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Stock Assessment of Broad Whitefish, Humpback Whitefish, and Least Cisco in Whitefish Lake, Yukon Delta National Wildlife Refuge, Alaska, 2001-2003

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Stock Assessment of Broad Whitefish, Humpback Whitefish and Least Cisco in Whitefish Lake, Yukon Delta National Wildlife Refuge, Alaska, 2001-2003

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Abstract

Whitefish *Coregoninae* spp. are an important subsistence fish harvested year-round in the Kuskokwim River drainage, Alaska. Subsistence regulations specific to whitefish in Whitefish Lake, a tributary lake to the Kuskokwim River, were enacted in 1992 after concerns were raised about reduced size and abundance of broad whitefish *Coregonus nasus*. A flexible picket weir, otolith microchemistry, and floy tags were used to assess abundance, age at length composition, and migratory patterns of broad whitefish, humpback whitefish, *C. pidschian*, and least cisco *C. sardinella* between 2001 and 2003. Multi year returns of Floy® tags indicated fidelity to the lake. Otolith chemical analysis indicated broad whitefish, humpback whitefish and least cisco sampled in Whitefish Lake are primarily amphidromous. Emigrations were highest in 2003 for broad whitefish (254) and in 2002 for humpback whitefish (31,985) and least cisco (26,195). Maximum ages were 20, 29, and 14 for broad whitefish, humpback whitefish and least cisco, respectively. Extensive migrations were indicated through the return of tagged whitefish harvested by subsistence fishers between the villages of Tuluksak and Medfra, Alaska, a distance of 671 rkm.

Introduction

Broad whitefish *Coregonus nasus* and humpback whitefish *C. pidschian* have long been considered the most important non-salmon subsistence species in the lower Kuskokwim River drainage (R. Baxter, Alaska Department of Fish and Game (ADFG), unpublished data*)*. Baxter investigated the possible development of a commercial whitefish fishery on the lower Yukon and Kuskokwim Rivers in the early 1970's. During that time, gill net surveys of lakes on the Kuskokwim Delta and in tributaries to the Kuskokwim River indicated that broad whitefish were more abundant than humpback whitefish. One survey in 1974 of Whitefish Lake resulted in the capture of 28 broad whitefish and 9 humpback whitefish in an overnight gill net set (R. Baxter, ADFG, unpublished data). Baxter noted that broad whitefish were considered the most desirable by subsistence users because they had fewer parasites and a superior flesh. Between 1967 and 1970, commercial sales in the local Bethel market consisted of approximately 18,000 whitefish or 24,594 kilograms (kg), most of which were broad whitefish. Baxter noted that humpback whitefish rarely entered the local market and that the majority of broad whitefish harvest was taken as bycatch during the August coho salmon *Onchorynchus kitsuch* fishery.

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Whitefish contribute substantially to the overall subsistence harvests in the Kuskokwim River drainage. Fishers harvest whitefish throughout the year utilizing gill nets under the ice during the winter, or in open water during the spring, summer, and fall, or by jigging (rod and reel, or stick). Some spearing occurs through the ice in the early winter in Ophir Creek, a tributary of Whitefish Lake. Whitefish have received little management attention in the Kuskokwim River over the past 30 years despite heavy subsistence use. Fisheries enumeration projects and annual subsistence harvest surveys have primarily focused on salmon (Ward et al. 2003). For example, catch calendars are mailed out annually to gather harvest information on subsistence caught salmon, but surveys focusing on non-salmon species only occur occasionally.

Brelsford (1987) surveyed three of 19 villages located on the Kuskokwim River. These three villages, Aniak, Crooked Creek, and Red Devil are located within the middle section of the drainage. Seasonal harvest information was gathered for fish by harvest area and dates harvested, but information was not recorded by species or amount harvested. Harvest surveys were conducted in the village of Kwethluk in 1990 (Coffing 1991) and in Akiachak in 1998 (Coffing et al. 2001). Coffing's Akiachak results showed that of the total number of non-salmon harvested, blackfish *Dallia pectoralis* constituted 27%, burbot *Lota lota* 17.8%, northern pike *Esox lucius* 15.2%, broad whitefish 12.8%, smelt *Osmerus mordax* 11.3%, humpback whitefish 11.1% and inconnu *Stenodus leucichthys* 1.0% (Coffing et al. 2001). Broad and humpback whitefish comprised 24% of the non-salmon harvest. A majority of Kwethluk residents harvested a greater amount of non-salmon fish compared to salmon. Non-salmon harvest totaled over 62,595 kg, or approximately 121 kg per household. During times of reduced salmon abundance (e.g., 1999-2002), non-salmon species may play an even more important role in the subsistence way of life common throughout the drainage.

