Fisheries and Oceans Canada / Pêches et Océans Canada
Science / Sciences

Canadian Science Advisory Secretariat (CSAS)

Research Document 2013/063

Central and Arctic Region

The biology and relative abundance of Shortjaw Cisco (*Coregonus zenithicus*) in Lake Nipigon

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November 2013

Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the Secretariat.

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

ISSN 1919-5044

Correct citation for this publication:

Pratt, T.C. 2013. The biology and relative abundance of Shortjaw Cisco (*Coregonus zenithicus*) in Lake Nipigon. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/063. v + 13 p.

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ABSTRACT

Shortjaw Cisco (*Coregonus zenithicus*) were originally described in Lake Nipigon in the 1920s, and have been consistently identified in the limited number of subsequent cisco surveys of the lake. With the exception of ecomorphological and genetic research conducted on the cisco community of Lake Nipigon in the late 1990s, little attention has been focused on any cisco species from this lake. DFO Science was charged with conducting a pre-COSEWIC assessment for Shortjaw Cisco, and this manuscript assesses the current:

1) life history characteristics;
2) the characteristics or elements of the species habitat;
3) threats to the species; and
4) population trends with a limited time series for Shortjaw Cisco from Lake Nipigon.

The relative abundance of Shortjaw Cisco has declined more than 50% in Lake Nipigon from the 1998-99 through 2008-09 period, and no recent strong year-classes were observed. Mean age of the population is ~12 years, and annual mortality estimates are low (11.7%). The Lake Nipigon Shortjaw Cisco population is dominated by females (sex ratio is 65% female), which appear to have greater longevity than males. Shortjaw Cisco in Lake Nipigon prefer shallower depths (mean depth of capture 30.2 m) than their conspecifics from the Great Lakes. The Shortjaw Cisco population in Lake Nipigon is a *Mysis* spp. specialist, with the majority of individuals consuming only this prey species. Anthropogenic threats are limited on Lake Nipigon, as only a small fishery is prosecuted on the lake. Observed declines are more likely due to food web changes due to invasive species, or competition with other native fishes.

Biologie et abondance relative du cisco à mâchoires égales (*Coregonus zenithicus*) dans le lac Nipigon

RÉSUMÉ

La présence du cisco à mâchoires égales (*Coregonus zenithicus*) dans le lac Nipigon a été décrite pour la première fois dans les années 1920 et l'espèce a été régulièrement identifiée à l'occasion des quelques relevés de ciscos effectués par la suite dans ce lac. À l'exception des recherches écomorphologiques et génétiques menées sur la communauté des ciscos du lac Nipigon à la fin des années 1990, on a peu étudié les espèces de ciscos de ce lac. Le Secteur des sciences du MPO a été chargé de réaliser une évaluation du cisco à mâchoires égales préalable à celle du COSEPAC. Le présent manuscrit évalue les éléments suivants :

1) les caractéristiques du cycle biologique;
2) les caractéristiques ou éléments de l'habitat de l'espèce;
3) les menaces qui pèsent sur l'espèce;
4) les tendances de la population, tirées d'une série chronologique limitée pour le cisco à mâchoires égales du lac Nipigon.

L'abondance relative du cisco à mâchoires égales a décliné de plus de 50 % dans le lac Nipigon pendant la période comprise entre 1998-1999 et 2008-2009 et on n'a pas observé de classes d'âge récentes importantes. L'âge moyen des populations est d'une douzaine d'années et les estimations de la mortalité annuelle sont faibles (11,7 %). La population de cisco à mâchoires égales du lac Nipigon est composée en majorité de femelles (le sex-ratio est de 65 % de femelles) car la longévité de ces dernières semble supérieure à celle des mâles. Les ciscos à mâchoires égales du lac Nipigon préfèrent des eaux moins profondes (profondeur moyenne de capture : 30,2 m) par rapport à leurs congénères des Grands Lacs. La population du lac Nipigon est spécialisée, la majorité de ses membres se nourrissant uniquement de *Mysis* spp. Les menaces anthropiques sont limitées dans le lac Nipigon dans la mesure où seule une petite pêche y est pratiquée. Les déclins observés résultent plus vraisemblablement des changements du réseau trophique dus à des espèces envahissantes ou de la compétition d'autres poissons indigènes.

INTRODUCTION

Shortjaw Cisco (*Coregonus zenithicus*) was originally described in Lake Nipigon by Koelz (1929). The existence of a Shortjaw Cisco morph in Lake Nipigon was confirmed by ecomorphological and genetic lines of evidence (Turgeon et al. 1999). Shortjaw Cisco were readily identifiable from other cisco species in Lake Nipigon based on gill-raker and head morphology, and there was partial microsatellite differentiation for Shortjaw Cisco that was not apparent for its congeners (Turgeon et al. 1999). Shortjaw Cisco primarily consumed *Mysis* and were captured in shallow (10-30 m) depths (Turgeon et al. 1999). No other published research has been conducted on this species in this lake.

