected for the final model: bathymetry, historical substrate, predicted reefs, and mean annual upwelling index. King et al.'s (personal communication, 2025) model predicted that suitable reproductive habitat for Round Whitefish was historically distributed along portions of the north-central and western shorelines from Brighton to the Hamilton region, along the southwest shoreline between the Hamilton area and the mouth of the Niagara River, and in Chaumont Bay. The expert panel determined that the reproductive habitat suitability model showed reproductive habitat where Round Whitefish has been known to occur. The expert panel assigned the modeled probability of occurrence data type a score of moderate support for the non-ephemeral presence line of evidence.

Observational data (low support) – Round Whitefish were observed in Lake Ontario, just south of Toronto, during the 1920s to the 1990s (5 total sampling events), but only two of these observations were made during the spawning season (ROM 1925; ROM 1926; Howell 1970; Anderson and Coker 1991; Carlson et al. 2016). The expert panel assigned a score of low support to the observational data type for the non-ephemeral presence line of evidence because there were few observational data.

Table 24. Results describing how the "historically viable population" criterion was met for hypothesized unoccupied Round Whitefish *Prosopium cylindraceum* spatial unit. Unweighted "data type scores" show the average scores for each data type prior to weighting and SD is the standard deviation of data type scores among individual expert panelists. "Line of evidence ranks" show the overall support a line of evidence provided for the spatial unit criterion (gray = data deficient, yellow = low support, orange = moderate support, red = high support). Ranks were calculated by weighting, then averaging associated data type scores. "-" indicates data deficiency.

Line of evidence	Data type	Data type score	SD	Line of evidence rank
Non-ephemeral presence	Harvest	2.40	0.52	Moderate (1.67)
	Survey	2.10	0.32	
	Modeled probability of occurrence	1.60	0.52	
	Observational	1.00	0.00	
	Telemetry	-	-	
	Tagging/marking	-	-	
	Microchemistry	-	-	
Reproduction	Demography	-	-	Data Deficient
	Reproductive Status	-	-	
	Observation	-	-	
Genetic / genomic	Genetic / genomic	-	-	Data Deficient

Lack of contemporary occupancy criterion (focal organisms are entirely absent from the focal area or only ephemerally present): The lack of contemporary occupancy criterion received **moderate support** from the contemporary absence line of evidence (Table 25). The genetic/genomic line of evidence was **data deficient**. One line of evidence was required to achieve at least a moderate level of support to meet this criterion. Thus, the lack of contemporary occupancy criterion was met.

LINES OF EVIDENCE

Contemporary absence

The survey data type provided **moderate support** for the contemporary absence line of evidence, while the harvest and modeled probability of occurrence data types provided **low support**. The observation, telemetry, conventional marking, and microchemistry data types were **data deficient.**

Harvest data (low support) – Only 61 pounds of Round Whitefish have been harvested (all in one year) during the contemporary period (2000 and after) despite consistent commercial fishing effort near Brighton (S. Beech, personal communication, 2025a). The expert panel determined that the harvest data type was data deficient for the western region of the unoccupied spatial unit. Therefore, the expert panel scored the harvest data type as low support for the contemporary absence line of evidence.

Survey data (moderate support) – The expert panel considered both surveys that targeted Round Whitefish and more general fish surveys that did not specifically target Round Whitefish, but using gears to which Round Whitefish were vulnerable. Contemporary surveys have captured few Round Whitefish (CPUE = ≤ 0.06) from Brighton to Petre Point between 2000-present (OMNR 2012; Hoyle 2015; OMNR 2020; OMNR 2022) and no Round Whitefish anywhere else in Lake Ontario despite substantial sampling effort from 2014-2019 (S. Beech, personal communication, 2025c). The expert panel scored the survey data type as moderate support for the contemporary absence line of evidence.

Modeled probability of occurrence (low support) – K. King (personal communication, 2025) generated a maximum entropy (Elith et al. 2011) contemporary reproductive habitat suitability model using georeferenced contemporary Round Whitefish spawning records from CORHIST (spawning occurrence data range: 2000 – present; Brant et al., 2024). Ten environmental variables were considered for contemporary maximum entropy modeling (see modeled probability of occurrence section above for full list) and four variables with the most predictive power were selected for the final model: bathymetry, historical substrate, and mean annual upwelling index. King et al.'s (personal communication, 2024b) final model predicted that suitable reproductive habitat for Round Whitefish is currently primarily distributed along the north-central shore from the Pickering area to Port Hope with additional isolated patches of predicted reproductive habitat near Hamilton, Toronto, and Chaumont Bay. The expert panel determined that the reproductive habitat suitability model generally showed reproductive habitat where Round Whitefish have been collected during the contemporary period and the absence of suitable reproductive habitat where Round Whitefish have not been detected. However, many expert panelists cautioned that the absence of spawning habitat shown by the model could be partially due to the sparse contemporary spawning data available to generate the model. The expert panel assigned the modeled probability of occurrence data type a score of low support for the contemporary absence line of evidence.

Table 25. Results describing how the "contemporary absence" criterion was met for the hypothesized unoccupied Round Whitefish *Prosopium cylindraceum* spatial unit. Unweighted "data type scores" show the average scores for each data type prior to weighting and SD is the standard deviation of data type scores among individual expert panelists. "Line of evidence ranks" show the overall support a line of evidence provided for the spatial unit criterion (gray = data deficient, yellow = low support, orange = moderate support, red = high support). Ranks were calculated by weighting, then averaging associated data type scores. "-" indicates data deficiency.

Line of evidence	Data type	Data type score	SD	Line of evidence rank
Absence	Harvest	1.40	0.53	Moderate (1.5)
	Survey	2.10	0.33	
	Modeled probability of occurrence	1.20	0.41	
	Observational	-	-	
	Telemetry	-	-	
	Conventional marking	-	-	
	Microchemistry	-	-	
Genetic / genomic	Genetic / genomic	-	-	Data Deficient

3.4.2 Occupied Round Whitefish spatial unit

3.4.2.1 Occupied Round Whitefish spatial unit data synthesis

Facilitators compiled a catalog of 13 references (Table 26) and 31 georeferenced contemporary spawning observations (direct observations of spawning or mature individuals on spawning grounds; Figure 11) to facilitate assessment of the hypothesized occupied Round Whitefish spatial unit.

Table 26. Round Whitefish *Prosopium cylindraceum* "contemporary occupancy" criterion references (n = 13) organized by line of evidence and data type. Data type weights are shown before references in parentheses: + = weight of one applied to data type and ++ = weight of two applied to data type. Weights are not applied when data types are scored as data deficient. Gray shaded cells indicate the data type was not applicable to assess the line of evidence. Data deficient means that no data of a particular type were available at the time of assessment. GLFC = Great Lakes Fishery Commission; OMNR = Ontario Ministry of Natural Resources.

Data type	Line of evidence		
	Non-ephemeral presence	Reproduction	Genetic / genomic
Harvest	(+) GLFC (2022); S. Beech (personal communication, 2025a)		
Survey	(++) OMNR (2008); OMNR (2009); OMNR (2010); OMNR (2011); OMNR (2012); OMNR (2014); OMNRF (2015)		
Modeled probability of occurrence	(+) K. King (personal communication, 2025d)		
Demography		(+) OMNRF (2015)	
Reproductive status		(++) OMNR (2014); OMNRF (2015)	
Observation	(+) OMNR (2003)	(+) Data deficient	
Genetic / genomic			(++) Wood et al. (2016); Morgan et al. (2018)
Telemetry	(++) Data deficient		
Conventional marking	(+) Data deficient		
Microchemistry	(+) Data deficient		

3.4.2.2 Description of hypothesized occupied Round Whitefish spatial unit

The expert panel generated a single occupied Round Whitefish spatial unit hypothesis to formally assess containing one spatial unit encompassing a narrow stretch of Lake Ontario along the northern shoreline from the Pickering area (43.838415, -79.085082) to near Peter Rock (43.941434, -78.228913; Figure 12).

3.4.2.3 Occupied Round Whitefish spatial unit assessment results and discussion

The single criterion for delineating the data deficient hypothesized occupied Round White spatial unit hypothesis was met: "contemporary occupancy" (Table 27).

Contemporary occupancy criterion (focal organisms are entirely absent from the focal area or only ephemerally present): The contemporary occupancy criterion received **moderate support** from the genetic/genomic line of evidence, **moderate support** from the reproduction line of evidence, and **low support** from the non-ephemeral presence line of evidence (Table 27). Given that only one line of evidence was required to achieve at least a moderate level of support, this criterion was met.

LINES OF EVIDENCE

Non-ephemeral presence

The harvest, survey, and modeled probability of occurrence data types provided **low support** for the non-ephemeral presence line of evidence and the observation data type provided **no support**.

Harvest data (low support) – The only reported Round Whitefish harvest during the contemporary period was a 61-pound catch made between Cobourg and Nicholson Island in December 2000 (GLFC 2022; S. Beech, personal communication, 2025a). The expert panel found the commercial harvest record from 2000 to be significant, but assigned the harvest data type a score of low support for the non-ephemeral presence line of evidence due to the lack of additional data.

Survey data (low support) – Gillnet surveys targeting spawning Round Whitefish were conducted from Pickering to Peter Rock in November and December 2013 and 2014, during which six Round Whitefish and 172 Round Whitefish were collected, respectively (OMNR 2014; OMNRF 2015). Summer gillnet surveys during 2007-2009 from Newcastle to Collier Shoal also collected Round Whitefish (average CPUE = 2.3; OMNR 2008; OMNR 2009; OMNR 2010). Summer gillnet surveys near Cobourg conducted from 2010 to 2019 collected Round Whitefish in 2010 and 2011 (average CPUE = 0.6), but not during the period of 2012-2019 (OMNR 2011; OMNR 2012; OMNR 2020). The expert panel assigned the survey data type a score of low support for the non-ephemeral presence line of evidence because surveys caught Round Whitefish from 2007-2014, but did not sample Round Whitefish since 2014. The expert panel expressed a need for more survey work targeting Round Whitefish during the spawning season.

Modeled probability of occurrence data (low support) – K. King (personal communication, 2025) generated a maximum entropy (Elith et al. 2011) contemporary reproductive habitat suitability model using contemporary georeferenced Round Whitefish spawning records from CORHIST (spawning occurrence data range: 2000 – present; Brant et al., 2024). See the previous modeled probability of occurrence section for additional description of this model. King et al.'s model predicted that suitable reproductive habitat for Round Whitefish is currently primarily distributed along portions of the north-central shore from near Pickering to Port Hope with additional isolated patches of reproductive habitat predicted near Hamilton and Toronto and Chaumont Bay. The expert panel determined that the reproductive habitat suitability model showed reproductive habitat where Round Whitefish have been sampled during the contemporary period, providing some evidence that a viable Round Whitefish population could exist in the hypothesized occupied unit. However, expert panelists perceived this as indirect evidence, or not evidence at all, of the non-ephemeral presence of Round Whitefish in the hypothesized occupied spatial unit. Therefore, the modeled probability of occurrence data type was assigned a score of low support for the non-ephemeral presence line of evidence

Observational data (no support) – A single observational report of Round Whitefish within the hypothesized occupied spatial unit during the contemporary period was available, which consisted of this statement (OMNR 2003): "changes in round whitefish abundance, a species confined largely to north central Lake Ontario waters, are not well documented." Expert panelists decided that this observation was vague and due to the lack of additional observational data, assigned the observational data type a score of no support for the non-ephemeral presence line of evidence.

Reproduction

The demography and reproductive status data types provided **moderate support** for the reproduction line of evidence, while the observational data type was **data deficient**.

Demographic data (moderate support) – A 2014 spawning survey collected Round Whitefish in Pickering, Darlington, and Port Hope with an age range (based on otoliths; n = 172) of 4-22 years (OMNRF 2015). The expert panel found that this demographic data provided evidence of multiple Round Whitefish year classes within the hypothesized occupied spatial unit indicative of consistent reproduction. The expert panel assigned the demographic data type a score of moderate support due to the small quantity of demographic data.

Reproductive status data (moderate support) – OMNRF (2014; 2015) assessed Round Whitefish gonad condition within the hypothesized occupied spatial unit during the 2013 and 2014 spawning seasons and found that most of the 178 Round Whitefish captured were in spawning or pre-spawning condition. The expert panel found that reproductive status data indicated reproduction of Round Whitefish in the hypothesized occupied spatial unit and assigned the reproductive status data type a moderate support score for the reproduction line of evidence due to the limited quantity of data.

Genetic/Genomic

The genetic/genomic data type provided **moderate support** to the genetic/genomic line of evidence.

Genetic/genomic data (moderate support) – Morgan et al. (2018) inferred Round Whitefish population structure across the species' North American range, including 62 samples collected during 2012 and 2014 within the hypothesized occupied spatial unit, using microsatellite, mitochondrial DNA (mtDNA), and single-nucleotide polymorphism (SNP) loci. Morgan et al. (2018) confirmed the presence of Round Whitefish in Lake Ontario and found that Lake Ontario Round Whitefish are genetically distinct from Round Whitefish sampled in other areas. Wood et al. (2016) used microsatellite loci and 244 historical and contemporary Round Whitefish samples collected from Pickering to Peter Rock in November and December (years: 1979, 1980, 2013, 2014) to characterize population structure within the hypothesized spatial unit and found evidence for a single panmictic Round Whitefish population. The expert panel determined that genetic

data supported an extant and unique (i.e., genetically divergent from Round Whitefish sampled from other locations in North America) Round Whitefish population in the hypothesized occupied spatial unit, but found the available genetic data to be limited in terms of temporal coverage and quantity. Therefore, the expert panel assigned the genetic/genomic data type a score of moderate support for the genetic/genomic line of evidence.