In the early 1970's, the State of Alaska's commercial fishing regulations (5 AAC 39.780) for the Kuskokwim drainage required "a permit to fish for whitefish, inconnu, char and allied (similar) species in fresh and salt water". The regulations prohibited commercial fishing for whitefish or northern pike in Whitefish Lake and in the Johnson River, a tributary to the Kuskokwim River. Over exploitation was mentioned in 1973 as the probable cause of decreased numbers of whitefish in the Johnson River and Whitefish Lake (R. Baxter, ADFG, unpublished data). Local subsistence users in Aniak and Kalskag Alaska use Whitefish Lake as a primary area to target whitefish, especially broad whitefish. These subsistence users expressed concern over the decline in size and numbers of broad whitefish in Whitefish Lake. They pointed to previous times when large numbers of whitefish were removed and possibly taken to market in Bethel. These concerns led to the 1992 establishment of time and gear regulations for subsistence fishing in Whitefish Lake.

Broad whitefish, humpback whitefish and least cisco exhibit similar life history traits. These species enter freshwater tundra ponds and lakes in early spring after oxygen levels increase to tolerable levels, and feed during the spring and summer (Alt 1979, R. Baxter, ADFG, unpublished data). Whitefish are fall spawners and generally migrate upstream to river sections or tributaries with shallow fast flowing waters and clean gravel (Chang-Kue and Jessop 1997). Mature males generally leave the tundra lakes first followed by mature females (R. Baxter, ADFG, unpublished data). Whitefish are broadcast spawners and eggs settle into the gravel interstices. The eggs develop under the ice. In the spring fry wash downstream with spring floods opportunistically moving into feeding and rearing habitats. Whitefish mature after 4-8 years and begin their migration to spawning areas (Morrow 1980). Mature whitefish in northern populations may not be consecutive year spawners (Bond and Erikson, 1985, 1993). Immature and mature fish are sometimes found in different lakes. Lakes on the Tuktoyaktuk Peninsula on the Beaufort Sea, Canada, contained a large portion of immature rearing whitefish (Chang Kue and Jessop 1992). As spawning time approaches mature whitefish change physiologically. Spawning tubercles develop on scales along their sides and heads (McPhail and Lindsay 1970), and milt is readily expressed from males. Females develop egg masses that physically extend the body cavity. Eggs of females can comprise 15% and greater of the body mass in late summer and fall prior to spawning (Bond and Erickson 1985).

Broad whitefish, humpback whitefish and least cisco can exhibit several different life history types, amphidromous, lacustrine, or riverine. Some broad whitefish are known to spend parts of their life in brackish waters (Reist 1997). Broad whitefish that migrate from fresh water to the sea or brackish water, or vice versa not for spawning, but at some other time are classified as amphidromous. Anadromy refers to species that spend most of their life in marine waters and migrate to freshwater to spawn. Potamodromous populations spend their entire life in particular lakes, and riverine populations can spend their entire life in a particular river (Reist 1997). Juvenile broad whitefish from the Mackenzie River feed and rear in fresh water lakes and over-winter in brackish coastal waters until they are sexually mature around 8 years of age (Bond and Erickson 1985). These fish then migrate upstream and spawn. Rearing areas for juvenile broad whitefish in the Kuskokwim River are unknown. Very few spawning areas have been documented for whitefish in the upper river (Alt 1972). Brown (2000, 2004) chemically analyzed otoliths and determined that some Selawik River whitefish and Yukon River inconnu are amphidromous. This same life history characteristic is suspected of some Kuskokwim River whitefish.

No research or monitoring has been conducted on whitefish in the Kuskokwim River since the 1970's (Alt 1973, 1977; R. Baxter, ADFG, unpublished data). Some anecdotal data has emerged with the use of salmon monitoring weirs on tributaries to the Kuskokwim. For example, whitefish have been observed migrating through salmon monitoring projects on Kuskokwim River tributaries in late summer (Harper 1997, 1998; Harper and Watry 2001).

Study objectives included monitoring whitefish migration patterns, collect biological data on length at age, and determine life history types of whitefish in Whitefish Lake.