DFO Science was charged with assisting with a pre-COSEWIC assessment for Shortjaw Cisco. In particular, DFO was asked to review a number of aspects pertaining to the COSEWIC status report. This manuscript addresses a few of those aspects for Shortjaw Cisco from Lake Nipigon, including a review of 1) life history characteristics, 2) the characteristics or elements of the species habitat, and threats to that habitat, and 3) threats to the species. Additionally, 4) population trends with a limited time series are assessed.

METHODS

FIELD AND LABORATORY PROCEDURES

For fisheries management purposes, Lake Nipigon is divided into 16 fisheries management sectors (Figure 1). The fish community was initially assessed by the Ontario Ministry of Natural Resources and the Anishinabek/Ontario Fisheries Resource Centre in 1998 and 1999 using experimental monofilament gill nets. The gill nets were composed of nine 15.2 m by 2.4 m panels of graded monofilament gill net, ranging in mesh size from 25 mm to 127 mm in 13 mm increments. Eight sectors were assessed annually in a depth-stratified sampling effort, with 6, 6 and 3 replicates fished at shallow (10–30 m), moderate (30–60 m), and deep (>60 m) depth zones, respectively. Each sector was partitioned into a grid of 100 hectare sampling areas, and net set locations were randomly selected for each depth stratum from the grid of sampling areas. Thus, a total of 240 gill nets (15 nets per zone) were set over the two year sampling effort. This sampling effort was repeated in 2008 and 2009, allowing for an assessment of cisco population dynamics over the intervening decade. Gill nets were deployed on the bottom, and catches were tallied on-board by mesh size. Ciscoes captured in the 1998-99 sampling effort were identified on-board to species based on external morphological characteristics (primarily mouth and fin position, gill-raker characteristics, and colour). In 2008-09, ciscoes were still identified on-board, but all collected ciscoes were frozen after identification for later processing for life history characteristics.

In the laboratory, frozen fish were thawed and photographed (full body, head, and gill rakers). Biological parameters were collected including fork and total length (mm), weight (g), gender and state of maturity. Sagittal otoliths were also collected for age interpretation. Once extracted, the sagittal otoliths were washed and stored dry prior to sectioning. One otolith was randomly selected and embedded in epoxy resin. A thin transverse section (~300 nm) was made perpendicular to the sulcus acusticus with a double-bladed low-speed isomet saw. The section was mounted on a microscope slide and photographed using an Olympus SZX16 stereoscope with transmitted light and an Olympus QColor5 digital camera. Otolith sections were examined by two independent ‘agers’ for annulus characteristics, such as changes in circuli spacing and cutting over, prior to counting and measuring annuli. Ages were successfully assessed for all but 1 of the 109 fish.

DATA ANALYSIS

Growth was assessed using the von Bertalanffy growth equation, calculated with the assistance of the VONBIT software package (Stamatopoulos and Caddy 1999):

$L_t = L_\infty (1 - \exp - k(t - t_0))$,

where L_t = length at time t, L_∞ = theoretical maximum length, k = constant expressing the rate of approach to L_∞, and t_0 = theoretical age at which $L_t = 0$.

Mortality and survival analyses were computed with R Version 2.10.1 (R Development Core Team 2009), using the Fisheries Stock Assessment program (FSA-package) developed by Dr. Derek Ogle at Northland College, Wisconsin. An age-length key was used to assign an age to the single un-aged fish using the methods described by Isermann and Knight (2005). Mortality estimates were calculated from the descending limb of the catch curve for each species.

Diet was coarsely determined by assessing stomach contents using a dissecting microscope. Some organisms were classified generically as a group (zooplankton), others to genus (*Mysis*, *Diporeia*, *Bythotrephes*), while a third group were only identified to class (Bivalvia, Gastropoda, Insecta). The percentage of the stomach contents was assessed for each group.

Depth was assessed based on the presence or absence of Shortjaw Cisco from the gill net catch. Differences between nets with cisco present or absent were assessed using a t-test.

RESULTS

LIFE HISTORY CHARACTERISTICS

A total of 109 Shortjaw Cisco were captured in 2008-09; the basic biological characteristics of the captured cisco can be found in Table 1. The mean length of the captured specimens was 305.4 mm, and the mean weight was 366 g. Mean age was 12.1 years, with a maximum age of 26 years. Shortjaw Cisco were identified from 18 different year classes (Figure 2). The oldest fish was from the 1983 year-class, while the majority of the fish (56%) were assigned to year-classes produced from 1998–2001.