Table 27. Results describing how the "contemporary occupancy" criterion was met for the hypothesized occupied Round Whitefish *Prosopium cylindraceum* spatial unit. Unweighted "data type scores" show the average scores for each data type prior to weighting and SD is the standard deviation of data type scores among individual expert panelists. "Line of evidence ranks" show the overall support a line of evidence provided for the spatial unit criterion (gray = data deficient, yellow = low support, orange = moderate support, red = high support). Ranks were calculated by weighting, then averaging associated data type scores. "-" indicates data deficiency.

Line of evidence	Data type	Data type score	SD	Line of evidence rank
Non-ephemeral presence	Harvest	0.75	0.50	Low (0.67)
	Survey	1.45	0.52	
	Modeled probability of occurrence	0.80	0.42	
	Observation	0.00	0.00	
	Telemetry	-	-	
	Tagging/marking	-	-	
	Microchemistry	-	-	
Reproduction	Observation	-	-	Moderate (2.00)
	Demography	1.82	0.60	
	Reproductive status	1.54	0.52	
Genetic / genomic	Genetic / genomic	1.82	0.40	Moderate (2.00)

3.4.3 Conclusions

3.4.3.1 Delineated spatial units

This assessment determined that the criteria were met for the hypothesis containing one unoccupied spatial unit and one-occupied spatial unit (Figure 13). Therefore, **one unoccupied and one occupied spatial unit are delineated for Lake Ontario Round Whitefish**. These spatial units should be viewed as the most complex hypotheses for historical and contemporary Lake Ontario Round Whitefish population structure that were supported by the data available for this assessment. If new data become available, future assessments can revise Lake Ontario Round Whitefish spatial units. Furthermore, Indigenous Knowledge may also delineate spatial units for Lake Ontario Round Whitefish in the future, which may or may not be congruent with the spatial units delineated using Western Science.

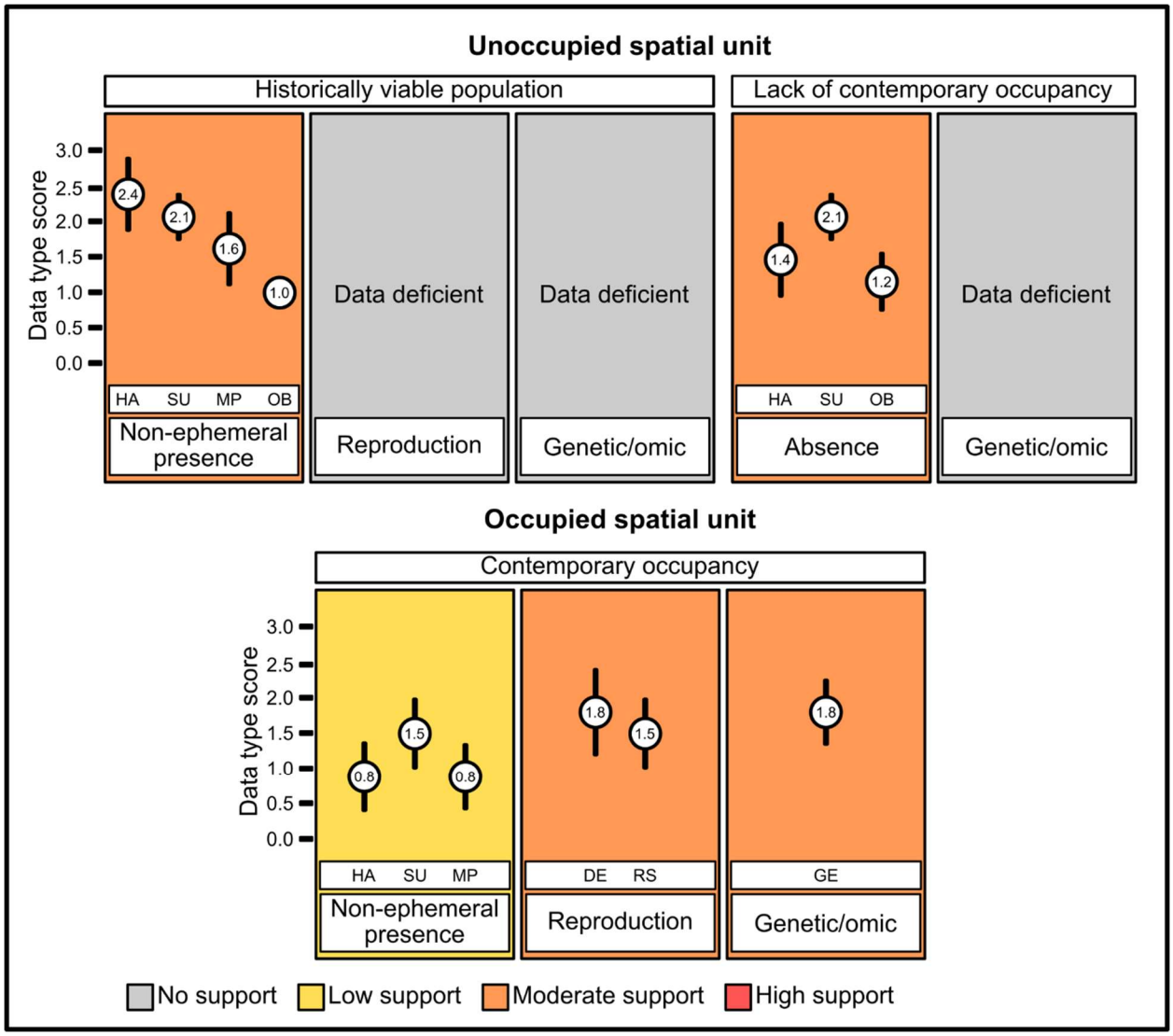


Figure 13. Summary of Lake Ontario Round Whitefish *Prosopium cylindraceum* spatial unit assessment results. The "historically viable population" and "lack of contemporary occupancy" criteria were assessed for the unoccupied unit hypothesis. The "contemporary occupancy" criterion was assessed for the occupied unit hypothesis. Circles show the average "data type scores" for each data type prior to weighting and vertical black bars show the standard deviation (SD) of data type scores among individual expert panelists. Data type codes: HA = harvest, SU = survey, MP = modeled probability of occurrence, OB = observation, DE = demography, RS = reproductive status, and GE = genetic/genomic. Data deficient data types are not shown (See Tables 24, 25, and 27). The colors of each line of evidence box correspond to the "line of evidence rank," which shows the overall support a line of evidence provides for the spatial unit criterion (see legend). Ranks are calculated by weighting, then averaging associated data type scores.

3.4.3.2 Key knowledge gaps

The expert panel identified four key knowledge gaps that inhibited Round Whitefish spatial unit delineation in Lake Ontario (see also data poor and data deficient data types in Tables 24, 25, and 27 that highlight additional knowledge gaps):

1. Where do Round Whitefish currently spawn within Lake Ontario? A little is known about some general areas that Round Whitefish spawn in Lake Ontario, but there is no understanding about microhabitat selection for reproduction or the impact of habitat on survival during embryonic and larval life history stages.

2. Do any Round Whitefish move into Lake Ontario tributaries for spawning or foraging and if so, which tributaries?

3. Outside of the spawning season, where do Round Whitefish move in Lake Ontario, including inter- and intra-season movement patterns and changes in movement patterns and habitat use associated with ontogeny?

4. What was the historical Round Whitefish population structure in Lake Ontario?

4. STEWARDSHIP IMPLICATIONS OF SPATIAL UNIT OVERLAP

Locations where multiple Lake Ontario coregonine spatial units overlap may represent areas where stewardship activities can benefit multiple taxa. Overlaps between multiple occupied spatial units, multiple unoccupied spatial units, or both occupied and unoccupied spatial units correspond to opportunities for multi-taxon conservation, multi-taxon restoration, or both conservation and restoration, respectively. Delineation of spatial units for multiple taxa can be used to identify general areas of stewardship interest. Subsequently, additional data (e.g., high resolution bathymetric or substrate data) can be leveraged if available to further inform stewardship planning. There are several areas in Lake Ontario where multiple coregonine spatial units overlap. There is overlap between occupied Cisco and Lake Whitefish spatial units in the Bay of Quinte and Chaumont Bay (Figure 14). There is overlap between Bloater and Cisco and Cisco and Lake Whitefish unoccupied spatial units throughout large expanses of Lake Ontario. There are two areas where overlap between unoccupied Round Whitefish, Cisco, and Lake Whitefish spatial units occurs: (1) along the northern shore of Lake Ontario in the Brighton area and (2) in west Lake Ontario extending from northeast of the Toronto area extending southwest past Hamilton (Figure 15). There are several areas where both occupied and unoccupied spatial units overlap, such as along portions of the northern shoreline south of Oshawa and along a stretch of the southern shoreline of Lake Ontario beginning west of Irondequoit Bay and extending east to Little Sodus Bay (Figure 16).

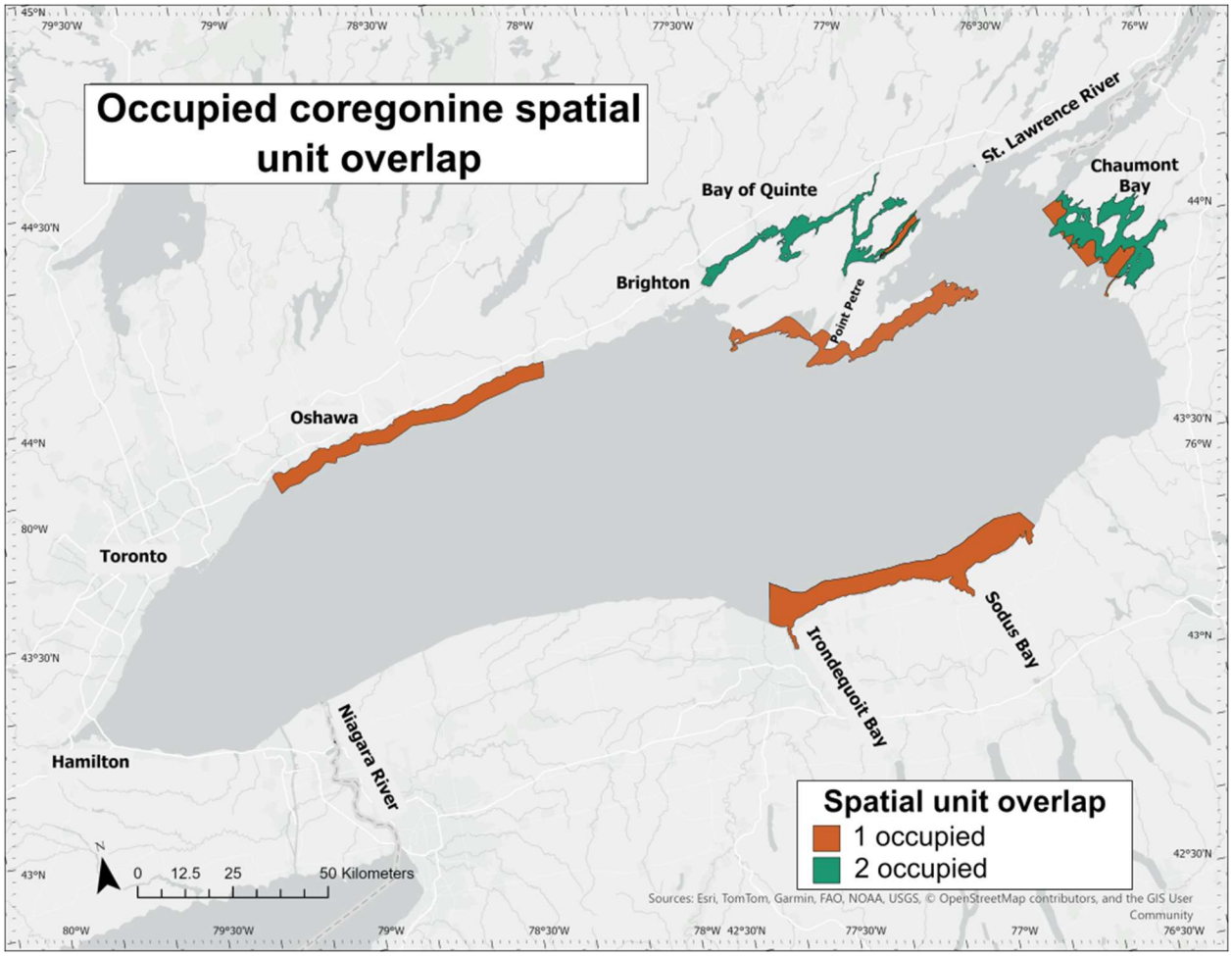


Figure 14. Map of Lake Ontario with colors demarcating overlap between occupied spatial units for Lake Whitefish *Coregonus clupeaformis*, Cisco *Coregonus artedi*, and Round Whitefish *Prosopium cylindraceum* (no occupied spatial unit was delineated for Bloater). Occupied spatial units represent reproductive habitat currently used by populations or subpopulations. Areas where multiple unoccupied spatial units overlap may provide opportunities to maximize the efficiency of restoration activities. Space not assigned to an occupied spatial unit is demarcated via dark gray shading (water) or light gray shading (islands). Space may not have been assigned to an unoccupied spatial unit because it did not historically contain coregonine reproductive habitat or there was no evidence of historical occupancy by coregonines regardless of reproductive habitat suitability. Overlap in occupied spatial units identifies general areas of historical importance to multiple coregonine species. Within these areas, additional species-specific differences in microhabitat use may be helpful to consider when planning stewardship activities.