Study Area

The Kuskokwim River is the second largest drainage in Alaska (Figure 1). The glacially turbid main stem originates in the Kuskokwim Mountains and the Alaska Range, on the northwest side of Mt. McKinley and courses for approximately 1,498 river kilometers (rkm). The river flows in a southwest direction and drains into the Bering Sea.

Whitefish Lake covers approximately 8,064 hectares, averages < 1.5 m in depth and is located approximately 20 km southeast of Lower Kalskag and 30 km southwest of Aniak, *(N61^{o} 24' W 160^{o} 01')* in the upper end of the Lower Kuskokwim River drainage. Ophir Creek and several smaller inlet streams drain approximately 44,340 hectares and enter the lake at an elevation of about 19.5 m. The outlet is connected to the Kuskokwim River via a sinuous 15 km river channel. Pondweed *Potamogetan* spp. is the primary rooted aquatic vegetation that occurs throughout the lake, and is very dense around the lake's perimeter. Lake turbidity is affected by suspension of bottom sediments through wave actions caused by high winds. Ophir Creek is the lake's largest inlet stream.

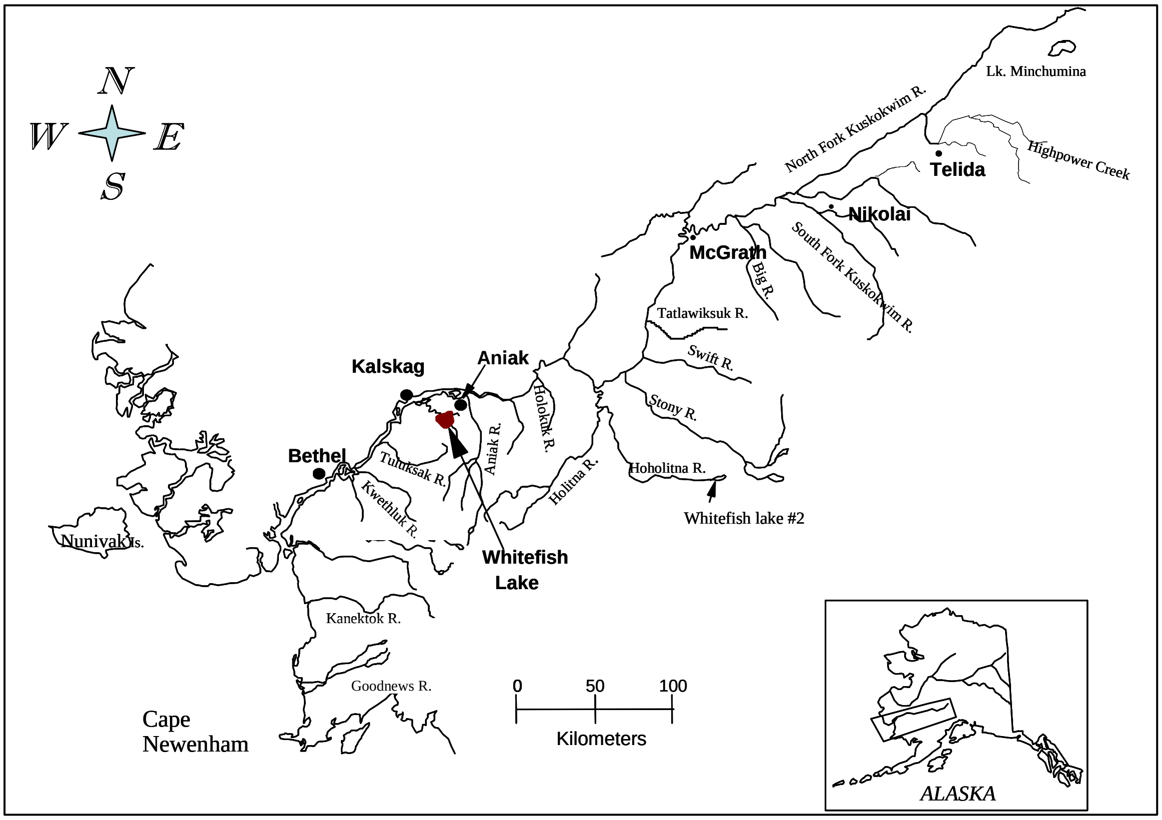

FIGURE 2.–Kuskokwim River drainage, Alaska.

