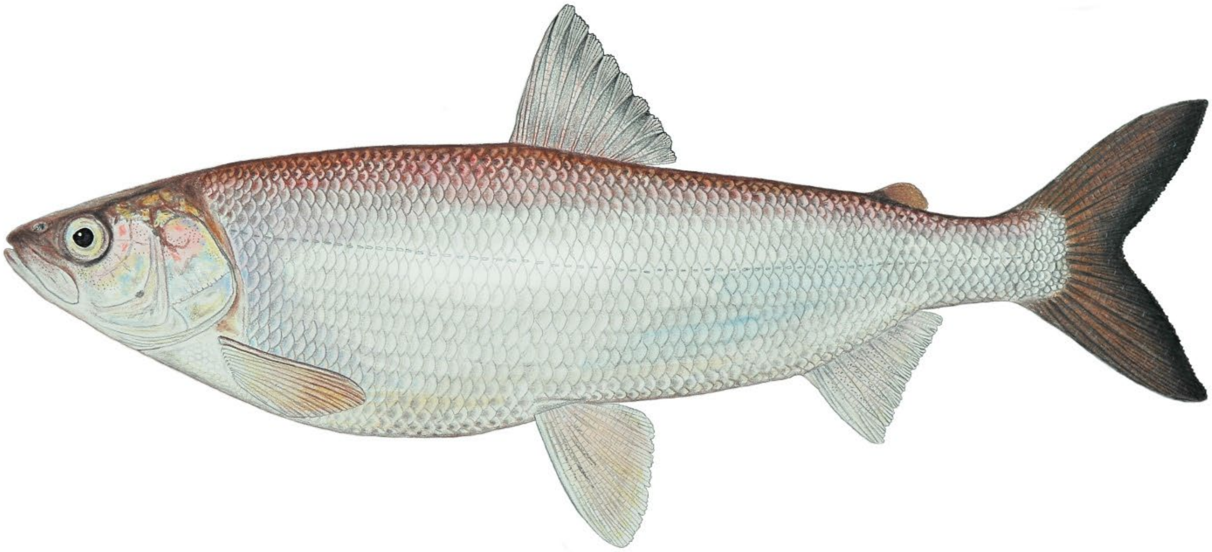
# DRAFT Recovery Strategy for the Shortjaw Cisco (*Coregonus zenithicus*) in Ontario



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# Declaration

The recovery strategy for the Shortjaw Cisco (*Coregonus zenithicus*) was developed in accordance with the requirements of the *Endangered Species Act, 2007* (ESA). This recovery strategy has been prepared as advice to the Government of Ontario, other responsible jurisdictions and the many different constituencies that may be involved in recovering the species.

The recovery strategy does not necessarily represent the views of all individuals who provided advice or contributed to its preparation, or the official positions of the organizations with which the individuals are associated.

The recommended goals, objectives and recovery approaches identified in the strategy are based on the best available knowledge and are subject to revision as new information becomes available. Implementation of this strategy is subject to appropriations, priorities and budgetary constraints of the participating jurisdictions and organizations.

Success in the recovery of this species depends on the commitment and cooperation of many different constituencies that will be involved in implementing the directions set out in this strategy.

# Responsible jurisdictions

Ministry of the Environment, Conservation and Parks
Fisheries and Oceans Canada

# Executive summary

Shortjaw Cisco (*Coregonus zenithicus*) is a freshwater member of the family Salmonidae (trouts and salmons) in the subfamily Coregoninae (freshwater whitefishes), representing a group of fishes known as “Coregonines”. Published descriptions of Shortjaw Cisco emphasize its overall silvery colour, imparted by a greenish, olive, or tan dorsal surface (back) shading to white ventrally (underside). Its common name references the lower jaw which is typically included within (i.e., is inferior to) the upper jaw. Shortjaw Cisco is listed as threatened on the *Species at Risk in Ontario* (SARO) *List*.

Nine cisco species occur or historically occurred in the Laurentian Great Lakes (including Lake Nipigon) and smaller inland lakes in Ontario. Eight of these species (including Shortjaw Cisco) comprise the “deepwater cisco” complex (historically known as chubs). These “species” have been described by some as infraspecific “subspecies”, “forms”, “morphotypes” or “ecotypes”. Most entities in the deepwater cisco complex share several overlapping character traits and lack significant genetic differentiation based on traditional genetic assessments using molecular markers. The remarkable range of cisco phenotypes encountered, and associated challenges of species assignment, has often been called the “Coregonine Problem”. Some authors have recommended lumping the deepwater ciscoes (or all ciscoes) into a single taxon.

Cisco form diversity occurring in a single water body has been called a “species pair” (where two morphotypes occur in sympatry) or “species flock” (where three or more morphotypes occur in sympatry). The mechanisms driving cisco morphological variation appear to represent niche availability, wherein additional cisco forms emerge in deeper waterbodies containing diverse assemblages of Opossum Shrimp (*Mysis diluviana*).

No single diagnostic character can enable reliable identification of Shortjaw Cisco. Species assignment requires consideration of an association or constellation of character traits, of which gill raker number is critical (as is premaxillary angle, to a lesser extent). Shortjaw Cisco morphology and character traits vary widely across waterbodies. The study of Shortjaw Cisco biology (and that of the broader cisco complex) is fraught with challenges arising from variability in physical characteristics, temporal changes in physical appearance, shifting taxonomic treatments, and overall identification issues. As a result, little reliable information is available to inform a detailed biological description of Shortjaw Cisco.

The distribution of Shortjaw Cisco in Ontario as currently understood overlaps with three Great Lakes (Huron, Michigan and Superior), Lake Nipigon and eleven inland lakes. The species is believed to be extirpated from Lake Michigan and Lake Huron. Recent and unpublished genomic analyses revealed that contemporary specimens identified as Shortjaw Cisco from Lake Superior aligned genetically with historical specimens of Shortnose Cisco (*C. reighardi*) from Lake Michigan, casting doubt on the present and historical status of Shortjaw Cisco therein. Genetic studies covering both the Laurentian Great Lakes and inland lakes have not found evidence of a phylogenetically distinct taxon referrable to “Shortjaw Cisco” beyond the scale of individual lakes. Such work implies that Shortjaw Cisco may be thought of as a collection of entities with multiple evolutionary origins having speciated independently and in parallel, ultimately converging on a common phenotypic variant (e.g., low gill rakered form). Based on current information, populations of Shortjaw Cisco appear to be more genetically aligned with sympatric morphotypes of other ciscoes (located in the same waterbody) than to allopatric Shortjaw Cisco (located in distinct waterbodies).

Owing to the aforementioned taxonomic and identification challenges, the habitat requirements of Shortjaw Cisco are poorly understood in both the Laurentian Great Lakes and inland lakes. Capture depths of adult specimens are more widely reported than other habitat parameters and often vary significantly between waterbodies. It is generally believed that Shortjaw Cisco adopts a pelagic (open water) life strategy with some bottom-feeding activity, and is mostly found at depths of 20 to 180 m.

The primary threats to the survival and the recovery of Shortjaw Cisco in Ontario (listed in order of severity) include (1) alterations to food web structure, (2) introduction of invasive (and non-native) aquatic species, (3) human-induced climate change and (4) overexploitation and incidental bycatch. Taxonomic uncertainty is a severe knowledge gap which impedes the recovery of Shortjaw Cisco in Ontario and elsewhere.

The recommended recovery goal for Shortjaw Cisco in Ontario is to maintain all existing distinct populations. The recommended protection and recovery objectives for Shortjaw Cisco in Ontario are as follows:

1. Conduct and support research and monitoring to advance the identification of distinct populations of Shortjaw Cisco and sympatric cisco taxa in Ontario.
2. Implement a strategic and intensive sampling program to clarify distribution, biology/life history, and habitat associations for all distinct populations of Shortjaw Cisco and sympatric cisco taxa in Ontario.
3. Implement a long-term monitoring program to quantify population abundance and trends in a subset of occupied waterbodies.
4. Undertake an updated threats assessment of all presumed historical and extant distinct populations of Shortjaw Cisco and sympatric cisco taxa in Ontario at a lake-specific level to support reassessment of the species' status.
5. Prepare and implement lake-specific management plans for all waterbodies containing distinct populations of Shortjaw Cisco.

If a decision to proceed with a habitat regulation is made following verification of taxonomy and collection of additional data, the habitat regulation should include all intermediate depths of occupied lakes, as this is where feeding and spawning activities are concentrated. In the Laurentian Great Lakes, the recommended depth range would extend between 15 and 200 m, consistent with published reports of capture depths and known spawning areas. The depth range of regulated habitat in inland lakes would likely be narrower and shallower in reflection of differing life history strategies of Shortjaw Cisco in such waterbodies and lake morphometry.

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# 1.0 Background information

## 1.1 Species assessment and classification

The following list provides assessment and classification information for the Shortjaw Cisco (*Coregonus zenithicus*). Note: The glossary provides definitions for abbreviations and technical terms in this document.

- SARO List Classification: Threatened
- SARO List History: Threatened (2008)
- COSEWIC Assessment History: Threatened (1987), Threatened (2003)
- SARA Schedule 1: No schedule, no status
- Conservation Status Rankings: G-rank: G3; N-rank: N2; S-rank: S2

## 1.2 Species description and biology

### Species description

*Initial classification*

Shortjaw Cisco is a freshwater member of the family Salmonidae (trouts and salmons) in the subfamily Coregoninae (freshwater whitefishes), representing a group of fishes known as “Coregonines”. The species was originally described by Jordan and Evermann (1909) as *Argyrosomus zenithicus* from a 1908 specimen obtained for scientific description in Duluth (Minnesota) which originated offshore of Isle Royale in Lake Superior. The genus *Argyrosomus* applied to North American ciscoes was substituted for *Leucichthys* in 1911 to correct an error in nomenclature (Jordan and Evermann 1911; Murray and Reist 2003), prompting recognition of the species as *Leucichthys zenithicus* (Dymond 1926). Shortjaw Cisco and other North American ciscoes were ultimately classified as *Coregonus* (Hubbs and Lagler 1958) which includes Lake Whitefish (*C. clupeaformis*) and Eurasian whitefishes. *Leucichthys* remains the valid subgenus.

The genus *Coregonus* takes its meaning from two modern Greek words, “κόρη” (kore; pupil of the eye) and “γωνιά” (gonia; angle), referring to how the pupil tends to project forward towards the snout (Holm et al. 2021; Scott and Crossman 1998). The species epithet *zenithicus* reflects the type specimen having been collected in Duluth, colloquially known as the “Zenith City” (Holm et al. 2021).

### *Traditional ecological knowledge*

Deepwater ciscoes, referred to as “jichkes” in Anishinaabemowin, are considered culturally and socioeconomically important to the people of the Saugeen Ojibway Nation (Duncan et al. 2023). Declines in the Lake Huron deepwater cisco complex created negative effects on their local economies and impacted culture and food availability (Duncan et al. 2023). While ciscoes are not known to possess a specific cultural importance to the Algonquins of Ontario (AOO), they hold deep significance for them from the holistic view of protecting ecosystem functions to safeguard the larger community (K. Mitchell pers. comm. 2024). Similarly, the AOO recognizes the importance of protecting future harvest rights through the protection of individual species, including for Shortjaw Cisco (K. Mitchell pers. comm. 2024).

### *Morphological description and character traits*

Shortjaw Cisco can only be described and understood within the context of the broader cisco species complex inhabiting the Laurentian Great Lakes (including Lake Nipigon) and other inland waterbodies occupied by cisco species. The wide array of cisco phenotypes within and across lakes has puzzled ichthyologists and research scientists who, for the past century, have sought to ascribe taxonomically valid names to the diversity encountered. The variously recognized “species” have been relegated by some to infraspecific “subspecies”, “forms”, “morphotypes” or “ecotypes”, terms which convey slightly different meanings but are nonetheless treated synonymously within this recovery strategy. Most entities share several overlapping character traits, and traditional molecular markers have displayed weak to negligible genetic differentiation.

Nine cisco species formally recognized by the American Fisheries Society (AFS; Page et al. 2023) occur or historically occurred in the Laurentian Great Lakes (and in some cases, inland lakes; see Table 1). Excluding Cisco (*C. artedi*) *sensu stricto* (in a strict sense), the remaining eight species comprise the “deepwater cisco” complex. Deepwater ciscoes were historically called “chubs” though this term is now restricted in use to the commercial fishing industry (Scott and Crossman 1998; Mandrak et al. 2014; S. James pers. comm. 2024). The official list of provincially recognized fishes maintained by the Natural Heritage Information Centre (NHIC) differs slightly from the AFS cisco list in that Longjaw Cisco is omitted (due to presumed synonymy with Shortjaw Cisco).

For clarity, the term “cisco” (lowercase) is applied in this recovery strategy to collectively reference all cisco species in Ontario (i.e., genus *Coregonus*, subgenus *Leucichthys*), as do the terms “ciscoes” and “cisco species complex”. “Cisco” (capitalized) refers exclusively to the taxon *C. artedi*.

Table 1. List of ciscoes in Ontario with their historical and/or contemporary distribution (modified and updated from Todd and Smith 1992; Eshenroder et al. 2016) based on current understandings of taxonomy and distribution. Currently inhabited (extant) waterbodies are bolded. Non-bolded waterbodies are those where the species is known or presumed to be extinct (E), extirpated (e) or introgressed (i), where its current status is uncertain (u), or where it has been reintroduced (r).

| Common Name | Scientific Name | Taxonomic Authority | Distribution in the Laurentian Great Lakes (including Lake Nipigon) | Recorded from Inland Lakes? |
|---|---|---|---|---|
| Longjaw Cisco | *C. alpenae* | Koelz, 1924 | Lake Michigan (E)<br>Lake Huron (i)<br>Lake Erie (E) | -- |
| Cisco | *C. artedi* | Lesueur, 1818 | **Lake Superior**<br>**Lake Nipigon**<br>**Lake Michigan**<br>**Lake Huron**<br>Lake Erie (e)<br>**Lake Ontario** | Yes |
| Bloater | *C. hoyi* | Milner, 1874 | **Lake Superior**<br>**Lake Nipigon**<br>**Lake Michigan**<br>Lake Huron (i)<br>Lake Ontario (r) | -- |
| Deepwater Cisco | *C. johannae* | Wagner, 1910 | Lake Michigan (E)<br>Lake Huron (E) | -- |
| Kiyi | *C. kiyi* | Koelz, 1921 | **Lake Superior**<br>Lake Michigan (e)<br>Lake Huron (i)<br>Lake Ontario (e) | -- |
| Blackfin Cisco | *C. nigripinnis* | Milner, 1874 | Lake Superior (u)<br>**Lake Nipigon**<br>Lake Michigan (E)<br>Lake Huron (E) | Yes |
| Nipigon Cisco | *C. nipigon* | Koelz, 1925 | **Lake Nipigon** | Yes |
| Shortnose Cisco | *C. reighardi* | Koelz, 1924 | Lake Superior (u)<br>Lake Michigan (E)<br>Lake Huron (i)<br>Lake Ontario (E) | -- |
| Shortjaw Cisco | *C. zenithicus* | Jordan and Evermann, 1909 | Lake Superior (u)<br>**Lake Nipigon**<br>Lake Michigan (e)<br>Lake Huron (i) | Yes |

Published accounts of Shortjaw Cisco emphasize its overall silvery colour, with a greenish, olive, or tan dorsal surface (back) shading to white ventrally (underside) (Scott and Crossman 1998; Eshenroder et al. 2016). Its body is elongated, laterally compressed, and covered by rounded and overlapping scales. Body size varies considerably by waterbody, with standard length measurements ranging from 150 millimetres (mm) up to about 400 mm (Todd 2003). Fin colour has been variously described as lightly to sometimes darkly pigmented (Scott and Crossman 1998) to lacking pigmentation (Eshenroder et al. 2016). Its mouth is small and lacking in teeth with a long maxillary extending to at least the middle of the eye. Like other Salmonidae, Shortjaw Cisco possesses a small adipose fin (a soft, fleshy fin located behind the dorsal fin) and distinct pelvic axillary process (a small, triangular appendage at the base of the pelvic fin) (Scott and Crossman 1998). Typical specimens of Shortjaw Cisco have fewer than 40 gill rakers on the first gill ("branchial") arch, which also tend to be shorter than other deepwater ciscoes (Becker 1983).

The name "Shortjaw Cisco" references the terminal lower jaw which is typically included within (i.e., is inferior to) the upper jaw (Becker 1983); thus, "shortjaw" refers only to the lower jaw being short, which alternatively may protrude slightly forward in some collections (Scott and Crossman 1998). Photographs of specimens attributed to Shortjaw Cisco held at the Royal Ontario Museum (ROM) are found below in Figure 1.

