A Field Guide to the Taxonomy of Ciscoes in Great Slave Lake, Northwest Territories, Canada

Great Lakes Fishery Commission

Miscellaneous Publication 2011-02

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August 2011

A Field Guide to the Taxonomy of Ciscoes in Great Slave Lake, Northwest Territories, Canada

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A school of adfluvial cisco (*Coregonus artedi*) seeking shelter and rest in a nearshore pool on their fall upstream migration through Tartan Rapids, Yellowknife River, Northwest Territories. P. Vecsei

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If you are not more confused after working on coregonines, then you are not doing your job right. -C.C. Lindsey

Introduction

This field guide is dedicated to C.C. Lindsey and was prepared at the request of the Interdepartmental Recovery Fund (IRF) and the Fisheries and Oceans Canada Species-at-Risk Act (SARA) working group. The shortjaw cisco (*Coregonus zenithicus*) is listed as threatened under SARA. A requisite to conserving the shortjaw cisco is the ability to identify and differentiate it from other ciscoes occurring in Great Slave Lake—the purpose of this guide is to provide assistance in that process.

Identifying the Coregonine Ciscoes of Great Slave Lake

To date, the taxonomy of Great Slave Lake ciscoes remains unresolved, and their diversity has not been adequately described. This situation creates a problem for fisheries management, particularly with respect to the shortjaw cisco (*Coregonus zenithicus*), a species at risk in Canada. This guide was developed to be a tool for distinguishing among ciscoes in Great Slave Lake, Northwest Territories, Canada. Technical terms are defined in the glossary at the end of the guide. The cisco species are notoriously difficult to identify due to their similarity, the existence of morphs within species (e.g., small adfluvial versus large lacustrine *C. artedi*), ontogenetic shifts in body morphology, a high degree of variation in body shape within species, and the potential for hybridization among species. While seemingly perplexing at first, basic anatomical characteristics can be used to differentiate the ciscoes.

The ciscoes of Great Slave Lake differ from their counterparts distributed farther southward (e.g., those in the Laurentian Great Lakes as well as inland lakes; Todd and Smith 1992). First, Great Slave Lake has not been influenced by invasive species and by other human-induced changes to the extent that the southern lakes have; it contains an intact assemblage of native coregonines. In this sense, Great Slave Lake is a model system for studying diversity within the cisco complex, and such studies may provide a better understanding of the patterns and processes driving the evolution of cisco diversity. The second major difference is that the key characteristics used to differentiate among ciscoes in the Laurentian Great Lakes are not as important as are other traits for differentiating among ciscoes in Great Slave and other northern lakes. For example, gillraker number is a primary feature for discriminating among ciscoes, but use of this characteristic is somewhat problematic in the north due to apparent changes in gillraker number with age (and/or body size), and in part because of the high degree of overlap in this characteristic among species and morphs. These differences necessitate a more thorough analysis of cisco diversity in Great Slave Lake that uses a broad suite of characteristics and ecological data. Herein, five Great Slave Lake ciscoes are differentiated and described, and their taxonomic affiliations are assessed.

Cisco Taxonomy

Previous Systematic Studies of Great Slave Lake Ciscoes

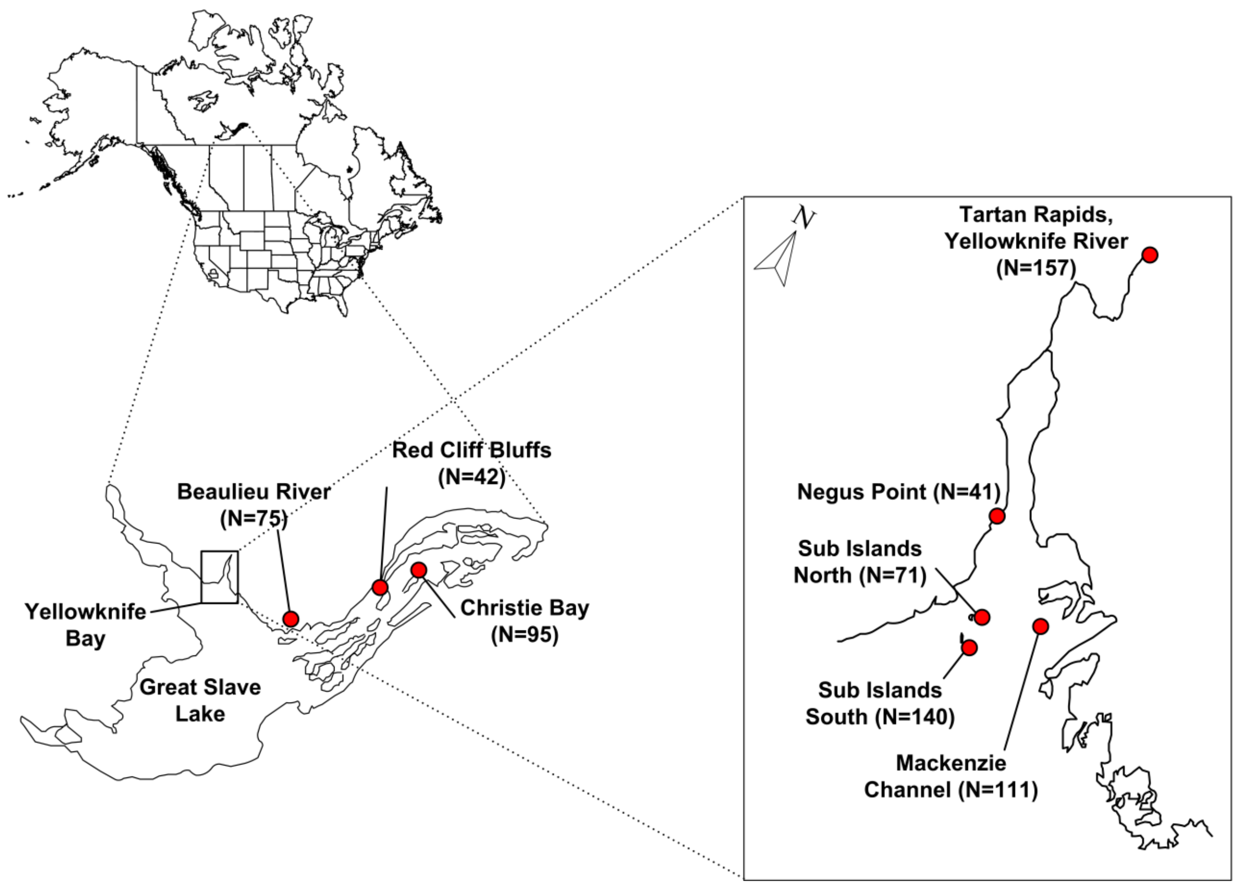
The ciscoes of Great Slave Lake have been described previously in five studies with various results, and the specimens from one study were reexamined by others twice. First, Harper and Nichols (1919) described a new species of cisco, *Leucichthys macrognathus*, on the basis of a single specimen collected from Great Slave Lake. This species is now considered synonymous with the shortjaw cisco. Rawson (1951) reported that at least three cisco species existed in Great Slave Lake—these collections were confirmed by J.R. Dymond to be the cisco (formerly lake herring) (*C. artedi*), a morph that resembled the blackfin cisco (*C. nigripinnis*), and a large morph that could not be identified to species. These specimens were deposited in the Royal Ontario Museum (ROM) and subsequently assessed by T.N. Todd (USGS Great Lakes Science Center, personal communication, 2008), R.L. Eshenroder (Great Lakes Fishery Commission), and N.E. Mandrak (Fisheries and Oceans Canada) who collectively suggested that the collection contained *C. artedi*, *C. nigripinnis*, *C. zenithicus*, and possibly least cisco (*C. sardinella*). Clarke (1973) identified two cisco species in Great Slave Lake—*C. artedi* and one that resembled *C. zenithicus*. Roberge et al. (1985) distinguished *C. artedi* from *C. sardinella* taken in multi-mesh gillnets from Great Slave Lake and mentioned a third morph that they did not describe, referring to it as unidentified. Using a suite of more than 30 morphometric and meristic characteristics, Murray and Reist (2003) were unable to confirm the presence of *C. zenithicus* in Great Slave Lake.

The fish collections, data processing, and analyses required to produce this guide were ongoing from 2007 to 2010. More than 1,000 specimens were collected, and approximately 800 were analyzed using geometric body shapes, 23 size-corrected linear morphometric measures, nine meristic counts, 30 osteological features, and buoyancies. Fatty acid profiles and stable carbon and nitrogen isotopes were analyzed from a subset of the individuals. In addition, nine habitat characteristics were measured at each collection site. Where possible, specimens were compared to historical collections from Great Slave Lake archived at the ROM. Users of this guide should be aware that the morphological and habitat descriptions provided are a function of the fish and habitats sampled; therefore, the variation that occurs within Great Slave Lake likely exceeds the variation described herein. This guide is a result of the first detailed morphometric and taxonomic analysis of cisco forms in Great Slave Lake. Similar to other taxonomies, it will evolve as new samples and new analytical methods improve our understanding of cisco diversity in this lake.

To aid in distinguishing among cisco morphs of Great Slave Lake, we took the liberty of adding descriptive terms to their common names. For example, *C. artedi* that have a riverine component to their life history are referred to as the "adfluvial cisco" to distinguish them from their conspecifics that do not enter rivers, the "lacustrine cisco." Although unconventional, the common nomenclature we have elected to use reduces ambiguity when referring to the morphs.

Locations Sampled in Great Slave Lake

Specimens used to create this cisco field guide were gillnetted and dipnetted from nine sites within the East Arm and Yellowknife Bay, Great Slave Lake, Northwest Territories. All gillnets were 200-m long x 1.8-m deep and were composed of eight 25-m panels of 12.7-, 25.4-, 38.1-, 50.8-, 63.5-, 76.2-, 88.9-, and 101.6-mm stretch mesh. Nets were deployed on bottom in depths of 10-237 m for <24 hours.



How to Use this Field Guide

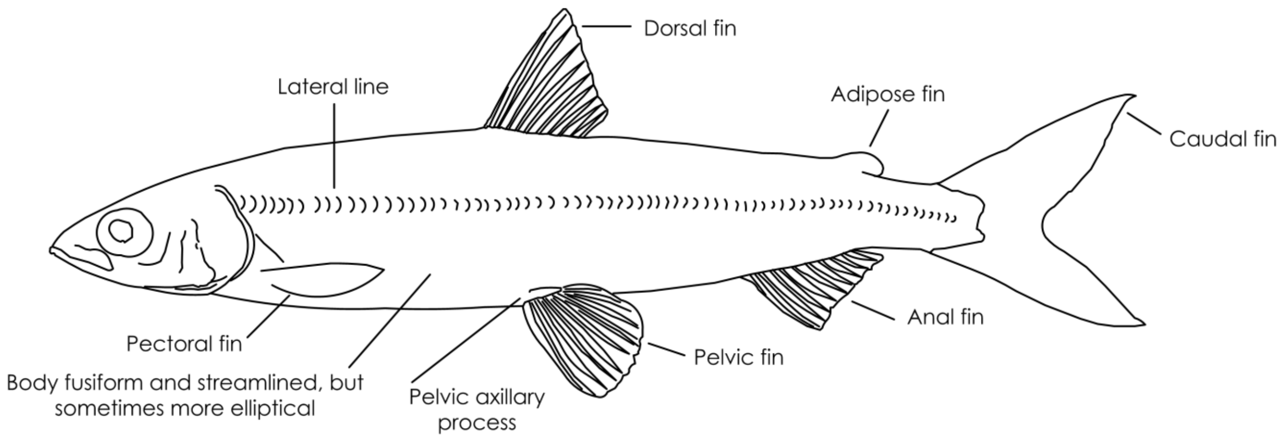
The first step in using this guide is to become familiar with the general anatomy of ciscoes and the potential variations in body form among them. With a fresh specimen in hand, the second step is to consult the key to narrow the identification down to one (or more) potential species or morphs. The key provides a weighting system for six characteristics: premaxillary angle (i.e., angle between the horizontal axis of the head and the premaxillae), lower jaw position, pelvic fin position, gillraker number, paired fin length, and eye diameter (orbital length). The degree to which each species or morph exhibits a particular characteristic is represented by circle size—large circles indicate a main character trait, medium circles indicate a moderate or occasional character trait, and small circles indicate a rare character trait (*sensu,* T. Todd (retired), unpublished data). For example, a lacustrine cisco is characterized by numerous gillrakers (46+), short paired fins, and a small eye; therefore, large circles appear under the columns for these traits. In contrast, the least cisco does not exhibit any of these character states; therefore, either nothing (i.e., character state has not been encountered) or small circles (i.e., rare character state) appear in the respective columns for that species. Note that a great deal of overlap in characteristics occurs; therefore, after the identification is narrowed down to one or more candidate species or morphs, consult the respective detailed sections and review information on habitat, biology, morphometrics, and meristics to complete the identification. Note that dorsal body coloration can be helpful in differentiating among cisco, but caution must be exercised when using this characteristic because coloration changes rapidly postmortem. The color illustrations in this guide are based on live or freshly captured specimens viewed in direct sunlight and may not be typical of specimens that are examined well after mortality.

