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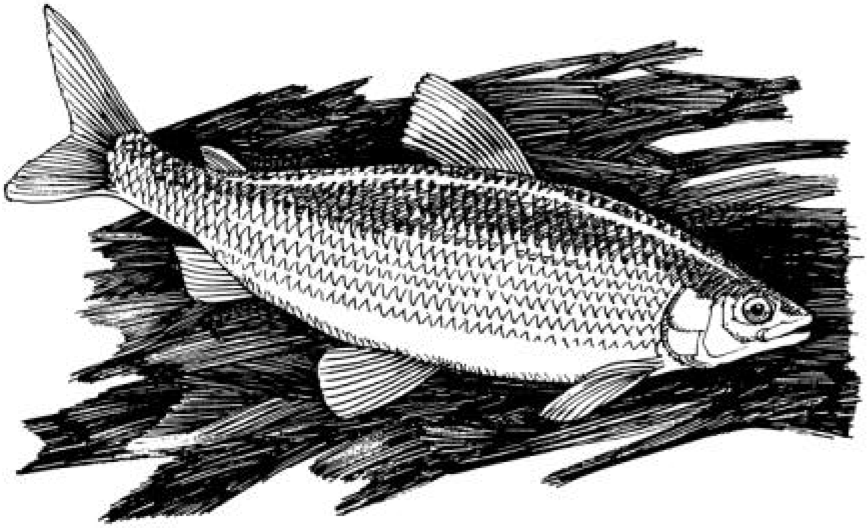
Distribution and Relative Abundance of the Shortjaw Cisco (*Coregonus zenithicus*) in Alberta



Alberta Species at Risk Report No. 3

Alberta
SUSTAINABLE RESOURCE DEVELOPMENT

Distribution and Relative Abundance of the Shortjaw Cisco (*Coregonus zenithicus*) in Alberta

Mark Steinhilber
and
Larry Rhude

Alberta Species at Risk Report No. 3

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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EXECUTIVE SUMMARY

The shortjaw cisco (*Coregonus zenithicus*) was designated *Threatened* in 1987 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2000), based on population declines in the Great Lakes. However, its general status in Alberta remains *May Be At Risk* (Alberta Sustainable Resource Development *In prep.*), primarily due to uncertainty regarding the provincial range of this species. Barrow Lake, located about 60 km north of Fort Chipewyan, contains the only verified population of shortjaw cisco in Alberta. Few fisheries surveys have been conducted in this area and what work has been done did not focus on locating shortjaw cisco. This species is similar in appearance to the common and widespread cisco or lake herring (*Coregonus artedi*) – a species that co-occurs with shortjaw cisco in Barrow Lake and other lakes across northern Canada – and can be easily misidentified. Therefore, a specific search for shortjaw cisco in the area around Barrow Lake was undertaken, by personnel familiar with this species, in an effort to gather additional information on its extent of occurrence in Alberta. Sampling was also conducted at Barrow Lake, following protocols consistent with surveys done in 1996 and 1997, to acquire data on shortjaw cisco population trends in this lake. This information will be used as an aid in determining the status of this species in Alberta.

Eight lakes in the region north of Lake Athabasca and east of Wood Buffalo National Park were surveyed by gillnetting in July and August 2000. No new populations of shortjaw cisco were found at these sites. Seven other nearby lakes had been sampled in 1996 and 1997 with similar results. Catch-per-unit-effort data from Barrow Lake suggest that this population of shortjaw cisco appears to have been stable over at least the past five years and probably the last 30 years. However, further monitoring is required to determine population trends with a scientifically acceptable level of confidence.

The factors that contributed to the decline of shortjaw cisco in the Great Lakes probably have had little impact on the Alberta population. Commercial overharvest, habitat degradation and competition with introduced species have not had a major influence on the Barrow Lake population. The limited amount of sport fishing that has occurred on this lake does not appear to have had an obvious adverse effect on the shortjaw cisco population; however, even low angler harvest can potentially disrupt the ecological balance that sustains this unique cisco population. It is recommended that the pike and walleye catch be closely monitored and regulated to ensure that predator removal has no detrimental effects on the shortjaw cisco population. No gillnetting should be allowed at Barrow Lake, with the exception of population monitoring surveys conducted every five years. Future work should focus on a search for other shortjaw cisco populations in the region around Barrow Lake, in Lake Athabasca, and in areas farther south where shortjaw cisco have been reported but their existence is unverified.

1.0 INTRODUCTION

Ciscoes are trout-like fishes (slender shape, abdominal pelvic fins, adipose fin present) that either spend much of their life in the ocean but return to fresh water to spawn (anadromous) or live entirely in freshwater. Generally, they are silvery-blue in colour with darker backs and lighter undersides, although the amount of pigmentation varies among populations. Ciscoes, along with the whitefishes and inconnu, are members of the subfamily Coregoninae. Nelson (1994) places these in the family Salmonidae together with the grayling, trout and salmon. They differ from other salmonids in having larger scales than trout or salmon and no teeth on the bones of the jaws.

Ciscoes are holarctic in distribution with many species endemic to North America or Eurasia. Two species are known to occur in Alberta (Nelson and Paetz 1992). One is the widespread and common cisco or lake herring, *Coregonus artedi* LeSueur 1818, and the other is the shortjaw cisco, *Coregonus zenithicus* (Jordan and Evermann 1909) (Figure 1), which has a restricted distribution. The two species are best identified by counting the number of gillrakers (slender bony protuberances off the gill arches) on the first gill arch. The full range of shortjaw cisco gillraker number is 30-46 (Scott and Crossman 1973, Steinhilber 2000); however, 98% of specimens examined from localities across North America (n=122) had 44 gillrakers or fewer (M. Steinhilber, unpublished data; Figure 2). Gillraker counts in lake herring can range from 38 to 64 (Scott and Crossman 1973); however, 98% of Alberta specimens examined (n=665) exhibited 42-59 gillrakers (M. Steinhilber, unpublished data). Usually, shortjaw cisco can also be distinguished from lake herring by their longer snout, shorter gillrakers, longer upper jaw, lower jaw that does not extend beyond the upper jaw, and more vertical upper jaw tip (premaxillary bones) (Todd and Smith 1980). In addition, Alberta shortjaw cisco can be separated from co-occurring lake herring by their larger size, shallower head, smaller eye, and longer dorsal fin (Steinhilber 2000). Caution must be exercised when attempting to identify ciscoes based on one or a few characters because morphological plasticity and local adaptation have produced a great deal of variation in this group. All Alberta cisco populations with mean gillraker counts less than 43 should be examined carefully and voucher specimens should be retained for future analysis and verification of identity.