Shortjaw Cisco from Saganaga Lake,
Thunder Bay District, Ontario.
Photo credit: Royal Ontario Museum

Shortjaw Cisco from Lake Nipigon,
Thunder Bay District, Ontario.
Photo credit: Royal Ontario Museum

Figure 1. Specimens identified as Shortjaw Cisco presently held at the ROM.

### *Taxonomic description*

Cisco diversity in the Laurentian Great Lakes was initially summarized by Zoologist Walter Koelz in 1929, who recognized nine species and seven subspecies in his seminal *Coregonid Fishes of the Great Lakes* (Koelz 1929). Koelz's interest in ciscoes was in part practical – the cisco fishery was then of great economic importance and solid data was needed to inform management and maximize yields – but he was also driven to explore the origins and evolution of Coregonines and their relationship with congenerics in Europe and Asia. The mid-twentieth century was a period of intense study in North American cisco diversity and systematics, leading to the production of several monographs centring on Lake Ontario (Pritchard 1931), eastern North America (Koelz 1931), northwestern Canada (Dymond 1943), and central Canada (Clarke 1973). These works were published alongside countless studies seeking to clarify various aspects of cisco life history (e.g., Stone 1947) and population trends (e.g., Smith 1964). Interspecific (i.e., between species) and infraspecific (i.e., within species) variation in ciscoes was well known and described at length by Koelz (1929, 1931) and others active at that time (e.g., Dymond 1926; Dymond and Hart 1927). The remarkable range of cisco phenotypes encountered, and associated challenges of species assignment, signify what Svärdson (1949) originally called the “Coregonid Problem” (some authors preferring “Coregonine Problem”, see Eshenroder et al. 2016).

Over time, taxonomic expansion (i.e., acceptance of new species or forms via “splitting”) and contraction (i.e., synonymizing previously accepted species or forms via “lumping”) has given rise to an ever-changing list of recognized cisco taxa across Ontario and northcentral North America. For example, Nipigon Cisco (*C. nipigon*) was synonymized with Cisco (Scott and Crossman 1998), a decision later endorsed by others (Smith and Todd 1984), only to be resurrected 40 years later based on updated morphometric analysis from Lake Saganaga along the Minnesota/Ontario border (Etnier and Skelton 2003; Page et al. 2013). Other times, a described entity was later found to be taxonomically invalid, such as the case of *C. prognathus* (often recognized as a subspecies of Blackfin Cisco, *C. nigripinnis prognathus*) due to poor condition of the original type specimen (Todd 1981). Shortnose Cisco was believed extinct (Mandrak 2018) until recent work using genomic techniques (coupled with the suspicions of field researchers for over a decade) convincingly proved otherwise (Page et al. 2023; O. Gorman pers. comm. 2024).

While the taxonomic validity of Shortjaw Cisco (and other deepwater ciscoes) has at times been questioned, such debate has often focused on the relative merits of lumping the species with other deepwater ciscoes possessing fewer gill rakers (Clarke 1973; Bailey and Smith 1981; Smith and Todd 1984) or combining it with all ciscoes into a single taxon represented by Cisco *sensu lato* (in a broad sense; Turgeon and Bernatchez 2003; Eshenroder et al. 2016). Advancement of a species flock framework (e.g., Turgeon et al. 1999; DFO 2013a) to guide cisco systematics and management has been offered as a way to navigate this taxonomic confusion, to which more fulsome attention is directed later in this recovery strategy.

The currently accepted circumscription of Shortjaw Cisco synonymizes and/or separates the following entities occurring in the Great Lakes region:

- Koelz (1931) originally described *C. bartletti* from Siskiwet Lake on Isle Royale (known as Siskiwet Lake Cisco), which some authors have placed in synonymy with Shortjaw Cisco (Etnier and Skelton 2003). No records of *C. bartletti* are apparent from Ontario or Canada, though the proximity of Isle Royale to Lake Superior implies an evolutionary relationship with the Lake Superior cisco species flock.
- Todd and Smith (1980) synonymized *C. cyanopterus* (known as Bluefin, sometimes considered a subspecies of Blackfin Cisco, *C. nigripinnis cyanopterus*) and *C. reighardi dymondi* (a subspecies of Shortnose Cisco) from Lake Nipigon and Lake Superior with Shortjaw Cisco, which remains current (Eshenroder et al. 2016). The Bluefin morphotype substantially exceeded the size of other Shortjaw Cisco forms in Lake Superior (Eshenroder et al. 2016).
- Bailey and Smith (1981) synonymized Longjaw Cisco with Shortjaw Cisco, which has since been reversed (Page et al. 2023) on the basis of convergent evidence

including reproductive biology, morphometrics and trophic niche (Eshenroder et al. 2016).

NatureServe (2024) reports *C. zenithicus bartletti* as an “intraspecies” of Shortjaw Cisco, and also lists Bluefin, *C. reighardi dymondi* and Longjaw Cisco in synonymy with Shortjaw Cisco.

*Genetic description*

The origins of intra-lake cisco diversity wherein several species/forms occur in sympatry has been explored through various conceptual models (reviewed in Turgeon and Bourret 2013 and Turgeon et al. 2016). Owing to phenotypic plasticity and capacity for local adaptation, one possible explanation is that all forms/species in the same waterbody represent a single lineage, with morphological differences merely reflecting particular lake environments. This “plasticity theory” is akin to but distinct from the view that cisco diversity is best explained by way of adaptive radiation of Cisco *sensu stricto* (i.e., *C. artedi*) following colonization of the proglacial, ancestral Great Lakes from glacial refugia, in which all deepwater ciscoes are treated as a morphotype within a broadly defined Cisco (Koelz 1929; Clarke 1973; Eshenroder et al. 2016; Eshenroder and Jacobson 2020). A separate possibility is that the forms/species occurring in sympatry reflect post-glacial colonization of a waterbody by genetically independent lineages from different source populations.

The plausibility of these hypotheses was considered through genetic and morphological study of Shortjaw Cisco and Cisco by Turgeon and Bourret (2013) and Turgeon et al. (2016), who concluded that neither hypothesis fit the observed data. Rather, the authors posited that the emergence of Shortjaw Cisco (alongside Cisco) in the investigated waterbodies ranging from Algonquin Provincial Park (PP) in Ontario to the Northwest Territories reflected a series of recent (i.e., post-glacial) and independent speciation events occurring repeatedly (i.e., in parallel) across its North American range, and was thus termed the “Parallel Origins Hypothesis”. In these studies, Shortjaw Cisco was found to be morphometrically distinguishable from sympatric Cisco (particularly in gill raker number and jaw morphology), but such differences across lakes were not consistent to the extent that some Shortjaw Cisco closely resembled Cisco in other waterbodies. It was further found that Shortjaw Cisco were more closely aligned genetically with sympatric morphotypes of Cisco than to Shortjaw Cisco from other lakes. Similar results have been obtained through study of sympatric forms of Cisco and Blackfin Cisco, in which both species were more closely related genetically when in sympatry and more genetically differentiated from conspecifics in other lakes, suggesting repeated in-situ origins for the diversity observed (Piette-Lauzière et al. 2019). Taken collectively, these studies found no evidence of a phylogenetically distinct taxon referrable to either “Shortjaw Cisco” or “Blackfin Cisco” beyond the scale of an individual lake, implying that each entity actually represents a collection of entities with multiple evolutionary origins, having speciated independently and in parallel (at least within the waterbodies investigated) and converging on a common phenotypic variant (e.g., low gill rakered form). This speciation process would be superimposed over disparate and hydrologically disconnected lakes across the post-glacial landscape, creating numerous opportunities for emergence of sympatric cisco forms where suitable conditions are present (including a form with a low gill-raker count which has traditionally been called “Shortjaw Cisco”).

Previous genetic investigations which considered allelic diversity (Todd 1981), mitochondrial DNA (mDNA; Reed et al. 1998), and microsatellite polymorphisms (Turgeon and Bernatchez 2003) were unable to reveal differences between Shortjaw Cisco and other ciscoes occurring in sympatry. Traditional genetic analyses involving mDNA and microsatellite markers have generally been unable to resolve differences among cisco species/forms (N. Mandrak pers. comm. 2024; O. Gorman pers. comm. 2024). Even in circumstances of clear morphological variation between cisco morphotypes, corresponding genetic variation has sometimes remained elusive (Turgeon and Bernatchez 2001a, 2001b; Turgeon et al. 2016). Analyzing a larger portion of the genome is often required to genetically discriminate between ciscoes which are comparatively “young” species in evolutionary terms (Ackiss et al. 2020). Evidence for the genetic distinctiveness of Shortjaw Cisco relative to sympatric ciscoes in Ontario was first revealed using Amplified Fragment Length Polymorphism (AFLP) markers (Turgeon and Bourret 2013; Turgeon et al. 2016; S. Reid pers. comm. 2024), with purported evidence ranging from strong (e.g., Lake Nipigon, Trout Lake, Lake of the Woods), to weak (White Partridge Lake, Lake Superior), to absent (Brule Lake). This work found no evidence that Shortjaw Cisco represented a homologous lineage as the species was always more closely related to other sympatric ciscoes than allopatric populations of Shortjaw Cisco from other waterbodies (Turgeon and Bourret 2013; Turgeon et al. 2016).

Newer and more advanced genomic tools – including restriction site-associated DNA (RAD) sequencing (Ackiss et al. 2020) and transcriptomics (Bernal et al. 2022) – have been able to distinguish previously unresolved differences among ciscoes, including the identification of specimens to particular species/forms and detection of hybrids. RAD sequencing has successfully discriminated between Cisco, Bloater and Kiyi (as well as hybrids) from specimens collected in Lake Superior (Ackiss et al. 2020). Transcriptome sequencing (also known as RNA-sequencing) was successfully employed alongside morphometrics and stable isotope analysis to distinguish low levels of genetic differentiation between Shortjaw Cisco and Bloater (Bernal et al. 2022). Recent and unpublished genomic analyses of scale samples by Dr. Amanda Ackiss at the United States Geological Survey (USGS) and colleagues revealed that contemporary specimens identified as Shortjaw Cisco from Lake Superior aligned genetically with historical Shortnose Cisco records from Lake Michigan, leading to the “rediscovery” of Shortnose Cisco from Lake Superior (T. Pratt pers. comm. 2024) while simultaneously casting doubt on the present and historical status of Shortjaw Cisco therein (now the subject of further study).

### *Species identification*

Throughout the twentieth century, Shortjaw Cisco (like all fishes) was differentiated solely on the basis of morphometrics, which incorporated both morphology (e.g., body shape) and meristics (e.g., gill raker counts). Such an approach to taxonomy and species assignment (which held sway until genetic techniques emerged) presents obvious limitations when applied to phenotypically plastic groups such as Coregonines. Previous efforts to typify the physical appearance of Shortjaw Cisco (and other deepwater ciscoes) in specific waterbodies (e.g., Dymond 1926; Koelz 1929; Muir et al. 2014; Eshenroder et al. 2016) or geographic regions (e.g., Dymond and Pritchard 1930; Dymond 1943; Clarke 1973; Becker 1983; Scott and Crossman 1998) remain valuable but cannot definitively depict a “representative form” of the species in light of several confounding and interwoven factors:

- **Varying character traits:** Shortjaw Cisco possesses a high capacity to modify its outward appearance in response to environmental stimuli (phenotypic plasticity) resulting in considerable variation in physical traits such as size and head shape (Muir et al. 2011). Such variation is known both within (Clarke 1973; Bailey and Smith 1981; Gorman and Todd 2007) and across (Boguski et al. 2014; Turgeon et al. 2016) waterbodies. Differences in local biophysical conditions (e.g., lake morphometry, predator-prey dynamics) partly or substantially explain the morphological patterns observed (Ridgway et al. 2022). Varying physical traits may even occur in the absence of environmental cues; snout length, eye diameter and maxillary length of lab reared Shortjaw Cisco were found to be highly variable between parents and offspring (Todd et al. 1981).
- **Phenotypic changes over time:** Temporal changes in biophysical conditions may meaningfully affect outward appearance given the strong influence of environment on phenotype expression. Subtle but remarkable deviations in certain Shortjaw Cisco character traits have been discovered across collections from the early twentieth, mid-twentieth, and twenty-first centuries, such as steepness of the premaxillary angle and body size (Eshenroder et al. 2016). These temporal phenotype changes could have resulted from genetic drift, introgression/hybridity with other ciscoes, differing selection pressures, or a combination thereof (Eshenroder et al. 2016).
- **Likelihood of misidentification:** Many character traits used to discriminate cisco species overlap, which increases the possibility of attribution errors. The number of specimens assigned to Shortjaw Cisco forming part of species treatments and/or scientific study that in fact represent other cisco taxa is unknown but may be meaningful. In studying ecomorphological concordance in Lake Nipigon ciscoes, Turgeon et al. (1999) remarked that atypical specimens of Shortjaw Cisco (“morphotype B”) might represent Nipigon Cisco. Bernal et al. (2022) similarly acknowledged that putative Shortjaw Cisco in their study may have been misidentified (i.e., specimens of Shortjaw Cisco may not have been collected at all) given the range of premaxillary angles observed which overlapped considerably with Bloater (along with the results of the isotopic analysis). Classification success can be applied to report concordance between morphological and genetic identification, and vice versa (Turgeon et al. 2016). Recent genomic assessments have revealed probable misidentifications of historical deepwater cisco collections determined on the basis of morphology alone (O. Gorman pers. comm. 2024). Morphology-based identification is further

complicated by phenotypic plasticity and temporal shifts in character traits as described above.

- **Shifting taxonomic framework:** Other members of the deepwater cisco complex have been variously synonymized with and separated from Shortjaw Cisco on multiple occasions (e.g., Todd and Smith 1980). Previously published treatments pronouncing ranges of key morphometrics become unreliable (if not obsolete) when specimens used to produce such ranges are relocated to another taxa. Eshenroder et al. (2016) highlight the resulting increase in maximum standard lengths of Shortjaw Cisco originally reported by Koelz (1929) had Bluefin been treated in synonymy at that time (as accepted today). This shifting taxonomy was historically driven by differences in professional opinion, arising from adoption of genetic and ecological (e.g., stable isotope) criteria which have greatly influenced cisco systematics.

Ontogenetic changes in certain cisco character traits (e.g., orbital size, gill raker length) emerge as individual fish progress through successive life stages and may also complicate identification, though taxonomic keys relied on by practitioners (e.g., from Koelz 1929; Eshenroder et al. 2016) relate only to adult fish (O. Gorman pers. comm. 2024).

The need for multivariate approaches to guide morphologically-based cisco identification has been known for some time (Clarke 1973). No single diagnostic character can enable reliable identification of Shortjaw Cisco. Species assignment proceeds by appraising an association or constellation of character traits, of which gill raker (bony projections on the gill arch which aid in retaining food particles) number is critical (Todd 2003) and tends to be less than 40 (Becker 1983). Gill raker number is inherited from female ancestors (Todd and Stedman 1989) and varies less in response to environmental cues than other character traits (i.e., is highly heritable) (Lindsey 1981; Østbye et al. 2005). Gill raker number reflects trophic niche and feeding strategies, with fewer gill rakered species such as Shortjaw Cisco and Shortnose Cisco tending to be less effective in capturing smaller zooplankton prey (Kahilainen et al. 2011).

Published descriptions of Shortjaw Cisco closely resemble Shortnose Cisco which (as described above) was considered extinct until recently (O. Gorman pers. comm. 2024). Clarke (1973, p. 146) described phenotypes of these two ciscoes in the Laurentian Great Lakes as forming “a continuous series with no distinctive features separating them”. Both species share a similar steep premaxillary angle and blunted snouts, traits which are not possessed by other deepwater ciscoes (Eshenroder et al. 2016). Individuals that have been identified as Shortjaw Cisco generally possess a longer maxillary, longer paired fins, and more gill rakers (39 – 43), with Shortnose Cisco possessing fewer gill rakers (34 – 38) (Koelz 1929), though specimens of both species may possess gill raker counts of 32 or lower (Eshenroder et al. 2016). Contemporary collections of Shortjaw Cisco are smaller and can be confused with Bloater and Kiyi, particularly by practitioners with less experience covering the rarer deepwater forms (Eshenroder et al. 2016).

Relative to other deepwater ciscoes, Shortjaw Cisco possesses a uniquely steep premaxillary angle (60 – 75°), truncated snout, and shallow body depth, which (in concert with gill raker number) should be considered alongside other traits including orbital length, jaw characteristics, fin lengths, and paired-fin pigmentation (Eshenroder et al. 2016). Character trait differences amongst deepwater ciscoes are subtle and may reflect weak (and recent) genetic differentiation (Ackiss et al. 2020) and/or incomplete reproductive isolation through allochrony (Smith and Todd 1984).