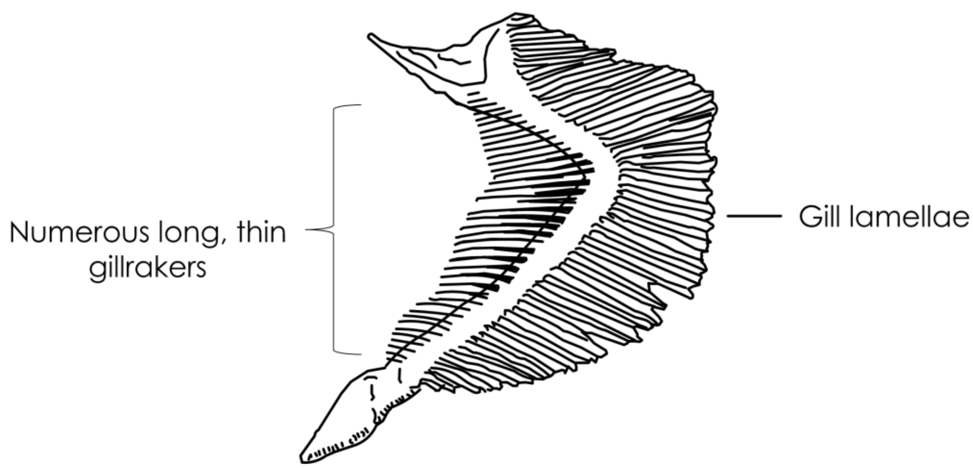
An Example Identification

Consider a cisco collected from a 40-m depth in Yellowknife Bay. The specimen is 180-mm fork length; the dorsum is peanut brown in color; and it has an included jaw, a broad dorsal fin, narrow pectoral fins that are short, and a small- to medium-sized eye. On the basis of its external anatomy, the specimen narrows down to either adfluvial cisco or shortjaw cisco. Next, consult the illustrated section for these two candidate species. After viewing the color illustrations, the line drawings of detailed morphological features, and the descriptions, this hypothetical specimen should have been identified as a shortjaw cisco. The rationale behind this identification is that, while most characteristics are common to both the adfluvial cisco and the shortjaw cisco, an included jaw and peanut-brown dorsal coloration are inconsistent with the characteristics of an adfluvial cisco. If doubts remain after consulting this guide, we suggest retaining a voucher specimen or a scaled digital image, and consulting with an expert.

Cisco Anatomy

Ciscoes are specialized zooplanktivores. Some of their morphological adaptations are thought to reflect the sizes, types, and behaviors of their various prey. In general, ciscoes are distinguished by a single dorsal fin that is shorter than the head; dorsal rays fewer than 16; a small body size that is fusiform and streamlined, but sometimes elliptical in shape; a small mouth that does not extend beyond the eye; teeth that are weak or absent; numerous (>32), long, thin gillrakers; a complete lateral line; pelvic fins and pelvic axillary process; an adipose fin; and a forked caudal fin (Scott and Crossman 1973).

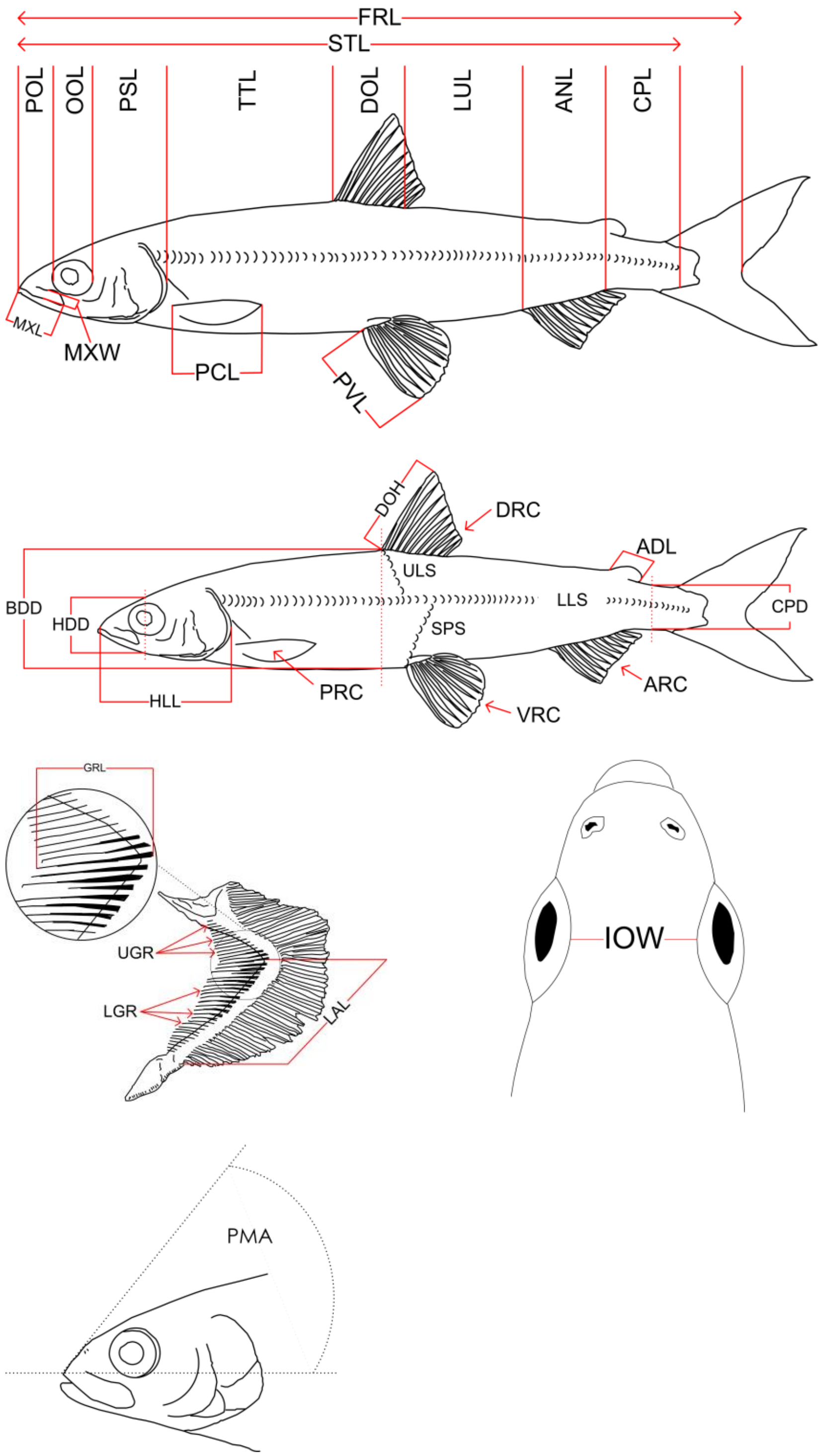




Notes:

- Collectively, the pectoral and pelvic fins are referred to as paired fins.
- The gillrakers act as a sieve to filter small food particles from the water column. As the fish opens its mouth, water is drawn in via negative pressure and passes over the gillrakers and out the opercles (gill covers). As the water passes out of the mouth, zooplankton and other food items in the water are retained within the mouth and can be swallowed.

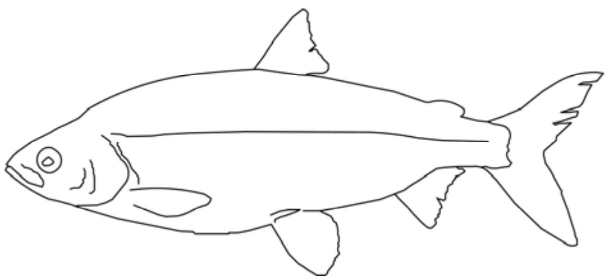
Morphometrics and Meristics



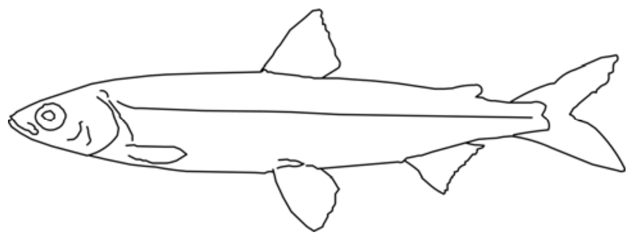
ADL—Adipose length
ANL—Anal fin length
ARC—Anal rays
BDD—Body depth
CPD—Caudal peduncle depth
CPL—Caudal peduncle length
DOH—Dorsal fin height
DOL—Dorsal fin length
DRC—Dorsal rays
FRL—Fork length
GRL—Middle gillraker length
HDD—Head depth
HLL—Head length
IOW—Interorbital width
LAL—Lower arch length
LGR—Lower gillrakers
LLS—Lateral line scales
LUL—Lumbar length
MXL—Maxillary length
MXW—Maxillary width
OOL—Orbital length
PCL—Pectoral fin length
PMA—Premaxillary angle
POL—Preobital length
PRC—Pectoral rays
PSL—Post orbital length
PVL—Pelvic fin length
SPS—Suprapelvic scales
STL—Standard length
TTL—Trunk length
UGR—Upper gillrakers
ULS—Scales above the lateral line
VRC—Pelvic rays

Variation within versus between Species

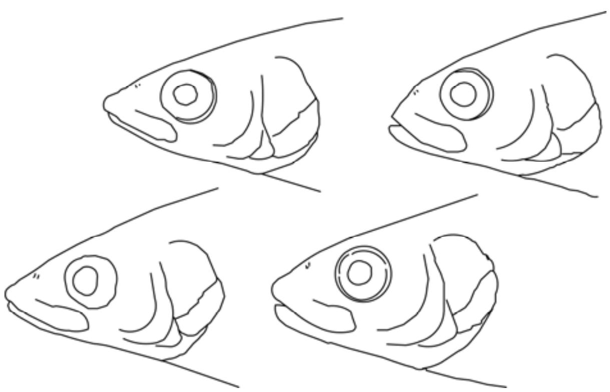
Two levels of variation complicate cisco taxonomy. The first level is intraspecific variation—variation in body form within a species. For example, ciscoes can take on a very robust body form when inhabiting large lakes or a very small, streamlined form when inhabiting low-productivity lakes or rivers (top row). In a further complication, ontogenetic changes in morphology occur over the life of an individual (e.g., gillraker number appears to increase with age). The second level of variation is interspecific—variation between species. The bottom row depicts both of these kinds of variation. Note the subtle differences in eye size, snout length, and jaw position within the shortjaw cisco and the least cisco groups and the striking differences in mouth orientation and eye size between these two species. In the shortjaw cisco, the mouth is oriented slightly down (inferior), whereas the mouth is oriented up (superior) in the least cisco. One must be cognizant of both types of variation as interspecific variation helps separate two putative species, whereas intraspecific variation may blur the distinction between them.