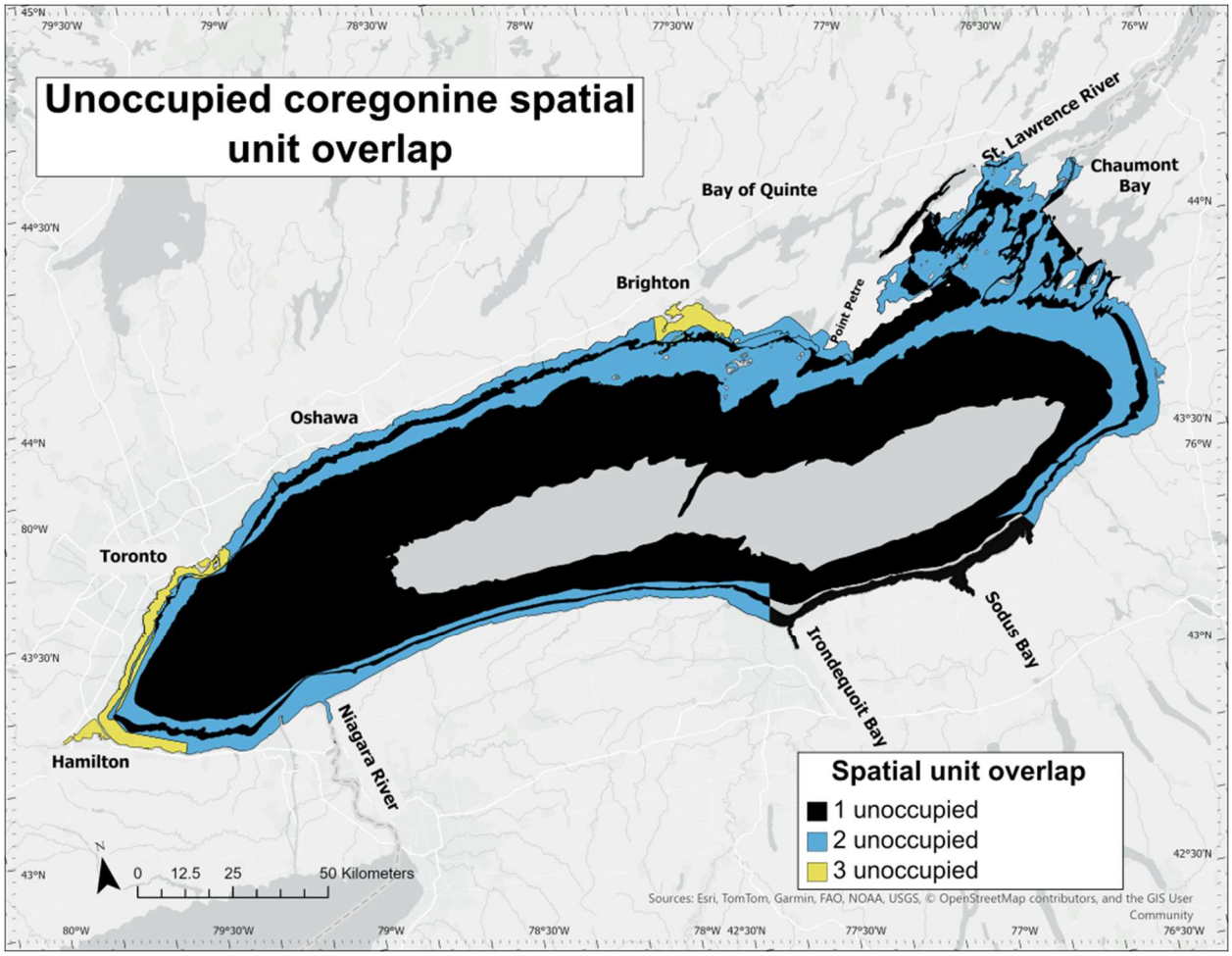


Figure 15. Map of Lake Ontario with colors (including black) demarcating overlap between unoccupied spatial units for Bloater *Coregonus hoyi*, Lake Whitefish *Coregonus clupeaformis*, Cisco *Coregonus artedi*, and Round Whitefish *Prosopium cylindraceum*. Unoccupied spatial units represent reproductive habitat that was historically used by populations or subpopulations of focal organisms. Areas where multiple unoccupied spatial units overlap may provide opportunities to maximize the efficiency of restoration activities. Space not assigned to a spatial unit is demarcated via dark gray shading (water) or light gray shading (islands). Space may not have been assigned to an unoccupied spatial unit because it did not historically contain coregonine reproductive habitat or there was no evidence of historical occupancy by coregonines regardless of reproductive habitat suitability. Overlap in unoccupied spatial units identifies general areas of historical importance to multiple coregonine species. Within these areas, additional species-specific differences in microhabitat use may be helpful to consider when planning stewardship activities.

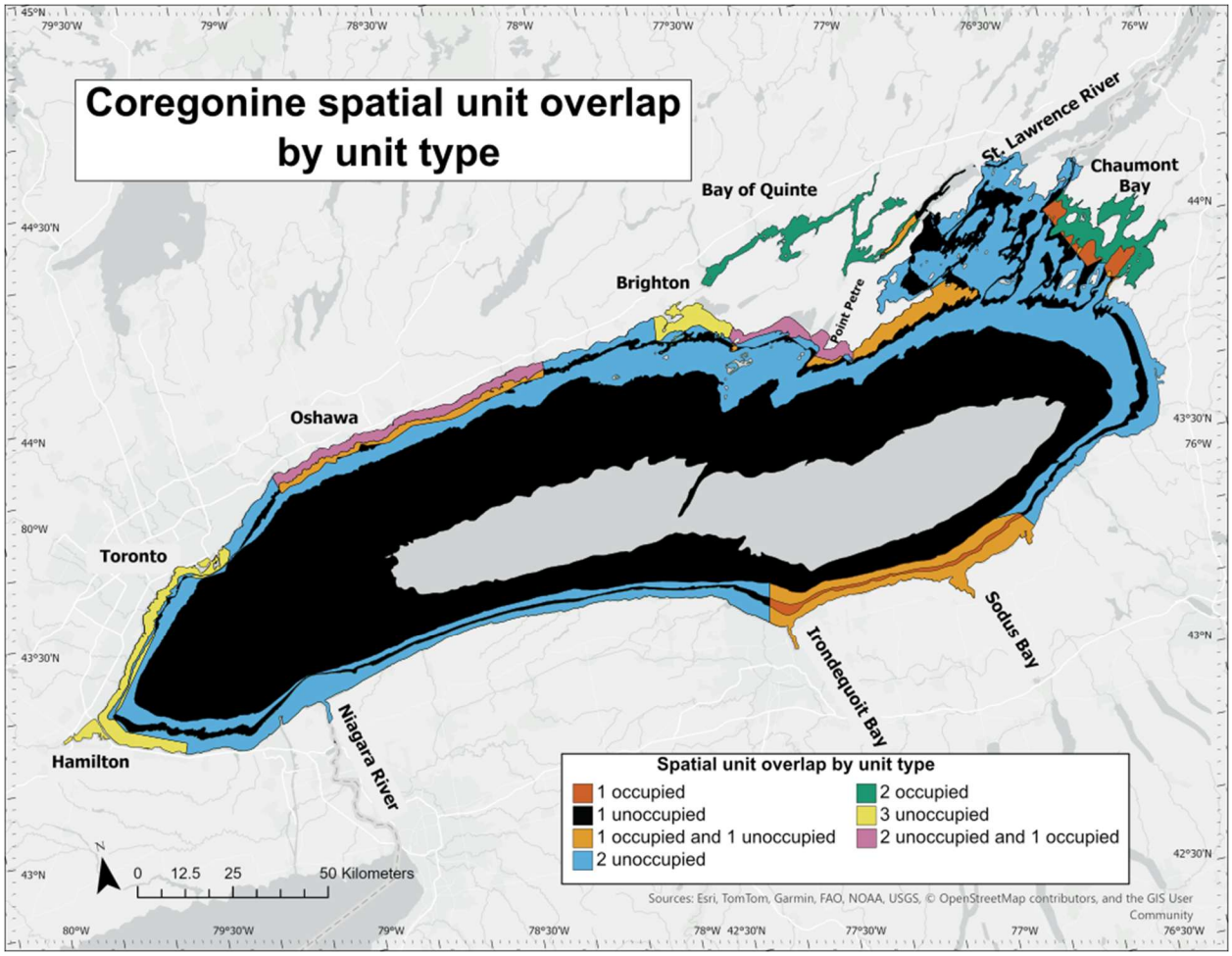


Figure 16. Map of Lake Ontario with colors (including black) demarcating overlap between spatial unit types (occupied and unoccupied) for Bloater *Coregonus hoyi*, Lake Whitefish *Coregonus clupeaformis*, Cisco *Coregonus artedi*, and Round Whitefish *Prosopium cylindraceum*. Spatial units represent reproductive habitat that was historically used (unoccupied spatial units) or is currently used (occupied spatial units) by populations or subpopulations. Areas where multiple spatial units overlap may provide opportunities to maximize the efficiency of restoration and conservation activities. Space not assigned to a spatial unit is demarcated via dark gray shading (water) or light gray shading (islands). Space may not have been assigned to a spatial unit because either it did not contain coregonine reproductive habitat (neither historically or contemporarily) or there was no evidence of historical or contemporary occupancy by coregonines regardless of reproductive habitat suitability. Overlap in spatial units identifies general areas of historical and/or contemporary importance to multiple coregonine species. Within these areas, additional species-specific differences in microhabitat use may be helpful to consider when planning stewardship activities.

5. REFERENCES

Ackiss, A. S., Grundel, R. Jonas, J. L., Jones, N. Krabbenhoft, N. T. Lauzon, R. Mandrak, N. E., O'Malley, B., Pearse, D., Pratt, T. C., Redford, B., Ridgway, M., Smith, J., & Muir, A. M. (2023). Delineating spatial units for coregonine conservation, restoration, and stewardship. https://www.greatlakesciscoes.org/restoration-framework/planning/

Anderson, P. & Coker, G. A. (1991). Royal Ontario Museum Specimen. [Fish]. Toronto: Royal Ontario Museum. Cat no. ROMI064634

Balesic, H. (1979c) Literature review of physical characteristics and fishes of the nearshore zone of Lake Ontario. Ontario Hydro Research Division Report No. 79-165-K.

Bean, T.H. (1903). Catalogue of the Fishes of New York. Bulletin 60, Zoology 9. Albany, NY.

Beech, S. (2023). Lake Whitefish and Cisco Commercial Catch Sampling. 4 p. Part 3.3. In Lake Ontario Fish Communities and Fisheries: 2022 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources, Picton, Ontario, Canada.

Beech, S. J., Elliott, C. W., Ridgway, M. S., Brown, E., & Tufts, B. L. (2024). Spatial comparison of two lake whitefish (*Coregonus clupeaformis*) spawning aggregations from the Bay of Quinte and eastern Lake Ontario. *Journal of Great Lakes Research*, 102443. https://doi.org/10.1016/j.jglr.2024.102443

Bernard, A. M., Ferguson, M. M., Noakes, D. L., Morrison, B. J., & Wilson, C. C. (2009). How different is different? Defining management and conservation units for a problematic exploited species. *Canadian Journal of Fisheries and Aquatic Sciences*, 66(9): 1617-1630. https://doi.org/10.1139/F09-106

Brant, C. O., Tyrrell, K. F., & Hannahs, K. A. (2024). Historical coregonine spawning, nursery, and general occurrence point locations in the Great Lakes of North America and their tributaries: U.S. Geological Survey data release, https://doi.org/10.5066/P13PPGAH.

Brown, T. A., Sethi, S. A., Rudstam, L. G., Holden, J. P., Connerton, M. J., Gorsky, D. Karboski, C. T., Chalupnicki, M. A., Sard, N. M., Roseman, E. F., & Prindle, S. E. (2022). Contemporary spatial extent and environmental drivers of larval coregonine distributions across Lake Ontario. *Journal of Great Lakes Research*, 48(2): 359-370. https://doi.org/10.1016/j.jglr.2021.07.009

Bunnell, D. B., Ackiss, A. S. Alofs, K. M. Brant, C. O. Bronte, C. R. Claramunt, R. M., Dettmers, J. M., Honsey, A. E., Mandrak, N. E., Muir, A. M., & Santucci Jr., V. J. (2023). A science and management partnership to restore coregonine diversity to the Laurentian Great Lakes. *Environmental Reviews*, *31*(4), 716-738. https://doi.org/10.1139/er-2022-0109

Carlson, D. M., Daniels, R., & Wright, J. (2016). Atlas of inland fishes of New York. New York State Education Department, Albany, New York. pp. 201-358.

Christie, W.J. (1967). Vital statistics of Lake Ontario whitefish. Glenora Fisheries Station. MS unpublished.