Numerous studies have reported character traits such as gill raker counts and jaw morphology which fall outside previously published ranges for Shortjaw Cisco in either the Laurentian Great Lakes or inland lakes (e.g., Boguski et al. 2014; Turgeon et al. 2016). Todd and Steinhilber (2002) differentiate a type of Shortjaw Cisco possessing shorter and less numerous gill rakers from two smaller waterbodies (George Lake, Manitoba and Basswood Lake, Ontario) from a type from nine other larger waterbodies possessing longer and more numerous gill rakers. Turgeon et al. (2016) found that jaw morphology was phenotypically distinct within lakes but highly variable across lakes, which (as described earlier) primarily derive from Laurentian Great Lakes specimens. Body length is well known to vary substantially across waterbodies.

Eshenroder et al. (2016) recommend the use of lake-based morphological keys for Coregonines over a single universal key, and further emphasized the utility in applying a probabilistic, weighted approach to discriminate the most critical traits (rather than selecting between two mutually-exclusive options, as is the case with dichotomous keys). Given the extensive limitations and low success of morphologically-based identification, species recognition and assignment in the North American cisco complex should rely on a combination of morphological and genetic/genomic evidence (Turgeon et al. 2016; Ackiss et al. 2000), ideally paired with biological or ecological evidence such as stable isotope analysis (Schmidt et al. 2011; Bernal et al. 2022).

## Species biology

The study of Shortjaw Cisco biology (and that of the broader cisco complex) is notoriously fraught with challenges arising from phenotypic plasticity, temporal changes in physical appearance, shifting taxonomic treatments, and overall identification issues. Coupled with the need to disentangle Laurentian Great Lakes populations from inland lake populations, which have unique evolutionary and ecological contexts, Shortjaw Cisco biology is poorly understood.

Recognizing the uncertainties and limitations inherent in our current taxonomic and biological understanding of Shortjaw Cisco, and the need to separate Shortjaw Cisco biology in the Laurentian Great Lakes (including Lake Nipigon) from inland lakes, the information presented as follows overlaps with three general categories of knowledge:

- Knowledge of entities described as Shortjaw Cisco (to date) which inhabit the Laurentian Great Lakes (inclusive of Lake Nipigon);

- Knowledge of entities described as Shortjaw Cisco (to date) which inhabit inland lakes (i.e., waterbodies excluding the Laurentian Great Lakes); and
- Knowledge of deepwater ciscoes generally (in both the Laurentian Great Lakes and inland lakes) where insights about Shortjaw Cisco biology can be inferred.

Scant information is available to inform a biological description of Shortjaw Cisco from inland lakes in Ontario, thus there is limited presentation of such information for these populations below.

*Growth and maturity*

Shortjaw Cisco undergo significant periods of growth during their first year, with females typically growing more quickly than males (Todd 2003). Mean population age in Lake Nipigon was found to be 12 years and dominated by females (65%), which are longer-lived than males (Pratt 2013). These findings may reflect broader patterns for ciscoes in the Laurentian Great Lakes, as surveys conducted in Lake Superior found that females dominated sex ratios for all cisco species present in the lake (Pratt and Chong 2012). Similarly, female ciscoes in Lake Superior tended to grow larger and live longer than their male counterparts (Pratt and Chong 2012), conditions also reported for Shortjaw Cisco (Alberta Environment and Sustainable Resource Development 2014). Maximum sizes reported vary between waterbodies, with some adults measuring less than 150 mm (millimetres) up to a maximum of 467 mm standard length (Pratt et al. 2008), with some of the largest specimens reported from Alberta (Alberta Environment and Sustainable Resource Development 2014). Maximum ages of specimens from Ontario are 26 years (Lake Nipigon; Pratt 2013) and 25 years (Lake Superior; Pratt and Chong 2012). Sexual maturity is thought to occur at year five (Todd 2003).

Information regarding development and life stages of Shortjaw Cisco is scant. Shortjaw Cisco has been reported to reach 90 mm in total length by age one (Pratt et al. 2008), and larval and juvenile life stages are considered most vulnerable (Todd 2003).

*Reproductive biology and spawning*

Shortjaw Cisco spawning is generally believed to have occurred in the fall in Lake Michigan and Lake Huron (Todd 2003), although Todd and Smith (1980) documented late fall (November to December) and spring (May to June) spawning in Lake Superior. Koelz (1929) observed female Shortjaw Cisco approaching ripeness in June in Whitefish Bay, Lake Superior. Spawning times of Shortjaw Cisco in inland lakes are unknown.

Shortjaw Cisco are broadcast spawners, with females depositing eggs over the lake bottom to be fertilized by males (often over clay in the Laurentian Great Lakes), and require a three-month development period, although rates are temperature dependent (Todd 2003). Water temperature requirements for egg development are not known, although Todd et al. (1981) successfully incubated wild caught Shortjaw Cisco eggs in a hatchery setting at a mean daily temperature of six degrees Celsius. Shortjaw Cisco are not known to exhibit parental care of young (Berlin et al. 1977) and fecundity remains a knowledge gap, although it is expected to be similar to other deepwater ciscoes such as Bloater which may produce a number of eggs ranging from 3,230 to 18,768 depending on fish size (Emery and Brown 1978).

*Diet and trophic interactions*

Ciscoes are generally considered particulate feeders, ingesting prey items opportunistically as food particles become trapped by their gill rakers when they encounter them (Todd 2003). Owing to depth distribution, the diets of deepwater ciscoes within the Great Lakes are typically comprised of copepods (Copepoda) and water fleas (Cladocera) alongside benthic invertebrates such as benthic crustaceans (*Mysis* spp.) and *Diporeia* spp. (Todd 2003). Ciscoes occupying inland lakes in Algonquin PP are known to feed exclusively on Opossum Shrimp (*M. diluviana*) in lakes where these organisms are present, choosing phantom midges (*Chaoborus* spp.) in their absence (Ridgway et al. 2020; Ridgway et al. 2022; Reid and Dextrase 2024). The importance of Opossum Shrimp to ciscoes occupying many inland lakes cannot be overstated, and their presence (in combination with waterbody depth) is hypothesized as a predictor of cisco diversity by facilitating niche opportunity (Ridgway et al. 2020; Ridgway et al. 2022).

Hoff and Todd (2004) found that Opossum Shrimp formed much of the diet of Shortjaw Cisco captured in Lake Superior, and Shortjaw Cisco in Lake Nipigon are also considered *Mysis* spp. specialists (Pratt 2013). Wain (1993) found that Cisco and Shortjaw Cisco (i.e., diet not differentiated by species) primarily fed on large calanoid copepods (98.2% of diet), along with negligible Opossum Shrimp (1.4%) and algae (0.4%).

Analysis of stable carbon and nitrogen isotope ratios from museum archived and contemporary tissue samples revealed that Shortjaw Cisco and other sympatric ciscoes from the upper Great Lakes and Lake Nipigon (i.e., exclusive of Lake Erie and Lake Ontario) exhibited clear and significant ecological differentiation (Schmidt et al. 2011). Niche partitioning was suggested both over time and among lakes for all periods. Isotope ratios for Blackfin Cisco and Shortjaw Cisco aligned more closely in Lake Superior. A separate isotopic analysis from Lake Superior suggested that Shortjaw Cisco occupies a wide trophic niche, feeding opportunistically in both the benthic and pelagic zones and occupying similar intermediate water depths and trophic position as Bloater (Bernal et al. 2022).

Within the Laurentian Great Lakes, Shortjaw Cisco may also act as an important prey source for the native apex predator Lake Trout (*Salvelinus namaycush*) and Burbot (*Lota lota*) (Blanke et al. 2018; Pratt et al. 2008). Deepwater ciscoes within the Great Lakes are generally considered important prey items for native predators. Downward shifts in trophic position resulting from anthropogenic stressors, such as heavy commercial harvesting of larger fish, have been documented in deepwater ciscoes from Lake Michigan and Lake Superior over the past century using stable isotope analysis (Blanke et al. 2018).

*Movement patterns*

Seasonal differences in depth occupancy were reported historically in Lake Superior based on depth variance in spring (110 – 144 m), summer (55 – 71 m) and winter (73 – 90 m) captures (Dryer 1966), although contemporary data are lacking.

## 1.3 Distribution, abundance and population trends

Outside of Ontario, Shortjaw Cisco has also been described from the Canadian provinces of Manitoba (Boguski et al. 2014), Saskatchewan (Houston 1988; Todd 2003), Alberta (Steinhilber and Rhude 2001) and the Northwest Territories (Muir et al. 2014) along with Minnesota, Wisconsin, Illinois, Indiana and Michigan (which border the upper Great Lakes and/or southern Lake Michigan) in the United States (US).

All waterbodies in which Shortjaw Cisco has been documented in Ontario and is assumed to be currently extant are listed below in Table 2 and illustrated in Figure 2. The distribution as currently understood overlaps with three Great Lakes (Huron, Michigan, and Superior), Lake Nipigon and eleven inland lakes. As noted later in this section, the presence of Shortjaw Cisco in certain inland lakes is based on historical and questionable morphological information (e.g., Attawapiskat Lake) or on low-gill raker counts without other corresponding differences in character traits from sympatric Cisco (e.g., Brule Lake, S. Reid pers. comm. 2024). For consistency with current published accounts of the species' distribution (per peer-reviewed or grey literature, government documents, and/or NHIC), all lakes in which Shortjaw Cisco has previously been described are noted in Table 2 below.

Table 2. Waterbodies historically and/or currently inhabited by Shortjaw Cisco in Ontario (modified from Todd 2003 and unpublished COSEWIC documentation received from N. Mandrak) based on current understandings of taxonomy and distribution.

| Waterbody | Generalized Location in Ontario | Species/Forms Present | Primary Source of Shortjaw Cisco Record(s) | Additional Relevant References |
|---|---|---|---|---|
| **Laurentian Great Lakes** | | | | |
| Lake Huron | Great Lake | *C. alpenae*<br>*C. artedi*<br>*C. hoyi*<br>*C. johannae*<br>*C. kiyi*<br>*C. nigripinnis*<br>*C. reighardi*<br>*C. zenithicus* | Koelz (1929) | Scott and Crossman (1973), Eshenroder et al. (2016) |

| | | | | |
|---|---|---|---|---|
| Lake Michigan | Great Lake | *C. alpenae*<br>*C. artedi*<br>*C. hoyi*<br>*C. johannae*<br>*C. kiyi*<br>*C. nigripinnis*<br>*C. reighardi*<br>*C. zenithicus* | Koelz (1929) | Scott and Crossman (1973), Eshenroder et al. (2016) |
| Lake Nipigon | North of Lake Superior | *C. artedi*<br>*C. hoyi*<br>*C. nigripinnis*<br>*C. reighardi*<br>*C. zenithicus* | Dymond (1926) | Scott and Crossman (1973), Eshenroder et al. (2016) |
| Lake Superior | Great Lake | *C. alpenae*<br>*C. artedi*<br>*C. hoyi*<br>*C. kiyi*<br>*C. nigripinnis*<br>*C. reighardi*<br>*C. zenithicus* | Koelz (1929) | Scott and Crossman (1973), Eshenroder et al. (2016) |
| **Inland Lakes** | | | | |
| Attawapiskat Lake | Kenora District | *C. artedi*<br>*C. zenithicus* | Ryder et al. 1964 | Clarke (1973) |
| Brule Lake | Frontenac County | *C. artedi*<br>*C. zenithicus* | Turgeon and Bourret (2013), Turgeon et al. (2016) | -- |
| Deer Lake | Kenora District | *C. zenithicus* | Clarke (1973) | -- |
| Gunflint/Magnetic Lake | Thunder Bay District (along Minnesota/ON border) | *C. artedi*<br>*C. zenithicus* | Ethier and Skelton (2003) | -- |
| Lac Seul | Kenora District | *C. nigripinnis*<br>*C. zenithicus* | Dymond and Pritchard (1930) | Clarke (1973) |
| Lake of the Woods | Rainy River/Kenora District | *C. artedi*<br>*C. zenithicus* | Turgeon and Bernatchez (2001a) | Turgeon and Bernatchez (2003), DFO (2013a), Turgeon and Bourret (2013), Turgeon et al. (2016) |
| Lake Saganaga | Rainy River/Thunder Bay District (along Minnesota/ON border) | *C. artedi*<br>*C. nipigon*<br>*C. zenithicus* | Ethier and Skelton (2003), Turgeon and Bernatchez (2001a, 2003) | |

| | | | | |
|---|---|---|---|---|
| Sandy Lake | Kenora District | *C. zenithicus* | Clarke (1973) | -- |
| Sandybeach Lake (Big Sandy Lake) | Kenora District | *C. artedi*<br>*C. zenithicus* | Wain (1993) | DFO (2013a), Reid and Wain (2016), |
| Trout Lake | East of North Bay | *C. artedi*<br>*C. zenithicus* | Turgeon and Bourret (2013) | Clarke (1973), DFO (2013a), Turgeon et al. (2016). |
| White Partridge Lake | Algonquin PP | *C. artedi*<br>*C. zenithicus* | Turgeon and Bernatchez (2001a) | DFO (2013a), Turgeon and Bernatchez (2003), Turgeon and Bourret (2013), Turgeon et al. (2016) |

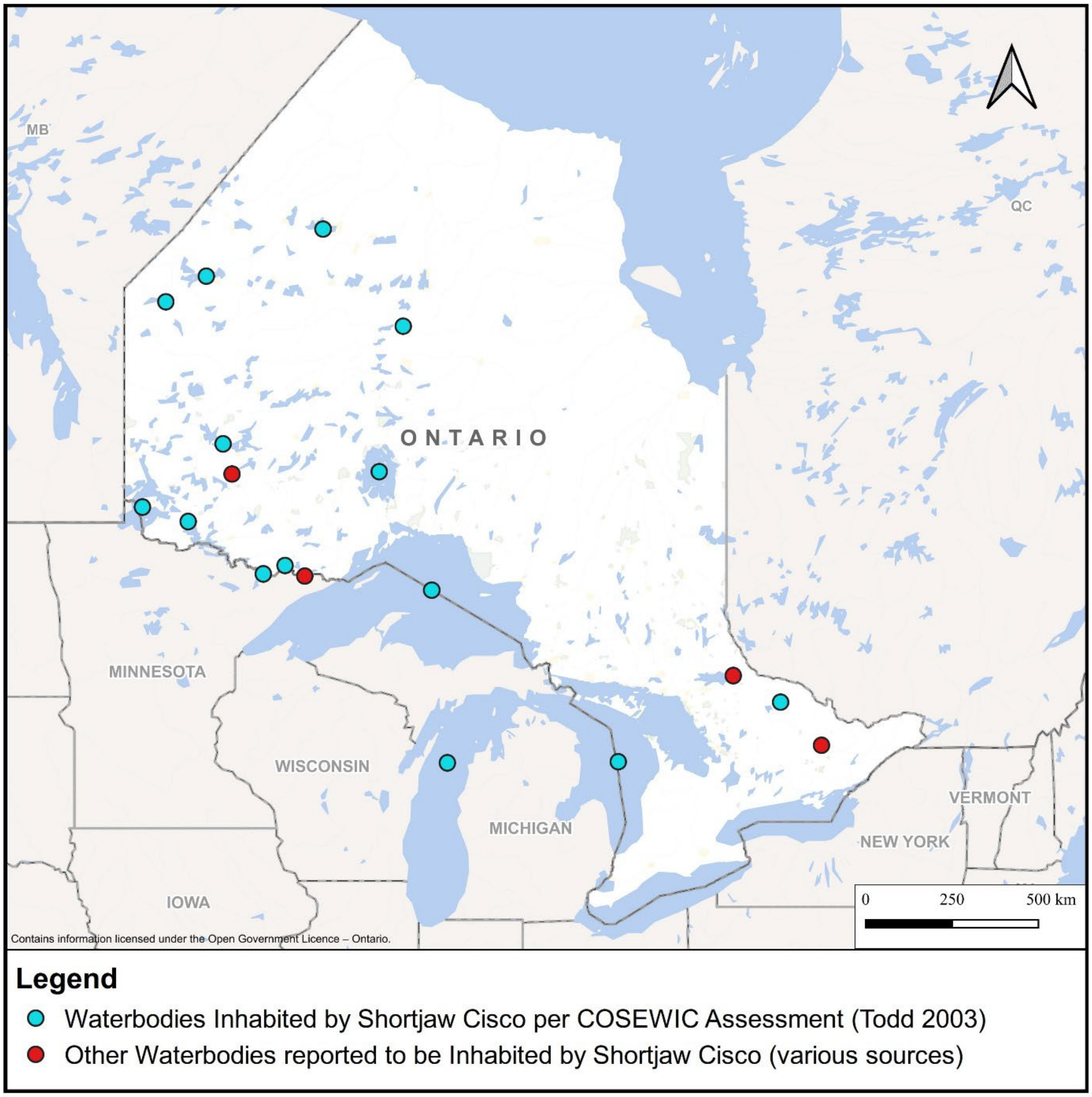

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Figure 2. Reported distribution of Shortjaw Cisco in Ontario.