Age-at-maturity is younger than 6 years, as all 109 fish sampled were already mature. Females dominated the population, as the sex ratio for Shortjaw Cisco in Lake Nipigon was 65% female (71 females, 38 males). The growth rate and asymptotic length estimates were k = 0.05 and Linf = 340.5 mm, respectively (Figure 3); no differences in growth were apparent between males and females. Females may have greater longevity, as few male Shortjaw Cisco older than age 16 were observed (Figure 3).

The annual rate of mortality for Shortjaw Cisco sampled during the survey, based on catch-curve analysis, was 11.7%, while the corresponding annual rate of survival was 88.3% (Figure 4). The instantaneous rate of mortality was estimated to be Z = 0.124.

Mysis dominated the diet of Shortjaw Cisco in Lake Nipigon. They were the sole or dominant diet item of 88% of the fish that had food in their stomachs (Figure 5). The remaining diets were dominated by zooplankton. Approximately 40% (44 fish) had empty stomachs.

HABITAT

Only depth data are available as habitat characteristics for Shortjaw Cisco in Lake Nipigon. Shortjaw Cisco were captured in relatively shallow depths (mean depth of capture 30.2 (SE ± 1.4) m. The mean depth of the net sets without Shortjaw Cisco capture (mean depth without capture 41.7 (SE ± 1.8) m) were significantly deeper ($t = 3.5$, $P = 0.0005$; Figure 6). No Shortjaw Cisco were captured deeper than 55 m.

THREATS

A small First Nation fishery is prosecuted on Lake Nipigon, and Shortjaw Cisco could be a by-catch in that fishery. Data from the lake-wide survey indicates that only 7% of the Shortjaw Cisco were captured in mesh sizes larger than 76 mm, so restricting commercial effort to larger mesh-sizes would help protect Shortjaw Cisco (Table 2).

POPULATION TRENDS

There was a >50% decline in the number of Shortjaw Cisco captured between the 1998-99 and 2008-09 sampling events (Table 3). These declines were apparent across the entire lake (Figure 1, Table 3), though small increases were observed in a few fisheries sectors. These declines are consistent with decreases observed for other cisco species in the lake (data not shown).

DISCUSSION

Shortjaw Cisco abundance in Lake Nipigon is declining, and the life history characteristics of the remaining fish reflect this decline. The greater than 50% decrease from 1998-99 to 2008-09 was likely even larger than could be reflected here, given that little attention was made to identifying ciscoes in Lake Nipigon prior to 1999 (Rick Salmon, Ontario Ministry of Natural Resources, pers. comm.). Only 20% of the ciscoes identified as Shortjaw Cisco from the 1998-99 sampling period were from 1998, and the vast majority of those fish came from a single sector after a training session was implemented in late August, 1998. There has been an overall reduction in the number of all ciscoes from Lake Nipigon on the order of 75%, so the observed decline is real and likely underestimated.

The life history data presented herein are the first since Koelz (1929) initially surveyed the cisco communities of the Great Lakes. As with earlier investigations on cisco species from Lake Superior (Yule et al. 2008; Pratt and Chong 2012), using otoliths to estimate age resulted in an increase in our interpretation of the longevity of Shortjaw Cisco. The oldest ages assessed in Lake Nipigon, 26 years, are comparable to those seen in Lake Superior (25 years; Pratt and Chong 2012). In turn, these age estimates result in higher survival (and lower mortality) estimates which again are comparable to those for ciscoes from Lake Superior (Yule et al. 2008; Pratt and Chong 2012). The von Bertalanffy analysis demonstrated a higher asymptotic length for Shortjaw Cisco from Lake Nipigon (340 mm) than the adjacent Lake Superior (291 mm), but similar slow growth rates (Pratt and Chong 2012). Sex ratios in cisco species fluctuate depending on recruitment patterns, and the female dominance observed in Lake Nipigon is a common feature of cisco populations (Bunnell et al. 2006). Additionally, the apparent greater longevity of females in the Shortjaw Cisco population in Lake Nipigon is found in many cisco populations, and there are a number of explanations for differential survival of the sexes including increased mortality due to predation or vulnerability to a fishery, differences in growth rate and an associated survival trade-off, or differences in reproductive activity or maturation schedule (Bunnell et al. 2006). As there were no apparent differences in growth rate, it is unlikely that the first three hypotheses could be applicable in Lake Nipigon.