In 1987, the shortjaw cisco was designated *Threatened* by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2000). This designation was based primarily on a decline in the population of this species in the Great Lakes since about the middle of the 20th century (Todd 1985, Fleischer 1992, T. Todd, pers. comm.). This decline is believe to be a result of a combination of commercial overfishing, sea lamprey predation, increased competition from introduced fishes, and introgression and competition with other cisco species.

Outside the Great Lakes basin, the shortjaw cisco is believed to be widespread across northern North America from about southeastern Ontario to Great Slave Lake, Northwest Territories (Clarke 1973, Scott and Crossman 1973, Lee *et al*. 1980). The distribution of this species throughout this large and predominantly remote range is sporadic and the number of occurrences (IUCN 1994) may be relatively few (Figure 3). However, many

Figure 1. Shortjaw cisco (upper – 411 mm fork length) and lake herring (lower – 215 mm fork length) from Barrow Lake.

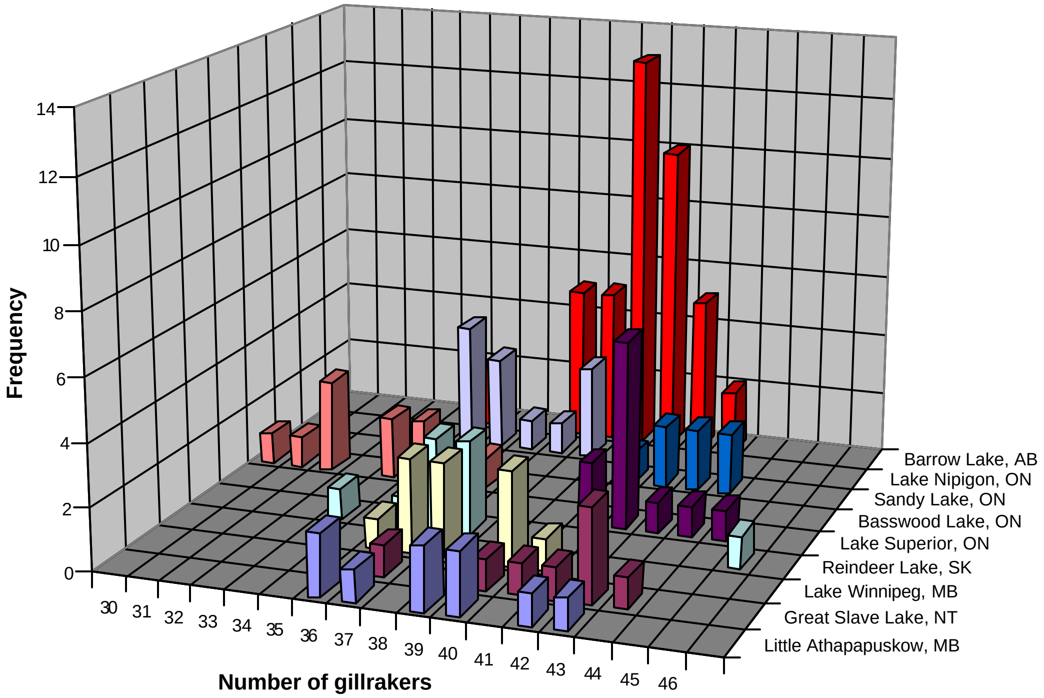

Figure 2. Gillraker number frequencies for nine shortjaw cisco populations from across the range of this species. Only 2 of 122 individuals exhibited gillraker counts in excess of 44. The one specimen from Reindeer Lake, Saskatchewan with 46 gillrakers may represent an anomaly or misidentification.

Figure 3. North American distribution of shortjaw cisco. Stars indicate extirpated populations in the Great Lakes.

questions exist regarding the actual distribution of shortjaw cisco outside of the Great Lakes basin. Much of this uncertainty is a result of a paucity of sampling effort through much of the remote range of this species. To complicate matters, the taxonomy of shortjaw cisco is questionable despite much recent effort to resolve issues regarding the identity and evolutionary history of populations of this species. Therefore, the size of the shortjaw cisco genetic reservoir in northern North America is virtually unknown. This information is critical for an accurate assessment of the global threat of extinction of this species. If the shortjaw cisco is widespread with large, stable and secure populations outside of the Great Lakes, its global status may be quite different than if these populations are small, disjunct and precarious (or do not represent shortjaw cisco at all!). This uncertainty can only be addressed by surveying many lakes across Canada and by conducting detailed taxonomic comparisons (both morphological and genetic) among individual populations.

Only one verified population of shortjaw cisco occurs in Alberta (Nelson and Paetz 1992). Based on a 1966 survey, Paterson (1969) first reported its existence in Barrow Lake in the Canadian Shield region of the province. Reports of this species from the Alberta side of Lake Athabasca (Dymond and Pritchard 1930), Gregoire Lake (Tripp and Tsui 1980), and possibly Cold Lake (Clarke 1973) are unverified and remain questionable. The species is currently ranked *May Be At Risk* by Alberta Fisheries and Wildlife (Alberta Sustainable Resource Development *In prep.*).

The number of occurrences of a species in a particular jurisdiction is an important criterion in many schemes developed to assess extinction risk (e.g., IUCN criteria). Yet these numbers may have little meaning in the absence of some indication of search effort. The importance of including a per-unit-search effort component will vary among species depending on such factors as accessibility of the species’ habitat, its habits or biological attributes (secretive, cryptic coloration) and its importance to humans. Populations of species that coexist in close proximity to human habitation, are easy to detect or have been studied intensively might be estimated and tracked reasonably by simply counting the number of occurrences. However, populations of species that occur primarily in remote areas, are difficult to detect (or identify) or have not been studied in detail may be vastly underestimated if numbers are based on reports from chance encounters or incidental captures in general biological inventories. For these species, targeted inventory and monitoring strategies, employed in carefully selected locations and habitats, may be essential for gathering the baseline data needed for an accurate assessment of distribution, abundance, population trend and extinction risk. Search effort, in these cases, becomes a critical component of the number of occurrences criterion that will figure prominently in management decisions and recovery planning.