### Ancestral lineages

Freshwater fish habitats were absent from Ontario during maximum ice coverage associated with the Wisconsinan glacial period (Mandrak and Crossman 1992), which forced fish movement to refugia beyond the glacial margins. Following glacial retreat from Ontario (circa 8,000 to 15,000 years ago, depending on location), fish accessed new habitats in lakes and rivers supported by glacial meltwater. Much North American fish speciation is theorized to derive from these diverse habitats which became available after glacial retreat, with some referring to this period as a “postglacial speciation burst” (Turgeon et al. 1999). Ciscoes within the Laurentian Great Lakes (and inland lakes) are no exception.

Genetic evidence from the past two decades is strongly suggestive of two separate cisco lineages having colonized the post-glacial landscape in Ontario, originating in the Atlantic Coastal refugium (eastern) and Mississippian refugium (western) (Turgeon and Bernatchez 2001a, 2001b; Turgeon et al. 2016). Others have speculated that sub-refugia within the two main refugia (i.e., Atlantic Coastal and Mississippian) may have also been present (Eshenroder and Jacobson 2020). The existence of two distinct refugia is supported by evidence of genetic clustering in an east to west pattern. The eastern cluster included Lake Superior and all inland lakes east/southeast of Georgian Bay, while the western cluster included Scorch Lake (southwest of Timmins, Ontario), Lake Nipigon, Lake-of-the-Woods, and other lakes to the northwest in Manitoba and the Northwest Territories (Turgeon et al. 2016). Specimens from Lake Huron and Lake Michigan were not included in the study but based on geography may align with the eastern cluster. As described earlier, Cisco and Shortjaw Cisco morphotypes occurring in sympatry (and in the same eastern or western genetic cluster) were found to be more closely related to each other than to conspecifics in allopatry from the opposing genetic cluster (Turgeon et al. 2016). Similar results were obtained in a study of Cisco and Blackfin Cisco in Algonquin PP and Lake Nipigon (Piette-Lauzière et al. 2019), wherein each separate morphotype was more closely related genetically to the sympatric morphotype than putative conspecifics in other waterbodies.

### Laurentian Great Lakes and Lake Nipigon

Lake Superior is the largest, deepest, and coldest of the Laurentian Great Lakes, conditions which are generally conducive to the development and maintenance of a cisco species flock. Of all the Great Lakes, Lake Superior contains the most intact assemblage of cisco taxa encompassing Cisco, Bloater, Kiyi, Shortjaw Cisco and Blackfin Cisco (Bunnell et al. 2023). As noted previously, emerging research based on a combination of morphological and genomic evidence points to the likely presence of Shortnose Cisco within Lake Superior, a species previously thought extinct (O. Gorman pers. comm. 2024).

Current taxonomic challenges notwithstanding, it is widely reported that Shortjaw Cisco abundance in Lake Superior has plummeted such that it went from the most abundant to one of the least frequently captured cisco species in recent years (Hoff and Todd 2004; Bronte et al. 2010; Bunnell et al. 2023). Historically (1894 – 1950) commercial yields of deepwater cisco in Lake Superior (consisting of Bloater, Kiyi and Shortjaw Cisco) totaled 11 million metric tons, with Shortjaw Cisco representing the majority of catches (Hoff and Todd 2004). Contemporary surveys conducted by Hoff and Todd (2004) within the US waters of Lake Superior replicating earlier sampling efforts found that Shortjaw Cisco relative abundances had declined by at least 99 percent and were “so low that they were not significantly different from zero” (Hoff and Todd 2004). Similarly, Bronte et al. (2010) report that Shortjaw Cisco comprised less than one percent of captures during contemporary surveys.

Surveys conducted in Canadian waters of Lake Superior in 2004 replicating the methods used by Koelz (1929) found that Shortjaw Cisco comprised 10 percent of the deepwater cisco assemblage (Pratt and Mandrak 2007). Although these numbers were significantly lower than those reported in the 1920s, they exceeded numbers reported in other areas of the lake (Pratt and Mandrak 2007). Specimens included within the 2007 study were identified based on presence of an included jaw along with the presence of few/short gill rakers (Pratt and Mandrak 2007). Later surveys conducted by Pratt (2012) found that Shortjaw Cisco remained widespread across the lake, particularly within embayment areas, but was no longer the dominant deepwater cisco species.

Some authors (e.g., Lawrie and Rahrer 1973) attribute Shortjaw Cisco declines in Lake Superior to commercial overharvest, while others (see Bronte et al. 2010) propose that a decline in keystone predators (Lake Trout) released Shortjaw Cisco from predation pressure, leading to trophic changes. These Shortjaw Cisco population declines are thought to have occurred prior to Sea Lamprey (*Petromyzon marinus*) and Rainbow Smelt (*Osmerus mordax*) introductions (Bronte et al. 2010).

The fish community of Lake Nipigon has traditionally been discussed alongside the Laurentian Great Lakes owing to its size and historical hydrologic connection to Lake Superior, having formed a northern bay within broader glacial Lake Algonquin (Dymond 1926). Despite the fact that existing genetic evidence suggests that Shortjaw Cisco in Lake Nipigon aligns with the western cisco cluster whereas Shortjaw Cisco in Lake Superior aligns with the eastern cisco cluster (Turgeon et al. 2016), fish biologists have continued to consider the cisco complex in Lake Nipigon as part of the broader Laurentian Great Lakes (S. Reid pers. comm. 2024).

Lake Nipigon is the shallowest of the Laurentian Great Lakes, is dotted with islands, and outflows to the Nipigon River ultimately discharging to Lake Superior at Nipigon Bay. Koelz (1929) hypothesized that the waterfall at the river’s source acted as a barrier to fish passage from Lake Superior. Shortjaw Cisco has been identified consistently in Lake Nipigon since the 1920s; however, a decline of greater than 50 percent has been observed from 1998/1999 through 2008/2009 (Pratt 2013). Pratt (2013) suggests that declines in Lake Nipigon may be more significant but cannot be confirmed due to a lack of historical sampling data. Shortjaw Cisco included in the study were identified on the basis of morphology (gill raker and head morphology) as well as partial microsatellite differentiation (Turgeon et al. 1999; Pratt 2013). It is hypothesized that declines in Lake Nipigon are being driven by changes in the food web (such as those arising from invasive species introductions) as commercial fishing operations are not prevalent (Pratt 2013).

Lake Huron is the second largest of the Great Lakes, receiving water from Lake Superior through the St. Marys River and Lake Michigan through the Straits of Mackinac. Historically, Lake Huron supported Blackfin Cisco, Cisco, Deepwater Cisco, Kiyi, Shortnose Cisco, and Shortjaw Cisco (Mandrak et al. 2014). Based on the historical Koelz (1929) survey data, Shortjaw Cisco (including the previously synonymized Longjaw Cisco) comprised approximately 25 percent of the deepwater cisco community in Lake Huron, although the species was considered uncommon in

Georgian Bay. Surveys conducted in the 1950s reflect similar conditions, with Shortjaw Cisco comprising 19 percent of the total deepwater cisco catch (Mandrak et al. 2014).

Until recently, the last verifiable record of Shortjaw Cisco in Lake Huron derived from a 1982 specimen collected near Southampton, Ontario, and as a result the species was considered extirpated from the lake (Mandrak et al. 2014). Recent intensive sampling efforts undertaken between 2002 and 2012 appeared to reveal that Shortjaw Cisco was still present in Lake Huron, albeit in extremely low numbers (Mandrak et al. 2014). Shortjaw Cisco was collected in Lake Huron from the North Channel basin (located north of Tobermory) in 2007, and at five sites near Lion's Head in 2012 (Mandrak et al. 2014). These records of Shortjaw Cisco have since been reclassified as part a broad "hybrid swarm" complex also consisting of Bloater, Kiyi, Longjaw Cisco, and Shortnose Cisco (Eshenroder et al. 2016). Shortjaw Cisco is therefore now considered introgressed in Lake Huron.

No evidence exists to suggest that Shortjaw Cisco was ever present in Lake Erie, which is shallow and generally not conducive to facilitating or maintaining cisco diversity. Historically, Lake Erie contained Cisco (as well as a second form of Cisco: *C. artedi albus*) and Longjaw Cisco (Bunnell et al. 2023; N. Mandrak pers. comm. 2024). Previous reports (e.g., Todd 2003) reference the presence of Shortjaw Cisco in Lake Erie; however, this reflects changing taxonomy as Longjaw Cisco was synonymized with Shortjaw Cisco until recently (Page et al. 2023) as discussed above.

Lake Ontario is the smallest Laurentian Great Lake by surface area and is known for steeply sloping shores, outletting to the St. Lawrence River. Shortjaw Cisco has never been reported in Lake Ontario, although the lake is thought to have contained a cisco species flock comprised of Shortnose Cisco, Bloater, and Cisco (Bunnell et al. 2023). Lake Ontario currently supports Cisco, though in numbers which are greatly reduced from historical abundances (Bunnell et al. 2023).

### Inland lakes

The evolutionary circumstances in which Shortjaw Cisco has emerged in inland lakes are uniquely different and best considered separately from the Laurentian Great Lakes (S. Reid pers. comm. 2024; M. Ridgway pers. comm. 2024). Uncertainty remains in relation to whether Shortjaw Cisco within the Laurentian Great Lakes (and Lake Nipigon) have a shared phylogenetic history with populations in inland lakes (Pratt et al. 2008; DFO 2013a; Reid and Dextrase 2024). No formal or comprehensive taxonomic evaluations have been undertaken for inland lakes purported to be inhabited by Shortjaw Cisco (Pratt et al. 2008). Cisco diversity in the inland lakes of Ontario is thought to extend only to Cisco, Blackfin Cisco and Shortjaw Cisco (DFO 2013a), though the recently recognized Nipigon Cisco should also be included given reports from Lake Saganama (Etnier and Skelton 2013).

Despite long-standing recognition of Shortjaw Cisco from the Laurentian Great Lakes (including Lake Nipigon), some authors have wondered whether the species occurs in inland lakes at all (e.g., Scott and Crossman 1998) even prior to the advent of genetic tools. Taxonomic keys are shaped by the specimens used to produce them and are thus limited in application to the spatial areas from which the collections derive (N. Mandrak pers. comm. 2024). Ichthyologists and research scientists working in inland lakes historically applied keys supporting Coregonine identification from the Laurentian Great Lakes (e.g., Dymond 1926; Koelz 1929) out of convenience as lake-specific resources were not available (S. Reid pers. comm. 2024; N. Mandrak pers. comm. 2024). Ryder et al. (1964) tentatively assigned specimens from Big Trout Lake and Attawapiskat Lake to Shortjaw Cisco, suggesting that additional systematic study was required for verification (and wrote similarly for Blackfin Cisco). Clarke (1973) appears to have assigned the collection from Attawapiskat Lake to Cisco (i.e., *C. artedi*). Despite this, both records were accepted as “reported localities” for Shortjaw Cisco in the 2003 COSEWIC Assessment and Status Report (Todd 2003). Turgeon et al. (2016) suggest recognizing inland Shortjaw Cisco as morphotypes of *C. artedi* and abandoning use of a scientific binomial to describe it, recognizing that each inland lake population represents a wholly unique evolutionary outcome. The 2013 DFO Scientific Advisory Report (DFO 2013a) describes inland lake cisco diversity as being comprised of Cisco, Blackfin Cisco and “putative” Shortjaw Cisco. Further complicating the study of inland lake Shortjaw Cisco are populations which exhibit gill raker counts and snout angles “outside ranges reported for the Great Lakes” (Turgeon et al. 2016).

The presence of functionally complex assemblages of Opossum Shrimp has been theorized to facilitate cisco form diversity within the Laurentian Great Lakes (Eshenroder and Burnham-Curtis 1999), with morphological variation driven by niche opportunity/availability. The development of cisco species pairs in smaller inland lakes (e.g., either Cisco/Shortjaw Cisco or Cisco/Blackfin Cisco) appears to have arisen from complex interplay between post-glacial colonization, waterbody depth, and presence of Opossum Shrimp prey sources (Ridgway et al. 2020; Ridgway et al. 2022). Opossum Shrimp distribution in contemporary North American lakes is predicated on lake depth and elevation in relation to post-glacial lake inundation levels (Ridgway et al. 2022; M. Ridgway pers. comm. 2024). In other words, lakes with sufficient depth which were colonized by Opossum Shrimp (being within the envelope of a proglacial lake) possess a greater potential to support multiple forms of cisco (i.e., species pairs or flocks). Based on a subset of the HydroLAKES dataset (which included lake depth data) and presumed presence of Opossum Shrimp, Ridgway et al. (2022) identified 1,019 inland lakes which could support multiple (i.e., two or more) cisco forms, suggesting that less than five percent of lakes supporting multiple cisco forms may be currently known. The presence of Opossum Shrimp in Algonquin PP more than doubled cisco available ecological niche size when compared to lakes where phantom midges were the dominant prey item, with few exceptions.

Shortjaw Cisco has been described from eleven different inland lakes in Ontario (see Table 2) based on specimens possessing physical characters (e.g., gill raker number) that roughly align with published treatments of this species from the Laurentian Great Lakes. This variant is currently known from eleven different waterbodies. It is unknown whether such Shortjaw Cisco-like forms represent a homologous lineage conforming to typical phylogenetic species standards, since the necessary genomic studies have not yet been performed. Whether Shortjaw Cisco in inland lakes derive from an ancestral and phylogenetically valid Shortjaw Cisco species from the Laurentian Great Lakes, or alternatively derive from sympatric conspecifics as implied by recent studies (Turgeon et al. 2016; Piette-Lauzière et al. 2019), or possibly derive from some other species or evolutionary process altogether, requires further exploration.

There is no available (current or historical) information on population abundance or trends for inland lakes.

### Distribution Summary

A summary of the historical and current distribution of Shortjaw Cisco in Ontario based on the studies and information reviewed above is offered as follows:

1. The entity described as Shortjaw Cisco occurring in Ontario waterbodies can be traced to a minimum of two separate ancestral lineages emerging from Atlantic Coastal (eastern) and Mississippian (western) refugia.
2. The entity described as Shortjaw Cisco occurring in Ontario appears (based on current evidence) to represent a repeated pattern of convergent evolution, with no apparent phylogenetic relationship linking the allopatric populations.
3. The historical distribution of Shortjaw Cisco in the Laurentian Great Lakes was thought to have overlapped with Lake Superior (type locality), Lake Nipigon, Lake Huron (including Georgian Bay), Lake Michigan and Lake Erie (due to synonymy with Longjaw Cisco).
4. The current distribution of Shortjaw Cisco in the Laurentian Great Lakes was thought to be restricted to Lake Superior and Lake Nipigon, with populations in Lake Huron and Lake Michigan assumed to be extirpated (or functionally extirpated by introgression).
5. The current status of Shortjaw Cisco in Lake Superior is uncertain as a result of recent (and unpublished) genomic study in which specimens previously ascribed to Shortjaw Cisco were found to be genetically aligned with Shortnose Cisco from Lake Michigan (O. Gorman pers. comm. 2024), as is (by extension) its current status in Lake Nipigon.
6. Resulting from the aforementioned genomic study, the historical status of Shortjaw Cisco in Lake Superior is also uncertain and currently undergoing further study (O. Gorman pers. comm. 2024).
7. Given the above, extirpated populations in Lake Huron and Lake Michigan are also considered uncertain.
8. The entity described as Shortjaw Cisco is no longer considered to be extirpated in Lake Erie as a result of resurrection of the previously synonymized Longjaw Cisco (i.e., the historical distribution of Shortjaw Cisco does not include Lake Erie).
9. Recent genetic study suggests that Shortjaw Cisco (and the similar Blackfin Cisco) in several inland lakes in Ontario does not represent an entity with shared ancestry but has resulted from parallel and repeated speciation events which converged on a similar morphotype in response to niche opportunity.

10. It is possible that many additional inland lakes harbouring Shortjaw Cisco-like fish may be discovered given the widespread availability of suitable conditions for in-situ cisco speciation.

It is emphasized that this summary reflects the best information available to date and should be considered tentative, particularly in light of research led by USGS and partners which is ongoing.