The use of primarily shallow and mid-depth zones by Shortjaw Cisco in Lake Nipigon is consistent with a previous habitat study on this lake (Turgeon et al. 2009), which stands in stark contrast to the assertion that Shortjaw Cisco is a deepwater cisco form (COSEWIC 2009). Turgeon et al. (1999) also identified *Mysis* as the dominant prey for Shortjaw Cisco in Lake

Nipigon, and this remains the case a decade later as *Mysis* was the only or dominant food item in ~90% of the Shortjaw Cisco examined with prey items in their stomachs. *Mysis* are a key prey item for Shortjaw Cisco across their range (COSEWIC 2009; Vescei et al. 2012). There were 8 individuals that had exclusively zooplankton diets identified in this survey, which is a small difference from the earlier study (Turgeon et al. 1999).

There are few obvious anthropogenic threats to the Shortjaw Cisco in Lake Nipigon. The presence of a small First Nation fishery (primarily for Lake Whitefish (*Coregonus clupeaformis*), Lake Trout (*Salvelinus namaycush*), and Walleye (*Sander vitreus*)) is likely the only possibly human-induced mortality source. Rainbow Smelt (*Osmerus mordax*) invaded Lake Nipigon in the mid-1970s, and were at their highest abundance during the 1998-99 survey (Rick Salmon, Ontario Ministry of Natural Resources, pers. comm.). Rainbow Smelt have been hypothesized to impact native cisco populations for many decades (e.g., Crowder 1980), and have specifically been posited to negatively impact Shortjaw Cisco in two lakes (Wain 1993; Etnier and Skelton 2003). However, Rainbow Smelt abundance has also been declining in concordance with the declines in native ciscoes in Lake Nipigon (Rick Salmon, Ontario Ministry of Natural Resources, pers. comm.). Finally, there have been changes in the fish community with the resurgence of other benthic fishes (Burbot (*Lota lota*) and Longnose Sucker (*Catostomus catostomus*)) over the past decade, which may be influencing ciscoes in the lake through competition and/or predation.

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TABLES AND FIGURES

Table 1. Basic biological characteristics of Shortjaw Cisco captured in Lake Nipigon in 2008-09 as part of the decennial sampling survey.

	Fork length (mm)	Weight (g)	Age
Mean (± SE)	305.4 (2.9)	366.0 (10.0)	12.1 (0.4)
Range	222–374	127.2–645.7	6–26

Table 2. Mesh size distribution of Shortjaw Cisco captured in graded-mesh gill nets in Lake Nipigon in 2008-09.

Mesh size (mm)	N Shortjaw Cisco captured
38	12
51	26
64	33
76	30
89	5
102	3

Table 3. Total and mean catch (fish / net km) of Shortjaw Cisco by management sector from the 1998-99 and 2008-09 sampling period in Lake Nipigon.

Sector	**Sampling dates**	**Total catch**	**Mean catch (N / net km, ± SE)**
1	11/08/1998 to 18/08/1998	2	0.97 (0.66)
	20/08/2008 to 10/09/2008	1	0.49 (0.49)
2	28/07/1998 to 12/08/1998	0	0.00 (-)
	09/07/2009 to 13/07/2009	2	0.97 (0.66)
3	12/08/1998 to 16/08/1998	0	0.00 (-)
	08/07/2008 to 12/07/2008	0	0.00 (-)
4	22/08/1999 to 27/08/1999	55	26.8 (10.30)
	08/08/2008 to 13/08/2008	29	14.13 (6.11)
5	08/09/1999 to 12/09/1999	2	0.97 (0.66)
	05/07/2009 to 09/07/2009	1	0.49 (0.49)
6	07/07/1998 to 12/07/1998	1	0.49 (0.49)
	10/08/2009 to 22/08/2009	1	0.49 (0.49)
7	21/07/1999 to 26/07/1999	34	16.57 (6.82)
	06/08/2009 to 11/08/2009	11	5.36 (2.52)
8	05/07/1999 to 10/07/1999	32	15.59 (4.56)
	11/08/2008 to 15/08/2008	9	4.39 (1.99)
9	22/07/1998 to 26/07/1998	0	0.00 (-)
	26/07/2009 to 29/07/2009	9	4.39 (3.41)
10	12/07/1999 to 16/07/1999	0	0.00 (-)
	17/08/2009 to 22/08/2009	3	1.46 (1.06)
11	23/08/1999 to 27/08/1999	0	0.00 (-)
	28/07/2008 to 01/08/2008	18	8.77 (2.69)
12	19/07/1998 to 23/07/1998	0	0.00 (-)
	23/07/2008 to 27/07/2008	4	1.95 (1.51)
13	09/08/1999 to 14/08/1999	64	31.19 (12.07)
	16/07/2009 to 20/07/2009	9	4.39 (3.41)
14	18/08/1998 to 22/08/1998	0	0.00 (-)
	21/07/2008 to 25/07/2008	7	3.41 (1.57)
15	25/08/1998 to 30/08/1998	43	20.96 (7.41)
	04/07/2008 to 09/07/2008	1	0.49 (0.49)
16	19/07/1999 to 23/07/1999	0	0.00 (-)
	22/07/2009 to 27/07/2009	4	1.95 (1.12)
Mean catch per night	1998/99	**0.97**	**7.01 (1.35)**
	2008/09	**0.45**	**3.32 (0.61)**