Christie, W.J. (1973). A review of the changes in the fish species composition of Lake Ontario (Technical Report No. 23). Great Lakes Fishery Commission. https://www.glfc.org/pubs/TechReports/Tr23.pdf

Department of Marine and Fisheries (1904). Thirty-sixth annual report of the Department of Marine and Fisheries 1903. Sessional Paper No. 22
https://waves-vagues.dfo-mpo.gc.ca/Library/4076445x_1903.pdf

Dymond, J. R., J. L. Hart, & Pritchard, A. L. (1929). The fishes of the Canadian waters of Lake Ontario. University of Toronto Press.

Elith, J., Phillips, S. J., Hastie, T., Dudík, M., Chee, Y. E., & Yates, C. J. (2011). A statistical explanation of MaxEnt for ecologists. *Diversity and Distributions*, *17*(1), 43-57. https://doi.org/10.1111/j.1472-4642.2010.00725.x

Eshenroder, R. L, Vecsei, P., Gorman, O. T., Yule, D. L., Pratt, T. C., Mandrak, N. E., Bunnell, D. B., & Muir, A. M. (2016). Ciscoes (Coregonus, subgenus Leucichthys) of the Laurentian Great Lakes and Lake Nipigon [online]. www.glfc.org/pubs/misc/Ciscoes_of_the_Laurentian_Great_Lakes_and_Lake_Nipigon.pdf.

Fry, F. E. (1937). The summer migration of the cisco, (*Leucichthys artedi*) (LeSueur), in Lake Nippissing, Ontario. Ontario Fisheries Research Laboratory. https://hdl.handle.net/20.500.14394/29028

Gatch, A., Gorsky, D., Biesinger, Z., Bruestle, E., Lee, K., Karboski, C., Bartron, M. L., & Wagner, T. (2021). Evidence of successful river spawning by lake trout (*Salvelinus namaycush*) in the Lower Niagara River, Lake Ontario. *Journal of Great Lakes Research*, 47(2): 486-493. https://doi.org/10.1016/j.jglr.2020.12.007

Gatch, A. J., Gorsky, D., Weidel, B. C., Biesinger, Z. F., Connerton, M. J., Davis, C., Lachance, H., & O'Malley, B. P. (2023). Seasonal habitat utilization provides evidence for site fidelity during both spawn and non-spawning seasons in Lake Ontario cisco Coregonus artedi. Journal of Great Lakes Research, 49(5): 1045-1058. https://doi.org/10.1016/j.jglr.2023.06.008

George, E. M., Stott, W., Young, B. P., Karboski, C. T., Crabtree, D. L., Roseman, E. F., & Rudstam, L. G. (2017). Confirmation of cisco spawning in Chaumont Bay, Lake Ontario using an egg pumping device. *Journal of Great Lakes Research*, 43(3): 204-208. https://doi.org/10.1016/j.jglr.2017.03.024

George, E.M., D.L. Crabtree, M.P. Hare, J.M. Lepak, and L. Rudstam (2018). Identifying research priorities for cisco in Lake Ontario: A workshop summary report. https://ecommons.cornell.edu/handle/1813/60807.

George, E. M. (2019). Cisco *Coregonus artedi* restoration in Lake Ontario: ecology, genetics, and science communication (Doctoral dissertation, Cornell University).

Great Lakes Fishery Commission (GLFC). 2022. Commercial fish production in the Great Lakes 1867–2020. [data set]. www.glfc.org/great-lakes-databases.php

Green, C. K. (1908). The increase of whitefish and lake trout in Lake Ontario. *Transactions of American Fisheries Society*, 37: 82-84.

Griffiths, R. W., Schloesser, D. W., Leach, J. H., & Kovalak, W. P. (1991). Distribution and dispersal of the zebra mussel (*Dreissena polymorpha*) in the Great Lakes region. *Canadian Journal of Fisheries and Aquatic Sciences*, 48: 1381-1388. https://doi.org/10.1139/f91-165

Goodyear, C. S., Edsall, T. A., Ormsby Dempsey, D. M., Moss, G. D., & Polanski, P. E. (1982). Atlas of the spawning and nursery areas of Great Lakes fishes. Volume 9: Lake Erie. U.S. Fish and Wildlife Service FWS/OBS-82/52 (9).

Harris, E. (1906). Our Great Lakes fisheries: A vanishing heritage. Toronto: William Briggs.

Hart, J. L. (1930). The spawning and early life history of the whitefish, *Coregonus clupeaformis* (Mitchill), in the Bay of Quinte, Ontario. *Contributions to Canadian Biology and Fisheries*, 6(1): 165-214. https://doi.org/10.1139/f31-007

Haymes, G. T., & Kolenosky, D. P. (1984). Distribution and characteristics of spawning Round Whitefish in Lake Ontario, 1976-1981. Ontario Fisheries Technical Report Series, 14.

Hemming, V., Burgman, M. A., Hanea, A. M., McBride, M. F., & Wintle, B. C. (2018). A practical guide to structured expert elicitation using the IDEA protocol. *Methods in Ecology and Evolution*, *9*(1): 169-180. https://doi.org/10.1111/2041-210X.12857

Hlina, B. L., Robinson, R. L., Bloomfield, E. J., Metcalfe, B. W., & Johnson, T. B. (2025). Monthly differences in the movement ecology of lake whitefish (*Coregonus clupeaformis*) in eastern Lake Ontario. *Journal of Fish Biology*. https://doi.org/10.1111/jfb.70269

Holmes, J. A., & Whillans, T. H. (1984). Historical review of Hamilton Harbour fisheries. Canadian Technical Report of Fisheries and Aquatic Sciences 1257. publications.gc.ca/pub?id=9.891781&sl=0

Howell, D. (1970). Royal Ontario Museum Specimen. [Fish]. Toronto: Royal Ontario Museum. Cat no. ROM27624

Hoyle, J. A., Johannsson, O. E., & Bowen, K. L. (2011). Larval Lake Whitefish abundance, diet and growth and their zooplankton prey abundance during a period of ecosystem change on the Bay of Quinte, Lake Ontario. *Aquatic Ecosystem Health & Management*, 14(1): 66-74. https://doi.org/10.1080/14634988.2011.548730

Hoyle, J. A. (2015). Fish species composition, distribution and abundance trends in the open-coastal waters of northeastern Lake Ontario, 1992–2012. *Aquatic Ecosystem Health & Management*, 18(1): 89-100. https://doi.org/10.1080/14634988.2014.936804

Karatayev, A. Y., Burlakova, L. E., Mehler, K., Elgin, A. K., Rudstam, L. G., Watkins, J. M., & Wick, M. (2022). Dreissena in Lake Ontario 30 years post-invasion. *Journal of Great Lakes Research*, 48(2): 264-273. https://doi.org/10.1016/j.jglr.2020.11.010

Kerr, J. W., and F. W. Kerr. (1860-1898). Handwritten diary as fisheries investigators, 1860-1898. R. Ont. Mus., 18 vol., (transcribed notes by Christine Regier 1975-76).

Koelz, W. (1926). Fishing industry of the Great Lakes. US Government Printing Office 1001.

Koelz, W. (1929). Coregonid fishes of the Great Lakes. Bulletin of the Bureau of Fisheries, Part 2. Washington, Government Printing Office: 1048(XLIII). Available at: https://pubs.usgs.gov/publication/1000241

McKenna Jr, J.E. and Johnson, J.H., 2009. Spatial and temporal variation in distribution of larval lake whitefish in eastern Lake Ontario: signs of recovery?. Journal of Great Lakes Research, 35(1), pp.94-100. https://doi.org/10.1016/j.jglr.2008.10.004

Mills, E. L., Dermott, R. M., Roseman, E. F., Dustin, D., Mellina, E., Corm, D. B., & Spidle, A. P. (1993). Colonization, ecology, and population structure of the ‘‘quagga” mussel (Bivalvia: Dreissenidae) in the lower Great Lakes. *Canadian Journal of Fisheries and Aquatic Sciences*, 50: 2305-2314. https://doi.org/10.1139/f93-255

Mills, E. L., Casselman, J. M., Dermott, R., Fitzsimons, J. D., Gal, G., Holeck, K. T., Hoyle, J. A., Johannsson, O. E., Lantry, B. F., Makarewicz, J. C., Millard, E. S., Munawar, I. F., Munawar, M., O’Gorman, R., Owens, R. W., Rudstam, L. G., Schaner, T., & Stewart, T. J. (2005). A synthesis of ecological and fish community changes in Lake Ontario, 1970-

2000. Great Lakes Fishery Commission Technical Report 67. https://repository.library.noaa.gov/view/noaa/42592/noaa_42592_DS1.pdf

Morgan, T. D., Graham, C. F., McArthur, A. G., Raphenya, A. R., Boreham, D. R., Manzon, R. G., Wilson, J. Y., Lance, S. L., Howland, K. L., Patrick, D. H., & Somers, C. M. (2018). Genetic population structure of the round whitefish (*Prosopium cylindraceum*) in North America: multiple markers reveal glacial refugia and regional subdivision. *Canadian Journal of Fisheries and Aquatic Sciences*, 75(6): 836-849. https://doi.org/10.1139/cjfas-2016-0528

O'Gorman, R., Elrod, J. H., & Hartman, W. L. (1989). Survey of the fish stocks in U.S. waters of Lake Ontario during IFYGL, 1972, in: Thomas, N.A., Christie, W.J., Gannon, S.A. (Eds.), Status of the IFYGL Biota of Lake Ontario during International Field Year for the Great Lakes.

O'Malley, B. P., Minihkeim, S. P., Sanfilippo, T. A., Goretzke, J. A., & Holden, J. P. (2022). Bottom trawl assessment of Lake Ontario's benthic preyfish community, 2021. https://www.glfc.org/pubs/lake_committees/common_docs/REPORT_2021_FallPreyfishSurvey_20220524_approved.pdf

O'Malley, B. P., Minihkeim, S. P., Mitchinson, O. M. Stahl, S. D., Goretzke, J. A., & Holden, J. P. (2024). Bottom trawl assessment of Lake Ontario's benthic preyfish community, 2023. https://glfc.org/pubs/lake_committees/common_docs/OMalley_etal_2024_LObenthicpreyfish.pdf

O'Malley, B. P., Minihkeim, S. P., Mitchinson, O. M., Stahl, S. D., Weidel, B. C., Connerton, M. J., Goretzke, J. A., Sunderland, L., Bloomfield, E. J., Farrell, C. J. & Gorsky, D. (2024b) Lake Ontario August gillnet survey and Lake Trout assessment, 2024. Great Lakes Fishery Commission. Available at: https://www.glfc.org/pubs/lake_committees/common_docs/OMalley_et_al_2024_laketroutreport.pdf

Ontario Game and Fisheries Department. (1911). Fourth Annual Report (1910). https://www.biodiversitylibrary.org/item/61397

Ontario Game and Fisheries Department. (1915). Eighth Annual Report (1914). https://www.biodiversitylibrary.org/item/69014

Ontario Game and Fisheries Department. (1916). Ninth Annual Report (1915). https://www.biodiversitylibrary.org/item/69014

Ontario Game and Fisheries Department. (1943). Thirty-fifth Annual Report (1941-1942). https://www.biodiversitylibrary.org/item/61473

Ontario Ministry of Natural Resources (OMNR). (1994). Lake Ontario Fish Communities and Fisheries: 1993 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/

Ontario Ministry of Natural Resources (OMNR). (1995). Lake Ontario Fish Communities and Fisheries: 1994 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/

Ontario Ministry of Natural Resources (OMNR). (1996). Lake Ontario Fish Communities and Fisheries: 1995 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/

Ontario Ministry of Natural Resources (OMNR). (1997). Lake Ontario Fish Communities and Fisheries: 1996 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/
Ontario Ministry of Natural Resources (OMNR). (1998). Lake Ontario Fish Communities and Fisheries: 1997 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/
Ontario Ministry of Natural Resources (OMNR). (1999). Lake Ontario Fish Communities and Fisheries: 1998 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/
Ontario Ministry of Natural Resources (OMNR). (2001). Lake Ontario Fish Communities and Fisheries: 2000 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/
Ontario Ministry of Natural Resources (OMNR). (2002). Lake Ontario Fish Communities and Fisheries: 2001 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/
Ontario Ministry of Natural Resources (OMNR). (2003). Lake Ontario Fish Communities and Fisheries: 2002 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/
Ontario Ministry of Natural Resources (OMNR). (2004). Lake Ontario Fish Communities and Fisheries: 2003 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/
Ontario Ministry of Natural Resources (OMNR). (2005). Lake Ontario Fish Communities and Fisheries: 2004 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/
Ontario Ministry of Natural Resources (OMNR). (2006). Lake Ontario Fish Communities and Fisheries: 2005 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/
Ontario Ministry of Natural Resources (OMNR). (2007). Lake Ontario Fish Communities and Fisheries: 2006 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/
Ontario Ministry of Natural Resources (OMNR). (2008). Lake Ontario Fish Communities and Fisheries: 2007 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/
Ontario Ministry of Natural Resources (OMNR). (2009). Lake Ontario Fish Communities and Fisheries: 2008 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/
Ontario Ministry of Natural Resources (OMNR). (2010). Lake Ontario Fish Communities and Fisheries: 2009 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/
Ontario Ministry of Natural Resources (OMNR). (2011). Lake Ontario Fish Communities and Fisheries: 2010 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/

Ontario Ministry of Natural Resources (OMNR). (2012). Lake Ontario Fish Communities and Fisheries: 2011 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/