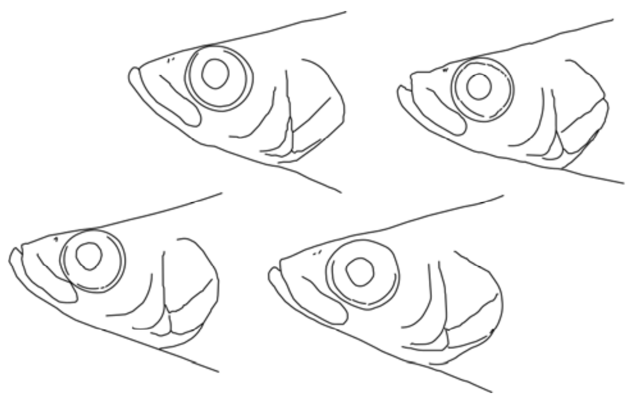
Lateral profile of the large lacustrine cisco, *C. artedi*.



Lateral profile of the small adfluvial cisco, *C. artedi*.

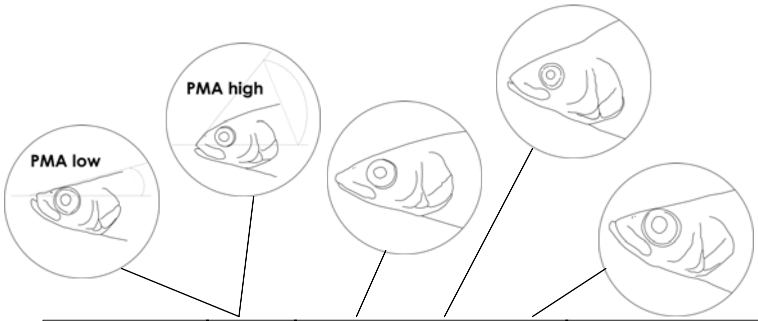


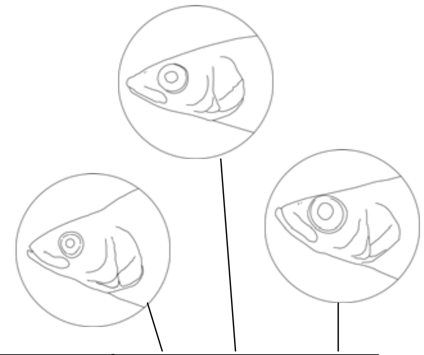
Intraspecific (i.e., within species) variation in head profile of the shortjaw cisco (*C. zenithicus*).



Intraspecific variation in the head profile of the least cisco (*C. sardinella*).

Key to the Ciscoes



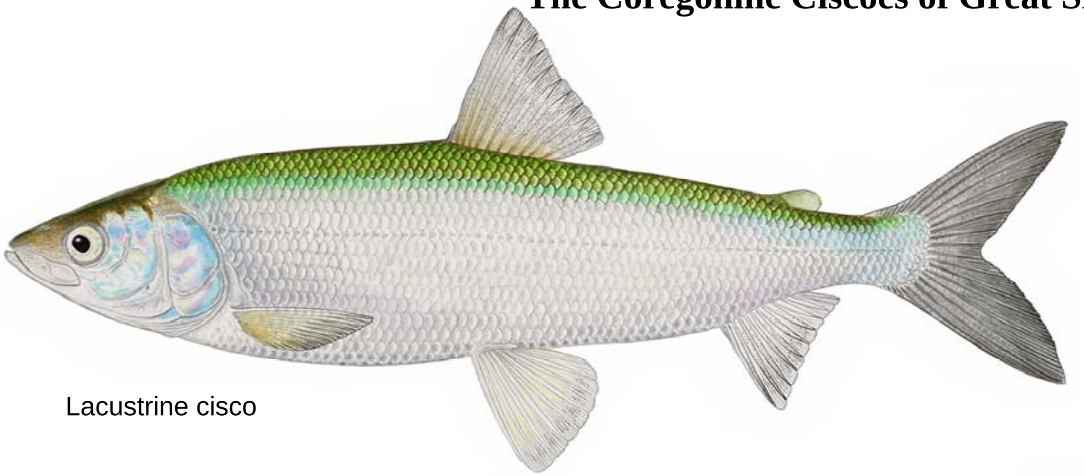


	PMA*	Lower jaw position			Pelvic fin position[1]			Gillraker number				Paired fin length[2]			Eye diameter (OOL)[3]		
Morph/ Species		Included	Terminal	Extended	Anterior	Middle	Posterior	35-40	41-45	46-50	51+	Short	Medium	Long	Small	Medium	Large
Lacustrine cisco	43± 0.64		Main	Rare		Main	Rare			Moderate	Main	Main			Main		
Adfluvial cisco	46± 0.52	Rare	Main			Main			Main			Main			Rare	Main	
Big-eye cisco	34 ± 1.43		Main	Rare		Main	Rare	Moderate	Main				Main				Main
Least cisco	24 ± 1.12			Main	Main				Main					Main			Main
Shortjaw cisco	51 ± 0.92	Main	Rare			Rare	Main	Main	Moderate			Main			Rare	Main	

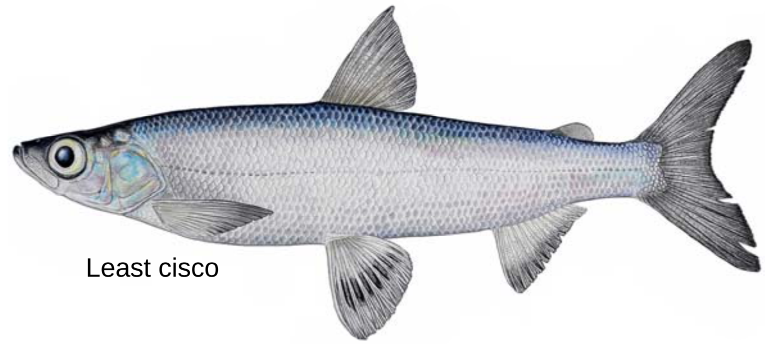
Main character state — Moderate or occasional character state — Rare character state

* Mean ± SE premaxillary angle
[2] Relative to standard body length
[1] Pelvic fin position relative to 50% standard body length
[3] Relative to head length

The Coregonine Ciscoes of Great Slave Lake

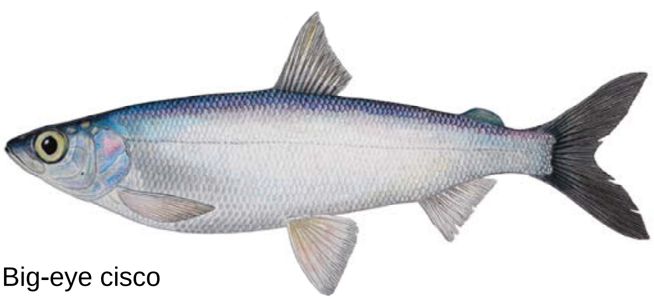


Lacustrine cisco

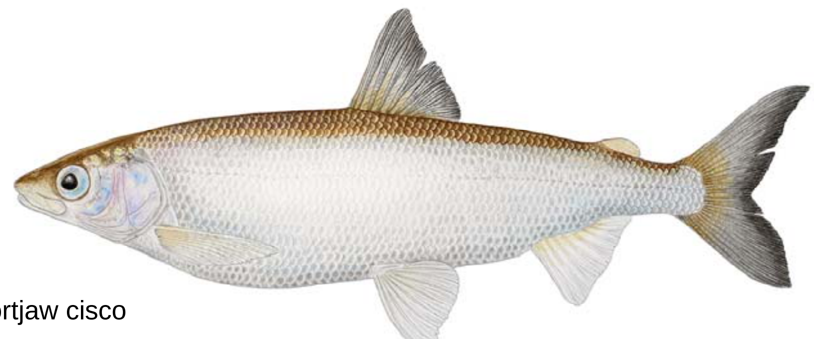


Least cisco

Adfluvial cisco



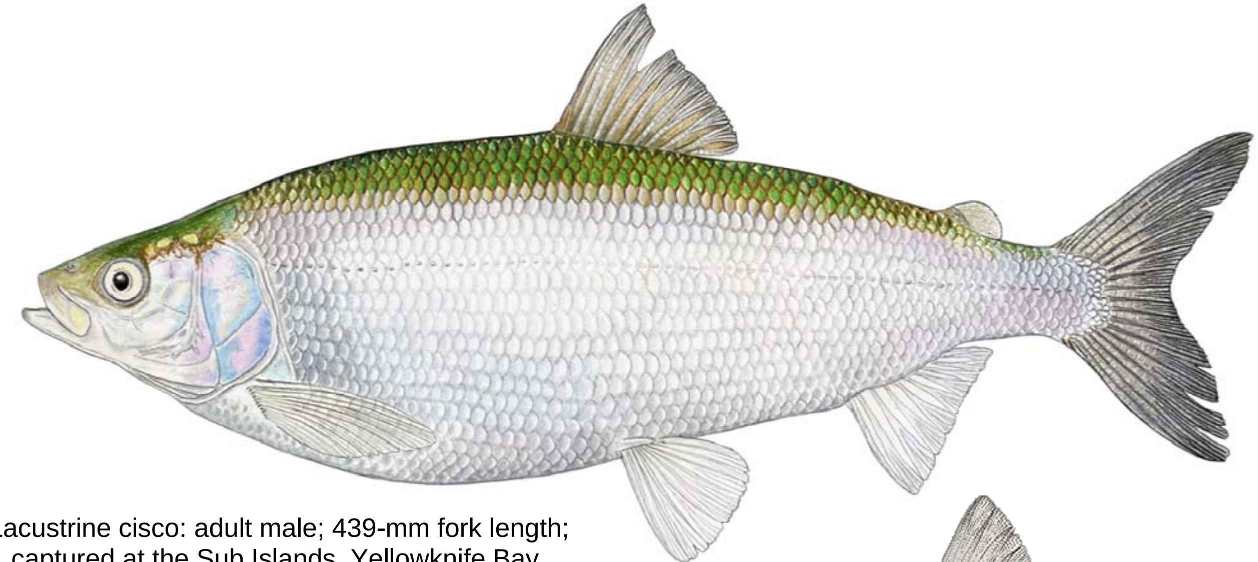
Big-eye cisco



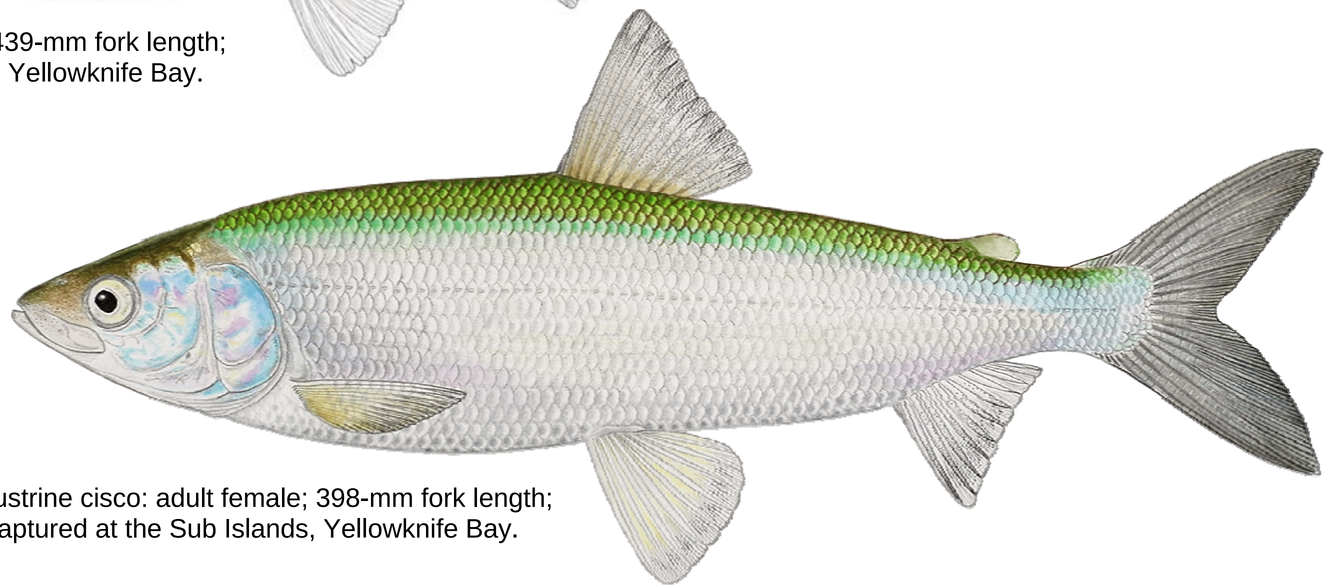
Shortjaw cisco

100 mm

Lacustrine cisco (*Coregonus artedi*)