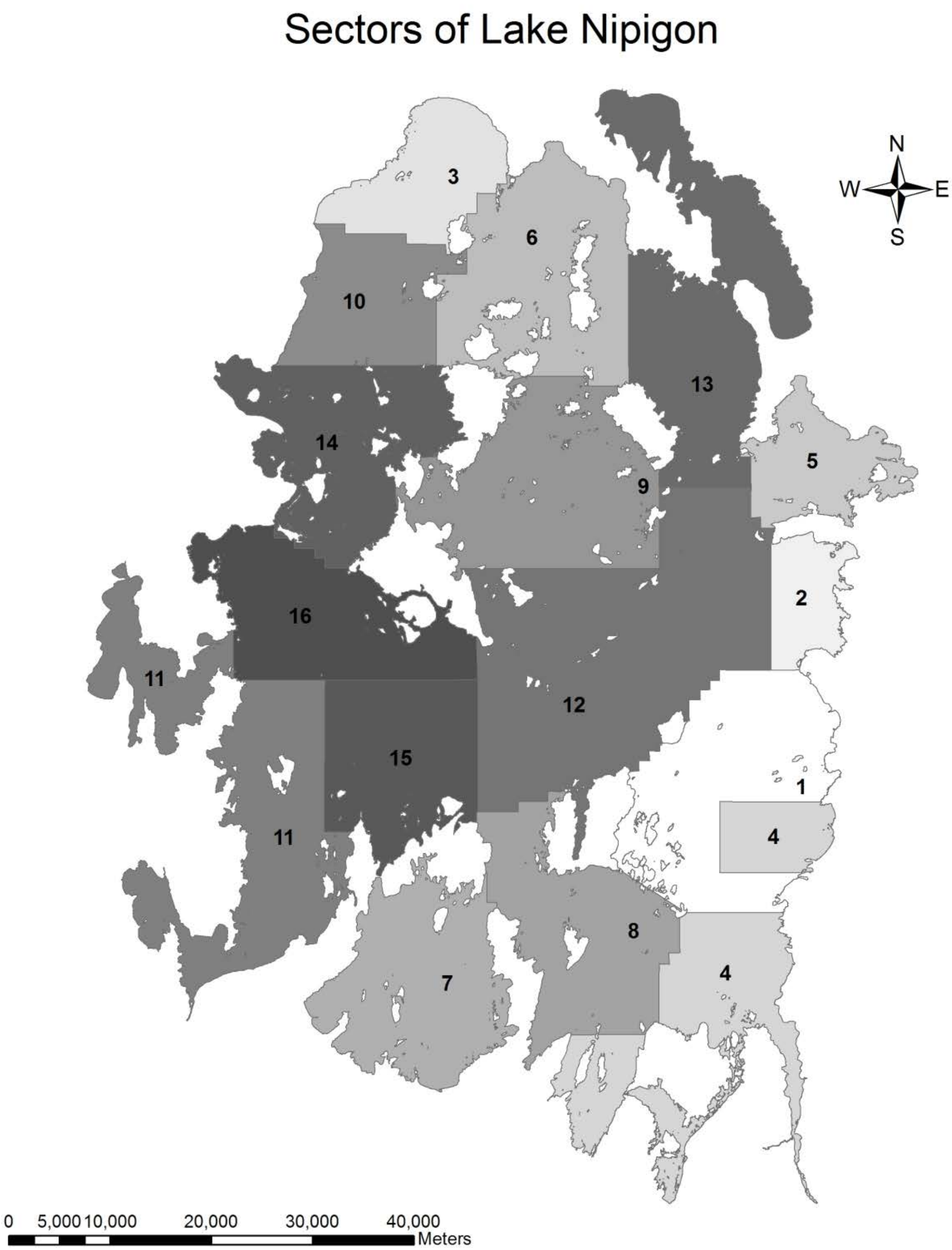

Figure 1. Map of fisheries management sectors in Lake Nipigon.