Ontario Ministry of Natural Resources (OMNR). (2013). Lake Ontario Fish Communities and Fisheries: 2012 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/

Ontario Ministry of Natural Resources (OMNR). (2014). Lake Ontario Fish Communities and Fisheries: 2013 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/

Ontario Ministry of Natural Resources and Forestry (OMNRF). (2015). Lake Ontario Fish Communities and Fisheries: 2014 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources and Forestry, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/

Ontario Ministry of Natural Resources and Forestry (OMNRF). (2016). Lake Ontario Fish Communities and Fisheries: 2015 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources and Forestry, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/

Ontario Ministry of Natural Resources and Forestry (OMNRF). (2017). Lake Ontario Fish Communities and Fisheries: 2016 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources and Forestry, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/

Ontario Ministry of Natural Resources and Forestry (OMNRF). (2018). Lake Ontario Fish Communities and Fisheries: 2017 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources and Forestry, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/

Ontario Ministry of Natural Resources and Forestry (OMNRF). (2019). Lake Ontario Fish Communities and Fisheries: 2018 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources and Forestry, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/

Ontario Ministry of Natural Resources (OMNR). (2020). Lake Ontario Fish Communities and Fisheries: 2019 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources and Forestry, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/

Ontario Ministry of Natural Resources (OMNR). (2021). Lake Ontario Fish Communities and Fisheries: 2020 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources and Forestry, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/

Ontario Ministry of Natural Resources (OMNR). (2022). Lake Ontario Fish Communities and Fisheries: 2021 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources and Forestry, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/

Ontario Ministry of Natural Resources (OMNR). (2023). Lake Ontario Fish Communities and Fisheries: 2022 Annual Report of the Lake Ontario Management Unit. Ontario Ministry

of Natural Resources and Forestry, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/

Ontario Ministry of Natural Resources (OMNR). (2024). Lake Ontario Fish Communities and Fisheries: 2023 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources and Forestry, Picton, Ontario, Canada. https://www.glfc.org/loc_mgmt_unit/

Owens, R.W., & Dittman, D. E. (2003). Shifts in the diets of slimy sculpin (Cottus cognatus) and lake whitefish (*Coregonus clupeaformis*) in Lake Ontario following the collapse of the burrowing amphipod *Diporeia*. *Aquatic Ecosystem Health & Management*, 6(3): 311-323. https://doi.org/10.1080/14634980301487

Owens, R. W., O'Gorman, R., Eckert, T. H., Lantry, B. F., & Munawar, M. (2003). The offshore fish community in southern Lake Ontario. State of Lake Ontario: Past, present, and future. Edited by M. Munawar. Ecovision World Monograph Series. Aquatic Ecosystem Health and Management Society, Burlington, Ontario, Canada. https://doi.org/10.14321/j.ctt1mtz6pt

Paufve, M. R., Sethi, S. A., Weidel, B. C., Lantry, B. F., Yule, D. L., Rudstam, L. G., Jonas, J. L., Berglund, E., Connerton, M. J., Gorsky, D., & Herbert, M. E. (2022). Diversity in spawning habitat use among Great Lakes Cisco populations. *Ecology of Freshwater Fish*, 31(2): 379-388. https://doi.org/10.1111/eff.12637

Patrick, P. H., Di Giuseppe, M., Manolopoulos, H., Tai, M.-K., Poulton, S., & Wright, J. (2020). Entrainment of fish eggs and larvae at an operating nuclear generating station using improved methodology. *Lake and Reservoir Management*, 37: 186-198. https://doi.org/10.1080/10402381.2020.1843207

Pritchard, A. L. (1928). A preliminary study of the genus *Leucichthys* in the Canadian waters of Lake Ontario (Publications of the Ontario Fisheries Research Laboratory No. 32). University of Toronto Studies, Toronto, Ontario, Canada.

Pritchard, A. L. (1931). Taxonomic and Life History Studies of the Ciscoes of Lake Ontario, 78 Toronto, ON: The University of Toronto Press. https://books.google.com/books/about/Taxonomic_and_Life_History_Studies_of_th.html?id=s76f7aIKml8C

Pritchard, A. L. (1931b). Spawning habits and fry of the cisco (*Leucichthys artedi*) in Lake Ontario. *Contributions to Canadian Biology and Fisheries,* 6: 225–240.

Rathbun, R., & Wakeham, W., & Joint Fisheries Commission. (1897). Report of the joint commission relative to the preservation of the fisheries in waters contiguous to Canada and the United States. https://www.biodiversitylibrary.org/page/36990930#page/6/mode/1up

Salvesen, K. E. (2015). *Lake trout restoration in the Great Lakes: from hatchery to natural reproduction* [Master's thesis, The Pennsylvania State University]. https://etda.libraries.psu.edu/catalog/24889

Smith, H. M. (1892). Report on an investigation of the fisheries of Lake Ontario. Bull. U.S. Fish Comm. 10:177-215.

Smith, H. M. (1894). Notes on two hitherto unrecognized species of American whitefishes. US Government Printing Office.

Smith, H. M., M-M. Snell, & Collins, J.W. (1891). Review of the fisheries of the Great Lakes in 1885. U.S. Government Printing Office: 328 p.

State of New York (1925). Conservation Commission Fourteenth Annual Report for the Year 1924. Legislative Document (1925), No. 29. Albany: J.B. Lyon Company, Printers

Stone, U. B. (1938). Growth, Habits, and Fecundity of the Ciscoes of Irondequoit Bay, New York. *Transactions of the American Fisheries Society,* 67: 234-245.

Stone, U. B. (1947). A study of the deep-water cisco fishery of Lake Ontario with particular reference to the bloater *Leucichthys hoyi* (Gill). *Transactions of the American Fisheries Society*, 74(1): 230-249. https://doi.org/10.1577/1548-8659(1944)74[230:ASOTDC]2.0.CO;2

Stott, W., Yule, D., Davis, C., Donner, K., Ebener, M., Lenart, S., & Olds, C. (2022). Genetic population structure of cisco*, Coregonus artedi*, in the Laurentian Great Lakes. *Journal of Great Lakes Research*, 48(6): 1696-1709.

U.S. Geological Survey, Great Lakes Science Center. (2022). Great Lakes Research Vessel Catch (RVCAT) Database: U.S. Geological Survey data release, https://doi.org/10.5066/P9XVOLR1.

Weidel, B. C., Hoyle, J. A., Connerton, M. J., Holden, J. P., & Vinson, M. R. (2021). Lake Ontario cisco population dynamics based on long-term surveys. *Advances in Limnology,* 66: 85-103. https://doi.org/10.1127/adv_limnol/2021/0070

Weidel, B. C., Ackiss, A. S. Chalupnicki, M. A., Connerton, M. J., Davis, S., Dettmers, J. M., Drew, T., Fisk, A. T., Gordon, R., Hanson, S. D., & Holden, J. P. (2022). Results of the collaborative Lake Ontario bloater restoration stocking and assessment, 2012–2020. *Journal of Great Lakes Research*, 48(2): 371-380. https://doi.org/10.1016/j.jglr.2021.11.014

Weidel, B. C., Gutowsky, L., Goretzke, J., Holden, J. P., & Minihkeim, S. (2022b). Lake Ontario April prey fish survey results and Alewife assessment, 2022. https://glfc.org/pubs/lake_committees/ontario/Weideletal_AprilPreyFishSurveyAlewifeAssess2022.pdf

Weidel, B. C., Goretzke, J., Holden, J. P., Mitchinson, O., & Minihkeim, S. (2023). Lake Ontario April prey fish survey results and Alewife assessment, 2023. https://glfc.org/pubs/lake_committees/ontario/WeidelEtal_2023LkOntario_AprilPreyfishAlewifeReport.pdf

Wells, L. (1969). Fishery survey of US waters of Lake Ontario. Great Lakes Fishery Commission Technical Report, 14: 51-57. https://pubs.usgs.gov/publication/2000045

Whillans, T. H. (1977). Fish community transformation in three bays within the lower Great Lakes. M.S. Thesis, University of Toronto.

Wood, J., Hoyle, J. A., & Wilson, C. (2016). Genetic analysis of round whitefish (*Prosopium cylindraceum*) stock structure in Lake Ontario. Ministry of Natural Resources and Forestry, Science and Research Branch, Peterborough, Ontario. Science and Research Technical Report TR–11 10 p. https://www.publicdocs.mnr.gov.on.ca/srb/Pubs/TR-11.pdf

Appendix 1: Spatial unit delineation steps

Pre-workshop steps

(1) *Initial preparations:* Facilitators synthesized data for the Lake Ontario species from peer-reviewed articles, gray literature (e.g., agency reports), online databases (e.g., GLFC 2022 and Brant et al. 2024), and museum records. Data pertaining to the species outside of Lake Ontario and data from other Lake Ontario fishes (i.e., proxy data) were not used for this assessment following the recommendation of the team responsible for spatial unit delineation method development. Facilitators generated a data synthesis that concisely summarized key information. Then, facilitators assembled an expert panel with a wide range of expertise related to the Lake Ontario focal species and the data types evaluated during this assessment. The experts reviewed the data synthesis and added relevant references, unpublished data, and personal observations that were missing.

(2) *Formulate a priori spatial unit hypotheses:* Meetings were held during which expert panels formulated *a priori* spatial unit hypotheses for each Lake Ontario species to formally test during subsequent spatial unit delineation workshops based on the data syntheses and their expert knowledge. This step, and the following steps, may be repeated in an iterative manner, if necessary, which was the case for this assessment.

(3) *Revise data synthesis:* Facilitators restructured the data syntheses to conform to the knowledge hierarchy for the relevant spatial units and aid interpretation of data in the context of the *a priori* hypotheses.

Spatial unit delineation workshop (IDEA Protocol)

(4) *Investigate:* Experts reviewed the revised data synthesis, then made any necessary adjustments to the *a priori* spatial unit hypotheses. Then, for each hypothesis, experts independently and anonymously assigned scores to data types based on the amount of support they thought data provided for the line of evidence under consideration (data deficient = no score, no support = 0, low support = 1, moderate support = 2, and high support = 3).

(5) *Discuss:* After the initial round of scoring, experts discussed their scores, including points of consensus and conflict.

(6) *Estimate*: A final round of independent scoring was conducted in which experts could retain their original scores or change them based on the discussion. For all three spatial unit hypotheses assessed, steps 5-7 were repeated for every data type associated with each line of evidence for all criteria (Tables 1-4).

(7) *Aggregate*: Facilitators aggregated individual scores using the methods described in section 2.3 to determine the level of support the expert panel collectively thought data types provided for lines of evidence (i.e., weighted average data type scores) and lines of evidence provided for criteria (i.e., line of evidence ranks).

Appendix 2: Personal communications

Appendix 2 Table 1. Descriptions of personal communications. USGS = U.S. Geological Survey; OMNR = Ontario Ministry of Natural Resources; MDNR = Michigan State University; MSU = Michigan State University;

Reference	Description
A. Ackiss, USGS, personal communication, 2024a	Genetic data presented at workshop on small sample size of contemporary Bloater; three Bloater were captured and sequenced in 2023 and all had Lake Michigan genotypes. A Cisco/Bloater hybrid was also identified in October 2023 samples
A. Ackiss, USGS, personal communication, 2024b	RADseq genetic data shared via email and presented during the workshop comparing genetics between Bay of Quinte Cisco and Chaumont Bay Cisco.
S. Beech, OMNR, personal communication, 2024a	Shared expert opinion during the workshop on the lack of harvest data during Lake Whitefish reproduction using knowledge about commercial harvesting in Ontario waters.
S. Beech, OMNR, personal communication, 2024b	Acoustic telemetry figures and description shared via email showing evidence of two Lake Whitefish moving up into the Trent River – one for three years (2019, 2020, 2021) and one for one year (2020).
S. Beech, OMNR, personal communication, 2024c	Reproductive status data shared via email including gonadosomatic and visceral fat indices for Lake Whitefish in the Bay of Quinte versus the southern shore of Prince Edward County.
S. Beech, OMNR, personal communication, 2024d	Telemetry data shared via email and presented at the workshop including two Cisco that were tagged and observed from the Bay of Quinte in and outside of spawning season during 2018-2019.
S. Beech, OMNR, personal communication, 2024e	Reproductive status gonadosomatic index information shared via email for Cisco collected from the Bay of Quinte between 2022-2023.
S. Beech, OMNR, personal communication, 2025a	Commercial harvest records caught in zone 1-1 of Ontario waters shared via email, including catches between 1993-2024.
S. Beech, OMNR, personal communication, 2025b	Survey data from OMNR's fall Lake Trout gillnetting surveys shared via email, including Round Whitefish collections between 1985-1995 in September.
S. Beech, OMNR, personal communication, 2025c	Survey data from the Lake Ontario Management Unit's long term community index gillnetting program shared via email. Data includes Round Whitefish collections between 1972-1999 and fixed sampling sites that have had zero Round Whitefish catches during historical and contemporary periods.
J. Holden, OMNR, personal communication, 2024	Shared expert opinion during the workshop on the lack of harvest data during Lake Whitefish reproduction. Using knowledge about commercial harvesting in Ontario waters, expressed that a lack of harvest data in Chaumont Bay may indicate a different spawning time than the other units.
J. Homola, MSU, personal communication, 2024	RAD capture genetic data shared via email, including samples of Lake Whitefish from Chaumont Bay and the Bay of Quinte.
T. Johnson, OMNR, personal communication, 2024	Shared expert opinion during the workshop on the lack of harvest data during Lake Whitefish reproduction. Using knowledge about commercial harvesting in Ontario waters, expressed that a lack of harvest data in Chaumont Bay may indicate a different spawning time than the other units.