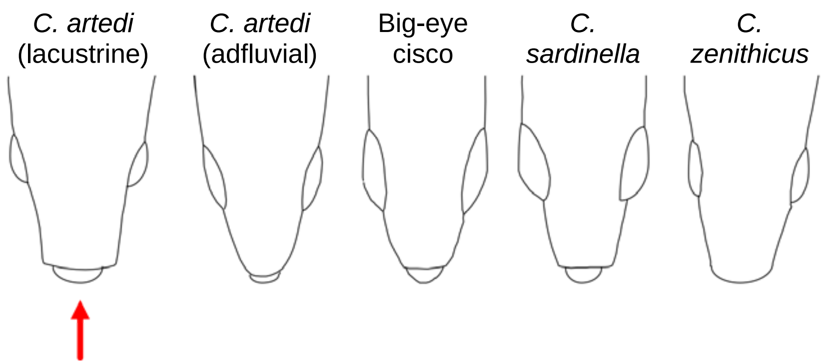


Lacustrine cisco: adult male; 439-mm fork length; captured at the Sub Islands, Yellowknife Bay.

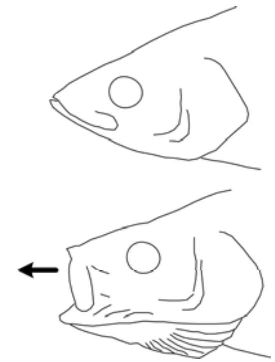


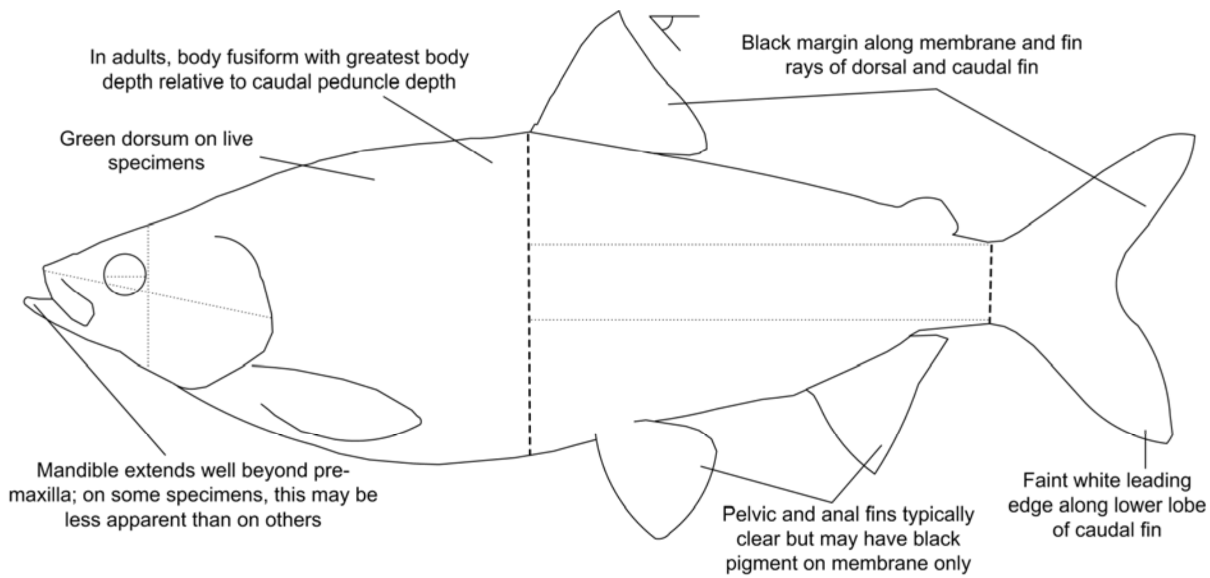
Lacustrine cisco: adult female; 398-mm fork length; captured at the Sub Islands, Yellowknife Bay.

Key Characteristics



The red arrow indicates the snout morphology as viewed dorsally; the black arrow indicates the mouth orientation with jaws extended.





Description

Body robust, deep, and fusiform; adults reaching 572-mm STL and 2495 g (Scott and Crossman 1973; ROM collection #13498). Differs from other sympatric ciscoes in that adults are largest, have the longest snout (POL), have short paired fins, and have the smallest eye diameter (OOL) relative to head length (HLL). The lacustrine cisco differs from the similar shortjaw cisco because the lacustrine cisco's mandible typically surpasses the premaxilla, dorsal coloration on live specimens is greener, the caudal fin lobes are more distinctly pointed, the snout is longer, and adult size is larger.

Habitat

Distribution is lakewide (Rawson 1951) and overlaps with all other ciscoes in Great Slave Lake. Ranges of physicochemical habitat variables measured in September/October were: mean water temperature (on bottom), 5.3-14.8ºC; dissolved oxygen (DO), 11.5-15.1 $mg \cdot l^{-1}$; conductivity, 100-206 µmhos; and pH, 6.4-7.9. Substrates at capture sites consisted primarily of clay and silt but also bedrock. Juveniles and adults were captured at water depths of 16-120 m. Large adults (>350 mm) have been captured only at three sites in Yellowknife Bay (i.e., Sub Islands South, Sub Islands North, and Mackenzie Channel). In Great Slave Lake, age-0 and age-1 juveniles inhabit nearshore shallow-water areas similar to those occupied by lake whitefish (*Coregonus clupeaformis*) (Rawson 1951).

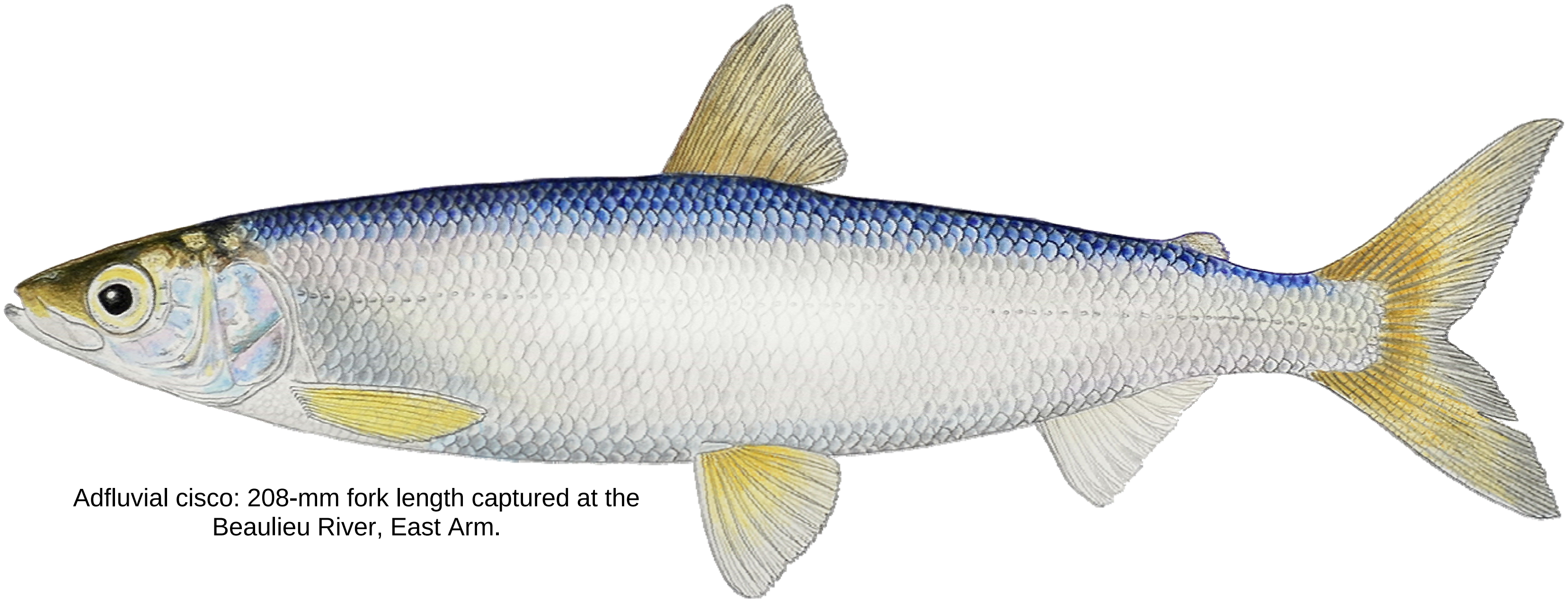
Notes on Biology

Considerable information exists on the biology of this species across its range (Scott and Crossman 1973). Spawning locations in Great Slave Lake are unknown; however, elders of the Yellowknives Dene First Nation and local commercial fishers suggest that spawning occurs in nearshore areas over rocky shoals, which is consistent across the species range. Mature individuals of both sexes can be caught during October. Males mature at age 3 and females at age 4. Among Great Slave Lake cisco, the lacustrine cisco has the fastest growth rate, the largest size, and the oldest age (33 yr based on sagittal otoliths).

Taxonomic Affiliation

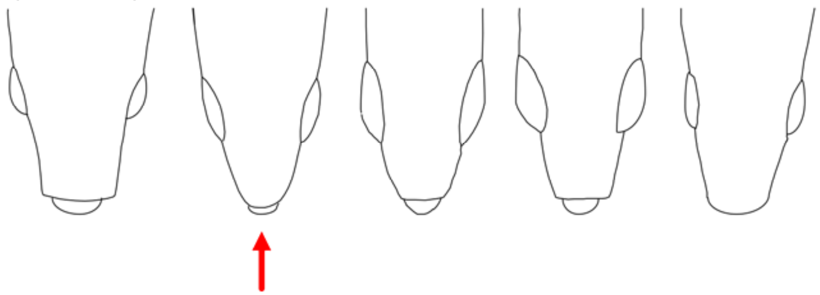
McPhail and Lindsey (1970) considered *C. artedi* to be a species complex and referred to it as the "*Coregonus artedi* complex" owing to the high degree of variation in body form, size, and life-history types. All characteristics of the lacustrine cisco in Great Slave Lake fit within the ranges of variation observed across the distribution of *C. artedi* (Scott and Crossman 1973).