Shortjaw cisco populations outside the Great Lakes basin fall into that category of organisms for which a simple number of occurrences is of little value to resource managers. Not only does this species occur mainly in remote, poorly sampled parts of the country, but it is notoriously variable morphologically and difficult to identify. The first objective of this study was to sample as many lakes as possible in northeastern Alberta, using the best available knowledge of shortjaw cisco biology and taxonomy, to search for other populations of this fish. There were no *a priori* reasons to expect to find additional populations in this area. In this context, the data are equally valuable whether the species was present or absent at any site. The value of the work lies in providing a search effort framework upon which number of occurrences can be evaluated.

The second objective was to gather additional data on the abundance of shortjaw cisco in Barrow Lake and to attempt some estimate of population trend. Precise estimates of population size and trend typically require a mark-recapture protocol employed consistently over many years. The actual sampling effort needed to produce results that satisfy a given statistical confidence level can be calculated by a power test. These tests are based on some initial estimate of sampling variance and compute the number of sampling points, both spatially and temporally, needed to refute a null hypothesis of no population change at pre-determined confidence levels. The data acquired in this study may be useful for assessing sampling variance but were not intended to yield estimates of population size or a calculated value for trend. Catch-per-unit-effort (number of shortjaw cisco captured/hour per m^2 of net) and abundance relative to sympatric (co-occurring) lake herring (*Coregonus artedi*) were used as an index of the shortjaw cisco population at Barrow Lake.

2.0 STUDY AREA

The eight lakes surveyed in July and August, 2000 were all in the Canadian Shield region of northeastern Alberta (Figure 4). This region, designated the Kazan Uplands (Alberta Environmental Protection 1998), is characterized by exposed, lichen-covered Precambrian bedrock that forms rolling hills covered predominantly by jack pine (*Pinus banksiana*) forests. Willow (*Salix* spp.) and black spruce (*Picea mariana*) dominate in poorly drained areas. Aspen poplar (*Populus tremuloides*), balsam poplar (*Populus balsamifera*) and white spruce (*Picea glauca*) are common in moderately well drained areas, and jack pine dominates on rocky uplands, along north-facing slopes, and on areas of glacial outwash (Hastings and Ellis 1990, Strong and Leggat 1992). This is the coolest and wettest portion of the extensive Boreal Mixedwood region in Alberta (Strong and Leggat 1992). Numerous wetlands, ranging from eutrophic marshes to large, oligotrophic lakes, occupy low-lying areas. Drainage is to the Slave River via slow-moving streams that may become choked with submergent rooted vegetation as the growing season progresses. The lakes in the southeastern portion of this region drain into Lake Athabasca and then to the Slave River.

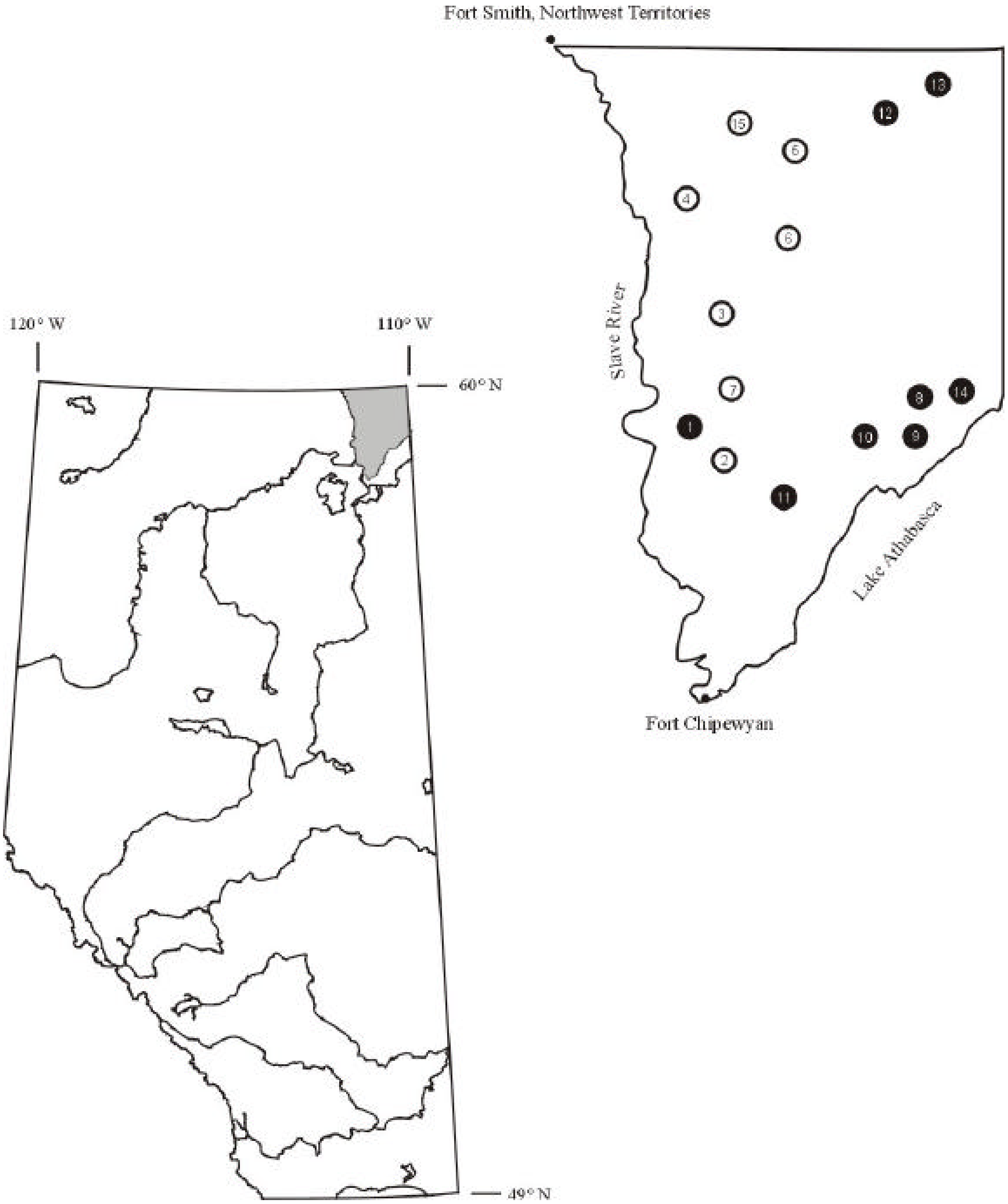

Figure 4. Location of the study area in northeastern Alberta and the lakes surveyed. Closed circles represent lakes surveyed in this study. Open circles are sites surveyed by Steinhilber (2000) and L. Rhude. 1) Barrow Lake, 2) Ryan Lake, 3) Bocquene Lake, 4) Myers Lake, 5) Unnamed Lake # 1, 6) Daly Lake, 7) Darwin Lake, 8) Wylie Lake, 9) Winnifred Lake, 10) Unnamed Lake #2, 11) Fletcher Lake, 12) Dawson Lake, 13) Bayonet Lake, 14) Burstall Lake, 15) Leland Lake.