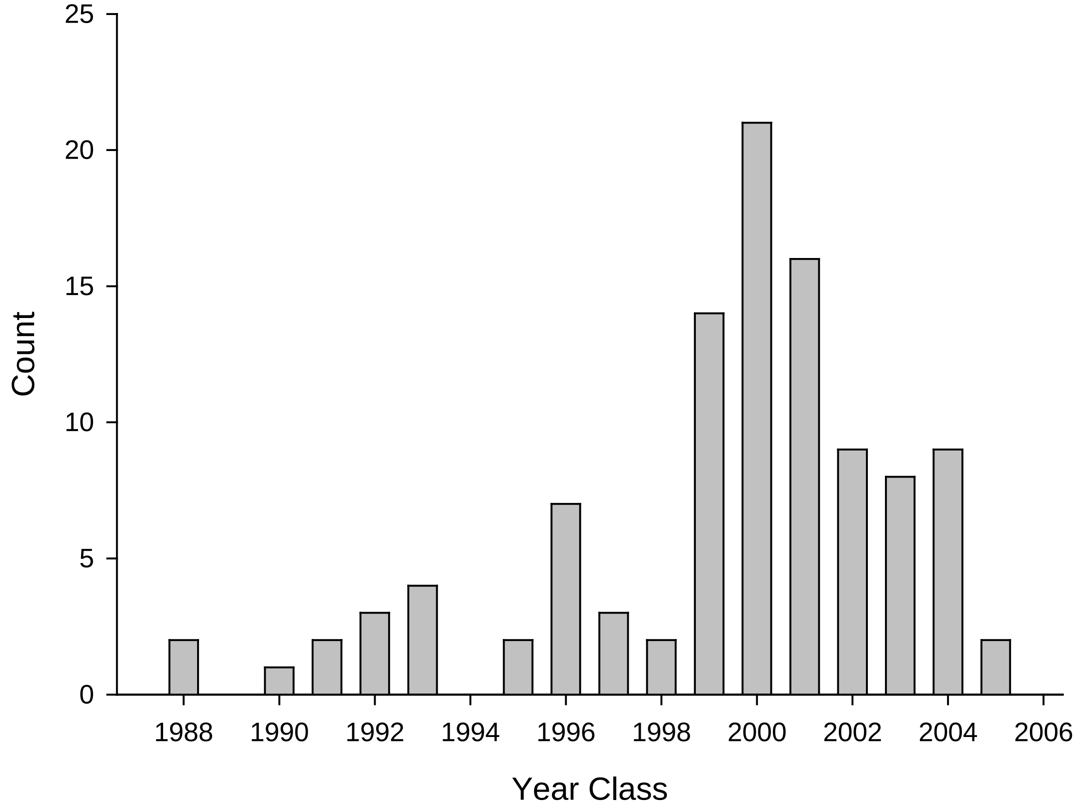

Figure 2. Shortjaw Cisco year-class strength from fish captured in the 2008-09 lake-wide survey.

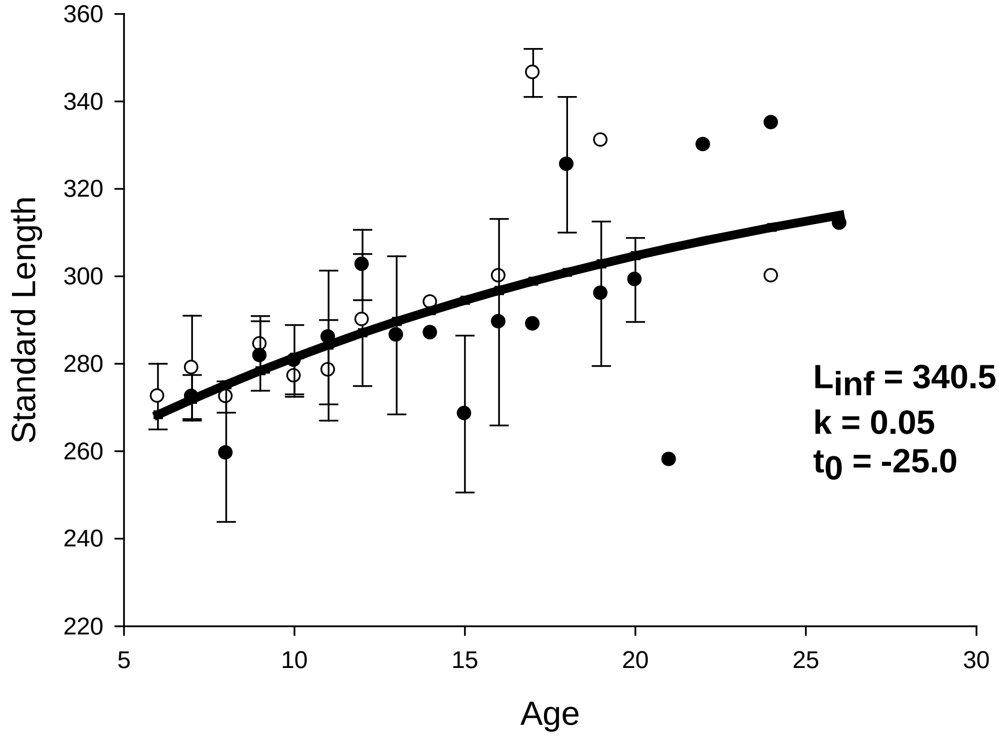

Figure 3. Mean size-at-age, by sex, for Shortjaw Cisco from Lake Nipigon. Male data are represented with open circles, while female data are represented with closed circles. Error bars are standard error. The lines represent a sexes combined fitted von Bertalanffy growth curve, and curve parameters are located in the lower right hand corner.