Adfluvial cisco (*Coregonus artedi*)

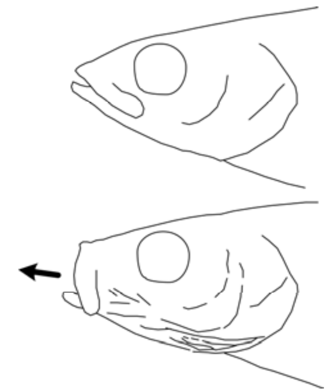


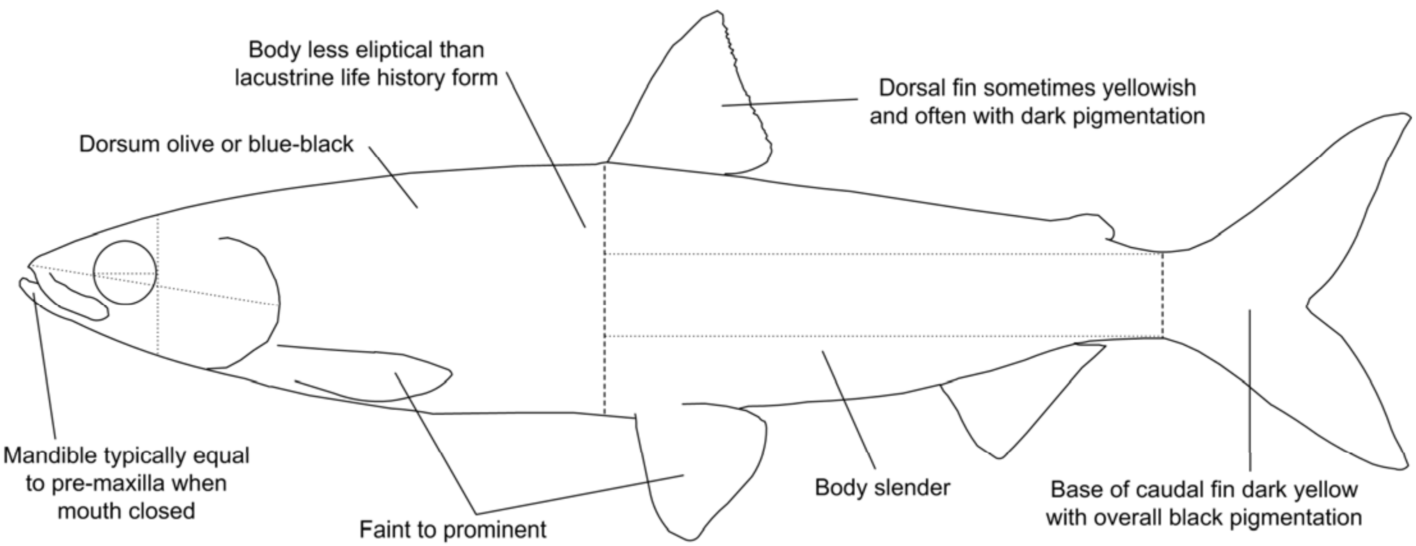
Adfluvial cisco: 208-mm fork length captured at the Beaulieu River, East Arm.

Key Characteristics



The red arrow indicates the snout morphology as viewed dorsally; the black arrow indicates the mouth orientation with jaws extended.





Description

Differs from other sympatric ciscoes in that the adult body is small, fusiform, and elongate with adults reaching 192-mm STL and 89 g; the eye is medium relative to head length and set along the medial body axis; and the fins have a yellow hue. Compared to lacustrine cisco, the adult body is more fusiform and more elongate than deep, the eye is larger (relative to HLL), the snout is shorter, and the jaw is terminal. Compared to the big-eye cisco, its eye is smaller (relative to HLL), it lacks a black chin, and the head and maxilla have less black pigmentation.

Habitat

Adult adfluvial ciscoes utilize both lake and river habitat. This morph can be caught en masse during fall (September-October) when large numbers of reproductively mature individuals enter rivers, presumably for spawning (Golder 2008). Spawning habitat within rivers has not been verified because spawning likely occurs during December when it is logistically challenging to collect fish. With the possible exception of the Slave River cisco (species unknown; Tripp et al. 1981), the adfluvial cisco appears to be the only morph in Great Slave Lake that uses riverine habitat. Information on the distribution of this morph after it returns to the lake is limited. For example, although large numbers of fish enter the Yellowknife River during the fall, throughout the rest of the year, it is rarely caught in gillnets in Yellowknife Bay. This morph can be found in less than 1 m of water at riverine sites and as deep as 70 m at lacustrine sites in the East Arm. When captured in rivers, physicochemical habitat variables during September-October ranged as follows: water temperature in rivers, 5.3ºC in the Beaulieu River to 7.9ºC at Tartan Rapids; water temperature in the lake, 14.8ºC; DO, 12.3-15.2 $mg \cdot l^{-1}$; conductivity, 55 µmhos at Tartan Rapids to 201 µmhos at Christie Bay; and pH, 7.3 at Beaulieu River to 8.2 at Tartan Rapids. Substrates at riverine capture sites were gravel, cobble, and boulder and, at Christie Bay, were clay and silt. Spawning, larval, and juvenile habitat is unknown.

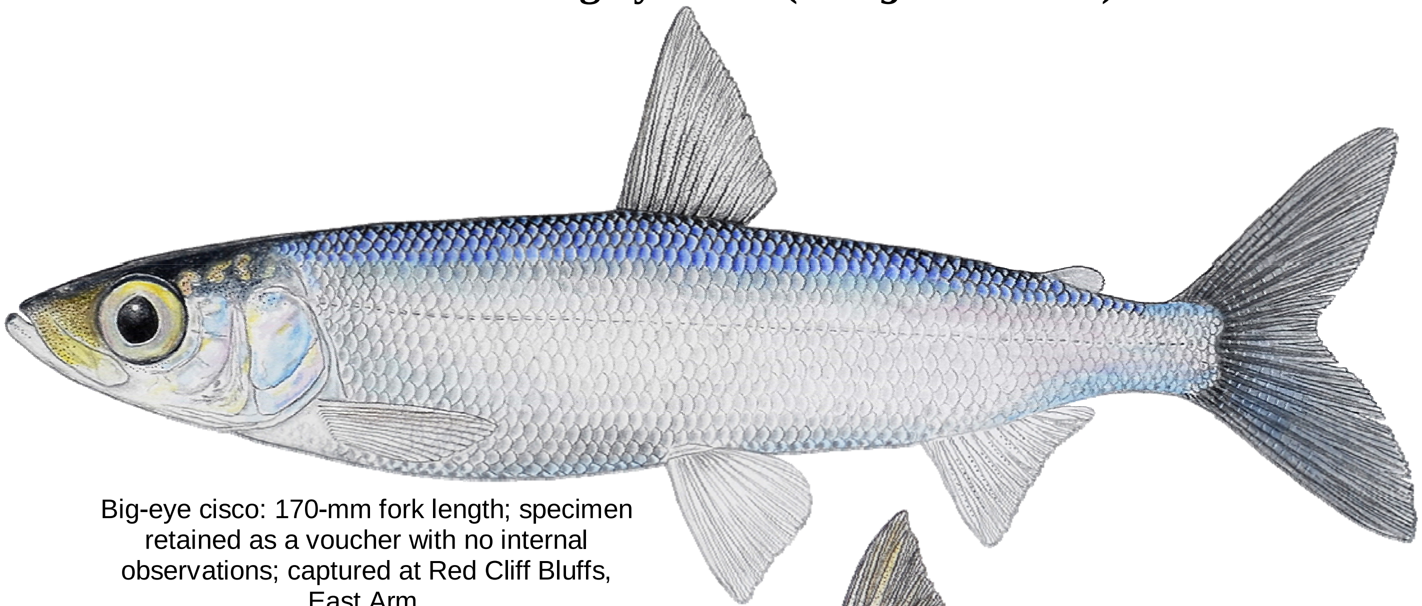
Notes on Biology

The life-history trait of spawning in fast-flowing shallow water in rivers has been documented for some northern populations of *C. artedi* (Turgeon and Bernatchez 2003) as well as Laurentian Great Lakes populations (e.g., Fielder 1998). Within Great Slave Lake, we confirmed the adfluvial morph from the Beaulieu, Snowdrift, Stark, and Yellowknife Rivers. Spawning likely occurs during the late fall (Golder 2008). The exact timing and spawning sites are unknown; however, the Yellowknives Dene First Nation elders say that spawning begins when the edges of the lake freeze. Mean age is 4 (range 2-9 yr) and age-at-maturity is 3-5 yr. The adfluvial morph exhibits a much shorter life span than its lacustrine counterpart. Nothing is known about food habits, because sampling has been conducted primarily during fall when fish are migrating into rivers—stomachs are then typically empty.

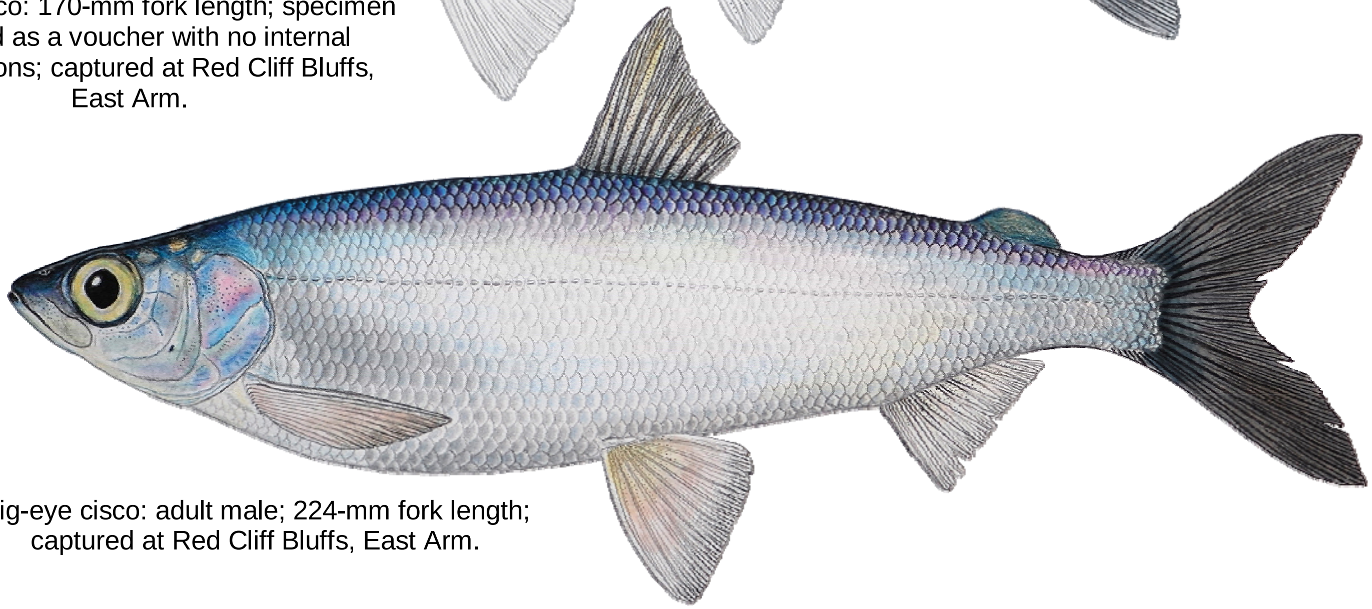
Taxonomic Affiliation

The adfluvial cisco apparently is a short-lived, small-bodied "dwarf" form of *C. artedi*. While most of its characteristics fall within the range for the lacustrine cisco, general gross morphological differences distinguish the two morphs. In addition, the life-history characteristic of migrating into rivers during the fall, presumably for spawning, and its age and growth structure set this morph apart from its lacustrine conspecific. No large-bodied, old (i.e., >9 yr) individuals have been captured in rivers during the fall migration; therefore, this morph appears to be reproductively isolated from its lacustrine counterpart. As such, adfluvial cisco should be managed independently from other cisco and recognized with the name we suggest here; however, for taxonomic purposes, they are probably best recognized as a morph within the *C. artedi* complex (*sensu* Turgeon and Bernatchez 2003).

Big-eye cisco (*Coregonus artedi*)

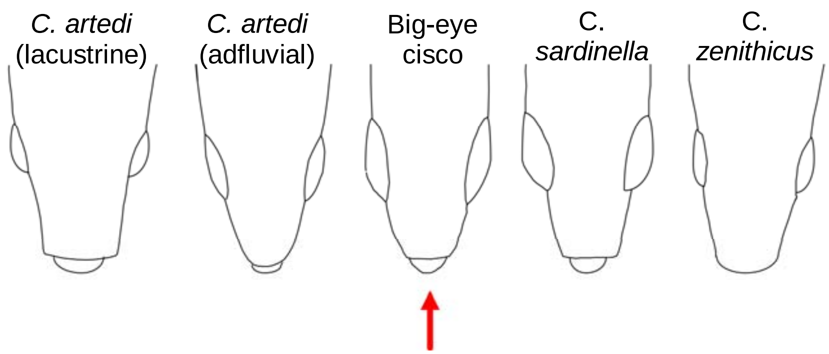


Big-eye cisco: 170-mm fork length; specimen retained as a voucher with no internal observations; captured at Red Cliff Bluffs, East Arm.