Selection of survey sites was based on general similarities in basin morphometry between each candidate lake and Barrow Lake. Bathymetric maps and limnological data were acquired from unpublished lake survey reports prepared for Alberta Fish and Wildlife Division in the 1960s and ’70s. Prior knowledge that at least one species of cisco inhabited each lake was also an important criterion in site selection. The lakes chosen were Barrow Lake (59° 15’N, 111° 13’W), Fletcher Lake (59° 07’N, 110° 50’W), Wylie Lake (59° 19’N, 110° 23’W), Winnifred Lake (59° 14’N, 110° 24’W), Burstall Lake (59° 20’N, 110° 11’W), Dawson Lake (59° 52’N, 110° 27’W), Bayonet Lake (59° 56’N, 110° 18’W) and an unnamed lake (59° 13’N, 110° 33’W) (Figure 4). Selected physical attributes of the lakes surveyed are shown in Table 1.

Table 1. Morphometry of lake basins surveyed.

Lake	Area (km^2)	Max. Length (km)	Max. Width (km)	Max. Depth (m)	Mean Depth (m)
Barrow[1]	3.81	5.0	1.7	21.9	11.0
Wylie[2]	23.0	9.8	5.0	23.2	6.1
Winnifred[3]	4.21	4.7	2.4	11.3	3.3
Dawson[4]	3.57	8.1	1.6	18.9	6.0
Bayonet[4]	4.38	8.6	1.0	33.8	6.1
Burstall[5]	8.41	9.0	2.3	19.5	4.9
Fletcher[6]	0.99	3.0	0.5	13.1	5.2
Unnamed[3]	2.55	5.1	1.2	14.0	5.5

Data Sources: [1]Turner (1967), [2]Turner (1966), [3]Rhude (1975a), [4]Rhude (1975b), [5]Rhude (1975c), [6]Rhude (1975d).

3.0 METHODS

Study sites were accessed by floatplane from Fort Smith, NWT. Gillnetting was conducted over a two or three day period at each lake. Nets consisted of a 60 m panel of 3.8 cm (1.5 in) mesh, a 30 m panel of 6.4 cm (2.5 in) mesh, and a 30 m panel of 8.9 cm (3.5 in) mesh. All mesh sizes are stretched measures and all panels were 2 m deep. Nets were fished for varying lengths of time depending on weather conditions, capture success and logistic constraints. Capture rate was standardized by calculating catch-per-unit-effort (number of specimens captured/hr/m^2 of net). Nets were checked and specimens were removed approximately every four hours in an attempt to minimize non-target mortality. Lengths, weights and aging structures were acquired from selected specimens, and voucher specimens were retained for preservation in the research collection at the Provincial Museum of Alberta. Tissue samples (muscle and liver) for genetic analyses were excised from most vouchers prior to fixation of the carcass in 10% buffered formalin. These samples are housed in super-cold storage at the Provincial Museum. The carcasses were transferred to 70% ethanol after several weeks of fixation.

The precise location of net placement sites on each lake was based largely on apparent similarities to net sites or to habitats that yielded shortjaw cisco in a study at Barrow Lake in 1996 and 1997 (Steinhilber 2000). These areas were typically in 8-18 m of water over a distinctly sloping bottom. Nets were usually placed on or near the bottom, although surface sets and the occasional mid-water set were also deployed. Nets were moved regularly to sample as much of the lake as possible within the time available. In Barrow Lake, nets were placed at the same locations and depths as in 1996 and 1997 to enhance comparability among years.

Quantitative taxonomic analysis of the ciscoes captured was limited to enumeration of gillrakers on the first, left branchial arch of a random sample of preserved specimens. The number of gillrakers is the most important morphological character currently used in cisco taxonomy. Population modes and ranges are often cited as evidence for a species' identity. All rakers, including bony rudiments, on the upper (epibranchial) and lower (ceratobranchial) arch were counted under magnification. Data were graphed and examined for any evidence of bimodality in gillraker number within lakes, which would suggest the presence of sympatric (co-occurring) populations.

Other external characters were evaluated qualitatively to assist in species identification. Upper jaw length, gillraker length, orbit diameter and head depth have been shown to be useful in distinguishing lake herring from shortjaw cisco (Steinhilber 2000, Steinhilber *et al*. 2001). These traits were used in conjunction with gillraker number to support the identifications. A detailed quantitative analysis of a suite of external characters is currently underway. Tissues for genetic analysis were sent to Dr. Jim Reist at the Freshwater Institute, Department of Fisheries and Oceans, in Winnipeg. Results from these analyses are forthcoming. Specimens from Winnifred Lake were aged by microscopic examination of otoliths following Mackay *et al*. (1990) and Stevenson and Campana (1992). Ages were not validated.

Data from all fishes retained and preserved at the Provincial Museum of Alberta have been entered into the Museum's Ichthyology collection database. These data, and the specimens, are available to all interested users. Selected data will also be entered into the Fisheries Management Information System (FMIS) and the Biodiversity/Species Observation Database (BSOD).

4.0 RESULTS

Six hundred and sixteen cisco were captured at seven lakes in July and August 2000. Burstall Lake did not yield any cisco, but a single rare round whitefish (*Prosopium cylindraceum*) specimen was acquired here. No new populations of shortjaw cisco were found. Preliminary taxonomic analysis of subsets of all cisco populations demonstrated modal gillraker counts in the lake herring (*Coregonus artedi*) range (about 43-60) (Table 2).

Table 2. Gillraker counts from ciscoes collected in July and August 2000. Modal values suggest that all lakes, other than Barrow Lake, contained only lake herring.

Lake	n	Modal gillraker count	Range of gillraker counts
Fletcher Lake	39	45	42-50
Wylie Lake	10	46	42-49
Winnifred Lake	58	45	39-48
Dawson Lake	6	45	41-45
Bayonet Lake	28	46	42-50
Unnamed Lake	13	48	48-52
Barrow Lake – lake herring	50	48	44-53
Barrow Lake – shortjaw cisco	42*	40	35-43

*combined sample of all shortjaw cisco collected from 1996-2000.