## 1.4 Habitat needs

Owing to the same taxonomic and identification challenges reiterated throughout this recovery strategy, the habitat requirements of Shortjaw Cisco are poorly understood in both the Laurentian Great Lakes and inland lakes. Capture depths of adult specimens (allowing for inferences of physical resource use and trophic niche, at least in later life stages) are more widely reported than other habitat parameters, and often vary significantly between waterbodies. It is generally understood that this species adopts a pelagic/limnetic (open water) life strategy, inhabiting the deep hypolimnion area of lakes due to stable water temperatures and dissolved oxygen (DO) concentrations (Pratt et al. 2008). Prey availability and character adaptations to feeding on Opossum Shrimp (e.g., snout morphology) likely influence depth distribution, as is true for other deepwater ciscoes (Eshenroder et al. 2016). Cisco require coldwater habitat with high levels of DO and temperatures below 17 degrees Celsius in Ontario (Vascotto 2006). Although specific values are not known for Shortjaw Cisco, it is presumed that the species requires similar temperatures and DO concentrations.

### Laurentian Great Lakes and Lake Nipigon

Shortjaw Cisco appears to occupy specific depth distributions in the Laurentian Great Lakes which are both distinctive from or somewhat overlapping with other members of the deepwater cisco complex, depending on the species and lake investigated. Shortjaw Cisco is typically captured at depths ranging from 45 to 144 m within the Laurentian Great Lakes overall (Todd 2003), though accounts from shallower water and in depths of up to 183 m are also known (Scott and Crossman 1998). Kiyi is known to have occupied the deepest waters of the Laurentian Great Lakes both historically and contemporaneously, generally occupying waters greater than or equal to 125 m deep (Gorman and Todd 2007), whereas Bloater tended to be historically captured in the shallowest waters (< 40 m) compared to the other deepwater conspecifics, though it also occupied deeper waters (Schmidt et al. 2011; Eshenroder et al. 2016). Overall, the historical dataset suggests Shortjaw Cisco tended to occupy moderate depth ranges which overlapped substantially with Shortnose Cisco (and were somewhat similar to Bloater) but were deeper than Cisco (and Lake Whitefish) and shallower than Blackfin Cisco, Deepwater Cisco, and Kiyi (Koelz 1929).

In Lake Superior, Koelz (1929) reported the historical depth distribution of Shortjaw Cisco ranging from 20 to 183 m (11 to 100 fathoms), with gillnets set at 27 to 82 m (15 to 45 fathoms) averaging 2.4 times more productivity than those set at 110 to 183 m (60 to 100 fathoms). Dryer (1966) reported Shortjaw Cisco as concentrated at 91 to 108 m (50 to 59 fathoms). More recently, Shortjaw Cisco has been captured across gillnets set at less than 65 m, 65 to 104 m, and greater than 105 m depths (Pratt and Mandrak 2007), though the species may concentrate at "intermediate" depths of 80 to 110 m (Pratt 2012). There is evidence that Shortjaw Cisco is now found at greater depths than historically; Hoff and Todd (2004) found the mean depth of gillnets that captured Shortjaw Cisco (89 m) to be significantly different from those which did not (68 m), with the nets that failed to capture Shortjaw Cisco overlapping with the range of high productivity found by Koelz (1929). In general, deepwater ciscoes in Lake Superior tend to be captured between approximately 30 to 120 m in depth at nearshore sites approximately 5 to 10 km from shore (O. Gorman pers. comm. 2024). Current capture sites closely align with those historically sampled by Koelz (O. Gorman pers. comm. 2024).

In Lake Huron, contemporary sampling efforts by Mandrak et al. (2014) in 2012 resulted in positive collections of Shortjaw Cisco at five locations near Lion's Head (Bruce County, ON) in depths of 77 to 92 m, while two individuals were collected from the North Channel in 2007 at a depth of 59 m over silt substrate. Naumann and Crawford (2009) found depth to be the most important predictor of Shortjaw Cisco occupancy in Lake Huron utilizing modelling based on a combination of water depth, substrate slope, and cliff distance (distance to a sharp change in relief at the lake bottom). No correlation was found between substrate slope or cliff difference and Shortjaw Cisco presence, and depth alone was not considered sufficient to represent the species' habitat adequately (Naumann and Crawford 2009). The authors concluded that habitat for Shortjaw Cisco could not yet be adequately defined in Lake Huron owing to rarity of existing collections data and a need to explore other habitat factors. Spawning is reported over clay in depths of 55 to 91 m (30 to 50 fathoms) between Spectacle Reef and Forty Mile Point (adjacent from the northeastern portion of the upper peninsula, Michigan), said to have been the only spawning location known in Lake Huron, though evidence of spawning (i.e., presence of "small individuals") was noted in the southern section of the lake (Koelz 1929).

There is a dearth of information available pertaining to the habitat associations of the former Shortjaw Cisco population of Lake Michigan, which is believed extirpated. Based on data from the commercial "chub" fishery, Koelz (1929) reported captures of Shortjaw Cisco primarily between 22 to 165 m (12 to 90 fathoms) and reported spawning over clay at depths of 18 to 55 m (10 to 30 fathoms).

Lake Nipigon presents a unique case as the lake is relatively shallow (maximum depth = 165 m) compared to Lake Superior (maximum depth = 406 m), Lake Michigan (maximum depth = 281 m) and Lake Huron (maximum depth = 229 m). Shortjaw Cisco within Lake Nipigon have been found to occupy shallower depths than conspecifics in the Great Lakes. Koelz (1929) reported capture depths in 18 to 27 m (10 to 15 fathoms) and 55 m (30 fathoms; here comprising occupying 43% of the total take), with no captures at 102 m (56 fathoms). Koelz (1929) further reported University of Toronto captures chiefly in less than 55 m (30 fathoms) of water, concluding that the species likely occupies “moderate depth” in Lake Nipigon. Turgeon et al. (1999) reported Shortjaw Cisco with greatest abundance at depths of 10 to 30 m, and secondarily at 30 to 60 m. Pratt (2012) documented a mean capture depth of 30.2 m and no captures at depths greater than 55 m. Dymond (1926) reported a wider range of depth distributions in Lake Nipigon for Shortjaw Cisco, extending between 37 and 91 m. Limited captures below 60 m more recently may indicate more recent changes in depth distribution, though this requires further analysis.

Based on the studies referenced above, depth of capture across the Laurentian Great Lakes overall is reported to extend between 18 to 183 m (Scott and Crossman 1998), 18 to 163 m (Becker 1983), or 20 to 180 m (Lee et al. 1980). The range likely reflects a combination of seasonal movement variability (as reported by Dryer 1966) and lake-specific factors including life history strategies and lake morphometrics.

Spawning areas tend to overlap with the reported depth distributions for the Laurentian Great Lakes. Koelz (1929) reported spawning in the following habitat types:

- **Lake Superior:** clay substrates at depths of 37 to 73 m.
- **Lake Michigan:** sand and clay substrates at depths of 18 to 55 m.
- **Lake Huron (main basin):** clay at depths of 55 to 91 m.

### Inland lakes

No formal or comprehensive taxonomic evaluations have been undertaken for inland lakes purported to be inhabited by Shortjaw Cisco (Pratt et al. 2008), owing to (1) taxonomic uncertainty (as described throughout this recovery strategy), (2) general paucity of detailed habitat descriptions available, and (3) variability of habitat conditions (e.g., lake morphometrics).

The lack of habitat information available for previously described inland lake populations of Shortjaw Cisco is particularly severe and described thusly:

- **Attawapiskat Lake:** Shortjaw Cisco records from this inland lake are attributed to Ryder et al. 1964 (also summarized in Clarke 1973). No corresponding habitat information was provided.
- **Brule Lake** and **Trout Lake:** Evidence of Shortjaw Cisco occupation derives from Turgeon et al. (2016). This study centred on revealing morphological and genetic variation between Shortjaw Cisco and Cisco (i.e., *C. artedi*). No corresponding habitat information is provided.
- **Deer Lake**, **Sandy Lake,** and **Lac Seul:** Clarke (1973) advocating lumping Shortjaw Cisco and Shortnose Cisco into a broad taxon called *C. prognathus* (forming part of Blackfin Cisco, which was subsequently revealed to be invalid) (Todd 1981). It appears that previous recognition of Shortjaw Cisco from these lakes derives from recognition of this broad, low-gill rakered taxon (i.e., “low group”). Clarke (1973) offers no corresponding habitat information. The Sandy Lake specimen was collected by R. A. Ryder in 1961 and is housed at the ROM.

The collection notes provide method of capture but no corresponding habitat information. The Deer Lake specimen was originally collected and referenced in Ryder et al. (1964) and reattributed by Clarke (1973). Again, there is no corresponding habitat information.

- **Gunflint/Magnetic Lake** and **Lake Saganaga:** The presence of Shortjaw Cisco in these lakes derives from Etnier and Skelton (2003). No corresponding habitat information is provided.
- **White Partridge Lake:** Studies involving collections of Shortjaw Cisco from White Partridge Lake (Turgeon and Bernatchez 2001a, 2001b; Turgeon et al. 2016) centred on questions of taxonomy and offered no corresponding habitat information.
- **Sandybeach Lake (Big Sandy Lake):** This Shortjaw Cisco population was originally identified and described during completion of a master’s thesis (Wain 1993, further studied by Reid and Wain 2016). A total of 15 Shortjaw Cisco specimens were captured in pelagic gillnets; however, their presence only became known in the lab during morphological assessment, and thus no habitat information supports this collection (Wain 1993).

Inland lake depths required to support multiple (two or more) cisco morphotypes, coupled with the presence of Opossum Shrimp, range from greater than 25 m to greater than 200 m (Ridgway et al. 2020, 2022). The number of additional lakes harbouring undiscovered sympatric pairs of cisco, with one morphotype being in some cases referrable to a fewer gill rakered Shortjaw Cisco-like entity per current circumscription, could be in the hundreds (Eshenroder and Jacobson 2020) or more (Ridgway et al. 2022). While only a percentage of these inland lakes occur in Ontario, their likelihood of presence is near certain (M. Ridgway pers. comm. 2024).

## 1.5 Threats to survival and recovery

Coregonines historically comprised a significant proportion of the fish biomass within the Laurentian Great Lakes for over a century (Koelz 1929) until overexploitation and introgression led to significant declines and reconstitution of the cisco species complex (Eshenroder et al. 2016; Bunnell et al. 2023). Although there is still much to be learned surrounding the ecology and life history of deepwater ciscoes, and Shortjaw Cisco in particular, it is widely accepted that these marked declines in numbers have their origins in human activities and/or human-induced changes.

As described above, declines in cisco catch numbers have been reported since Koelz (1929). While Shortjaw Cisco may face somewhat different threats today, it is important to understand the legacy of historic stressors as well as the interactions between simultaneously occurring stressors. For instance, Bronte et al. (2010) put forward a compelling alternative to the hypothesis that overfishing was the sole cause of Shortjaw Cisco declines in Lake Superior; suggesting instead that reductions in predatory Lake Trout numbers and the subsequent expansion of *C. artedi* in the lake led to negative interactions between *C. artedi* and Shortjaw Cisco. It is also important to consider that population declines of Shortjaw Cisco in Lake Superior as described by Bronte et al.

(2010) occurred well before the introduction of Rainbow Smelt or Sea Lamprey in Lake Superior. This strongly suggests that many direct threats to Shortjaw Cisco remain a knowledge gap.

It is also understood that losses of a single component of the species flock may have unforeseen outcomes for the remaining organisms. Although there remains much to be learned about the species, the primary threats to the survival and recovery of Shortjaw Cisco based on our current understanding of the species include (1) alterations to food web structure, (2) introduction of invasive (and non-native) aquatic species, (3) human-induced climate change and (4) targeted fisheries and incidental bycatch.

### Alterations to food web structure

Shortjaw Cisco's unique evolutionary origins and innate phenotypic plasticity requires the presence of a unique combination of conditions to allow for maintenance of the traits which comprise our current understanding of the species. Specifically, numerous traits maintained through occupation of a unique trophic niche means Shortjaw Cisco is susceptible to changes in the biological communities they inhabit, including alterations to energy flows which may influence species selection pressures (Todd 2003; Pratt et al. 2008; S. Reid pers. comm. 2024). Specific threats (i.e., human activities) which may produce alterations to food web structures and changes in trophic niche, such as the introduction of aquatic invasive species (AIS), are described separately in greater detail within subsequent sections.

While the extent that human activities may alter Shortjaw Cisco food web structure and trophic niche remains a knowledge gap, deleterious results such as introgressive hybridization have been documented in ciscoes within the Laurentian Great Lakes and whitefishes in Europe. Todd and Stedman (1989) describe suspected introgressive hybridization of Cisco and Bloater in Lake Huron, supported by intermediate gill raker counts in specimens of the two species collected across 1917, 1956, and 1984/1985, despite gill raker length remaining fixed. Similar breakdowns in morphological characteristics utilized for identification were reported historically in Lake Michigan ciscoes during the 1970s (Todd and Stedman 1989). Todd and Stedman (1989) provide evidence suggesting that genetic barriers to hybridization in some Coregonines are absent, as evidenced by fertile hybrids produced in North American fisheries. Furthermore, Todd and Stedman (1989) report changes in relative Cisco and Bloater abundances within Lake Huron, positing that the changes stemmed from removals of large individuals by targeted fisheries and Sea Lamprey predation. Such changes in relative abundance between related species are often considered a precursor to hybridization, with hybridization preceding the eventual extinction of the less abundant species (Smith 1964).

Introgressive hybridization has also been documented in related European whitefishes. Vonlanthen et al. (2012) found that whitefish species diversity could be lost through speciation reversal through introgressive hybridization. Similarly, Frei et al. (2022) observed that habitat degradation led to a loss of reproductive isolation and speciation reversal resulting in extinction through hybridization for whitefishes, suggesting that cisco flocks within inland lakes may be susceptible to similar threats. Jacobs et al. (2019) hypothesize that the likelihood of diversity within a European whitefish species group reemerging after a collapse is predicated on the duration of the ecosystem disturbance that caused it.

Based on the above, alterations to food web structure and the resulting loss of reproductive isolation may pose a significant indirect threat to Shortjaw Cisco.

### Aquatic invasive species

In addition to the indirect threats discussed above in the context of possible alterations to food web structure, AIS and introduced non-native fish also pose direct threats to Shortjaw Cisco. The COSEWIC Assessment and Update Status Report (2003) and in prep. COSEWIC Update Status Report (Pratt et al. 2008) identify competition from introduced species, including Rainbow Smelt and Alewife (*Alosa pseudoharengus*), as well as Sea Lamprey feeding as possible threats to the species.

#### *Rainbow Smelt*

Rainbow Smelt was intentionally introduced to Crystal Lake in western Michigan in 1912 and was later found in Lake Michigan in 1923, eventually spreading throughout the remaining Laurentian Great Lakes (Myers et al. 2009). Due to a unique ability to tolerate a wide range of water temperatures, Rainbow Smelt numbers exploded in the Great Lakes during the late 1960s (Evans and Loftus 1987; Myers et al. 2009). Owing to a broad diet and spatial segregation across life stages, Rainbow Smelt invasions may cause significant shifts across trophic levels (Evans and Loftus 1987).

Much of the literature surrounding interactions between Rainbow Smelt and ciscoes focuses on interactions with *C. artedi*. Rainbow Smelt has been found to negatively impact Cisco in small lakes directly through larval predation and indirectly through food web alterations (Evans and Loftus 1987). Similarly, Rainbow Smelt introductions have been implicated in Cisco declines and extirpations (Myers et al. 2009). Despite the overwhelming evidence of Rainbow Smelt impacts to Cisco in small lakes (Evans and Loftus 1987), little information exists regarding their impact to ciscoes in the Great Lakes. A study conducted in Lake Superior found that Rainbow Smelt predation accounted for significant (15 – 52% and 37 – 100%) larval mortality across sampling sites in Thunder Bay and Black Bay, respectively (Myers et al. 2009). In Sandybeach Lake (also known as Big Sandy Lake) east of Dryden, ON, the introduction of Rainbow Smelt was implicated in the absence of Cisco in pelagic nets based on sampling data from 1990 (one year after Rainbow Smelt were introduced) and 2012 (13 years thereafter), along with a smaller number of older individuals captured in benthic gillnets and skewed sex ratio (Reid and Wain 2016).

Overall, it is expected that Rainbow Smelt introductions pose a direct threat to Shortjaw Cisco within inland lakes primarily as a result of predation (particularly larval consumption) and indirect competition (for zooplankton prey). Rainbow Smelt are speculated to threaten populations of Shortjaw Cisco in Lake Nipigon (introduced in 1976; Pratt 2013) and Lake Saganama (introduced in 1984; Etnier and Skelton 2003).