K. King, MDNR, personal communication, 2024a	Contemporary and historical Lake Ontario Bloater spawning habitat suitability model presented by Katelyn King from MDNR
K. King, MDNR, personal communication, 2024b	Contemporary and historical Lake Ontario Lake Whitefish spawning habitat suitability model presented by Katelyn King from MDNR
K. King, MDNR, personal communication, 2024c	Contemporary and historical Lake Ontario Cisco spawning habitat suitability model presented by Katelyn King from MDNR
K. King, MDNR, personal communication, 2025d	Contemporary and historical Lake Ontario Round Whitefish spawning habitat suitability model presented by Katelyn King from MDNR
B. O'Malley, USGS, personal communication, 2024a	Gillnet survey data on Lake Ontario embayments (around Chaumont Bay and southern shore bays) from 2018-2022 during the months of October through December shared via email.
B. O'Malley, USGS, personal communication, 2024b	Phenotypic data figures shared via email including Lake Whitefish gill raker counts from Chaumont Bay, the Bay of Quinte, and the southern shore of Prince Edward County between October and November of 2018-2019.
B. O'Malley, USGS, personal communication, 2024c	Reproductive status gonadosomatic index information shared via email for Cisco from collected from Chaumont Bay in 2023.
B. O'Malley, USGS, personal communication, 2024d	Phenotypic data shared via email and presented at the workshop including Cisco gill raker counts from Chaumont Bay, the Bay of Quinte, and the Galloo Islands.
B. Weidel, USGS, personal communication, 2024	Bottom trawl survey data (9,500 trawls) across Lake Ontario between 2000-2024 shared via email; 1,954 trawls occurred from October through December

Appendix 3: Definitions

Appendix 3 Table 1. Unoccupied unit criteria and line of evidence definitions.

Historically viable population: historical (i.e., prior to European colonization) presence of a naturally reproducing (sub)population over an extended period of time.	
Line of evidence	**Definition**
Non-ephemeral historical presence	Persistent historical presence of the focal organisms.
Reproduction	Historical occurrence of natural reproduction indicative of a reproductively viable population or population segment of the focal organisms.
Genetic / genomic	Genetic or other "omic" data derived from the underlying genetic architecture that support the historical occurrence of the focal organisms.
Lack of contemporary occupancy criterion: Focal organisms are entirely absent from the focal area or only ephemerally present.	
Line of evidence	**Definition**
Absence of target organisms	Lack of persistent contemporary presence of focal organisms.
Genetic / genomic	Genetic or other "omic" data derived from the underlying genetic architecture that support the contemporary absence of the focal organisms.
Historical reproductive isolation criterion: historical (i.e., prior to European colonization) reproductive isolation between hypothesized spatial units. Reproductive isolation need not to have been absolute.	
Line of evidence	**Definition**
Limited movement and/or migration	Limited movement of focal organisms between hypothesized spatial units during the reproductive period and/or migrations to disparate localities for reproduction.
Reproductive differences	Differences between hypothesized spatial units in reproductive time, habitat, behavior, or morphology of reproductive organs that lead to assortative or non-random mating.
Genetic / genomic divergence	Genetic or other "omic" data derived from the underlying genetic architecture indicative of historical reproductive isolation among hypothesized spatial units.

Appendix 3 Table 2. Occupied unit criteria and line of evidence definitions.

Reproductive isolation: contemporary (i.e., after European colonization) reproductive isolation between hypothesized spatial units. Reproductive isolation need not be absolute.	
Line of evidence	**Definition**
Limited movement / migration	Lack of movement between discrete spawning aggregations or distinct migrations of groups of organisms to different areas for reproduction.
Reproductive differences	Differences in reproductive timing, behavior, habitat, etc. indicative of assortative mating.
Genetic / genomic divergence	Genetic or other "omic" divergence between two groups of organisms indicating reproductive isolation.
High efficacy of barriers	Barriers arising from geology hydrology, or anthropogenic barriers that reduce or eliminate gene flow leading to detectable genetic/genomic differences.

Distinct component of evolutionary legacy criterion: group of organisms representing distinct and important evolutionary history, which may be manifested via unique life history traits or local adaptation.	
Line of evidence	**Definition**
Life history variation	Divergence in life history traits reflective of distinct evolutionary histories.
Local adaptation / adaptive diversity	Adaptation to local environmental conditions.

Contemporary occupancy criterion (for data deficient cases only): contemporary presence of a naturally reproducing (sub)population over an extended period of time.	
Line of evidence	**Definition**
Non-ephemeral presence	Persistent contemporary presence of the focal organisms.
Reproduction	Contemporary occurrence of natural reproduction indicative of a reproductively viable population or population segment of the focal organisms.
Genetic / genomic	Genetic or other "omic" data derived from the underlying genetic architecture that support the contemporary occurrence of the focal organisms.

Appendix 3 Table 4. Data type definitions.

Term	Definition
Harvest	Data derived from recreational or commercial fisheries, such as catch quantity data.
Survey	Fisheries independent data collected using approaches that attempt to address biases that may result from methodology, temporal, or spatial factors.
Modeled probability of occurrence	Models of the probability of the historical non-ephemeral occurrence of focal organisms.
Demography	Demographic data, including births, deaths, age structure, growth, etc.
Reproductive status	Data describing the reproductive status of individuals, such as fecundity data, gonadosomatic indices, state of maturity, and maturity schedules.
Observation	Local knowledge (e.g., interviews of fishers) or other qualitative or quantitative data that are not harvest-associated and do not meet requirements of a formal survey.
Genetic / genomic	Genetic or 'omic' data, which encompasses a broad subset of data types including genomic, transcriptomic, proteomic, lipidomic, and metabolomic, that describe or derive from the underlying genomic architecture of a species.
Telemetry	Information about the movement/occurrence of focal organisms gained via telecommunication.
Conventional marking	Information about the movement/occurrence of focal organisms gained by marking individuals (e.g., fin clip, elastomer tag), typically via mark-recapture approaches.
Microchemistry	Data characterizing the chemical signatures in tissues that can provide information about occurrence, movement and barriers to movement, and resource use.
Resource partitioning	Information about organismal resource use that describes variation in fundamental niches (i.e., heritable phenotypic variation), rather than in realized niches, and may represent local adaptation. Data could include trophic ecology, diet, feeding; stable isotopes; fatty acids, contaminants.

Appendix 4: Spawning and possible spawning occurrence data

Appendix 4 Table 1. Bloater “spawning” and “possible spawning” (possible) observations from CORHIST (Brant et al. 2024). CORHIST data classifications are different than spatial unit delineation data types. CORHIST possible spawning data do not meet to the requirements to be considered reproductive status data under the spatial unit delineation data type scheme. Observations represent distinct events that may involve examination of multiple fish. Shown for each observation is the date the observation was made (Year, Month/season, Day), latitude (Lat.) and longitude (Long.) in decimal degrees, the time period (Period) assignment (historical or contemporary), classification as either spawning or possible spawning occurrence (Classification), and the original source, which may be a publication or natural history museum catalog number(s) (Citation). “Spawning” observations (n = 1) are direct observations of spawning, mature individuals, or spawning grounds and “possible spawning” observations (n = 9) are observations suggestive of spawning (e.g., aggregations of fish during the spawning season) but not direct observations of spawning/mature fish. Natural history museum codes: ROM = Royal Ontario Museum and UMMZ = University of Michigan Museum of Zoology. “-” indicates no information available.

Year	Month/season	Day	Lat.	Long.	Period	Classification	Citation
1860	Late Fall	NA	43.333	-79.615	Historical	Spawning	Koelz (1926)
1917	Nov	23	43.286	-79.632	Historical	Possible spawning	Koelz (1929)
1926	March	28	43.516	-79.434	Historical	Possible spawning	UMMZ 59603
1983	April	28	43.347	-77.373	Historical	Possible spawning	UMMZ 212360
1926	Feb	12	43.5	-79.453	Historical	Possible spawning	ROM I002312
1925	November	10	43.434	-79.632	Historical	Possible spawning	ROM I001802, ROM I001804, ROM I001805, ROM I001807 - ROM I001811
1925	November	3	43.261	-79.596	Historical	Possible spawning	ROMI001795
1926	March	28	43.512	-79.443	Historical	Possible spawning	ROM I002407, ROM I002411, ROM I002425, ROM I002428, ROM I002431 - ROM I002443
1875	NA	NA	43.514	-76.583	Historical	Possible spawning	Koelz (1926)
1890	NA	NA	43.396	-78.868	Historical	Possible spawning	Koelz (1926)

Appendix 4 Table 2. Lake Whitefish "spawning" and "possible spawning" (possible) observations from CORHIST (Brant et al. 2024). Observations represent distinct events that may involve examination of multiple fish. Shown for each observation is the date the observation was made (Year, Month, Day), latitude (Lat.) and longitude (Long.) in decimal degrees, the time period (Period) assignment (historical or contemporary), classification as either spawning or possible spawning occurrence (Classification), and the original source (Citation). "Spawning" observations (n = 43) are direct observations of spawning, mature individuals, or spawning grounds and "possible spawning" observations (n = 58) are observations suggestive of spawning (e.g., aggregations of fish during the spawning season) but not direct observations of spawning/mature fish.

Year	Month	Day	Lat.	Long.	Period	Classification	Citation
1927	November	-	44.137	-77.243	Historical	Spawning	Hart (1930)
1880	November	-	44.03	-76.501	Historical	Spawning	Goodyear et al. (1982)
-	November	-	43.381	-78.16	Historical	Spawning	Goodyear et al. (1982)
1900	November	-	44.133	-77.256	Historical	Spawning	Goodyear et al. (1982)
1900	November	-	44.136	-77.242	Historical	Spawning	Goodyear et al. (1982)
1977	November	-	43.867	-78.701	Historical	Spawning	Goodyear et al. (1982)
1927	November	-	44.131	-77.256	Historical	Spawning	Pritchard (1931b)
-	-	-	43.62	-79.402	Historical	Spawning	Goodyear et al. (1982)
1880	November	-	43.281	-76.955	Historical	Spawning	Goodyear et al. (1982)
1900	November	-	43.528	-76.361	Historical	Spawning	Goodyear et al. (1982)
1880	November	-	43.86	-76.38	Historical	Spawning	Goodyear et al. (1982)
1880	November	-	43.93	-76.406	Historical	Spawning	Goodyear et al. (1982)
1880	November	-	43.951	-76.15	Historical	Spawning	Goodyear et al. (1982)
1880	November	-	44.068	-76.217	Historical	Spawning	Goodyear et al. (1982)
1880	November	-	44.053	-76.162	Historical	Spawning	Goodyear et al. (1982)
1860	November	-	43.277	-79.879	Historical	Spawning	Goodyear et al. (1982)
1907	November	-	43.308	-79.788	Historical	Spawning	Goodyear et al. (1982)
1865	November	-	43.766	-79.135	Historical	Spawning	Goodyear et al. (1982)
1975	-	-	43.867	-78.8	Historical	Spawning	Goodyear et al. (1982)
-	November	-	43.901	-78.449	Historical	Spawning	Goodyear et al. (1982)
-	November	-	43.969	-77.978	Historical	Spawning	Goodyear et al. (1982)
-	November	-	43.897	-78.466	Historical	Spawning	Goodyear et al. (1982)
-	November	-	43.897	-78.288	Historical	Spawning	Goodyear et al. (1982)
-	November	-	43.934	-78.267	Historical	Spawning	Goodyear et al. (1982)
-	November	-	43.912	-77.876	Historical	Spawning	Goodyear et al. (1982)
1900	November	-	43.876	-77.036	Historical	Spawning	Goodyear et al. (1982)
1900	November	-	43.937	-76.828	Historical	Spawning	Goodyear et al. (1982)
1900	November	-	43.915	-76.907	Historical	Spawning	Goodyear et al. (1982)
1900	November	-	43.897	-76.971	Historical	Spawning	Goodyear et al. (1982)
1900	November	-	44.151	-77.333	Historical	Spawning	Goodyear et al. (1982)
1860	November	-	44.085	-77.568	Historical	Spawning	Goodyear et al. (1982)
1900	November	-	44.14	-77.003	Historical	Spawning	Goodyear et al. (1982)

1927	November	-	44.129	-77.278	Historical	Spawning	Hart (1930)
1865	November	21	43.761	-79.134	Historical	Spawning	Kerr and Kerr (1860-1898)
1891	November	17	44.131	-76.334	Historical	Spawning	Bean (1903)
-	Fall	-	43.949	-77.341	Historical	Spawning	Harris (1906)
1870	November	-	43.995	-77.593	Historical	Spawning	Harris (1906)
-	October	-	44.016	-77.614	Historical	Spawning	Harris (1906)
-	October	-	44.001	-77.527	Historical	Spawning	Harris (1906)
1917	November	21	43.897	-78.293	Historical	Possible	Koelz (1929)
1860 - 1900	fall	-	43.211	-79.527	Historical	Possible	Goodyear et al. (1982)
1860 - 1900	fall	-	43.25	-79.682	Historical	Possible	Goodyear et al. (1982)
1885	-	-	43.3	-77.673	Historical	Possible	Smith et al. (1891)
1871	November	20-21	43.258	-79.064	Historical	Possible	Kerr and Kerr (1860-1898)
1885	-	-	43.236	-77.616	Historical	Possible	Smith et al. (1891)
2015	October	19	43.56507	-76.4555	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2015	October	19	43.5387	-76.4347	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2015	October	8	43.28386	-79.7466	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2015	October	8	43.27934	-79.7062	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2015	October	8	43.60376	-79.4318	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2015	October	8	44.0437	-76.8599	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2015	October	5	43.96128	-76.5035	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2017	October	17	43.53756	-76.3965	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2020	October	18	43.54283	-76.4718	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	October	24	44.082	-76.9176	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	October	25	44.0988	-76.8961	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	October	25	44.08415	-76.916	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	October	25	44.08628	-76.9361	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	November	12	43.99012	-76.2027	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	November	12	43.99037	-76.2028	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)