Several specimens from Winnifred Lake exhibited gillraker counts in the shortjaw cisco range (about 30-40); however, preliminary analysis of other external characters suggested that these were low gillraker variants of lake herring. A unimodal gillraker number frequency distribution suggested a single cisco species (Figure 5), although the length-frequency distribution showed a small (dwarf) group and a larger (normal) group (Figure 6). Aging of 31 specimens also revealed two distinct length-at-age groups (Figure 7): a slow-growing, short-lived dwarf form and a faster growing, longer-lived normal form. Despite apparent differences in growth rate, the morphological differentiation between forms is insufficient to recognize these as distinct species.

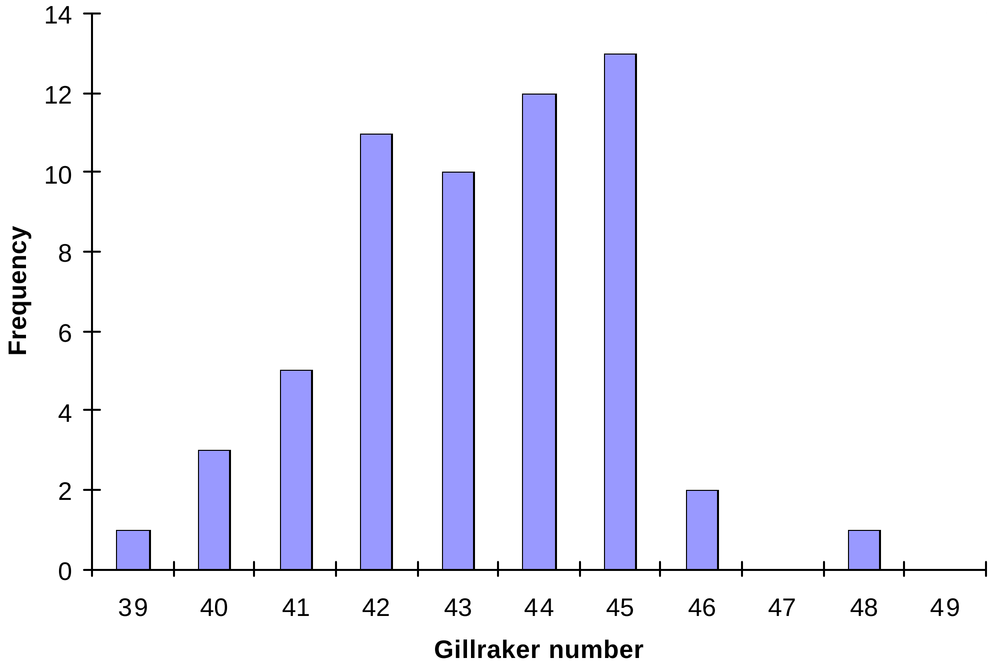

Figure 5. Gillraker counts for Winnifred Lake cisco. The distribution shows no evidence of a bimodality that would suggest two sympatric species.

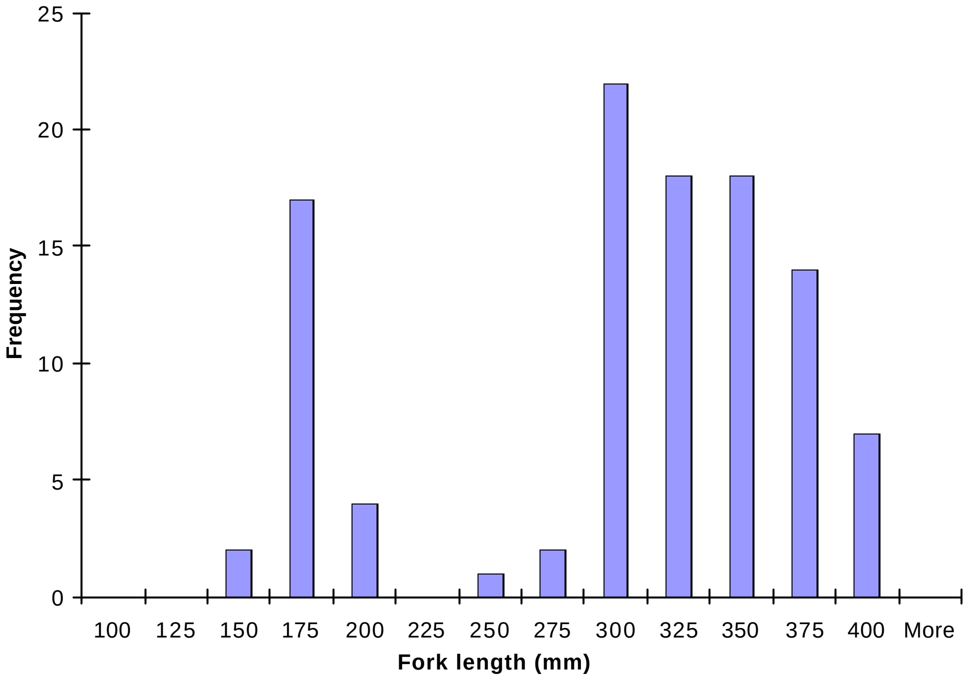

Figure 6. Length frequency distribution for Winnifred Lake cisco. The bimodal pattern suggests a small (dwarf) population and a large (normal) population.