### *Sea Lamprey*

Sea Lamprey was introduced to the Laurentian Great Lakes from the Atlantic Ocean, first detected in Lake Ontario around 1835 (although the exact date of introduction is debated, see Christie and Goddard 2003 and Eshenroder 2014 for further details), having entered the remaining Great Lakes by the 1950s (Hansen et al. 2016). Sea Lamprey host selection is known to depend on host size, with a preference for large hosts, although selection has been observed to change in response to host abundance (refer to Hansen et al. 2016 for greater details on Sea Lamprey ecology in the Great Lakes). The presence of Sea Lamprey within the Great Lakes and introductions into inland lakes may constitute a direct threat to Shortjaw Cisco (Todd 2003) if evidence were to suggest that they are adversely affecting the survival, growth or recruitment of Shortjaw Cisco. Impacts of Sea Lamprey to Shortjaw Cisco remain a knowledge gap, although much can be inferred from existing accounts of feeding on ciscoes resulting in negative outcomes in Lake Michigan (Smith 1964).

Sea Lamprey presence and/or introductions may also present an indirect threat to Shortjaw Cisco within the Great Lakes and inland lakes resulting from alterations to food web structure. The extirpation of larger cisco species (Deepwater Cisco and Blackfin Cisco) in Lake Huron is hypothesized to have occurred (in part) due to the additional pressure of feeding from Sea Lamprey, owing to selection preferences for large hosts. The extirpation of these ciscoes produced significant changes in food web structure within the lake, including a marked increase in Bloater (Todd and Steadman 1989). As discussed above, marked changes in relative abundance of related fish are often considered a precursor to hybridization and eventual extinction of the less abundant species (Todd and Steadman 1989).

### *Alewife*

Originally native to the Atlantic Coast, Alewife invaded the Laurentian Great Lakes between 1860 and 1955, likely entering Lake Ontario through the Lake Erie Canal (Smith 1970; Madenjian et al. 2011). Smith (1970) determined that Alewife had negatively impacted Cisco and Bloater abundance within the Great Lakes due to increased competition for food (zooplankton prey) and consumption of larval fish. Alewife numbers declined significantly from 1965 to 1990 as stocking programs bolstered predatory salmonid numbers within the Great Lakes (Madenjian et al. 2011). Revisiting the conclusions put forward by Smith (1970), Madenjian et al. (2011) posit that Alewife had minimal impacts on Cisco and Bloater within the Great Lakes, suggesting instead that overexploitation and destruction of spawning habitat were the most parsimonious explanation. It is not known whether Alewife poses direct or indirect threats to Shortjaw Cisco.

### Human-induced climate change

The COSEWIC Assessment and Update Status Report (Todd 2003) and draft COSEWIC Update Status Report (Pratt et al. 2008) identify thermal changes as a possible threat to Shortjaw Cisco. The effects of human-induced climate change on coldwater species such as Shortjaw Cisco are expected to directly stem from increasing water temperature, which may in turn indirectly alter habitat use, habitat quality and overall survival.

Suitable water temperature and DO collectively create an oxythermal habitat envelope for Shortjaw Cisco (and other coldwater fish). Increases in air and water temperature and decreases in ice cover and DO stemming from human-induced climate change are predicted within the Great Lakes (ELPC 2019). Air temperatures and water temperatures within the Great Lakes region are predicted to rise steadily throughout the twenty-first century which may influence the availability of suitable oxythermal habitat conditions for Shortjaw Cisco within the Great Lakes (ELPC 2019). Similarly, changes to winter ice cover, including late onset of ice cover, may negatively impact spawning, reproduction and recruitment (Scott and Crossman 1998; ELPC 2019).

Projected warming is similarly expected to decrease the volume and spatial extent of optimal and/or suitable habitat within inland lakes (Ridgway et al. 2018; Ridgway and Middel 2020), thereby potentially reducing the quantity and/or quality of Shortjaw Cisco habitat. Climate change may pose a significant indirect threat to Shortjaw Cisco within inland lakes, as long-term datasets reveal clear evidence of climate change influencing aquatic ecosystems in relatively pristine areas, such as inland lakes within Algonquin PP (Ridgway et al. 2018; Ridgway and Middel 2020). Ice-out dates in Algonquin PP are advancing by 1.7 days per decade based on current trends, alongside steadily increasing air temperatures (and subsequent water temperature increases) (Ridgway et al. 2018). Declines in Cisco abundance have been documented within the park, resulting from inland lake warming (Ridgway et al. 2018). Additional indirect threats resulting from increasing water temperatures may include changes in fish parasitism rates and northward shifts in invasive species ranges which may result in additional predation pressures or changes to food web structure (Ridgway et al. 2018).

### Overexploitation and incidental bycatch

Overexploitation by targeted fishing and/or incidental bycatch is a direct threat to Shortjaw Cisco (Pratt et al. 2008). While the impact of historical overfishing on Shortjaw Cisco is generally accepted as a leading factor in the collapse of Shortjaw Cisco in certain Great Lakes, others (see Bronte et al. 2010) hypothesize that overfishing was not the direct cause of Shortjaw Cisco declines in Lake Superior. Bronte et al. (2010) compared fishing effort in the lake versus relative abundance of Shortjaw Cisco from 1915 to 1995 and found Shortjaw Cisco declined at a rate which was unrelated to fishery intensity across years. Bronte et al. (2010) theorize that declines arose indirectly from the collapse of the Lake Trout population within the lake, with the resulting increase of *C. artedi* released from predation pressure leading to increased competition between Cisco and Shortjaw Cisco.

Current information suggests that overexploitation by fisheries does not pose a significant direct threat to Shortjaw Cisco in Ontario. Existing commercial fishing licenses number approximately 50 for Lake Superior, representing approximately 12 boats on the water (S. James pers. comm. 2024). These numbers are not predicted to increase as licenses are retired as license holders pass away and new licenses have not been issued for the lake since 1984 when quotas were initially set (S. James pers. comm. 2024). Each license is tied to 1 of 12 quota zones in the lake, specifying species, quota, gear type and location, with one license allowing for multiple nets to be set (S. James pers. comm. 2024).

The Ministry of Natural Resources MNR lumps catch data for deepwater ciscoes (primarily Bloater and Kiyi) into a catchall group referred to as “deep water chub” which has a quota of 287,807 kg in Lake Superior, a relic of historical popularity (S. James pers. comm. 2024). Despite the large quota, approximately nine kilograms of deep water chub catch was reported in 2022, a number which has remained relatively consistent over the past 20 years (S. James pers. comm. 2024).

Although Shortjaw Cisco receives protection under the *Endangered Species Act* (ESA), there is currently no prohibition on catching deepwater chub (S. James pers. comm. 2024), suggesting that some bycatch may occur. Reported incidental bycatch is predominantly comprised of suckers (*Catostomus* spp.) and Lake Trout (S. James pers. comm. 2024). However, owing to challenges associated with identification of Shortjaw Cisco based on morphology, is it not possible to determine the extent to which incidental bycatch poses a direct threat to the species.

## 1.6 Knowledge gaps

Long-standing taxonomic ambiguity coupled with more recent morphological and genetic studies have revealed that the historical and contemporary status of Shortjaw Cisco in Ontario is uncertain. It may be that some or many of the specimens previously assigned to Shortjaw Cisco in either the Laurentian Great Lakes and/or inland lakes are in fact referrable to (1) other existing cisco species/forms, (2) new morphotypes of existing cisco species/forms, (3) introgressed specimens which form a hybrid swarm with other ciscoes (e.g., Lake Huron) or (4) currently undescribed cisco species. Although there is no current evidence that a single, phylogenetically consistent Shortjaw Cisco entity occurs in inland lakes (populations therein appear to result from independent, repeated instances of ecological speciation converging on a fewer gill rakered morphotype), ongoing studies that apply more advanced genomic tools may confirm the taxonomic validity of Shortjaw Cisco in one or more Laurentian Great Lakes. Until a more comprehensive reassessment of cisco systematics covering the entire assemblage (i.e., species flocks) in Ontario emerges, receiving widespread acceptance by the relevant scientific community, definitive declarations of presence or absence in particular waterbodies (for Shortjaw Cisco or other members of the species flock) should be deferred (N. Mandrak pers. comm. 2024). Extensive study is currently underway in Lake Superior to clarify status (O. Gorman pers. comm. 2024) but this work covers only a single waterbody, and any results or conclusions derived therefrom may not transfer to Lake Nipigon (which contains a cisco assemblage from a different lineage; see Turgeon et al. 2016), other Laurentian Great Lakes, or inland lakes (from Ontario or elsewhere). Cisco diversity in inland lakes has barely been afforded any attention given greater interest in the Great Lakes (S. Reid pers comm. 2024; M. Ridgway pers. comm. 2024) and is integral to resolving taxonomic uncertainty in the group.

Overall, taxonomic uncertainty is a severe knowledge gap which seriously impedes the survival and recovery of Shortjaw Cisco in Ontario. By extension, this uncertainty gives rise to further knowledge gaps related to characterizing the species itself (e.g., biology, distribution, abundance, population trends, habitat needs), impeding efforts to confidently assess status and articulate recovery approaches that will effectively mitigate threats.

## 1.7 Recovery actions completed or underway

The period encapsulating the mid-2000s to the mid-2010s represented a “halcyon era” in which a groundswell of research and regulatory interest was directed towards Shortjaw Cisco (S. Reid pers. comm. 2024). Countless articles were published by provincial and federal research scientists and academics during this period (e.g., Pratt and Mandrak 2007; Pratt 2008; Pratt and Chong 2012; Pratt 2013; Boguski et al. 2014; Mandrak et al. 2014; Reid and Wain 2016; Turgeon et al. 2016). Similar interest was paid by US researchers at that time (Hoff and Todd 2004; Bronte et al. 2010; Gorman 2012; Eshenroder et al. 2016). Impetus for this work declined as the taxonomic challenges remained unresolved (T. Pratt pers. comm. 2024).

There has been renewed interest in the study of Great Lakes Coregonines in last few years led by USGS researchers with support from provincial and federal counterparts in Canada (T. Pratt pers. comm. 2024; O. Gorman pers. comm. 2024). Work is also being led by The Nature Conservancy and partners to capture gametes and experimentally raise Kiyi to support potential reintroduction efforts (T. Pratt pers. comm. 2024; see also Vinson et al. 2023). This work may have implications for the reintroduction of other deepwater ciscoes, including Shortjaw Cisco (if deemed an appropriate recovery option).

Whole genome sequencing is currently being undertaken by Dr. Amanda S. Ackiss and collaborators to compare contemporary cisco (including Shortjaw Cisco) scale samples from Lake Superior with scales from now extirpated Lake Michigan deepwater ciscoes (O. Gorman pers. comm. 2024). Similar work is also slated to begin in 2024 to address whether specimens collected from Lake Superior and identified as Shortjaw Cisco historically are genomically distinguishable from contemporary specimens (O. Gorman pers. comm. 2024).

# 2.0 Recovery

## 2.1 Recommended recovery goal

The recommended recovery goal for Shortjaw Cisco in Ontario is to maintain all existing distinct populations.

## 2.2 Recommended protection and recovery objectives

The recommended protection and recovery objectives for Shortjaw Cisco in Ontario are as follows:

1. Conduct and support research and monitoring to advance the identification of all distinct populations of Shortjaw Cisco and sympatric cisco taxa in Ontario.

2. Implement a strategic and intensive sampling program to clarify distribution, biology/life history, and habitat associations for all distinct populations of Shortjaw Cisco and sympatric cisco taxa in Ontario.

3. Implement a long-term monitoring program to quantify population abundance and trends in a subset of occupied waterbodies.

4. Undertake an updated threats assessment of all presumed historical and extant distinct populations of Shortjaw Cisco and sympatric cisco taxa in Ontario at a lake-specific level to support reassessment of the species' status.

5. Prepare and implement lake-specific management plans for all waterbodies containing distinct populations of Shortjaw Cisco.

## 2.3 Recommended approaches to recovery

Table 3. Recommended approaches to recovery of the Shortjaw Cisco in Ontario.

Objective 1: Conduct and support research and monitoring to advance the identification of all distinct populations of Shortjaw Cisco and sympatric cisco taxa in Ontario.

| Relative priority | Relative timeframe | Recovery theme | Approach to recovery | Threats or knowledge gaps addressed |
|---|---|---|---|---|
| Critical | Long-term | Research | **1.1** Conduct and support taxonomic research<br>• Combine morphological, biological, ecological, and/or genetic (particularly genomic) methods.<br>• Incorporate all Laurentian Great Lakes (including Lake Nipigon) and inland lakes (within and beyond Ontario) where Shortjaw Cisco has been identified.<br>• Confirm taxonomic status of all other cisco taxa occurring in sympatry. | Knowledge gaps:<br>• Taxonomy |
| Critical | Ongoing | Research | **1.2** Support ongoing USGS (and partner agency) cisco genomics research<br>• Support can be provided through specimen sharing, direct funding, and other forms of collaboration. | Knowledge gaps:<br>• Taxonomy |
| Critical | Long-term | Protection, Education and Outreach, Communication | **1.3** Organize and support initiatives to disseminate knowledge<br>• Organize and attend conferences, panels, and other forums where Coregonine experts can share knowledge.<br>• Provide science-based advice to inform a framework to identify distinct populations of Shortjaw Cisco. | Knowledge gaps:<br>• Taxonomy |

Objective 2: Implement a strategic and intensive sampling program to clarify distribution, biology/life history, and habitat associations for all distinct populations of Shortjaw Cisco and sympatric cisco taxa in Ontario.

| Relative priority | Relative timeframe | Recovery theme | Approach to recovery | Threats or knowledge gaps addressed |
|---|---|---|---|---|
| Critical | Long-term | Inventory, Monitoring and Assessment | **2.1** Clarify distribution<br>• Distribution studies can be integrated with the sampling program supporting taxonomic research.<br>• Sampling program design should consider various methods which maximize the likelihood of capturing sympatric cisco pairs/flocks.<br>• Sampling to include all currently reported Shortjaw Cisco populations.<br>• Conduct presence/absence surveys in inland lakes which appear to have suitable conditions for the emergence of cisco form diversity based on previous methodology described by Ridgway et al. (2022). | Knowledge gaps:<br>• Distribution |
| Necessary | Long-term | Inventory, Monitoring and Assessment | **2.2** Clarify movement patterns<br>• Select a subset of lakes for detailed sampling based on study goals and access considerations.<br>• Assess movement and occupancy patterns throughout the year through a combination of (1) passive acoustic telemetry and (2) intensive sampling in specific habitats and time-periods.<br>• Confirm the relative functional value, spatial distribution, and importance of different habitat types.<br>• Compare results between all sympatric cisco forms. | Knowledge gaps:<br>• Biology<br>• Habitat needs |

| Relative priority | Relative timeframe | Recovery theme | Approach to recovery | Threats or knowledge gaps addressed |
|---|---|---|---|---|
| Necessary | Long-term | Inventory, Monitoring and Assessment | **2.3** Clarify trophic niche and diet<br>• Conduct isotopic analysis to reveal trophic niche.<br>• Conduct stomach contents analysis to complement the isotopic analysis.<br>• Sample zooplankton during larval surveys to confirm prey availability.<br>• Compare results between sympatric cisco forms. | Knowledge gaps:<br>• Biology<br>• Habitat needs |
| Necessary | Long-term | Inventory, Monitoring and Assessment | **2.4** Clarify reproductive biology and spawning habitat associations<br>• Undertake annual surveys during the spawning season (once confirmed) involving passive acoustic telemetry and/or opportunistic gillnetting in suitable spawning habitat.<br>• Characterize the physical attributes (e.g., depth to substrate, substrate size classes, structure, distance from shore) of confirmed spawning areas, and compare with other areas that lack spawning activity.<br>• Clarify other aspects of reproductive biology including egg characteristics (e.g., size, number) and timing.<br>• Compare results between sympatric cisco forms. | Knowledge gaps:<br>• Biology<br>• Habitat needs |

| Relative priority | Relative timeframe | Recovery theme | Approach to recovery | Threats or knowledge gaps addressed |
|---|---|---|---|---|
| Necessary | Long-term | Inventory, Monitoring and Assessment | **2.5** Clarify larval habitat associations<br>• Genomic assessment required at study commencement to discriminate cisco taxa (including from whitefish).<br>• Determine timing of emergence, growth, and dispersal.<br>• Link larval surveys with known spawning areas to clarify hatching success, productivity, and functional value of different spawning areas or habitat types.<br>• | Knowledge gaps:<br>• Biology<br>• Habitat needs |