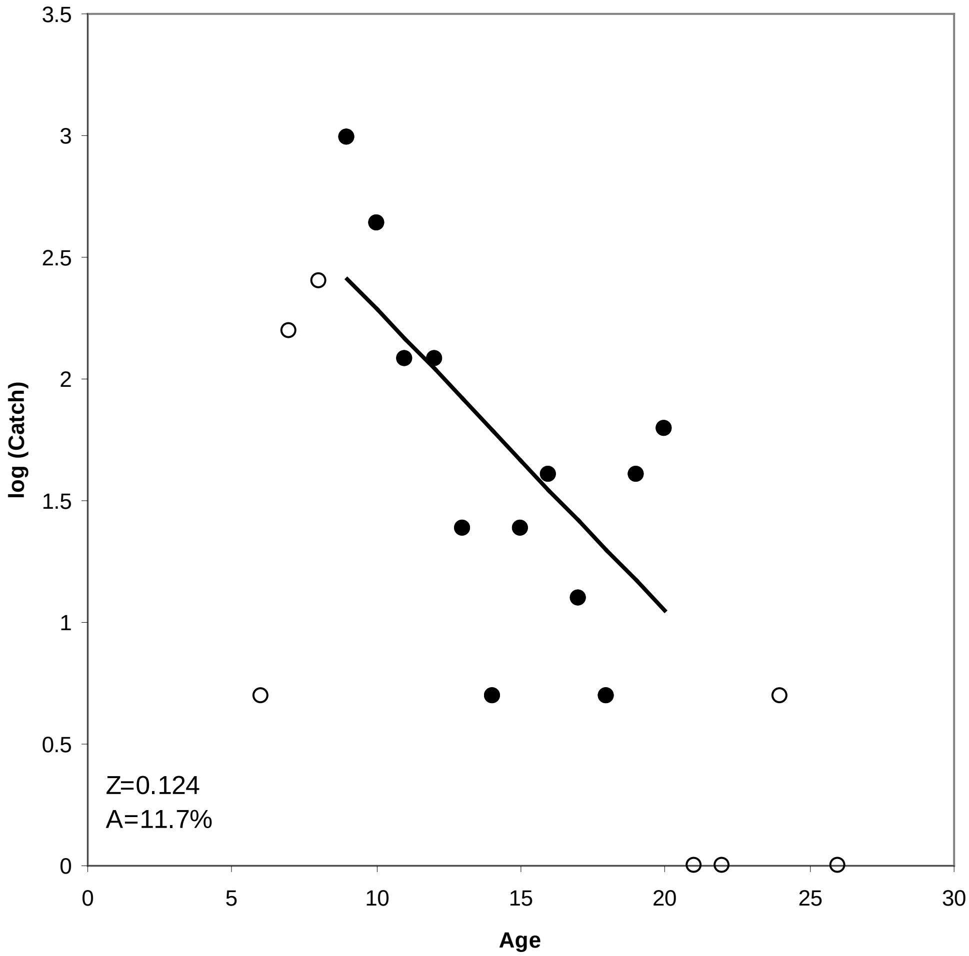

Figure 4. Rate of total annual mortality (A) and instantaneous mortality (Z) for Shortjaw Cisco captured in Lake Nipigon in 2008-09 based on catch-curve analysis. Dark circles indicate the age-classes used in the analysis.