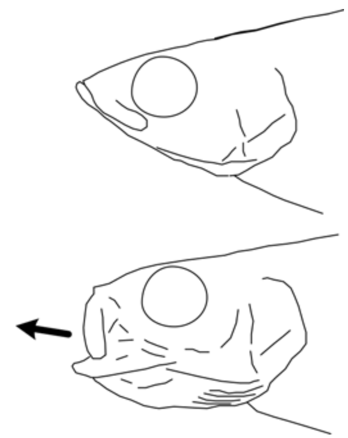


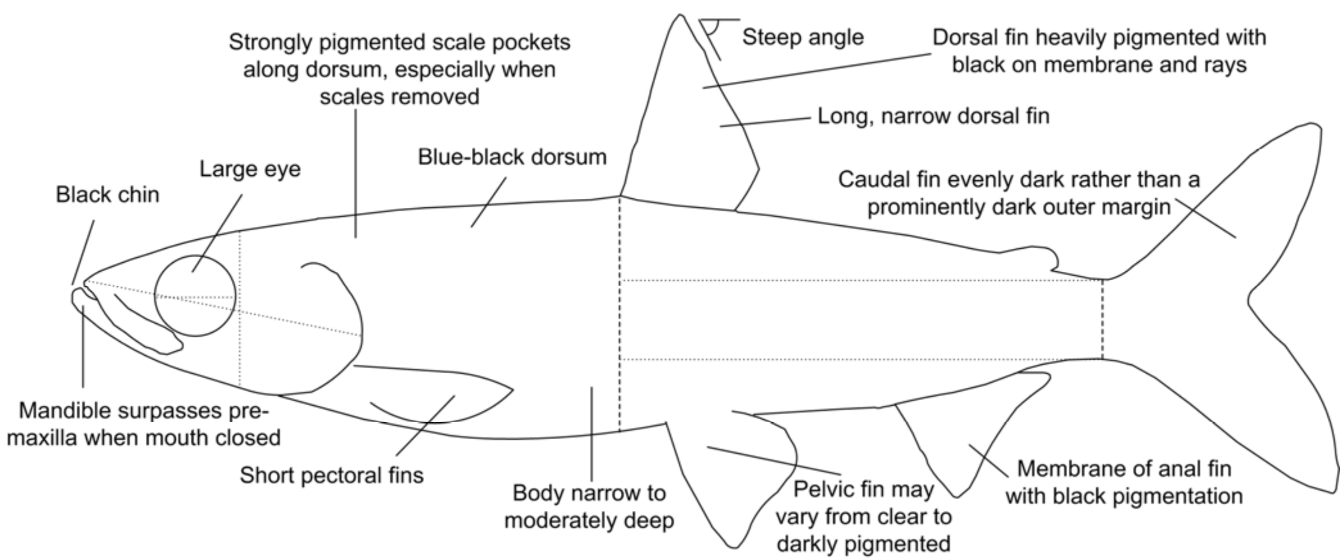
Big-eye cisco: adult male; 224-mm fork length; captured at Red Cliff Bluffs, East Arm.

Key Characteristics



The red arrow indicates the snout morphology as viewed dorsally; the black arrow indicates the mouth orientation with jaws extended.





Description

Body small, slender, and slightly elliptical; adults reaching 204-mm STL and 130 g. Differs from other sympatric ciscoes in that the eye diameter is very large relative to HLL, the preorbital is short relative to HLL; the dorsal fin is long, but narrow at the base; the head is short (relative to STL); and the scale pockets on the dorsum are darkly pigmented. Compared to the lacustrine cisco (i.e., the most similar morph), eye size is much greater for like-size individuals, body shape is less elliptical and not as deep, fewer gillrakers are present, and the body is more evenly pigmented with darker dorsal coloration (i.e., more blue than green) in live specimens. Smaller specimens can be mistaken for the least cisco, but the big-eye cisco lacks a superior mouth, has a smaller head, has a greater PMA, and the pelvic fin insertion is in the posterior 50% of STL.

Habitat

The big-eye cisco has not been previously described from Great Slave Lake; therefore, little is known about its habitat, biology, or ecology. This morph was captured on bottom, over clay, silt, and bedrock in water depths of 16-120 m, but primarily at 53-55 m. It was captured at all lacustrine locations within Yellowknife Bay and the East Arm of Great Slave Lake, although, in the East Arm, it was more common at deepwater sites. Ranges of physicochemical habitat variables measured in September/October were: mean water temperature (on bottom), 5.3-13.7ºC; DO, 11.5-15.1 $mg \cdot l^{-1}$; conductivity, 100-206 µmhos; and pH, 6.4-7.9.

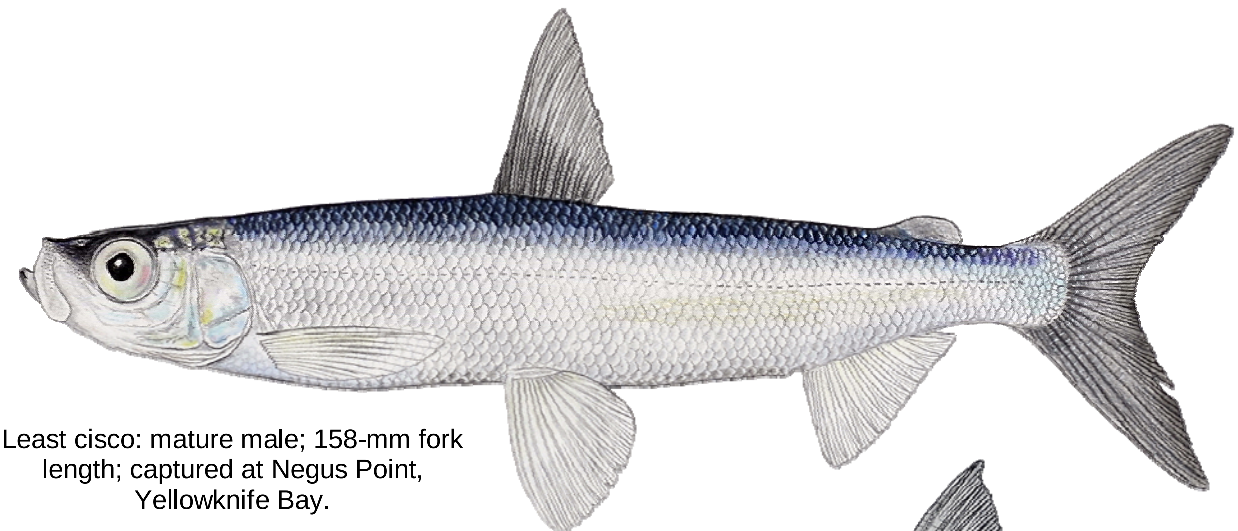
Notes on Biology

Spawning locations are unknown, but ripe females were captured during October in water depths ranging from 16-54 m. Females mature at age 5 and males at age 3. Nothing is known about its food habits.

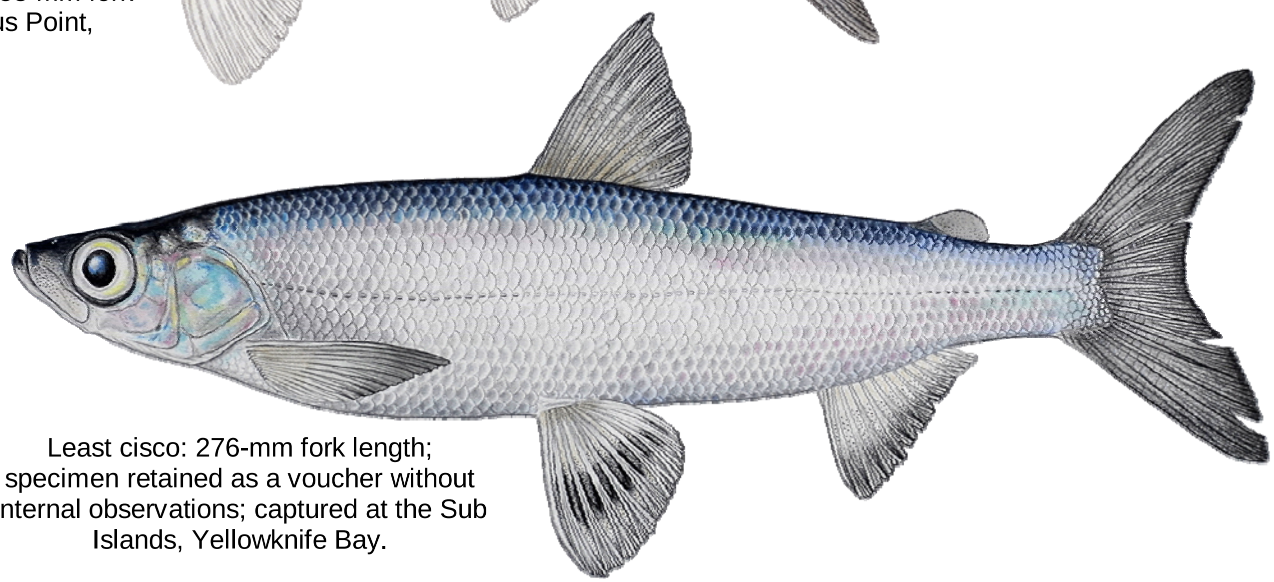
Taxonomic Affiliation

This guide provides the first description for Great Slave Lake of this morph, which was given the colloquial name big-eye cisco due to its large eyes. On the basis of statistical analyses of morphometric and meristic characters, this form is distinguishable from its conspecifics. Because few specimens (n~35) of this morph have been examined, its taxonomic affiliation is currently unknown, although it is most similar to the lacustrine and least cisco. Ecologically, it appears similar to the bloater (*C. hoyi*) of the Laurentian Great Lakes, but further study, especially of genetics, is required to determine the taxonomy of the big-eye cisco. Big-eye cisco is probably best recognized as a morph within the *C. artedi* complex (*sensu* Turgeon and Bernatchez 2003).

Least cisco (*Coregonus sardinella*)

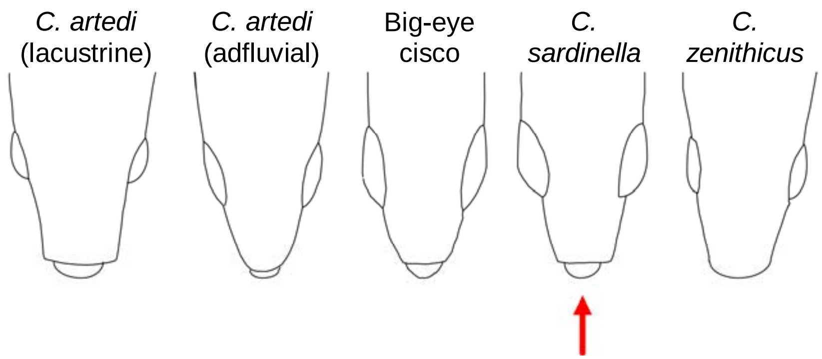


Least cisco: mature male; 158-mm fork length; captured at Negus Point, Yellowknife Bay.