Methods

Weir Construction and Operations

A flexible picket weir was installed and operated at the outlet of Whitefish Lake (*N61° 24' 854*", *W160° 01' 354*") during 2001, 2002, and 2003. The weir consisted of an upstream and downstream trap and boat passage. Weir panels were similar to those used on McLees Lake, Unalaska Island, Alaska (Gates and Palmer 2004). Daily migrations and speciation of whitefish were recorded as they migrated through the traps.

Physio-Chemical

Water temperatures were recorded using hand held thermometers and Optic® Hobo thermologgers. Water temperatures were recorded 150 meters downstream from the outlet of the lake. Secchi disc transparency, a measure of light penetration, was collected in the outlet stream daily between 8 A.M. and 10 A.M.

Abundance Estimation

Weir passage counts were used to determine total abundance of whitefish in Whitefish Lake. All whitefish leaving or entering the lake were examined for tags and if not tagged were tagged with numbered T-bar Floy® tags.

Biological Data

All fish captured were identified to species and a daily subsample collected. Data included fork length to the nearest 10 mm, and wet weight to the nearest 25 g using a Catillion® spring scale and net basket. Weight-length relationships were described by the equation:

$$Log_{10}W = a + b\,(Log_{10}L)$$

Where: W = weight in grams

L = fork length in millimeters

a = Y axis intercept

b = slope of the regression line

A Kolmogorov-Smirnov (KS) test (Sokal and Rohlf 1981) was used to test the hypothesis that length distributions from fish sampled in 2002 and 2003 were similar. This test was also used to compare lengths from subsistence harvests to weir samples.

Otolith Aging

Sagittal otoliths were collected for aging from a minimum of 10 fish within each 10 mm size group from each species. Otoliths were thin-sectioned (sectioned) in the transverse plane through the core (Secor et al. 1992), mounted on a glass slide, and polished to view annuli with transmitted light. Each section was approximately 200 µm thick. Otolith aging criteria followed the methods and illustrations of Chilton and Beamish (1982) and Howland et al. (2004).

Otolith Chemistry

Otoliths grow continually throughout a fish's life as calcium carbonate the principle component is precipitated on the outer surface (Campana 1999). Marine water has a relatively high concentration of strontium (Sr) ions in solution compared to freshwater (Martin and Meybeck 1979; de Villiers 1999). As a result, otoliths from fish that spend time in marine water are highly enriched with Sr compared to material precipitated on otoliths when they are in freshwater (Campana 1999). Areas with elevated levels of Sr in fish otoliths can be identified with an electron microprobe (Campana et al. 1997), and provide evidence of fish migrations to marine waters.

A random subsample of 10 otoliths each from broad whitefish, humpback whitefish, and least cisco were selected for otolith chemical analyses to detect if Whitefish Lake fish were amphidromous. The probability of selecting at least one amphidromous fish in a random sample of 10, if the actual proportion of amphidromous fish in the population is 0.5,was calculated based on the binomial probability distribution, using a range of sample sizes and a range of actual proportion values (Figure 2). Using a sample size of 10 produces a 97% probability of selecting at least one amphidromous fish when the actual proportion in the population was 0.3 and construed as an adequate sample size for investigation.

Sections selected for chemical analyses were polished on a lapidary wheel with 1 µm diamond abrasive and coated with a thin layer of conductive carbon in final preparation for analysis (Brown 2006). A wavelength-dispersive electron microprobe (WD-EM) was used for chemical analyses of otoliths. Classification of broad whitefish, humpback whitefish and least cisco from Whitefish Lake as freshwater resident or amphidromous life history forms was accomplished empirically by comparing their otolith Sr distribution graphs with known life history forms (Brown 2006).