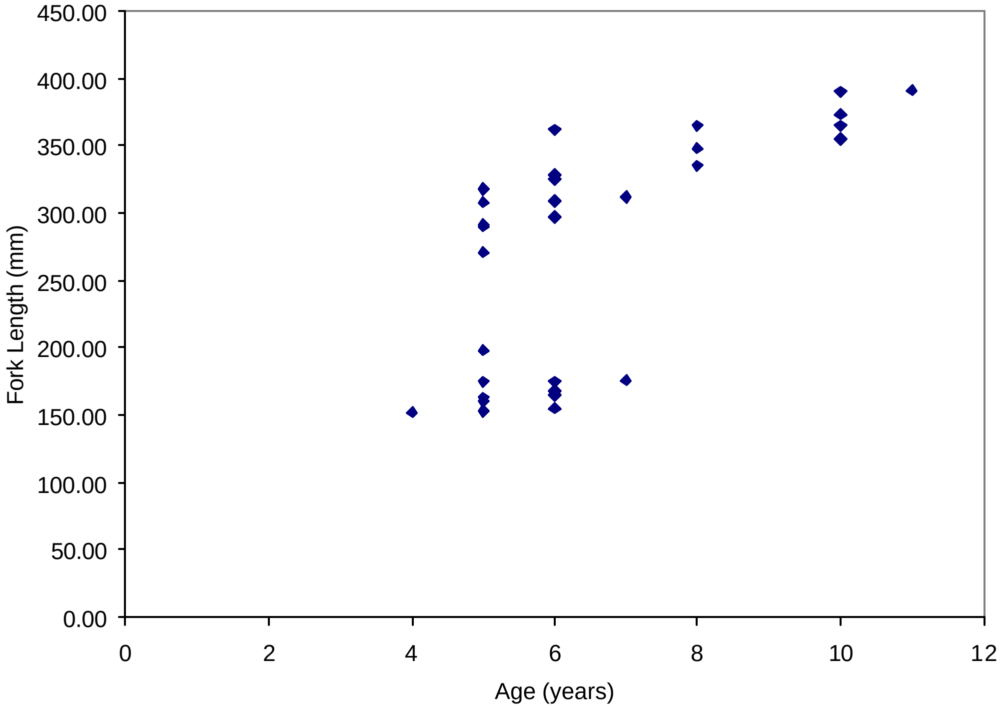

Figure 7. Length-at-age relationship for Winnifred Lake cisco. Two groups are discernible: a larger, slightly faster growing group and a smaller, slow growing group. The shorter life span apparent in the small form is typical of dwarf populations.

Relative abundance estimates and descriptions of cisco collected from each lake are outlined below. Abundances are ranked as follows: abundant – captured regularly in large numbers; common – captured regularly in small numbers; uncommon – captured on few occasions or at few sites in small numbers. Also included is the number of other fish species captured.

Fletcher Lake. Abundant (n=204). Cisco were the most common fish in this lake, outnumbering the second most frequently encountered species, lake whitefish (*Coregonus clupeaformis*), by about 10 to 1. Specimens had a mean fork length of 193 mm (range 157-255 mm) and mean fresh weight of 98 g (range 52-238 g). They were typical examples of lake herring. Other species captured were walleye (*Stizostedion vitreum*) (n=16), northern pike (*Esox lucius*) (n=4), lake whitefish (n=25) and white sucker (*Catostomus commersoni*) (n=2).

Unnamed Lake. Uncommon (n=13). Cisco were encountered sporadically in relatively shallow water (6-10 m deep). They had a mean fork length of 165 mm (range 125-199 mm) and mean fresh weight of 62 g (range 24-100 g). They appeared to represent typical lake herring. Other species captured were walleye (n=10), northern pike (n=42), lake whitefish (n=20), white sucker (n=18) and yellow perch (n=1).

Bayonet Lake. Common (n=38). Most cisco were captured in water approximately 20 m deep in nets set 5-8 m off the bottom (mid-water sets). They had a mean fork length of 170 mm (range 148-256), and mean fresh weight of 54 g (range 36-190 g) and resembled typical lake herring. Other species captured were northern pike (n=20), lake whitefish (n=97), lake trout (*Salvelinus namaycush*) (n=37) and burbot (*Lota lota*) (n=1).

Wylie Lake. Uncommon (n=10). All specimens were collected at a single sampling site located on the bottom in 20 m of water. Cisco in this lake were small and very slender, with a mean fork length of 148 mm (range 124-179 mm) and mean fresh weight of 32 g (range 18-52 g). Other species captured were northern pike (n=20), lake whitefish (n=160), white sucker (n=42) and lake trout (n=9).

Dawson Lake. Uncommon (n=7). Most specimens were collected near the bottom in 8-16 m of water. Cisco from this lake were small and slender, with a mean fork length of 144 mm (range 103-168 mm) and a mean fresh weight of 32 g (range 10-49 g). Other species captured were northern pike (n=8), lake whitefish (n=147), white sucker (n=15) and lake trout (n=27).

Winnifred Lake. Abundant (n=146). Cisco were collected at sampling sites throughout the lake. There were 123 specimens of the large or normal form with a mean fork length of 325 mm (range 243-394 mm) and mean fresh weight of 526 g (range 180-1030 g). There were 22 individuals of the dwarf form with a mean fork length of 167 mm (range 150-198 mm) and mean fresh weight of 54 g (range 38-99 g). All of these individuals were mature and at least four years of age (Figure 7). Other species captured were northern pike (n=164) and white sucker (n=90).

Barrow Lake. Abundant (n=199). Two species of cisco occur in this lake. The common lake herring had a mean fork length of 178 mm (range 128-238 mm) and mean fresh weight of 77 g (range 28-202 g). The uncommon shortjaw cisco had a mean fork length of 221 mm (range 144-411 mm) and mean fresh weight of 201 g (range 32-1060 g). Other species captured were walleye (n=11), northern pike (n=20), lake whitefish (n=102), white sucker (n=6) and burbot (n=3).

Of the 199 ciscoes collected at Barrow Lake from August 3-5, 2000, 23 were shortjaw cisco (the remainder were lake herring). Figure 8 shows the clear bimodality in gillraker number indicative of two sympatric species in this lake. Shortjaw cisco represented 11.6% of the cisco catch in 2000 and catch-per-unit-effort (CPUE) was calculated at 0.00078 shortjaw cisco/hr/m^2 of net. This is considerably higher than the following relative abundance and CPUE calculations from 1996 and 1997: July 1996 – 4.6% of catch, CPUE=0.00031 specimens/hr/m^2 (n=153); July 1997 – 5.7% of catch, CPUE=0.00035 specimens/hr/m^2 (n=158); October 1997 – 4.2% of catch, CPUE=0.00013 specimens/hr/m^2 (n=72). (It should be noted that percent of catch is a weak index of abundance as it is dependent on the population size of other species in the catch. However, this index has been widely used in historical descriptions of relative abundance of commercially important species – like some ciscoes – so is retained here to allow comparisons where CPUE data do not exist.) A high proportion of shortjaw cisco collected were immature (13 of 23 specimens), suggesting good reproduction and juvenile survival of this species in 1998 and 1999.