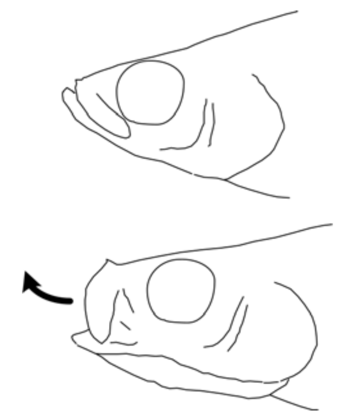


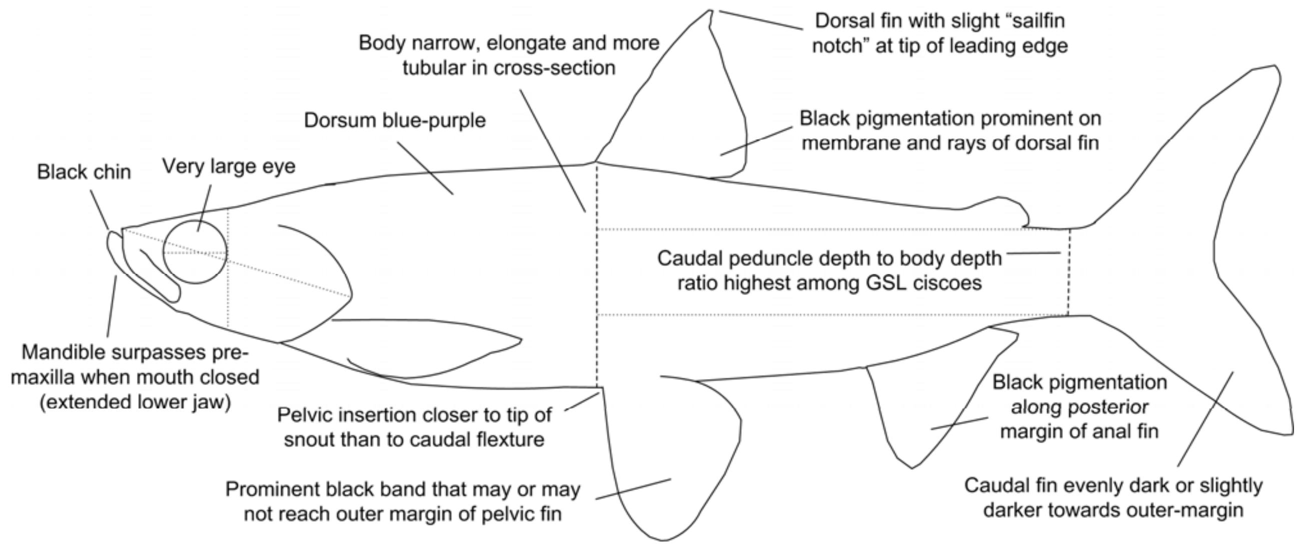
Least cisco: 276-mm fork length; specimen retained as a voucher without internal observations; captured at the Sub Islands, Yellowknife Bay.

Key Characteristics



The red arrow indicates the snout morphology as viewed dorsally; the black arrow indicates the mouth orientation with jaws extended.





Description

Body fusiform and elongate, adults reaching 298-mm STL and 255 g. Differs from other sympatric cisco in that eye size is very large, sometimes extending beyond the dorsal body margin; PMA is the lowest among the cisco; mouth nearly superior in orientation; extended lower jaw; IOW considerably smaller; pelvic fins long, reaching the anus; origin of pelvic fins closer to the tip of the snout than the caudal flexure; and the dorsal fin is long (DOH) but narrow at its base (DOL). Compared to the big-eye cisco (i.e., most similar morph), the mouth is more superior, the lower jaw is more extended, the body is more elongate, the PMA is lower, and the head is smaller relative to TLL.

Habitat

All least cisco were captured near islands located offshore in the main body of Yellowknife Bay. To date, none have been captured in the East Arm; however, W.A. Kennedy collected least cisco from the main basin of the lake in 1943 and 1946 (ROM collections # 16848, 16856, 17086, 17107, 17119, and 65046—identified subsequently as *C. sardinella*; original identification unknown), and it has been collected from the Mackenzie River (ROM collections # 15786, 15787, and 15788), which receives the outflow of Great Slave Lake. Least cisco distribution appears restricted to waters <40 m. Adults are captured on bottom at moderate water depths (15-54 m) over clay and silt substrates. Ranges of physicochemical habitat variables measured in September/October are: mean water temperature (on bottom), 7.7-13.9ºC; DO, 11.5-15.1 $mg \cdot l^{-1}$; conductivity, 100-206 µmhos; and pH, 6.4-6.8. Juveniles were captured at one nearshore site where water depth ranged from 10-19 m over rock and clay substrate. The spawning and larval habitat is unknown. Many *C. sardinella* populations use riverine habitat during at least part of their life cycle (McPhail 2007), yet, with the exception of the Mackenzie River record and a possible Slave River record (taxonomy uncertain; Tripp et al. 1981), the least cisco described here has not, to our knowledge, been captured in other rivers in the Great Slave Basin.

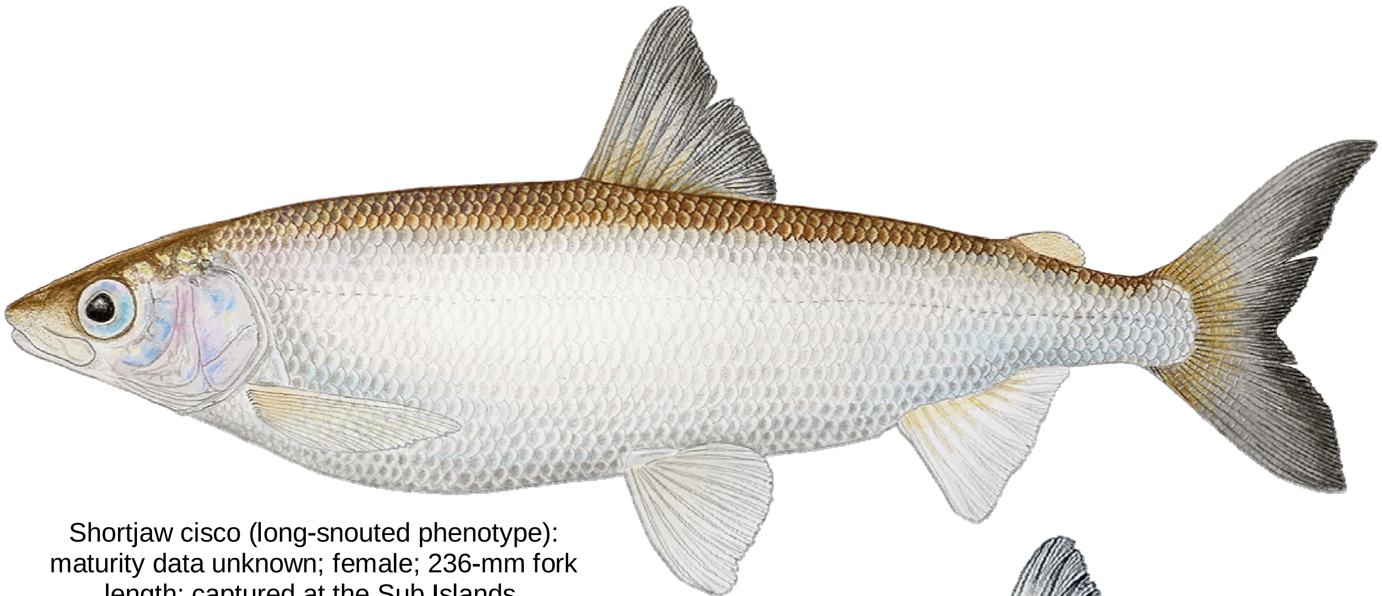
Notes on Biology

Little is known about the biology of least cisco in Canada. Spawning locations are unknown in Great Slave Lake; spawning occurred during late fall because both ripe males and females were captured during October. Age-at-maturity appears to be from 3-5 yr. Little is known about its food habits; however, opossum shrimp (*Mysis diluviana*), amphipods (*Diporeia* spp.), and copepods were identified in the gut contents of a few individuals. The maximum age of least cisco observed in Great Slave Lake was 26 yr, a considerably older age than recorded for the Siberian and Alaskan *C. sardinella*, which attain a maximum age of ~11 yr (McPhail and Lindsey 1970).

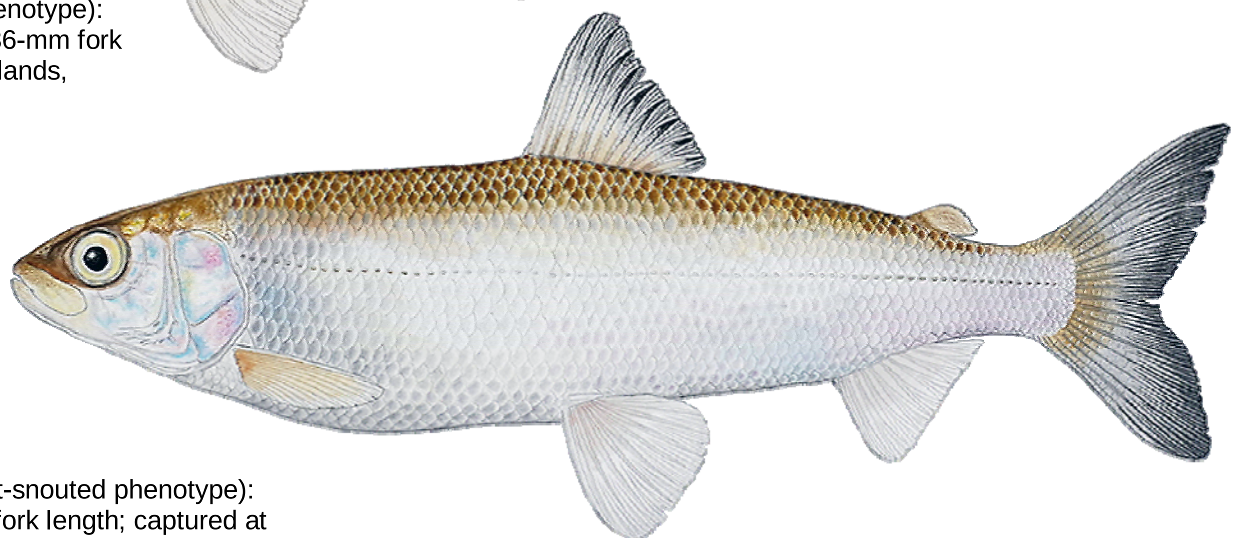
Taxonomic Affiliation

Specimens of least cisco from Great Slave Lake are archived in the ROM Ichthyology Collection but have been identified as both least cisco, *C. sardinella* (Arctic cisco assemblage), and blackfin cisco, *C. nigripinnis* (Laurentian cisco assemblage). Tripp et al. (1981) reported the possible presence of *C. sardinella* in the Slave River, a major tributary to Great Slave Lake. mtDNA sequences strongly demonstrate the existence of *C. sardinella* in the Great Slave Lake basin (Turgeon and Bernatchez 2003); however, these fish appear to differ morphologically from western *C. sardinella*, the latter being much deeper bodied and generally more robust. Similar ciscoes are common in the Arctic region from the Mackenzie River to Hope Bay. *C. sardinella* consists of numerous life-history types, which gives rise to the hypothesis that the species may occur as a complex of multiple species or morphs (McPhail 2007).

Shortjaw cisco (*Coregonus zenithicus*)

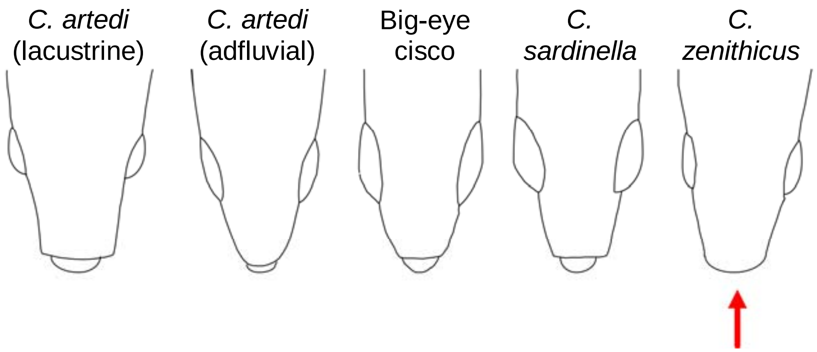


Shortjaw cisco (long-snouted phenotype): maturity data unknown; female; 236-mm fork length; captured at the Sub Islands, Yellowknife Bay.