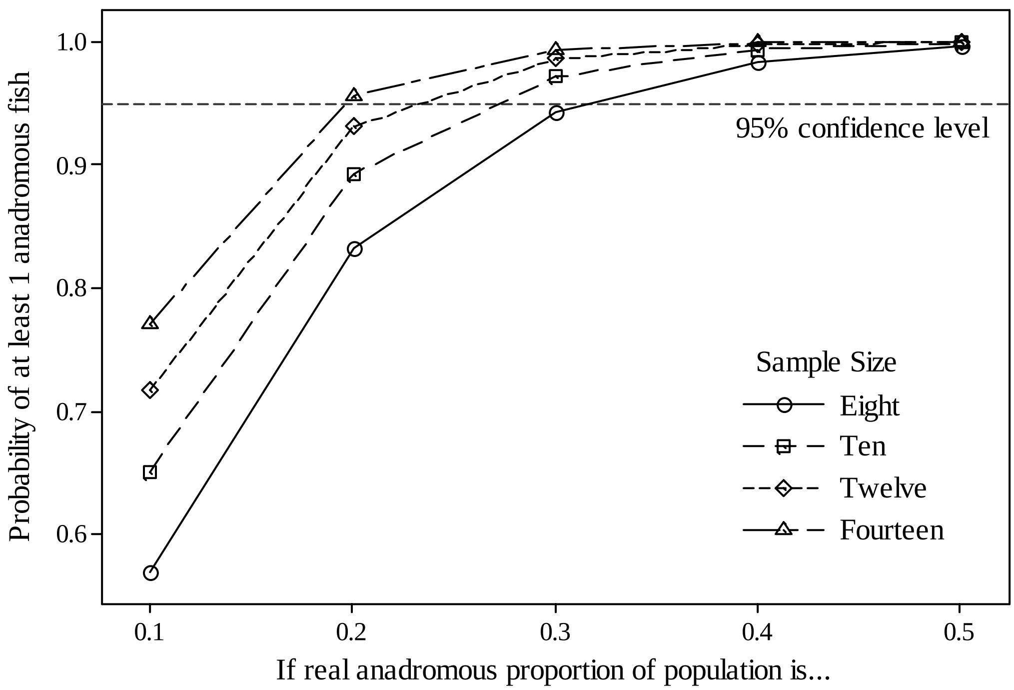

FIGURE 2.–Plot of the probability of detection of at least one amphidromous or anadromous fish in a given sized sample with a selection of hypothesized anadromous proportions in a population.

Maturity Investigations

A quantitative assessment of sexual development, gonadosomatic index (GSI), was used to determine maturity of coregonid species selected at random and sacrificed throughout their emigration for biological analysis. The GSI was calculated as the weight of gonads divided by the total body weight (before gonad removal) multiplied by100. Gonad tissue (eggs) was weighed using an electronic scale to the nearest gram. Sexually mature fish can be identified by mid-July if the GSI index is > 3.8 in broad whitefish and > 2.1 in least cisco (Bond and Erickson

1985). Sexual maturity of whitefish in Whitefish Lake was also determined by the presence of one, or a combination of spawning turbercles, running milt, and the GSI index. Sex was determined by observing expulsion of sex products or identification of gonads during GSI sampling.

Harvest

Subsistence harvests were quantified by conducting exit surveys of fishers as they left the lake during 2001-2003. Sub-samples were examined for length, and when allowed, otoliths and GSI data collected.

Catch per Unit of Effort (CPUE)–The fishery was characterized by the number of fish caught per boat, similar to deliveries in a commercial fishery. Catch for each boat (overnight set) was equal to catch per units of gear. Harvest locations within the lake were noted. During 2003, net lengths were either directly measured or calculated by dividing the number of total net floats by the number of floats per meter and converted to fathoms. Mesh size of sampled nets was measured for stretch length and classified as whitefish nets > 50 < 100 mm, chum salmon nets > 110 < 139 mm, and coho salmon nets > 140 < 165 mm.

Movements and Harvest Areas

The geographic range and harvest of whitefish using Whitefish Lake were investigated through tag recoveries. Broad whitefish, humpback whitefish and least cisco captured at the weir were tagged with gray colored Floy® T-bar tags. Each tag was individually labeled with a unique number, the wording KNA USFWS, and a 1-800 telephone number, to report tagged fish. To compare inter-and intra-year movements, tagged fish were assigned a statistical week beginning with the first week of each year.

Results

Weir Operations

High water turbidities required netting fish for positive identification. Fish were dip-netted out of the traps for identification, examined for tags and tagged if untagged, and released either up stream if immigrants or downstream if emigrants. In order to prevent crowding and minimize handling stress, the traps were closed during the day when water temperatures exceeded 15ºC.

2001–Installation of the weir was delayed due to the late approval of a land lease, and it was only operated between 21 September and 11 October 2001. On the night of 11 October, ice formed in the outlet. The weir was removed on 12 October after chipping panels from the ice.

2002–Weir installation occurred on 16 June and operations continued through 28 September. The final day of full counts was 25 September. A boat gate was installed to accommodate heavy subsistence related boat traffic by residents hunting waterfowl and moose, fishing, and berry picking. The large spring movement of fish into the lake was missed by the late installation of the weir (Figure 3). Personnel injuries during mid-summer reduced crew size, and precluded 24 hr operations during portions of June and July. During August and September, fish traps were closed when it was too dark to identify fish. September storm surges caused masses of rooted aquatic plants to plug the weir. On 26 September scouring reached depths of 2 meters, opening holes below the panels, sinking portions of the weir. The weir was removed on 28 September.