2018	November	12	44.02892	-76.17	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	November	12	44.0346	-76.1898	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	November	15	44.03398	-76.1345	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	November	15	44.05487	-76.215	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	November	13	43.26625	-76.9609	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	-	-	43.339	-78.715	Contemporary	Possible	Brown et al. (2022)
2018	-	-	43.259	-76.944	Contemporary	Possible	Brown et al. (2022)
2018	-	-	43.999	-77.743	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.109	-77.483	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.15	-77.393	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.131	-77.253	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.145	-77.199	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.166	-77.22	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.146	-77.192	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.2	-77.017	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.176	-77.066	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.151	-76.962	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.097	-77.046	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.042	-77.118	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.059	-77.07	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.054	-77.003	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.123	-76.881	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.108	-76.863	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.079	-76.369	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.086	-76.354	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.032	-76.35	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.049	-76.213	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.065	-76.15	Contemporary	Possible	Brown et al. (2022)
2018	-	-	43.982	-76.082	Contemporary	Possible	Brown et al. (2022)
2018	-	-	43.956	-76.137	Contemporary	Possible	Brown et al. (2022)
2018	-	-	43.903	-76.141	Contemporary	Possible	Brown et al. (2022)
2018	-	-	43.878	-76.19	Contemporary	Possible	Brown et al. (2022)
2004 - 2007	-	-	44.041	-76.197	Contemporary	Spawning	McKenna and Johnson (2009)
2004 - 2007	-	-	44.051	-76.163	Contemporary	Spawning	McKenna and Johnson (2009)
2004 - 2007	-	-	44.062	-76.233	Contemporary	Possible	McKenna and Johnson (2009)
2004 - 2007	-	-	44.056	-76.154	Contemporary	Possible	McKenna and Johnson (2009)
2004 - 2007	-	-	44.058	-76.163	Contemporary	Possible	McKenna and Johnson (2009)

2004 - 2007	-	-	44.046	-76.172	Contemporary	Possible	McKenna and Johnson (2009)
2004 - 2007	-	-	43.996	-76.198	Contemporary	Possible	McKenna and Johnson (2009)
-	-	-	43.83737	-77.1544	Contemporary	Spawning	T. Johnson (Personal Communication, 2025)
-	-	-	43.85418	-77.205	Contemporary	Spawning	T. Johnson (Personal Communication, 2025)

Appendix 4 Table 3. Cisco "spawning" and "possible spawning" (possible) observations from CORHIST (Brant et al. 2024). Observations represent distinct events that may involve examination of multiple fish. Shown for each observation is the date the observation was made (Year, Month, Day), latitude (Lat.) and longitude (Long.) in decimal degrees, the time period (Period) assignment (historical or contemporary), classification as either spawning or possible spawning occurrence (Classification), and the original source (Citation). "Spawning" observations (n = 73) are direct observations of spawning, mature individuals, or spawning grounds and "possible spawning" observations (n = 81) are observations suggestive of spawning (e.g., aggregations of fish during the spawning season) but not direct observations of spawning/mature fish. "-" indicates no information available.

Year	Month	Day	Lat.	Long.	Period	Classification	Citation
1868	November	27	43.282	-79.896	Historical	Spawning	Kerr and Kerr (1860-1898)
1868	November	30	43.281	-79.895	Historical	Spawning	Kerr and Kerr (1860-1898)
1869	November	-	43.275	-79.881	Historical	Spawning	Kerr and Kerr (1860-1898)
1927	November	-	44.137	-77.242	Historical	Spawning	Pritchard (1931b)
1865	November	25	43.279	-79.885	Historical	Spawning	Kerr and Kerr (1860-1898)
1865	November	28	43.281	-79.886	Historical	Spawning	Kerr and Kerr (1860-1898)
1897	November	-	44.074	-76.206	Historical	Spawning	Rathbun et al. (1897)
1897	November	-	44.034	-76.351	Historical	Spawning	Rathbun et al. (1897)
1895	November	-	44.069	-76.21	Historical	Spawning	Bean (1903)
1897	November	-	43.957	-76.272	Historical	Spawning	Rathbun et al. (1897)
1864	December	26	43.36	-79.606	Historical	Spawning	Kerr and Kerr (1860-1898)
1864	December	28	43.431	-79.632	Historical	Spawning	Kerr and Kerr (1860-1898)
1868	November	22	43.295	-79.803	Historical	Spawning	Kerr and Kerr (1860-1898)
1935	November	-	43.186	-77.524	Historical	Spawning	Stone (1938)
1936	November	-	43.232	-77.536	Historical	Spawning	Stone (1938)
-	November	-	43.228	-77.536	Historical	Spawning	Goodyear et al. (1982)
1900	November	-	44.133	-77.256	Historical	Spawning	Goodyear et al. (1982)
1900	November	-	44.136	-77.242	Historical	Spawning	Goodyear et al. (1982)
1897	November	-	43.921	-76.302	Historical	Spawning	Rathbun et al. (1897)
1897	November	-	44.045	-76.192	Historical	Spawning	Rathbun et al. (1897)
-	November	-	43.65	-76.183	Historical	Spawning	Goodyear et al. (1982)
-	November	-	43.668	-76.207	Historical	Spawning	Goodyear et al. (1982)
1880	November	-	43.611	-79.383	Historical	Spawning	Goodyear et al. (1982)
1880	November	-	43.628	-79.376	Historical	Spawning	Goodyear et al. (1982)
1926	October	-	43.539	-79.572	Historical	Spawning	Goodyear et al. (1982)

1930	November	-	44.095	-76.772	Historical	Spawning	Goodyear et al. (1982)
NA	November	-	43.25	-76.967	Historical	Spawning	Goodyear et al. (1982)
1900	November	-	43.327	-76.711	Historical	Spawning	Goodyear et al. (1982)
1880	November	-	43.845	-76.392	Historical	Spawning	Goodyear et al. (1982)
1880	November	-	43.954	-76.281	Historical	Spawning	Goodyear et al. (1982)
1880	November	-	44.032	-76.391	Historical	Spawning	Goodyear et al. (1982)
1880	November	-	44.044	-76.203	Historical	Spawning	Goodyear et al. (1982)
1880	November	-	44.072	-76.206	Historical	Spawning	Goodyear et al. (1982)
1917	November	-	43.236	-79.634	Historical	Spawning	Goodyear et al. (1982)
1860	November	-	43.28	-79.886	Historical	Spawning	Goodyear et al. (1982)
1860	November	-	43.292	-79.789	Historical	Spawning	Goodyear et al. (1982)
1860	November	-	43.276	-79.906	Historical	Spawning	Goodyear et al. (1982)
1860	November	-	43.272	-79.925	Historical	Spawning	Goodyear et al. (1982)
1920	November	-	44.004	-77.543	Historical	Spawning	Goodyear et al. (1982)
1920	November	-	44.013	-77.716	Historical	Spawning	Goodyear et al. (1982)
1970	November	-	44.001	-77.602	Historical	Spawning	Goodyear et al. (1982)
1970	November	-	44.02	-77.634	Historical	Spawning	Goodyear et al. (1982)
1900	November	-	44.151	-77.333	Historical	Spawning	Goodyear et al. (1982)
1900	November	-	44.151	-77.383	Historical	Spawning	Goodyear et al. (1982)
1874	November	-	43.277	-79.902	Historical	Spawning	Kerr and Kerr (1860-1898)
1924	November	-	43.246	-76.95	Historical	Spawning	State of New York (1925)
1924	November	-	43.331	-76.705	Historical	Spawning	State of New York (1925)
2016	November	8	43.51241	-76.4601	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	November	8	43.89623	-76.2064	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	November	12	43.99037	-76.2028	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	November	12	44.03283	-76.2188	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	November	12	44.04122	-76.2349	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	November	12	44.0254	-76.2	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	November	15	44.05875	-76.1734	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	November	19	43.95795	-76.2669	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	November	19	43.9581	-76.2665	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	November	15	44.05258	-76.1593	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	November	15	44.01783	-76.2139	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	November	15	44.06755	-76.214	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	November	19	43.90635	-76.2193	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	December	4	44.0421	-76.1959	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	December	4	44.04197	-76.1956	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)

2018	December	4	44.05697	-76.1872	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	December	4	44.05687	-76.1869	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	December	4	44.05633	-76.1528	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	December	4	44.05612	-76.1526	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	December	4	44.04152	-76.1595	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	December	4	44.0417	-76.1598	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	December	4	44.04727	-76.1705	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	December	4	44.047	-76.1703	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	December	4	44.06037	-76.2455	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	December	4	44.06038	-76.2451	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	December	4	44.05357	-76.2604	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	December	4	44.05333	-76.2601	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	December	4	44.02227	-76.2653	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	December	4	44.02257	-76.257	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	November	29	43.26105	-76.9617	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	November	15	43.31953	-76.71	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	November	13	43.26605	-76.9605	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2018	December	3	43.20608	-77.5223	Contemporary	Possible	U.S. Geological Survey Great Lakes Science Center (2022)
2014	March-April	-	44.06	-76.1527	Contemporary	Spawning	George et al. (2017)
2014	March-April	-	44.0547	-76.159	Contemporary	Spawning	George et al. (2017)
2014	March-April	-	44.0543	-76.1553	Contemporary	Spawning	George et al. (2017)
2014	March-April	-	44.0527	-76.161	Contemporary	Spawning	George et al. (2017)
2014	March-April	-	44.0507	-76.1635	Contemporary	Spawning	George et al. (2017)
2014	March-April	-	44.0453	-76.1719	Contemporary	Spawning	George et al. (2017)
2014	March-April	-	44.0393	-76.184	Contemporary	Spawning	George et al. (2017)
2014	March-April	-	44.0444	-76.197	Contemporary	Spawning	George et al. (2017)
2014	March-April	-	44.0541	-76.1566	Contemporary	Spawning	George et al. (2017)
2017-2018	-	-	44.0586	-76.1506	Contemporary	Spawning	Paufve et al. (2022)
2017-2018	-	-	44.0581	-76.156	Contemporary	Spawning	Paufve et al. (2022)
2017-2018	-	-	44.0561	-76.1529	Contemporary	Spawning	Paufve et al. (2022)
2017-2018	-	-	44.0544	-76.1559	Contemporary	Spawning	Paufve et al. (2022)
2017-2018	-	-	44.0555	-76.1596	Contemporary	Spawning	Paufve et al. (2022)
2017-2018	-	-	44.0509	-76.164	Contemporary	Spawning	Paufve et al. (2022)
2017-2018	-	-	44.0396	-76.1714	Contemporary	Spawning	Paufve et al. (2022)

2017-2018	-	-	44.0329	-76.1826	Contemporary	Spawning	Paufve et al. (2022)
2017-2018	-	-	44.0406	-76.1984	Contemporary	Spawning	Paufve et al. (2022)
2019	November-December	-	44.0567	-76.2124	Contemporary	Spawning	Gatch et al. (2023)
2019	November-December	-	44.0296	-76.2066	Contemporary	Spawning	Gatch et al. (2023)
2019	November-December	-	44.0533	-76.1597	Contemporary	Spawning	Gatch et al. (2023)
2019	November-December	-	44.0508	-76.187	Contemporary	Spawning	Gatch et al. (2023)
2019	November-December	-	44.0556	-76.1933	Contemporary	Spawning	Gatch et al. (2023)
2018	-	-	43.2135	-77.5344	Contemporary	Possible	Brown et al. (2022)
2018	-	-	43.2528	-76.956	Contemporary	Possible	Brown et al. (2022)
2018	-	-	43.2326	-76.9305	Contemporary	Possible	Brown et al. (2022)
2018	-	-	43.2978	-76.8345	Contemporary	Possible	Brown et al. (2022)
2018	-	-	43.3312	-76.7101	Contemporary	Possible	Brown et al. (2022)
2018	-	-	43.7031	-76.2136	Contemporary	Possible	Brown et al. (2022)
2018	-	-	43.8129	-76.2571	Contemporary	Possible	Brown et al. (2022)
2018	-	-	43.9113	-76.174	Contemporary	Possible	Brown et al. (2022)
2018	-	-	43.9815	-76.0891	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.0379	-76.1829	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.054	-76.3335	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.0265	-76.3329	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.1193	-76.8436	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.092	-76.9251	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.0521	-76.9788	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.0541	-77.0871	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.1208	-77.0709	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.1142	-77.016	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.1692	-77.0561	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.1682	-77.1068	Contemporary	possible	Brown et al. (2022)
2018	-	-	44.1501	-77.1898	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.1622	-77.2679	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.1368	-77.4109	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.1171	-77.4602	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.0872	-77.5714	Contemporary	Possible	Brown et al. (2022)
2018	-	-	43.9307	-77.2912	Contemporary	possible	Brown et al. (2022)
2018	-	-	43.9328	-77.2903	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.0105	-77.669	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.0904	-76.3658	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.0619	-76.3495	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.0372	-76.2414	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.0486	-76.1783	Contemporary	Possible	Brown et al. (2022)
2018	-	-	43.9984	-76.2118	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.0146	-76.1511	Contemporary	Possible	Brown et al. (2022)