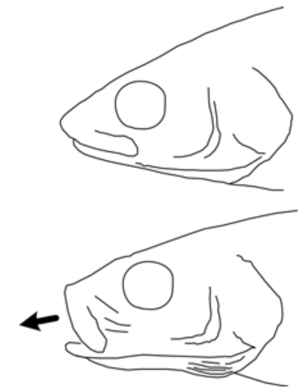


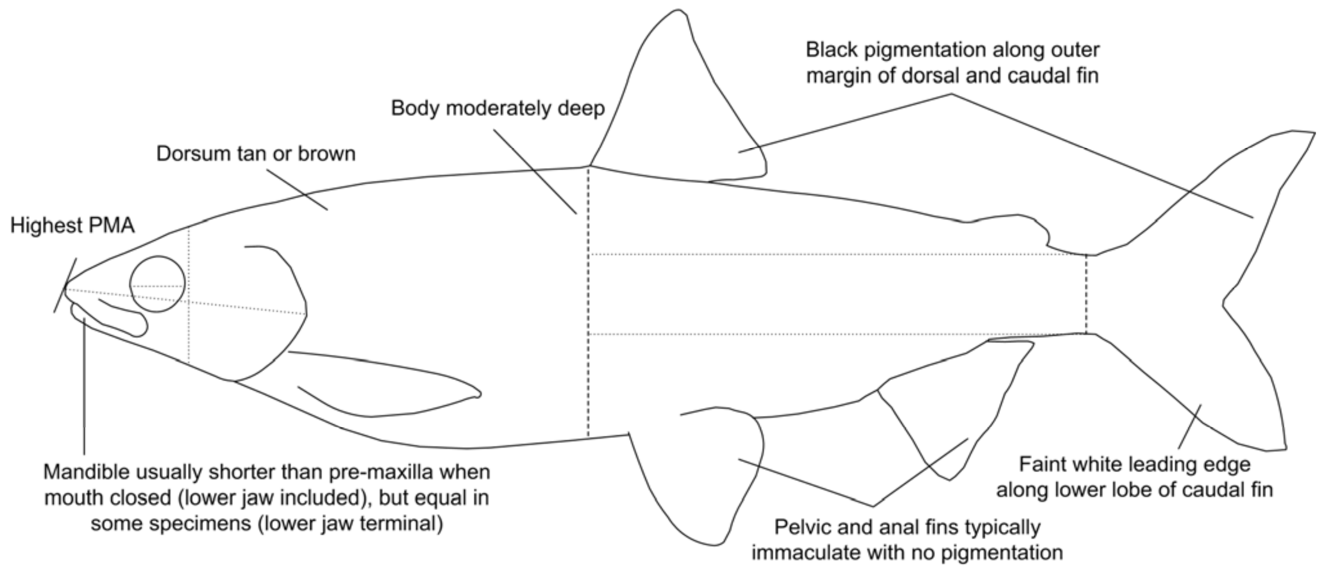
Shortjaw cisco (short-snouted phenotype): spent male, 295-mm fork length; captured at Christie Bay, East Arm.

Key Characteristics



The red arrow indicates the snout morphology as viewed dorsally; the black arrow indicates the mouth orientation with jaws extended.





Description

Body anteriorly ovate or elliptical; adults reaching 290-mm STL and 410 g. Shortjaw cisco differs from other sympatric ciscoes in that the mandible is usually shorter than the premaxilla when the mouth is closed (i.e., lower jaw included), the premaxillary angle is high (but not in all individuals), and the mouth projects slightly downward. Compared with the lacustrine cisco (i.e., most similar species), the shortjaw cisco has a dorsum that is tan/brown and lacks iridescence in live specimens, the eye is larger (relative to HLL), the mandible is shorter than the upper jaw (pre-maxilla), the lobes of the caudal fin are more rounded, and the gillrakers tend to be fewer in number. Among the Great Slave Lake ciscoes, only the shortjaw cisco lacks pigment or color on the pelvic and anal fins.

Habitat

Both adults and juveniles were captured on the bottom at moderate water depths (15-120 m), and their distribution overlapped with all other sympatric cisco. Ranges of physicochemical habitat variables measured in September/October are: mean water temperature (on bottom), 5.3-14.8ºC; DO, 11.5-14.1 $mg{\cdot}l^{-1}$; conductivity, 180-206 µmhos; and pH, 6.4-7.9. Substrates were primarily clay and silt but consisted of bedrock at one site. Juveniles were captured at one nearshore site where water depth ranged from 10-19 m over a rock and clay substrate.

Notes on Biology

Considerable information on the biology of the species exists across its range (Todd and Steinhilber 2002; Todd 2003). Spawning occurs during the fall; mature males and females were captured during September and spent fish were captured during October. Both sexes mature at age 2, which is consistent with other northern populations of this species except that, in the Laurentian Great Lakes, maturity occurs later (Todd 2003; Steinhilber et al. 2002). Little is known about the food habits of shortjaw cisco in Great Slave Lake; opossum shrimp and the amphipod *Diporeia* spp. are primary prey elsewhere; planktonic crustaceans (i.e., copepods and cladocerans) and aquatic insects are also consumed (Scott and Crossman 1973; Bajkov 1930).

Taxonomic Affiliation

In terms of its external gross morphology, meristic characters, and general appearance, the shortjaw cisco of Great Slave Lake generally conforms to the classical description of *C. zenithicus* elsewhere. The Great Slave Lake form differs most notably from southern populations in that it attains a greater maximum size and age (max = 22 yr, based on sagittal otoliths); exhibits a broader distribution of gillraker number (i.e., 33-46) and, unlike in central and southern populations, the mandible is often obviously shorter than the premaxillae giving the mouth a prominent subterminal aspect. In this sense, adult shortjaw cisco in Great Slave Lake are more readily distinguishable from conspecifics than in the central and southern parts of its range (AM, personal observation, 2009). In addition, a range of interesting morphologies is present in Great Slave Lake suggesting that differentiation may be occurring within this species. For example, a long-snouted variant, which lacks the pronounced down-curved premaxilla associated with the typical form, occurs but is less common than the typical form. The long-snouted variant has a fleshy, rounded, protruding snout more typical of the long-snouted mountain whitefish (*Prosopium williamsoni*), and it may be a local endemic.

Acknowledgements

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Glossary

Adfluvial	Living in lakes and migrating into rivers and streams to spawn (Coad and McAllister 2010).
Adipose length (ADL)	Distance from the point where skin and scales meet at the anterior end of the fin to the free posterior margin of the fin (Vuorinen et al. 1993).
Anal fin length (ANL)	Distance along the horizontal body axis between the origin and the posterior edge of the fin (Vuorinen et al. 1993).
Benthic	Bottom dwelling, pertaining to the sea, lake, or riverbed (Coad and McAllister 2010)
Body depth (BDD)	Vertical distance from the dorsal origin to the ventral surface of the body (Vuorinen et al. 1993).
Caudal peduncle depth (CPD)	Least vertical depth of the caudal peduncle (Vuorinen et al. 1993).
Caudal peduncle length(CPL)	Distance along the horizontal axis of the body between the posterior of the anal fin and the caudal flexure (Vuorinen et al. 1993).
Conspecific	Belonging to the same species. Conspecific subspecies are subspecies belonging to the same species (Coad and McAllister 2010).
Dorsal fin length (DOL)	Origin of dorsal fin to the posterior edge of the fin behind the final ray (Vuorinen et al. 1993).
Dorsal fin height (DOH)	Origin of dorsal fin to the tip of the longest ray (Vuorinen et al. 1993).
Extended jaw	The lower jaw extends beyond the upper jaw (Coad and McAllister 2010).
Fork length (FRL)	Distance from tip of premaxilla to the caudal fork with the fin open (Vuorinen et al. 1993).
Fusiform	Spindle-shaped; tapering at both ends in a streamlined fashion.
Gillraker	One of a series of variously shaped bony or cartilaginous projections on the inner side of the branchial arch. The rakers have epithelial denticles and both their gross and fine structure serves to retain food particles in the mouth. The gillraker count normally includes all rakers, even the rudiments, and is made on the front half of the first arch. The most anterior and posterior rakers are often small and delicate, easily torn, or lost if the arch is removed. Plankton feeders have numerous, crowded, elongate, and fine rakers; predators have few, separated, short, and stubby rakers (Coad and McAllister 2010).
Head depth (HDD)	Vertical distance through the pupil of the eye from the dorsal surface of the cranium to the ventral edge of the gular region (Vuorinen et al. 1993).
Head length (HLL)	Sum of preorbital, orbital, and post-orbital lengths.

Included jaw	Contained (e.g., the lower jaw is "included" when the upper jaw extends beyond and over it) (Coad and McAllister 2010).
Intraspecific	Within a species (Coad and McAllister 2010).
Interspecific	Between two or more species (Coad and McAllister 2010).
Lumbar length (LUL)	Distance along the horizontal body axis between the end of the dorsal fin and the origin of the anal fin (Vuorinen et al. 1993).
Lower arch length (LAL)	Length from the start of the lower arch to the base of the middle gillraker taken from the left side of the fish (Vuorinen et al. 1993).
Maxillary length (MXL)	Anterior point of premaxilla to posterior end of the maxilla (Vuorinen et al. 1993).
Maxillary width (MXW)	Greatest width along the maxillary (Vuorinen et al. 1993).
Meristics	Pertaining to serially repeated structures (e.g., scales, fin rays, and also to other structures that can be counted). The study and comparison of body-part counts (Coad and McAllister 2010).
Middle gillraker length (GRL)	Length of the gillraker on the ceratobranchial-epibranchial joint of the first arch taken from the left side of the fish (Vuorinen et al. 1993).
Morph	A “form” or “variant” (Coad and McAllister 2010).
Morphology	Appearance, form, and structure of an organism, especially based on external characters (Coad and McAllister 2010).
Morphometrics	Measurement of a body part (e.g. head length). The study and comparison of body-part measurements (Coad and McAllister 2010).
Ontogenetic	Adjective for ontogeny. Ontogeny equals the development from embryo to adult (Coad and McAllister 2010).
Orbital length (OOL)	Distance between anterior and posterior fleshy margins of the orbit (Vuorinen et al. 1993).
Opercle	Principal and largest paired dermal bone comprising the upper part of the gill cover above the subopercle (also called operculum) (Coad and McAllister 2010).
Paired fins	Collectively referring to the pair of pectoral fins and the pair of pelvic fins.
Pectoral fin length (PCL)	Extreme base of outermost ray to farthest tip of fin (Vuorinen et al. 1993).
Pelagic	Waters occurring above the bottom; non-benthic (Coad and McAllister 2010).
Pelvic fin length (PVL)	Extreme base of outermost ray to farthest tip of fin (Vuorinen et al. 1993).
Post orbital length (PSL)	Posterior fleshy margin of the orbit to posterior bony margin of the operculum (Vuorinen et al. 1993).

Pre-orbital length (POL)	Distance from the tip of the snout to the anterior margin of the orbit (Vuorinen et al. 1993).
Premaxillary angle (PMA)	Angle between the horizontal axis of the head and the premaxillae (Vuorinen et al. 1993).
Preobital length (POL)	Tip of the premaxilla to the anterior fleshy margin of the orbit (Vuorinen et al. 1993).
Sagittal otoliths	Largest of the otoliths (Coad and McAllister 2010). Bones in the head of the fish that are part of the sensory system. The otolith in the sicculus.
Standard length (STL)	Distance from the tip of the premaxilla to the caudal flexure (crease created when tail is flexed) (Vuorinen et al. 1993).
Terminal jaw	Mouth is situated at the tip of the body rather than ventral or subterminal (Coad and McAllister 2010).
Trunk length (TTL)	Distance along the horizontal body axis between the posterior margin of the operculum and the origin of the dorsal fin (Vuorinen et al. 1993).
Zooplanktivore	Animal that feeds on zooplankton (Thompson 1995).

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