2003–The weir operated from 2 May through 17 October. Lake ice broke up and flowed out of the lake between 11 and 15 May. The boat gate was lowered to relieve ice pressure on the weir and fish may have passed into or out of the lake undetected. For the rest of the year, the trap was operated during peak passage times. In 2003, the weir operated 24 hrs each day in anticipation of extreme peak daily passages as was observed in 2002 (Figure 3). Whitefish emigrations were noted to peak after 2200h when daylight faded.

Physicochemical

Water temperatures at the lake outlet were influenced by extensive shallow littoral areas that resulted in temperatures 1 to 2ºC above those in the middle of the lake. Emergent vegetation was present over approximately 25% of the lake surface by late summer. Boating was difficult in the southwest half of the lake where shallows have abundant emergent vegetation.

2002–Water temperatures exceeded 20^{o}C for 13 days with a maximum of 24^{o}C on 17 June (Figure 3). Temperatures steadily decreased after 5 August to less than 5^{o}C by 7 October. Oxygen levels measured at five locations across the lake on 2 April were less than 1.4 ppm, while the oxygen in Ophir Creek was above 10 ppm. Ice thickness on 2 April was approximately 1.2 meters over 0.25 m of water. Water levels were very high in the spring decreasing throughout the summer until the end of August (Figure 4).

2003–Early high temperatures prior to 9 May were the result of warm waters from the shallow ice-free area along the perimeter flowing out of the lake. Water temperatures dipped between 9 and 14 May as lake ice broke up and began moving out of the lake. Average daily temperatures exceeded 20^{o}C for 21 days during the season between 28 May and 9 August. The maximum average daily water temperature recorded was 24ºC on 9 August and steadily decreased to 3ºC by 30 September (Figure 3). Water depth on 17 July decreased to -0.5m, when strong winds blowing away from the outlet across the lake, disrupted outflow (Figure 4).

Water transparency

Secchi disk readings in 2003 ranged from 0.1 m to 1.8 m and averaged 0.47 m for the season (Figure 4). The high transparency readings in May 2003 were the result of ice cover on the lake. Wind caused visibility to decrease. Maximum secchi disk readings of 1.8 m reflect the maximum channel depth where readings were taken in the outlet.

Biological Data

Broad Whitefish

Timing of migrations 2001–The weir was operated for 21 days before being removed on 11 October. Due to the shortened operations period, only two broad whitefish passed through the weir into the lake and nine left the lake through the weir (Table 1, Appendix 1).

2002–Broad whitefish counts consisted of 147 emigrants and three immigrants. Peak emigrations of broad whitefish of 55 and 36 coincided with large numbers of least cisco and humpback whitefish leaving on 31 July and 1 August (Figure 3, Appendix 2). Thirty additional broad whitefish left the lake in late August. Only six broad whitefish left the lake in September prior to the 25^{th} when seven fish emigrated. Four additional broad whitefish left the lake from 26-28 September, days with only partial counts.

2003–The majority of the 57 broad whitefish immigration occurred between 2 and 31 May (Figure 3). A count of 254 broad whitefish left the lake between 4 June and 17 October. Daily counts were sporadic between 4 June and 20 September and did not exceed two individuals. Daily emigration picked up after 20 September and peaked on 27 September when 60 broad whitefish departed (Figure 3, Appendix 3). Broad whitefish comprised less than 3% of the whitefish counted entering the lake and less than 1% of the total number of whitefish leaving the lake during all three years.

Length-frequency distribution–Lengths were collected from 9, 29, and 254 broad whitefish passing the weir in 2001, 2002, and 2003 respectively. Lengths were pooled for all collections and ranged from 270 to 650 mm with a mean of 531 mm (Figure 5). A KS test of cumulative length frequencies indicated no significance difference (P =0.754, D=0.132) between the 2002 and 2003 collections.

TABLE 1. –Total upstream and downstream migration counts of broad whitefish, humpback whitefish and least cisco for 2001, 2002, and 2003 operations at Whitefish Lake weir.