Objective 3: Implement a long-term monitoring program to quantify population abundance and trends in a subset of occupied waterbodies.

| Relative priority | Relative timeframe | Recovery theme | Approach to recovery | Threats or knowledge gaps addressed |
|---|---|---|---|---|
| Critical | Long-term | Inventory, Monitoring and Assessment | **3.1** Devise and deliver a long-term monitoring program<br>• Monitoring program should establish baseline population data for the Laurentian Great Lakes and inland lakes.<br>• Monitoring should provide reliable inputs to population estimates (abundance, genetics, structure, and trends) to assist with determining whether particular distinct populations are self-sustaining.<br>• Monitoring program should incorporate collection of key chemical parameters (e.g., dissolved oxygen, temperature, pH at stratified depths) to clarify habitat associations and occupancy.<br>• Perform population viability assessments and project trends for all extant Shortjaw Cisco distinct populations and sympatric cisco taxa at a lake-specific level.<br>• Selection of a subset of lakes for long-term monitoring should be guided by the availability of existing aquatic datasets (e.g., other fish, aquatic habitats, lake morphometrics) and limited access restrictions. | Knowledge gaps:<br>• Abundance<br>• Population trends |

Objective 4: Undertake an updated threats assessment of all presumed historical and extant distinct populations of Shortjaw Cisco and sympatric cisco taxa in Ontario at a lake-specific level to support reassessment of the species' status.

| Relative priority | Relative timeframe | Recovery theme | Approach to recovery | Threats or knowledge gaps addressed |
|---|---|---|---|---|
| Critical | Long-term | Protection, Management | **4.1** Reassess threats to the survival and recovery of all extant populations at a lake-specific level<br>• Confirm the relative likelihood, magnitude and timing of threat severity.<br>• Determine if additional threats (beyond those previously identified) warrant consideration. | Knowledge gaps:<br>• Threats |

Objective 5: Prepare and implement lake-specific management plans for all waterbodies containing distinct populations of Shortjaw Cisco.

| Relative priority | Relative timeframe | Recovery theme | Approach to recovery | Threats or knowledge gaps addressed |
|---|---|---|---|---|
| Critical | Long-term | Management | **5.1** Prepare lake-specific cisco management plans for all waterbodies containing Shortjaw Cisco<br>• Management plans will target the survival and recovery of the cisco species pair/flock overall.<br>• Management plans will include lake-specific biological and habitat information, threats assessments (e.g., AIS) and mitigation framework, identification of knowledge gaps, and an implementation framework.<br>• Implement management plans with support from relevant agencies (e.g., DFO) or groups (e.g., First Nations) as appropriate. | Threats:<br>• Alterations to food web structure<br>• Aquatic invasive species<br>• Human-induced climate change<br>• Overexploitation and incidental bycatch |

| Relative priority | Relative timeframe | Recovery theme | Approach to recovery | Threats or knowledge gaps addressed |
|---|---|---|---|---|
| Necessary | Short-term | Management | **5.2** Prepare an invasive species prevention and management response plan specific to lakes with higher recreational pressures<br>- Management and response plan should be prepared as soon as possible and can then be adopted within (or modified through) the lake-specific cisco management plans.<br>- Assess feasibility and effectiveness of post-introduction management options to limit impacts of AIS. | Threats:<br>- Aquatic invasive species |

### Narrative to support approaches to recovery

In light of the taxonomic conundrum having plagued cisco classification for over a century, the entity known as Shortjaw Cisco and listed as threatened under the ESA has been treated through this recovery strategy as a collection of morphologically convergent forms with an uncertain phylogenetic relationship. While recent evidence suggests that at least some contemporary “Shortjaw Cisco” records from Lake Superior are in fact Shortnose Cisco (a species accepted as extinct), further assessment is needed before final pronouncements on presence/absence can be made. Considerable work is planned or underway using modern genomic tools (coupled with traditional morphological measurements) as a means to build a new taxonomic framework for Coregonines in North America.

Once cisco taxon boundaries have been successfully elucidated and discrimination amongst species/forms can be accomplished, the resulting outcome may merely represent a simple nomenclatural update. In other words, it is possible that those fish with a Shortjaw Cisco-like morphotype occupying intermediate depths and exhibiting low gill raker counts will continue to warrant conservation interest regardless of the scientific binomial applied to them (N. Mandrak pers. comm. 2024), provided that available evidence points to such entities being sufficiently discrete and evolutionarily significant. As one example, when phenotypic differences within Cisco-Shortjaw Cisco species pairs were investigated, the pairs themselves were found to differ morphologically and ecologically, suggesting that the speciation process playing out simultaneously in suitable waterbodies across Ontario will lead to unique evolutionary outcomes (Turgeon et al. 2016).

Cisco form diversity includes species pairs (as in inland lakes) or flocks (as in each Laurentian Great Lake and more rarely in inland lakes). This diversity appears to reflect niche opportunity in response to the complex interplay between waterbody depth and the presence of a diverse assemblage of Opossum Shrimp (Ridgway et al. 2022). Where the mechanisms (particularly trophic dynamics) that facilitated the emergence and maintenance of multiple cisco forms are altered (e.g., through introduction of AIS), irreversible genotypic and/or life history changes can be expected (N. Mandrak pers. comm. 2024; S. Reid pers. comm. 2024). Evidence of trophic collapse can be found in the introgressed “hybrid swarm” of deepwater ciscoes in Lake Huron (Eshenroder et al. 2016) in response to overfishing or collapse of the whitefish species pair in Como Lake (ON) following introduction of Spiny Water Flea (*Bythotrephes longimanus*; Reid et al. 2017). It may turn out that some Shortjaw Cisco-like morphotypes display insufficient evidence of reproductive isolation from sympatric conspecifics, warranting exclusion of such morphotypes from current conservation interest. However, any such determinations must be justified on a lake-specific basis and would not necessarily apply to other waterbodies.

Until proven otherwise, all previously accepted occurrences of Shortjaw Cisco in Ontario (see Figure 2) should be assumed extant and representative of the species’ current distribution. Approaches that assist in the survival and recovery of Shortjaw Cisco in Ontario as outlined below extend from this basis.

*Advance the identification of distinct populations*

Investigating the history of Shortjaw Cisco as a taxon offers a narrow glimpse at the broader "Coregonine Problem" introduced previously. This concept refers to several enduring and overlapping challenges related to confidently describing and differentiating the wide expression of cisco forms (within and across waterbodies) and ascribing phylogenetic relationships among them. Coregonines as a group are well-known for their plasticity and capacity for local adaptation (Lindsey 1981), which becomes manifest in differences such as morphology (e.g., jaw shape), meristics (e.g., gill raker count), physical resource use (e.g., depth distribution), trophic niche (e.g., diet), reproductive biology (e.g., timing) and life history (e.g., age structure). In some cases, observed morphological characters vary only slightly between taxa and overlap species boundaries across the cisco complex (Eshenroder et al. 2016).

The Coregonine Problem presents itself as a series of questions confronting taxonomists:

1. Is the particular group of ciscoes under review sufficiently discrete (morphologically, biologically, ecologically, and/or genetically) to be appropriately described as a form or morphotype, sometimes known as an Ecologically Significant Unit (ESU; Eshenroder et al. 2016)?
2. Is such a group (if accepted as discrete) best described as within-species variation (i.e., as a morphotype) or (alternatively) as a separate and distinct species?
3. Which traits (e.g., character, genetic) would one use to assign specimens to this group, and what is their relative diagnostic value vis-à-vis other traits?
4. How does such a group relate (phylogenetically) to other cisco forms (conspecific) or other species (congeneric), both sympatric (within the same waterbody) and allopatric (within other waterbodies)?
5. Is such a group evolutionary significant, in the sense that the group has advanced along an independent evolutionary trajectory and/or that its members possess adaptive, heritable traits, neither of which could be practically reconstituted?

Subsection 2(1) of the ESA defines "species" as inclusive of subspecies, varieties and genetically or geographically distinct populations. As a result, discrete groups of ciscoes which are not distinctive enough (based on morphological and/or genetic evidence) to be considered "species" in a taxonomic sense may still be classified as "species" in a legislative sense under the provincial ESA. COSEWIC applies the term Designatable Unit (DU) when considering the appropriateness of assessing subspecies, varieties or distinct populations within a taxonomic species under the federal *Species at Risk Act* (SARA), and has developed guidelines (COSEWIC 2020) to assist with DU recognition. Such guidelines require that a DU must be both "discrete" (i.e., limited transmission of heritable information from other DUs) and "evolutionarily significant" (i.e., DU harbours heritable adaptive traits or an evolutionary history not found elsewhere in Canada). The term “DU” is applied herein only when referring to the federal species assessment process led by COSEWIC under SARA.

Application of the species flock concept, first applied to ciscoes by Smith and Todd (1984) and further advocated thereafter (Reed et al. 1998; Turgeon et al. 1999; DFO 2013a; Turgeon et al. 2016), provides a helpful mechanistic framework for modern investigation of the Coregonine problem and a means to consider the above key questions.

The emergence of species flocks (synonymous with “species complexes”) in North America was facilitated by colonization of proglacial lakes following glacial retreat, wherein certain groups of fishes (including ciscoes) radiated into complexes of closely related forms in the same waterbody (Turgeon et al. 1999). Habitat/niche partitioning and food competition have been shown to drive cisco diversification (Turgeon et al. 2016; Ridgway et al. 2020; Ridgway et al. 2022; Bernal et al. 2022). Species flocks can attain high levels of morphological, physiological, and ecological variation within a waterbody, sometimes speciating. Reproductive isolation is presumed to be maintained by habitat-driven assortative mating (DFO 2013a), although the particular mechanism(s) may differ by lake and could include spatial segregation (e.g., spawning in different areas; Koelz 1929) and/or allochronic isolation (i.e., spawning at different times; Smith and Todd 1984). Suitability of the species flock concept as applied to ciscoes is supported by varying gill raker counts (structures involved in sifting food) which are highly heritable (i.e., do not vary much in response to environmental cues), with higher gill raker counts reflecting a predominantly planktivorous (pelagic) diet and lower gill raker counts reflecting a benthivorous diet (Turgeon et al. 1999).

This radiation process has given rise to two cisco morphotypes or “pairs” in smaller inland lakes (rarely three, as in Lake Saganaga), whereas multiple morphotypes form a “flock” in the Great Lakes (Turgeon et al. 1999; Ridgway et al. 2022), including eight species/forms (plus additional phenotypic variants) in Lake Michigan and Lake Huron (Eshenroder et al. 2016). The same evolutionary mechanisms have also produced “sympatric pairs” of Lake Whitefish in several waterbodies across Ontario and Canada (Rogers 2008).

Sympatric cisco pairs/flocks do not align neatly with traditional or simplistic species concepts (Todd and Smith 1980), complicating the administration of species status assessments at the federal and provincial levels in Canada. A COSEWIC Assessment and Updated Status Report for Shortjaw Cisco was prepared in 2003 wherein the previous classification of threatened (from 1987) was reaffirmed (Todd 2003). The reassessment was not accepted by the federal government and was referred back to COSEWIC for further consideration due to (1) lack of incorporation of First Nations traditional knowledge and (2) insufficient rationale for inclusion of a single DU (Canada Gazette 2006). In response, a new COSEWIC status report was drafted (Pratt et al. 2008) which grouped Shortjaw Cisco populations in the Laurentian Great Lakes (and Lake Nipigon) into one DU (DU1) and populations in inland lakes into a second DU (DU2). The draft 2008 status report update was not formally accepted due to lack of taxonomic certainty and Indigenous knowledge (N. Mandrak pers. comm. 2024). A reassessment of Shortjaw Cisco was planned as part of the standard COSEWIC ten-year cycle around 2013, culminating in a Science Assessment Report which summarized the proceedings of an experts meeting in October 2012 (DFO 2013b) and associated advice related to the development of Shortjaw Cisco specific DUs (DFO 2013a).

Following publication of the Eshenroder et al. (2016) monograph, a DU guidance document covering ciscoes across Canada was prepared by the COSEWIC Freshwater Fishes Subcommittee in 2018/2019 (N. Mandrak pers. comm. 2024). The Subcommittee recommended recognition of Shortjaw Cisco as separate DUs in each Great Lake where it historically or currently occurred and also as separate DUs in each inland lake exhibiting evidence of local adaption. This approach generally aligned with previous DU recommendations for Lake Whitefish species pairs (Rogers 2008). Ultimately, the updated DU guidelines for Canadian ciscoes was not approved by COSEWIC and it is unlikely that the status of Shortjaw Cisco will be reconsidered by COSEWIC until a governing DU framework has been formally approved (N. Mandrak pers. comm. 2024).

On this basis, long-standing taxonomic ambiguity has hindered progress towards achieving federal and provincial mandates related to the protection of Shortjaw Cisco as a threatened species and obscures even basic attempts to understand its distribution, biology, habitat requirements, and abundance in Ontario. Implementation of a research program which centres on resolving taxonomic uncertainty is therefore critical, though patience is needed as results materialize in future years. Similarly, formulation of a defensible recovery program for Shortjaw Cisco in Ontario would benefit from COSEWIC endorsement of a DU framework coupled with parallel efforts at the provincial level in Ontario to spearhead research and further assessment. Shortjaw Cisco as a taxonomic entity must be described and clarified before other recovery objectives can be considered in earnest.

While a DU framework has already been drafted and presented by the COSEWIC Freshwater Fishes Subcommittee, it was not approved (as detailed above) and is likely to require modification as new information becomes available. It is further highlighted that certain specimens previously ascribed to Shortjaw Cisco and accepted in authoritative documents (e.g., Todd 2003; Pratt et al. 2008) have been referred to other taxa by some (e.g., Attawapiskat Lake; Clarke 1973) and require more rigorous study.

There is overwhelming evidence that a single-species recovery approach will not successfully protect Shortjaw Cisco in Ontario (or elsewhere), requiring instead an assessment framework which acknowledges species flocks and the necessity of lake-specific evaluations. Recovery actions which are seen as critical or necessary to refine Shortjaw Cisco distinct populations include:

- Develop a taxonomically valid framework covering both Shortjaw Cisco and all sympatric cisco species using a combination of morphological, biological, ecological, and genetic/genomic techniques and criteria to corroborate results.

- Support ongoing cisco genomics research (led by the USGS and partner agencies) which have successfully resolved genetic differences between cisco taxa and show further promise.
- Organize and support initiatives to disseminate knowledge amongst the relevant scientific community with the intent of advancing COSEWIC acceptance of a federal Shortjaw Cisco DU framework (coupled with parallel efforts at the provincial level), which will then be considered by Committee on the Status of Species at Risk in Ontario (COSSARO) in the context of the provincial ESA to support assessment of the species.

It is likely that the aforementioned assessment framework will need to cover not only Shortjaw Cisco (and sympatric forms) but all ciscoes (subgenus *Leucichthys*) in Canada, consistent with the previously drafted guideline.

*Implement a strategic and intensive sampling program*

Once the defining characteristics of “Shortjaw Cisco” are clarified through a revised taxonomy and distinct population framework, details pertaining to the distribution, biology/life history, and habitat associations can proceed. Efforts to clarify distribution should seek to answer the following key questions:

- Is Shortjaw Cisco extant in Lake Superior and Lake Nipigon?
- Was Shortjaw Cisco present in the historical species flock occupying Lake Superior, Lake Michigan, and Lake Huron?
- What is the phylogenetic relationship (if any) between putative Shortjaw Cisco populations occurring across the Laurentian Great Lakes and inland lakes?
- Do lakes that appear to possess suitable conditions for the development of cisco species pairs (not yet rigorously sampled) contain additional cisco morphotypes, and if so does one of these morphotypes resemble Shortjaw Cisco?

An extensive sampling program must be devised and should consider various methods that maximize the likelihood of capturing sympatric cisco pairs/flocks, including:

- sampling timing (i.e., seasonality of captures)
- methodology (e.g., gillnets, bottom trawls in the Great Lakes)
- gear type (e.g., mesh sizes)
- net set location (e.g., bottom-set vs. suspended gillnets)
- duration
- interval

Deepwater ciscoes are not well-captured by bottom-set nets (M. Ridgway pers. comm. 2024) as typically deployed through the provincial Broad-scale Monitoring Program (Sandstrom et al. 2013). Inland lakes with potentially suitable conditions to support cisco species pairs (deeper than 25 m within envelope of proglacial lakes; see Ridgway et al. 2022) should be intensively sampled based on subregions/watersheds with similar glacial histories (M. Ridgway pers. comm. 2024).