2018	-	-	44.029	-76.1506	Contemporary	Possible	Brown et al. (2022)
2018	-	-	43.9661	-76.1812	Contemporary	Possible	Brown et al. (2022)
2018	-	-	43.9551	-76.1607	Contemporary	Possible	Brown et al. (2022)
2018	-	-	43.9637	-76.1258	Contemporary	Possible	Brown et al. (2022)
2018	-	-	43.9675	-76.1153	Contemporary	Possible	Brown et al. (2022)
2018	-	-	43.9751	-76.0919	Contemporary	Possible	Brown et al. (2022)
2018	-	-	43.9757	-76.1062	Contemporary	Possible	Brown et al. (2022)
2018	-	-	43.9373	-76.1632	Contemporary	Possible	Brown et al. (2022)
2018	-	-	43.9294	-76.1464	Contemporary	Possible	Brown et al. (2022)
2018	-	-	43.9194	-76.1584	Contemporary	Possible	Brown et al. (2022)
2018	-	-	43.8888	-76.1636	Contemporary	Possible	Brown et al. (2022)
2018	-	-	43.8698	-76.2009	Contemporary	Possible	Brown et al. (2022)
2018	-	-	43.9019	-76.2057	Contemporary	Possible	Brown et al. (2022)
2018	-	-	44.0498	-76.1823	Contemporary	Possible	Brown et al. (2022)
-	-	-	44.0398	-76.1955	Contemporary	Spawning	George et al. (2018)
-	-	-	44.1286	-77.2721	Contemporary	Spawning	George et al. (2018)
-	-	-	43.8632	-76.2062	Contemporary	Spawning	George et al. (2018)

Appendix 4 Table 4. Round Whitefish "spawning" and "possible spawning" (possible) observations from CORHIST (Brant et al. 2024). Observations represent distinct events that may involve examination of multiple fish. Shown for each observation is the date the observation was made (Year, Month, Day), latitude (Lat.) and longitude (Long.) in decimal degrees, the time period (Period) assignment (historical or contemporary), classification as either spawning or possible spawning occurrence (Classification), and the original source (Citation). "Spawning" observations (n = 57) are direct observations of spawning, mature individuals, or spawning grounds and "possible spawning" observations (n = 47) are observations suggestive of spawning (e.g., aggregations of fish during the spawning season) but not direct observations of spawning/mature fish. "-" indicates no information available.

Year	Month	Day	Lat.	Long.	Period	Classification	Citation
1970	November - December	-	43.869	-78.704	Historical	Spawning	Goodyear et al. (1982)
1970	November - December	-	43.866	-78.724	Historical	Spawning	Goodyear et al. (1982)
1925	November	10	43.4289	-79.6248	Historical	Spawning	ROM I001803
1991	December	4	43.66667	-79.2467	Historical	Spawning	ROM I064634
1980	-	-	43.80865	-79.0775	Historical	Spawning	Haymes and Kolenosky (1984)
1980	-	-	43.80307	-79.0608	Historical	Spawning	Haymes and Kolenosky (1984)
1980	-	-	43.81409	-79.0357	Historical	Spawning	Haymes and Kolenosky (1984)
1979	-	-	43.81404	-79.0235	Historical	Spawning	Haymes and Kolenosky (1984)
1979	-	-	43.82626	-78.9824	Historical	Spawning	Haymes and Kolenosky (1984)
1979	-	-	43.84607	-78.9421	Historical	Spawning	Haymes and Kolenosky (1984)
1981	-	-	43.84496	-78.9023	Historical	Spawning	Haymes and Kolenosky (1984)
1976	-	-	43.86818	-78.8166	Historical	Spawning	Haymes and Kolenosky (1984)
1977	-	-	43.86672	-78.7975	Historical	Spawning	Haymes and Kolenosky (1984)
1977	-	-	43.86634	-78.7533	Historical	Spawning	Haymes and Kolenosky (1984)
1977	-	-	43.86682	-78.7304	Historical	Spawning	Haymes and Kolenosky (1984)
1977	-	-	43.86596	-78.7148	Historical	Spawning	Haymes and Kolenosky (1984)
1977	-	-	43.87214	-78.6993	Historical	Spawning	Haymes and Kolenosky (1984)
1977	-	-	43.88712	-78.6605	Historical	Spawning	Haymes and Kolenosky (1984)
1980	-	-	43.8953	-78.5963	Historical	Spawning	Haymes and Kolenosky (1984)
1977	-	-	43.89503	-78.5675	Historical	Spawning	Haymes and Kolenosky (1984)
1978	-	-	43.90053	-78.4631	Historical	Spawning	Haymes and Kolenosky (1984)
1978	-	-	43.91238	-78.4263	Historical	Spawning	Haymes and Kolenosky (1984)
1978	-	-	43.91266	-78.4138	Historical	Spawning	Haymes and Kolenosky (1984)
1978	-	-	43.92092	-78.3895	Historical	Spawning	Haymes and Kolenosky (1984)
1978	-	-	43.92775	-78.3763	Historical	Spawning	Haymes and Kolenosky (1984)
1978	-	-	43.93094	-78.345	Historical	Spawning	Haymes and Kolenosky (1984)
1985	-	-	43.60833	-79.465	Historical	Possible	S. Beech (personal communication, 2025)
1986	-	-	43.95278	-78.0333	Historical	Possible	S. Beech (personal communication, 2025)
1986	-	-	43.95278	-78.0306	Historical	Possible	S. Beech (personal communication, 2025)
1986	-	-	43.93889	-78.2222	Historical	Possible	S. Beech (personal communication, 2025)

1986	-	-	43.61389	-79.475	Historical	Possible	S. Beech (personal communication, 2025)
1988	-	-	43.62222	-79.4694	Historical	Possible	S. Beech (personal communication, 2025)
1988	-	-	43.93333	-78.2225	Historical	Possible	S. Beech (personal communication, 2025)
1988	-	-	43.95333	-78.0194	Historical	Possible	S. Beech (personal communication, 2025)
1988	-	-	43.84139	-78.8717	Historical	Possible	S. Beech (personal communication, 2025)
1989	-	-	43.91444	-78.2261	Historical	Possible	S. Beech (personal communication, 2025)
1990	-	-	43.91639	-78.2228	Historical	Possible	S. Beech (personal communication, 2025)
1990	-	-	43.83306	-78.8836	Historical	Possible	S. Beech (personal communication, 2025)
1991	-	-	43.91917	-78.2211	Historical	Possible	S. Beech (personal communication, 2025)
1991	-	-	43.91917	-78.2211	Historical	Possible	S. Beech (personal communication, 2025)
1991	-	-	43.93556	-78.0272	Historical	Possible	S. Beech (personal communication, 2025)
1991	-	-	43.93556	-78.0272	Historical	Possible	S. Beech (personal communication, 2025)
1991	-	-	43.98861	-78.0178	Historical	Possible	S. Beech (personal communication, 2025)
1991	-	-	43.91361	-77.535	Historical	Possible	S. Beech (personal communication, 2025)
1991	-	-	43.83333	-78.8694	Historical	Possible	S. Beech (personal communication, 2025)
1991	-	-	43.82222	-78.8722	Historical	Possible	S. Beech (personal communication, 2025)
1992	-	-	43.91556	-78.2203	Historical	Possible	S. Beech (personal communication, 2025)
1992	-	-	43.91556	-78.2203	Historical	Possible	S. Beech (personal communication, 2025)
1992	-	-	43.83889	-78.85	Historical	Possible	S. Beech (personal communication, 2025)
1992	-	-	43.6	-79.4778	Historical	Possible	S. Beech (personal communication, 2025)
1992	-	--	43.825	-78.85	Historical	Possible	S. Beech (personal communication, 2025)
1992	-	-	43.83889	-78.85	Historical	Possible	S. Beech (personal communication, 2025)
1993	-	-	43.623	-79.4667	Historical	Possible	S. Beech (personal communication, 2025)
1993	-	-	43.623	-79.4667	Historical	Possible	S. Beech (personal communication, 2025)
1993	-	-	43.33333	-78.85	Historical	Possible	S. Beech (personal communication, 2025)
1994	-	-	43.95056	-78.0233	Historical	Possible	S. Beech (personal communication, 2025)
1994	-	-	43.93806	-78.0267	Historical	Possible	S. Beech (personal communication, 2025)
1994	-	-	43.94056	-78.2261	Historical	Possible	S. Beech (personal communication, 2025)
1994	-	-	43.9225	-78.2203	Historical	Possible	S. Beech (personal communication, 2025)
1994	-	-	43.92	-78.2225	Historical	Possible	S. Beech (personal communication, 2025)
1994	-	-	43.97056	-78.0175	Historical	Possible	S. Beech (personal communication, 2025)
1994	-	-	43.95389	-78.2272	Historical	Possible	S. Beech (personal communication, 2025)
1994	-	-	43.96111	-78.0275	Historical	Possible	S. Beech (personal communication, 2025)
1995	-	-	43.91917	-77.5358	Historical	Possible	S. Beech (personal communication, 2025)
1995	-	-	43.92139	-78.2183	Historical	Possible	S. Beech (personal communication, 2025)
1995	-	-	43.91528	-78.225	Historical	Possible	S. Beech (personal communication, 2025)
1995	-	-	43.90278	-78.2186	Historical	Possible	S. Beech (personal communication, 2025)
1995	-	-	43.9575	-78.0189	Historical	Possible	S. Beech (personal communication, 2025)
1995	-	-	43.93639	-78.2167	Historical	Possible	S. Beech (personal communication, 2025)
1995	-	-	43.94167	-78.0222	Historical	Possible	S. Beech (personal communication, 2025)
1995	-	-	43.81667	-78.85	Historical	Possible	S. Beech (personal communication, 2025)
1995	-	-	43.58333	-79.4667	Historical	Possible	S. Beech (personal communication, 2025)
1993	-	-	43.9993	-77.7127	Historical	Possible	S. Beech (personal communication, 2025)

2014	-	-	43.94117	-78.2468	Contemporary	Spawning	OMNRF (2015)
2014	-	-	43.94067	-78.2103	Contemporary	Spawning	OMNRF (2015)
2014	-	-	43.94067	-78.2103	Contemporary	Spawning	OMNRF (2015)
2014	-	-	43.9355	-78.2237	Contemporary	Spawning	OMNRF (2015)
2014	-	-	43.93367	-78.2268	Contemporary	Spawning	OMNRF (2015)
2014	-	-	43.93367	-78.2268	Contemporary	Spawning	OMNRF (2015)
2014	-	-	43.93567	-78.232	Contemporary	Spawning	OMNRF (2015)
2014	-	-	43.93567	-78.232	Contemporary	Spawning	OMNRF (2015)
2014	-	-	43.93733	-78.2243	Contemporary	Spawning	OMNRF (2015)
2014	-	-	43.93667	-78.2215	Contemporary	Spawning	OMNRF (2015)
2014	-	-	43.93667	-78.2215	Contemporary	Spawning	OMNRF (2015)
2014	-	-	43.94033	-78.205	Contemporary	Spawning	OMNRF (2015)
2014	-	-	43.94033	-78.205	Contemporary	Spawning	OMNRF (2015)
2014	-	-	43.94033	-78.205	Contemporary	Spawning	OMNRF (2015)
2014	-	-	43.9375	-78.2173	Contemporary	Spawning	OMNRF (2015)
2014	-	-	43.94183	-78.2088	Contemporary	Spawning	OMNRF (2015)
2014	-	-	43.94317	-78.2202	Contemporary	Spawning	OMNRF (2015)
2014	-	-	43.79967	-79.0657	Contemporary	Spawning	OMNRF (2015)
2014	-	-	43.806	-79.051	Contemporary	Spawning	OMNRF (2015)
2014	-	-	43.80333	-79.0482	Contemporary	Spawning	OMNRF (2015)
2014	-	-	43.80067	-79.054	Contemporary	Spawning	OMNRF (2015)
2014	-	-	43.79967	-79.0602	Contemporary	Spawning	OMNRF (2015)
2014	-	-	43.79983	-79.0658	Contemporary	Spawning	OMNRF (2015)
2014	-	-	43.863	-78.7428	Contemporary	Spawning	OMNRF (2015)
2014	-	-	43.86383	-78.738	Contemporary	Spawning	OMNRF (2015)
2014	-	-	43.86133	-78.7338	Contemporary	Spawning	OMNRF (2015)
2014	-	-	43.861	-78.7238	Contemporary	Spawning	OMNRF (2015)
2014	-	-	43.86217	-78.7155	Contemporary	Spawning	OMNRF (2015)
2013	-	-	43.91067	-78.4103	Contemporary	Spawning	OMNR (2014)
2013	-	-	43.93983	-78.2318	Contemporary	Spawning	OMNR (2014)
2013	-	-	43.9385	-78.23	Contemporary	Spawning	OMNR (2014)