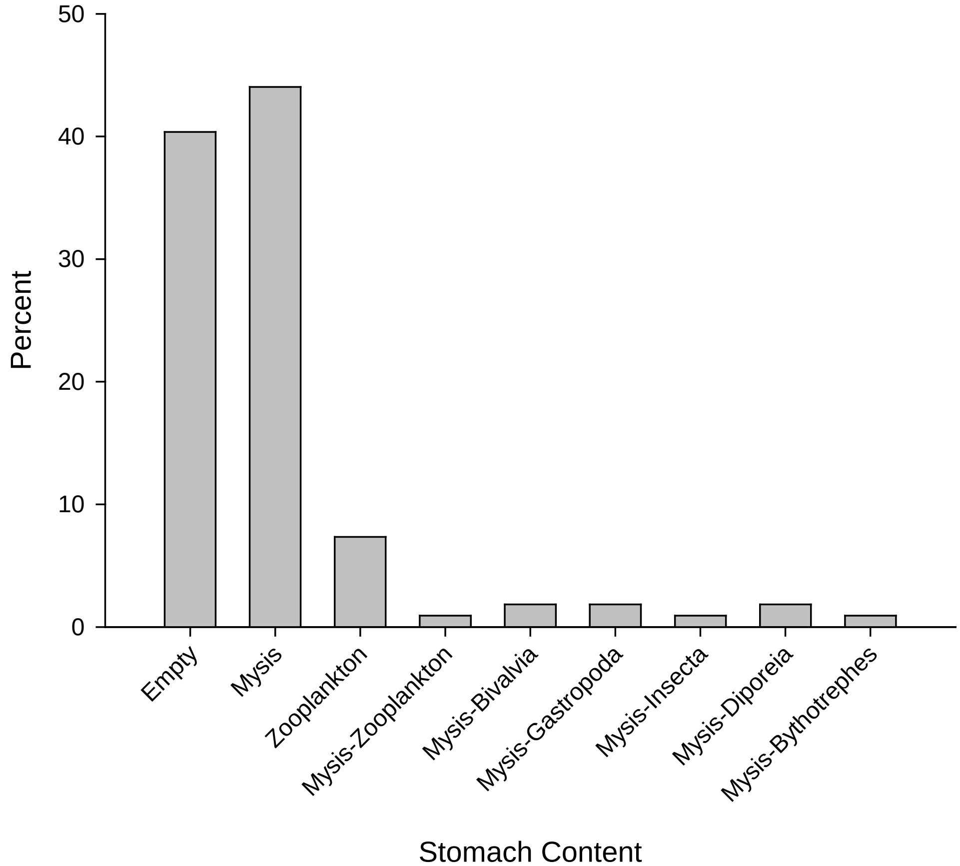

Figure 5. Stomach contents of Shortjaw Cisco captured in Lake Nipigon in 2008-09.

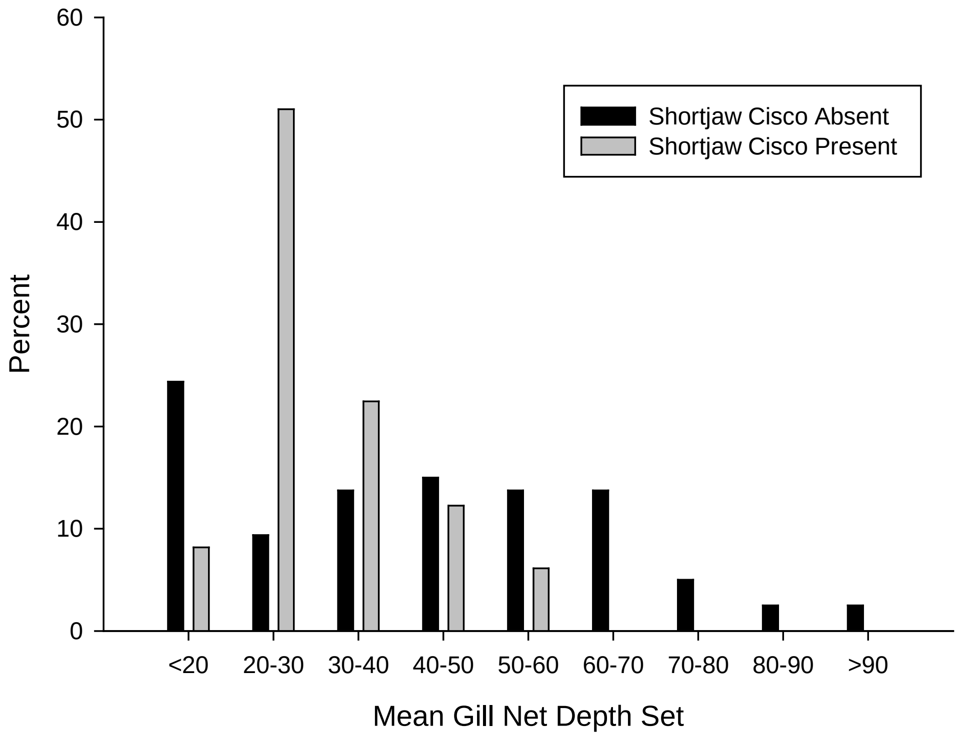

Figure 6. The percentage of gill net sets by 10 m depth bin that either captured Shortjaw Cisco (grey bars) or did not capture Shortjaw Cisco (black bars) from Lake Nipigon in 2008-09.