	Upstream Migration			Downstream Migration		
Weir Operations	Broad Whitefish	Humpback Whitefish	Least Cisco	Broad Whitefish	Humpback Whitefish	Least Cisco
09/21 - 10/11/2001	2	4	2	9	155	92
06/16 - 9/25/2002	3	82	121	147	31,985	26,195
05/02 - 10/18/2003	57	1,516	187	254	27,822	15,134

Length-weight relationships for male and female broad whitefish showed an allometric pattern with weight increasing at a faster rate than length (Figure 6). Length (L) and weight (W) relationships for broad whitefish collected at Whitefish Lake from both the weir passage (N=294) and subsistence harvested fish (N=113) are described by the equation:

$$Log_{10} W = -4.5418 + 2.9186 (Log_{10} L), r^2 = 0.807$$

Otolith chemistry–Otolith Sr distribution was evaluated along core to margin transects for ten broad whitefish collected in Whitefish Lake. Strontium concentration graphs from seven of 10 broad whitefish were consistent with those of known anadromous or amphidromous fish, containing greater overall variability than known freshwater resident fish (Figure 7 and 8). Strontium concentration graphs from three of 10 broad whitefish did not contain greater variability than is common for known freshwater resident fish. These data indicate that a majority of the broad whitefish spent a portion of their lives in marine environments prior to being sampled in Whitefish Lake.

Otolith age–Ages of 26 broad whitefish ranged from four to 20 years, and the mean age was 10 years (Figure 11). Growth slowed between age 4 and 6, but the largest fish was not the oldest. Due to the limited numbers of broad whitefish passing the weir, 98% of the otoliths collected in 2001 and 2002 were from the subsistence harvest.

Maturity investigations–GSI indexes of broad whitefish leaving the lake between June and October 2003 increased with successive emigration pulses (Figure 9). Large broad whitefish with a GSI of less than 5%, however, were sampled leaving the lake in September coinciding with fish having GSI's exceeding 18%. Fork length vs. GSI plots were used to determine minimum size at maturity for female broad whitefish. All broad whitefish sampled appeared to be mature, but a minimum size of maturity using a GSI value could not be determined with accuracy from the small sample size (Figure 10). Broad whitefish sampled with tubercles and running milt present indicated males matured as small as 380 mm. The smallest sampled mature broad whitefish female was 470 mm.

Abundance estimation–A Petersen estimator was used to estimate the total population of broad whitefish during 2003. The marking event consisted of 54 broad whitefish captured in the upstream trap and released into the lake. One of the 54 was a recapture from 2002 returning to Whitefish Lake. The history of several tagged broad whitefish complicated the estimate. For example, one broad whitefish was tagged entering the lake on 11 May, passed downstream undetected, and was harvested in the Kuskokwim River on 27 June 2003. This tag was removed from the tagged pool of fish. A second broad whitefish was tagged entering the lake on 12 May and recaptured reentering the lake on 25 May. A third fish was tagged entering the lake on 25 May and was recaptured reentering the lake on 12 June. These fish were counted only once in the 54 floy tagged fish. The weir was inoperable for periods during ice-breakup which is suspected to have contributed to movement without detection of the 11 and 12 May tagged fish. A total of 254 broad whitefish were captured in the downstream passage trap and examined for tags. Recaptures included 21 broad whitefish emigrating from the lake. The population estimate N=637 (95% CI $\pm$ 364), used weir recaptures for broad whitefish in 2003. Subsistence users harvested 141 broad whitefish during 2003, which included three recaptures. The estimated exploitation rate based upon the CI values is 14%-38% for broad whitefish.

Two factors indicate broad whitefish do not over winter in the lake but enter the lake in the spring prior to the operation of the weir. First, late winter dissolved oxygen levels are known to be below those necessary to support salmonids. Second, tagged broad whitefish leaving the lake in 2002 were not recaptured entering the lake during weir operations in 2003. However, tagged fish were harvested within the lake and several were recaptured leaving the lake in the fall of 2003.

Humpback whitefish

Timing of Migrations 2001–Whitefish Lake immigration and emigration were minimal during the shortened operation period. Only four humpback whitefish entered and 155 left the lake between 21 September and 11 October.

2002–Immigration of humpback whitefish was minimal compared to the emigration, indicating whitefish entered prior to weir installation (Table 1, Figure 3). Incomplete emigrant counts consisted of 31,985 humpback whitefish (Table 1; Appendix 2). Emigration started in the middle of June and daily counts peaked with 3,242 on 11 July, 3,165 on 17 July, and 3,111 on 18 July (Figure 3). Humpback whitefish exhibited a strong diel periodicity with most passing the weir after 2200 h, and before 0600 h. Incomplete counts were made on 9, 10, 11, 29, 31 July and 1 August when high water temperatures and crowding resulted in stressed whitefish in the trap. The trap gate was opened on these dates after 2400h to pass fish. Due to the water turbidity and mixed species, estimates were not made. A second small pulse of humpback whitefish was counted leaving the lake between 24 and 28 August. Except for four days, the September emigrations consisted of less than 50 fish per day.