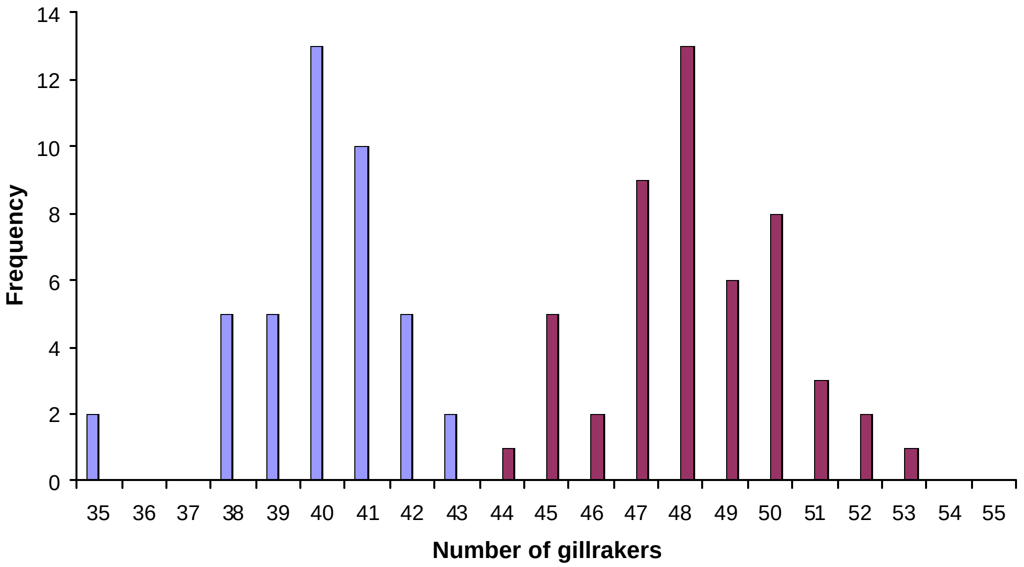

Figure 8. Gillraker counts for Barrow Lake cisco. The distinct bimodality is indicative of two species. (Note: the sample included all shortjaw cisco collected in this study and that of Steinhilber [2000]; all lake herring depicted were collected in 2000.)

Turner (1967) and Paterson (1969) reported that 16 of 77 ciscoes captured in Barrow Lake in 1966 were shortjaws. This was approximately 21% of the cisco catch. Based on their reported methodology, CPUE was roughly calculated at 0.00043 specimens/hr/m^2 for the mesh sizes employed in the present study (however, see below for a discussion of sampling biases and data comparability).

5.0 DISCUSSION

No new populations of shortjaw cisco were found in the lakes sampled in this study. To date, 15 lakes in the shield region of northeastern Alberta have been surveyed in an attempt to find this species (the eight mentioned above plus Ryan Lake, Darwin Lake, Bocquene Lake, Myers Lake, Daly Lake, Leland Lake and a second unnamed lake located at 59° 48'N 110° 50'W) (Figure 4). While many water bodies have yet to be studied, an increasingly confident assessment of the rarity of shortjaw cisco in this part of the province is now possible. It has become clear that this species is not widespread in the study area. Future work may reveal populations in addition to the one at Barrow Lake, but the probability that the number of occurrences will increase substantially (i.e., >5) appears small.

Catch-per-unit-effort data suggest that the population of shortjaw cisco in Barrow Lake has been relatively stable over the past 30 years (Turner 1967, Paterson 1969, Steinhilber 2000). Turner and Paterson used 1.5, 2.5, 3.5, 4.0, 4.5 and 5.5 inch mesh nets in their surveys. Ten cisco were captured in the 4 inch and 4.5 inch mesh nets. Although not explicitly stated, these were almost certainly shortjaw cisco as the lake herring in this lake are too small to become entangled in netting of this size. This means that the remaining 6 of the 16 shortjaw cisco they encountered were captured in 1.5, 2.5, or 3.5 inch mesh. These were the only mesh sizes used by Steinhilber (2000) and in the present study. Therefore, for comparability among years, it may be more appropriate to consider only those captures by Turner and Paterson that were in these three mesh sizes. If so, the proportion of shortjaw cisco in their total cisco catch was 7.8% (6 of 77 specimens), a number consistent with recent data. Based on this adjustment, their catch-per-unit-effort was also consistent with data from the past five years. However, it must be emphasized that comparisons among studies that employed different protocols are tenuous and must be interpreted cautiously. Consistently applied procedures are crucial for minimizing sampling variance and bias.

Gillnetting protocols were consistent between Steinhilber (2000) and the present study. The data from these two studies appear to indicate an increase in shortjaw cisco abundance over the past five years, although sampling error or natural population fluctuations could account for the variation. The number of sampling points is, as yet, inadequate to determine population trends. However, the preliminary numbers look promising. It was particularly encouraging to find a significant number of immature specimens. This suggests successful reproduction and good juvenile survival in 1998 and 1999. Long-term monitoring of the Barrow Lake population is needed to track population trends with any certainty.

In the Great Lakes, commercial overfishing, habitat degradation, competition with exotic species – particularly alewives (*Alosa pseudoharengus*) and rainbow smelt (*Osmerus mordax*) – and sea lamprey (*Petromyzon marinus*) predation have been implicated in reductions in cisco and whitefish numbers and extinction of several species (Smith 1964, Fleischer 1992). None of the factors responsible for declines of shortjaw cisco in the Great Lakes appear to be an immediate threat to populations in northeastern Alberta. Forestry, petroleum exploration and mining activities are minimal in the remote shield area of Alberta. Habitat degradation has not been a major factor although future land use activities may disrupt the ecological balance in Barrow Lake and create potentially unfavourable conditions for the survival of shortjaw cisco. Activities that promote increased sediment or nutrient loading could lead to eutrophication or destruction of spawning areas. Improved access into this area may also encourage an increase in sport or domestic fishing with direct and indirect effects on shortjaw cisco populations.

There are no records of any commercial fishing on Barrow Lake. The domestic fishery is probably insignificant given the remoteness of this lake; however, the large size of the shortjaw cisco in Barrow Lake would make it susceptible to capture in gill nets of mesh sizes used to capture walleye, northern pike and lake whitefish (*Coregonus clupeaformis*). In a small body of water like Barrow Lake, it is conceivable that low levels of gillnetting pressure could reduce shortjaw cisco populations to non-viable levels, particularly if this stress is accompanied by unusually high natural mortality (e.g., summer- or winter- kills).

Some sport fishing, primarily for walleye and northern pike, does occur at Barrow Lake but the impact on shortjaw cisco populations is uncertain. Only rarely are ciscoes taken by angling. However, gillnetting observations and stomach content analysis of walleye, pike and burbot (unpublished data) suggest that the smaller lake herring are preferred by predatory species. Overharvest of game species could reduce predation pressure on the already abundant lake herring and lead to increased populations and competition with shortjaw cisco. As the latter becomes relatively rarer, the effect of introgression with lake herring may increase (Svardson 1965, 1970). These factors could pose a threat to the unique shortjaw cisco gene pool in this lake.