It is evident that genomic tools will play a key role in clarifying the historical and current distribution of Shortjaw Cisco, in addition to traditional fish sampling methods (e.g., gillnetting). Other key goals the recommended sampling program serves to clarify include:

- movement patterns
- trophic niche and diet
- reproductive biology and spawning habitat associations
- larval habitat associations

Installation of acoustic receiver arrays in Algonquin PP (e.g., Smoke Lake) has yielded important insights into the seasonality of fish movement patterns (M. Ridgway pers. comm. 2023). Despite the obvious challenges and costs of installing receiver arrays in inland lakes to study cisco species flocks, the resulting data would significantly advance knowledge of seasonal habitat use and movement patterns and allow for comparisons over time. The acoustic data would also be comparable with the results of strategic gillnetting to provide a more fulsome picture of habitat use. Installation of receiver arrays to study sympatric ciscoes would be limited to the most accessible lakes.

Ensuring that the sampling program overlaps with both Shortnose Cisco and all other sympatric cisco forms will allow for comparisons across species and serve to clarify functional relatedness and relationships.

*Implement a long-term monitoring program*

Much of what is believed to be known about Shortjaw Cisco derives from sampling and research efforts over the past century, though this information represents an unreliable depiction of the species due to long-standing taxonomic uncertainty. Once “Shortjaw Cisco” as a taxonomic entity has been clarified, efforts to quantity its current population estimates at a lake-specific level should proceed with the ultimate intention to model population trends and trajectories. Given the high incidence of mortality associated with gillnetting (approximately 95%, M. Ridgway pers. comm. 2023), the regularity of monitoring should be selected in a way that minimizes impact. Unavoidable mortality does offer copious samples upon which modern morphometric and genetic analysis can be performed.

*Reassess status and threats*

Once the initial objectives of resolving Shortjaw Cisco taxonomy, biology, distribution, habitat needs, and distribution has been accomplished, an updated threats assessment of Shortjaw Cisco can proceed. A threats reassessment will facilitate verification of the presumed threats outlined in this recovery strategy and elsewhere (e.g., Todd 2003; Pratt et al. 2008) and confirm if additional threats are relevant, to be performed at a lake-specific level. This information (alongside distribution- and population-related data) can then be referred back to COSSARO (and COSEWIC) to inform future updated status reports and assessments.

*Prepare and implement lake-specific cisco management plans*

An intended outcome of recovery objective #4 is to clarify the conservation status of all previously reported populations of Shortjaw Cisco, along with any new populations which emerge through taxonomic revision or survey effort outlined in recovery objectives #1 and/or #2, respectively. Any such populations which are determined by COSSARO to be endangered or threatened will receive legislative protection under the ESA.

Lake-specific conservation approaches are necessary to maintain the long-term distinctiveness and viability of all entities within a cisco species pair or flock. Lake-specific management plans should be prepared and implemented for all waterbodies containing an endangered or threatened Shortjaw Cisco-like population. Such lake-specific management plans should summarize:

- lake characteristics and physical attributes (e.g., morphometry)
- biological and habitat information specific to Shortjaw Cisco and all sympatric cisco species within that particular lake
- long-term monitoring data (where available)
- threats
- threats mitigation framework, including lake-specific invasive species prevention and management response plans and clarification of threats associated with commercial and/or recreational harvesting
- data/knowledge gaps and information needs
- implementation framework, outlining roles and responsibilities of various Canadian provincial and federal agencies, US state and federal agencies, and other partners

The implementation of recovery actions intended to mitigate threats should not be delayed until the broader cisco taxonomy is resolved and lake-specific cisco management plans are prepared (which may be years or decades away). AIS introduction poses a severe risk to sympatric forms of cisco today, particularly in light of the known collapse of the Lake Whitefish species pair in Como Lake resulting in replacement by a single, larger species (Reid et al. 2017). It is therefore recommended that efforts to minimize the risk of AIS introduction be implemented be implemented as soon as possible, particularly in inland lakes containing Shortjaw Cisco-like populations where recreational pressures are higher.

## 2.4 Performance measures

Performance measures are specific standards which permit evaluation of progress made towards achieving the recovery goals and objectives outlined in this recovery strategy for Shortjaw Cisco in Ontario. Performance measures are offered for each recovery objective as follows:

1. Conduct and support research and monitoring to advance the identification of distinct populations of Shortjaw Cisco and sympatric cisco taxa in Ontario.

    - Number of research studies funded by the federal and provincial governments (2025 to 2029) that apply morphological, genetic/genomic, or other methods to clarify and discriminate Shortjaw Cisco and sympatric ciscoes, including annual funding levels ($).
    - Number of reports and/or publications related to Shortjaw Cisco taxonomy and that of sympatric cisco taxa (total).
    - Identification and general acceptance of a refined taxonomic definition of Shortjaw Cisco and related sympatric cisco species for the Laurentian Great Lakes (yes/no).
    - Identification and general acceptance of a refined taxonomic framework for Shortjaw Cisco and related sympatric cisco species for inland lakes (yes/no).

2. Implement a strategic and intensive sampling program to clarify distribution, biology/life history, and habitat associations for all distinct populations of Shortjaw Cisco and sympatric cisco taxa in Ontario.

    - Number of research studies funded by the federal and provincial governments (2025 to 2029) that consider the biology, distribution and/or habitat associations of Shortjaw Cisco and related sympatric cisco taxa (total), including funding levels ($).
    - Number of reports and/or publications related to the biology, distribution and/or habitat associations of Shortjaw Cisco and related sympatric cisco taxa (total).
    - Updated distribution map (or equivalent authoritative description of distribution) generated from a synthesis of supported research (yes/no).
    - Number of waterbodies (Great Lakes and/or inland lakes) surveyed as part of the sampling program (total).
    - Number of waterbodies (Great Lakes and/or inland lakes) where a detailed description of key life history characteristics (e.g., spawning habitat) has been published (total).
    - Number of new lakes in which a cisco species pair/flock has been discovered through the sampling program (total).

3. Implement a long-term monitoring program to quantify population abundance and trends in a subset of occupied waterbodies.

    - Establishment of a long-term monitoring program (yes/no), including annual funding levels ($).
    - Number of lakes forming part of the long-term monitoring program (total).
    - Number of population viability assessments performed at a lake-specific level (total).

4. Undertake an updated threats assessment of all presumed historical and extant distinct populations of Shortjaw Cisco and sympatric cisco taxa in Ontario at a lake-specific level to support reassessment of status.
    - Number of waterbodies where an assessment of threats has been completed for Shortjaw Cisco (total).
5. Prepare and implement lake-specific management plans for all waterbodies containing distinct populations of Shortjaw Cisco.
    - Number of lake-specific cisco management plans developed (total).
    - Number of lake-specific cisco management plans implemented (total).

## 2.5 Area for consideration in developing a habitat regulation

Under the ESA, a recovery strategy must include a recommendation to the Minister of the Environment, Conservation and Parks on the area that should be considered if a habitat regulation is developed. A habitat regulation is a legal instrument that prescribes an area that will be protected as the habitat of the species. The recommendation provided below by the author will be one of many sources considered by the Minister, including information that may become newly available following the completion of the recovery strategy should a habitat regulation be developed for this species.

It is well established that upland/terrestrial riparian zones adjacent to waterbodies provide indirect (and sometimes critically important) habitat for certain species (or life stages) of freshwater fish. Alternatively, benthivores and other deepwater pelagic fishes which occupy a profundal niche in lacustrine environments are less functionally reliant upon riparian condition or changes in riparian function (Caskenette et al. 2021; Richardson et al. 2010). Given that Shortjaw Cisco concentrates at depth (below the hypolimnion) to spawn and feed on a variety of benthic (e.g., *Mysis* spp., *Diporeia* spp.) and limnetic (e.g., copepods, cladocerans) organisms (Pratt et al. 2008), interactions with the surrounding terrestrial environment would be limited to such an extent that this area would not constitute “habitat” for Shortjaw Cisco (or other deepwater ciscoes) as defined under the ESA. A similar conclusion was reached for the Lake Whitefish species pair occupying Opeongo Lake in Algonquin PP (Consiglio et al. 2024).

In an effort to circumscribe habitat for Shortjaw Cisco offshore of the Saugeen/Bruce Peninsula (ON) in Georgian Bay/Lake Huron, Naumann and Crawford (2009) found that water depth was the most important explanatory variable for predicting presence/absence. Notwithstanding this finding, Naumann and Crawford (2009) ultimately concluded that Shortjaw Cisco habitat could not be sufficiently described due to (1) rarity of occurrence in the study area, and (2) the need to consider factors other than depth to predict occupancy (e.g., temperature, predator/prey abundance).

Habitat associations specific to Shortjaw Cisco as reviewed in this recovery strategy can be briefly summarized as follows:

- Spawning areas have been described and documented (Koelz 1929) as areas of a lake with a clay bottom at depths of 37 to 73 m (Lake Superior), sand and clay at depths of 18 to 55 m (Lake Michigan), and clay at depths of 55 to 91 m (Lake Huron, main basin).
- Depth distributions in Lake Superior, Lake Huron, and Lake Michigan generally average 45 to 144 m (Todd 2003) or 37 to 91 m in the shallower Lake Nipigon (Dymond 1926), which is overall intermediate relative to other deepwater ciscoes.
- A more fulsome depth of capture range extends between 18 to 183 m (Scott and Crossman 1998), with seasonal variations reported.

- No information pertaining to spawning areas, depth distributions or other habitat associations is available for any inland lake population in Ontario.

The intensive and concerted efforts aimed at clarifying the taxonomic and conservation status of Shortjaw Cisco and associated sympatric cisco taxa as recommended through this recovery strategy are intended to yield precise and reliable information pertaining to distribution and habitat occupancy. Existing published accounts of putative or presumed habitat associations for Shortjaw Cisco and other members of the deepwater cisco complex are based on live or captured specimens identified morphologically in the absence of genetic evidence or an accepted taxonomic framework, and as such should be considered speculative (O. Gorman pers. comm. 2024).

Subparagraph 11(2)(3)(iii) of the ESA requires that all recovery strategies include a recommendation specifying the area that should be considered when developing a habitat regulation. Specifying such an area is highly challenging given the severity of existing knowledge gaps related to Shortjaw Cisco. If a decision to proceed with a habitat regulation is made following verification of taxonomy and collection of additional data, the habitat regulation should include all intermediate depths of occupied lakes, as this is where feeding and spawning activities are concentrated. In the Laurentian Great Lakes, the recommended depth range would extend between 15 and 200 m, consistent with published reports of capture depths and known spawning areas. The depth range of regulated habitat in inland lakes would likely be narrower and shallower in reflection of differing life history strategies of Shortjaw Cisco in such waterbodies and lake morphometry. Lake-specific habitat mapping for all Shortjaw Cisco could be prepared where bathymetric contours are available.

Further refinement of this habitat recommendation may be possible once more information becomes available. For example, habitat for Shortjaw Cisco could be limited to areas within the recommended depth ranges which contain sufficient prey densities, whereas spawning habitat could be restricted to particular depth ranges, substrate types, and/or generalized locations specific to each lake occupied.

# Glossary

Adaptive radiation: Process in which organisms diversify rapidly from an ancestral species into a multitude of new forms, particularly when a change in the environment makes new resources available, alters biotic interactions or opens new environmental niches.

Adipose fin: A soft, fleshy fin located behind the dorsal fin and just forward of the caudal fin, found fish of certain families, believed to have some sensory function.

Allochrony: A situation where two biological entities occur in the same habitat but differ in terms of reproductive timing.

Allopatric: A group of organisms which are geographically isolated.

Benthivore: Fish that prey on shellfish, crustaceans and other small invertebrates that dwell on the lake bottom or seafloor.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC): The committee established under section 14 of the Species at Risk Act that is responsible for assessing and classifying species at risk in Canada.

Committee on the Status of Species at Risk in Ontario (COSSARO): The committee established under section 3 of the *Endangered Species Act, 2007* that is responsible for assessing and classifying species at risk in Ontario.

Conservation status rank: A rank assigned to a species or ecological community that primarily conveys the degree of rarity of the species or community at the global (G), national (N) or subnational (S) level. These ranks, termed G-rank, N-rank and S-rank, are not legal designations. Ranks are determined by NatureServe and, in the case of Ontario's S-rank, by Ontario's Natural Heritage Information Centre. The conservation status of a species or ecosystem is designated by a number from 1 to 5, preceded by the letter G, N or S reflecting the appropriate geographic scale of the assessment. The numbers mean the following:

1 = critically imperiled
2 = imperiled
3 = vulnerable
4 = apparently secure
5 = secure
NR = not yet ranked

Congeneric: Belonging to the same genus.

Conspecific: Belonging to the same species.

Dorsal: Referring or related to the back or upper side of an organism's body.

*Endangered Species Act, 2007* (ESA): The provincial legislation that provides protection to species at risk in Ontario.

Extant: Still in existence; surviving.

Gill raker: Bony or cartilaginous projection from the gill arch which serve to sieve and retain food particles.

Homologous: Similar in evolutionary origin, typically referring to genes descended from a common ancestor.

Hypolimnion: Deeper and colder layer in a thermally stratified body of water.

Ichthyologist (pl. Ichthyologists): the scientific study of fish.

Introgression: Transfer of genetic information from one species to another as a result of hybridization between them and repeated backcrossing. Laurentian Great Lakes: Large and interconnected freshwater lakes occupying central and eastern North America.

Limnetic: Referring to (living in) an open body of water.

Maxilla (pl. Maxillae): The upper jaw of bony fish consisting of relatively plate-like bones.

Maxillary: one of two bones comprising the upper jaw of a fish.

Meristics: Counting quantitative features of animals and plants.

Morphotype: Group of different types of individuals of the same species.

Niche: A position or role taken by a particular kind of organism within its community.

Nuptial tubercles: Raised structures made of keratin typically shed after breeding.

Ontogenetic: of or relating to the origin and development of individual organisms.

Oxythermal: Referring to both oxygen and temperature collectively.

Pelagic: Referring to open water.

Pelvic axillary process: A small, triangular projection at the upper end of the base of the pelvic fin.

Phenotype: the set of observable characteristics of an individual resulting from the interaction of its genotype with the environment.

Phylogenetic: Relating to the evolutionary development and diversification of a species or group of organisms, or of a particular feature of an organism.

Premaxilla (pl. Premaxillae): Foremost portion of the upper jaw of bony fish.

Premaxillary angle: Angle between the horizontal axis of the head and the premaxillae.

Profundal: The part of a thermally stratified lake that extends downward from the upper part of the hypolimnion to the bottom of the lake or in very deep lakes to 600 meters.

Proglacial: In front of, at, or immediately beyond the margin of a glacier or ice sheet.

Species (sp.) (pl. spp.): A category of classification ranking immediately below the genus, containing a group of organisms in which any two individuals of the appropriate sex may produce offspring.

*Species at Risk Act* (SARA): The federal legislation that provides protection to species at risk in Canada. This Act establishes Schedule 1 as the legal list of wildlife species at risk. Schedules 2 and 3 contain lists of species that at the time the Act came into force needed to be reassessed. After species on Schedule 2 and 3 are reassessed and found to be at risk, they undergo the SARA listing process to be included in Schedule 1.

Species at Risk in Ontario (SARO) List: The regulation made under section 7 of the *Endangered Species Act, 2007* that provides the official status classification of species at risk in Ontario. This list was first published in 2004 as a policy and became a regulation in 2008 (Ontario Regulation 230/08).

Standard length: A fish's body length from the tip of its nose to the end of its last vertebrae.

Sympatric: A group of organisms occurring within the same area and overlapping in distribution.

Synonym: A taxonomic name which has the same application as another, especially one which has been superseded and is no longer valid.

Thermocline: Transition layer between warmer, less dense water at the surface and cooler, denser water below; a product of lake stratification in summer.

Thermal stratification: Settling of colder water below warmer water in a waterbody, producing layers with distinct thermal characteristics.

Taxon: A scientifically classified group or entity.

Trophic niche: The unique position an organism occupies in a food web.

# List of abbreviations

AFS: American Fisheries Society
AIS: Aquatic Invasive Species
AOO: Algonquins of Ontario
COSEWIC: Committee on the Status of Endangered Wildlife in Canada
COSSARO: Committee on the Status of Species at Risk in Ontario
DO: Dissolved Oxygen
DU: Designatable Unit
DFO: Fisheries and Oceans Canada
ESA: Ontario’s *Endangered Species Act, 2007*
ESU: Ecologically Significant Unit
ISBN: International Standard Book Number
MECP: Ministry of the Environment, Conservation and Parks
MNR: Ministry of Natural Resources
NHIC: Natural Heritage Information Centre
ON: Ontario
PP: Provincial Park
ROM: Royal Ontario Museum
SARA: Canada’s *Species at Risk Act*
SARO List: Species at Risk in Ontario List
US: United States
USGS: United States Geological Survey

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