Records provided by Northern Sport Fishing (Hansen 1989, 1990, 1991, 1996 and 1998) show that angling pressure on Barrow Lake was low, ranging from zero angler days in 1998 to 100 in the other years in which data were provided. Over the 5 years on record, a mean of 80 angler days were spent on Barrow Lake each year. Harvest of game species appears to be low as, on average, 30 walleye and 42 northern pike were kept each year. Although the current sportfishing pressure on Barrow Lake is minimal, overharvest of some species can occur with remarkably little angler effort (M. Sullivan, pers. comm.). This is especially true in northern lakes, where fish growth rates tend to be slow and maturation time prolonged. The use of Barrow Lake by anglers should be monitored, perhaps with the assistance of local floatplane pilots and owners of fishing lodges on or near the lake. Catch limits for game species could be adjusted accordingly to ensure the ecological balance in the lake is maintained.

6.0 MANAGEMENT IMPLICATIONS AND FUTURE DIRECTIONS

Prior to Steinhilber (2000) and the present study, it was difficult for fisheries managers to evaluate the level of extirpation risk for Alberta shortjaw cisco. With no search effort context, the number of known occurrences was virtually meaningless. The results of these two studies permit a more confident assessment of the rarity of this species in the province. It is clear that shortjaw cisco are not common, and it is unlikely that a significant number of new populations will be discovered. The one known population should be managed accordingly.

The objectives of this study were simple: to assist in putting the Barrow Lake shortjaw cisco population into a search effort context and to acquire additional data on the size and trend of this population. Both of these objectives were achieved to the extent possible in a one-year study. Assessments of distribution and population trend can be made with increasing confidence as more sites are sampled and as known populations are monitored over extended periods of time. It is recommended that species inventories using sampling protocols suitable for shortjaw cisco continue in the shield region of Alberta. Priority should also be given to examination of specimens from lakes where shortjaw cisco have been reported but not verified. These include Lake Athabasca, Gregoire Lake and Cold Lake. All cisco specimens should be examined by personnel with experience in shortjaw cisco identification. Voucher specimens should be retained and deposited in a museum collection for future reference.

Protocols for long-term monitoring of the Barrow Lake shortjaw cisco population should be considered carefully. The survey effort required to yield trend data at a high statistical confidence level (e.g., 95%) may impose unacceptable stress on this population. Annual gillnetting surveys could have a negative impact on population size over time and are not recommended. Alternative protocols such as electrofishing, trawling, trapping, or open water seining are largely untested on this species and may be logistically infeasible because of the relative inaccessibility of the study area. Experimental testing of these non-lethal survey techniques at Barrow Lake would be worthwhile. Adopting an alternative protocol would likely preclude the use of historical data (acquired by gillnetting), but this may be an unavoidable sacrifice if robust trend data are a priority in the future. An additional benefit to the use of a non-lethal protocol is the potential application in a mark-recapture study. This type of survey tends to be cost- and labour-intensive but produces the best possible estimates of absolute abundance.

In the event of a failure to find a suitable alternative to gillnetting, it is recommended that this protocol continue to be employed in Barrow Lake at five-year intervals. This low sampling frequency may never produce trend data at a 95% confidence level, but will provide resource managers with some indication of the status of this population while minimizing any negative impact. The available data suggest that the present population of shortjaw cisco in Barrow Lake is probably large enough to tolerate this limited sampling. In the event of a decline, however, removal of even a few individuals may be detrimental to the population. Priority should be given to testing alternative protocols to gillnetting.

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Appendix 1. Summary of specimen data for Barrow Lake shortjaw cisco collected in 2000.

Catalogue No.	Collector	Date Collected	Fork Len. (mm)	Weight (g)	Sex	Maturity
L00.14.1	Steinhilber, M.; Hawkings, G.	August 3, 2000	147	34	male	immature
L00.14.2	Steinhilber, M.; Hawkings, G.	August 3, 2000	296	350	male	adult
L00.14.3	Steinhilber, M.; Hawkings, G.	August 3, 2000	144	34	undetermined	immature
L00.14.6	Steinhilber, M.; Hawkings, G.	August 3, 2000	158	44	male	immature
L00.14.7	Steinhilber, M.; Hawkings, G.	August 3, 2000	193	83	male	immature
L00.14.8	Steinhilber, M.; Hawkings, G.	August 3, 2000	272	275	male	adult
L00.14.10	Steinhilber, M.; Hawkings, G.	August 3, 2000	300	445	female	adult
L00.14.13	Steinhilber, M.; Hawkings, G.	August 3, 2000	207	110	female	adult
L00.14.14	Steinhilber, M.; Hawkings, G.	August 3, 2000	148	38	male	immature
L00.14.16	Steinhilber, M.; Hawkings, G.	August 3, 2000	303	400	male	adult
L00.14.17	Steinhilber, M.; Hawkings, G.	August 3, 2000	190	78	undetermined	immature
L00.14.24	Steinhilber, M.; Hawkings, G.	August 4, 2000	333	545	undetermined	adult
L00.14.25	Steinhilber, M.; Hawkings, G.	August 4, 2000	259	605	female	adult
L00.14.26	Steinhilber, M.; Hawkings, G.	August 4, 2000	309	430	male	adult
L00.14.46	Steinhilber, M.; Hawkings, G.	August 4, 2000	147	39	undetermined	immature
L00.14.48	Steinhilber, M.; Hawkings, G.	August 4, 2000	145	32	undetermined	immature
L00.14.50	Steinhilber, M.; Hawkings, G.	August 4, 2000	150	41	undetermined	immature
L00.14.101	Steinhilber, M.; Hawkings, G.	August 4, 2000	304	370	male	adult
L00.14.102	Steinhilber, M.; Hawkings, G.	August 4, 2000	192	82	undetermined	immature
L00.14.103	Steinhilber, M.; Hawkings, G.	August 4, 2000	213	118	male	immature
L00.14.104	Steinhilber, M.; Hawkings, G.	August 4, 2000	162	44	undetermined	immature
L00.14.106	Steinhilber, M.; Hawkings, G.	August 5, 2000	307	335	male	adult
L00.14.107	Steinhilber, M.; Hawkings, G.	August 5, 2000	195	93	undetermined	immature

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