2003–Humpback whitefish comprised 64% of the whitefish emigration, and 86% of the immigrants into the lake in 2003 (Table 1). Seventy-five percent of the immigration total of 1,516 humpback whitefish entered the lake in May. The remainder entered in smaller pulses in September and October (Figure 3). Some of these fish were tagged leaving the lake and within a few hours, to a few days, returned to the lake. Emigration during 2003 totaled 27,822, and consisted of five major pulses, each separated by distinct lulls in passage. The first pulse peaked on 13 June and the last on 29 September. The maximum daily emigration of humpback whitefish was 1,820 on 8 July. Additional emigration peaks of $\geq$ 1,000 humpback whitefish per day followed in August and late September (Figure 3). Humpback whitefish comprised the majority of the fish counted through the upstream and downstream traps in all three years.

Length-frequency distributions–Humpback whitefish lengths were collected from 155 samples in 2001 and ranged from 200 to 490 mm with a mean of 355 mm (Figure 12). The 2002 sample of 5,821 ranged from 210 to 550 mm and had a uni-modal distribution with the largest group being 420 mm and a mean length of 415 mm. The 2003 sample of 20,449 ranged from 220 to 510 mm and had a uni-modal distribution with a mode of 420 mm and a mean of 413 mm, similar to 2002. A KS test of cumulative length frequencies indicated lengths of fish in 2002 differed from those in 2003 (P < 0.001, D=0.31).

Length-weight relationships for male and female humpback whitefish showed an allometric pattern with weight increasing at a faster rate than length (Figure 6). Length (L) and weight (W) relationships for Whitefish Lake humpback whitefish are described by the equation:

$Log_{10} W = -3.3635 + 2.4287 (Log_{10} L)$, $r^2 = 0.712$,

Otolith chemistry–Otolith Sr distribution was evaluated along core to margin transects for ten humpback whitefish collected in Whitefish Lake. Strontium concentration graphs from all 10 humpback whitefish sampled were consistent with those of known amphidromous or anadromous fish. These samples contained greater overall variability than known freshwater resident fish and precipitous peaks of Sr concentration characteristic of known amphidromous or anadromous species (Figure 7 and 8). These data indicate that a majority of the humpback whitefish spent a portion of their lives in marine environments prior to being sampled in Whitefish Lake.

Otolith age–A sample of 99 humpback whitefish ranged from age 1 to 29 years, and averaged 10 years. Age at length analysis indicated growth slowed after age 6, the onset of sexual maturity (Figure 10). Overlap of length at age indicated the largest fish were not the oldest (Figure 11).

Maturity investigations–Humpback whitefish GSI percentages increased with each emigration sample between 2 May and 17 October 2003 (Figure 9). However, large humpback whitefish with a GSI ≤ 3% were sampled in September and October at the same time as fish with a GSI ≥ 12%. Minimum size at maturity for female humpback whitefish was approximately 350 mm (Figure 10).

Between 1 and 16 October 424 humpback whitefish harvested in the subsistence fishery near Ophir Creek were examined and classified as mature current year spawners, mature non-consecutive spawners or immature individuals. Classification was based upon the presence or absence of spawning tubercles or the expression of milt or eggs (Figure 13). Both the presence of spawning tubercles and the expression of sex products corroborated with the GSI results that humpback whitefish were mature around 350 mm. One 310 mm female was classified as mature due to the presence of expressible eggs yet did not have developed tubercles. Approximately 25% of the subsistence harvested fish were classified as mature non consecutive spawners.

Least cisco

Timing of Migrations-2001– Migration of least cisco into Whitefish Lake was minimal and consisted of only two fish. Ninety-two least cisco were counted leaving the lake between 21 September and 11 October.

2002–Only 121 least cisco were counted immigrating through the weir during operations. The emigration count of 26,195 was considered incomplete (Table 1, Figure 3). This was the result of the trap remaining open from 0:00h to 08:00h on 7, 9, 10 and 11 July. The crew was unable to handle a large pulse of whitefish that emigrated over short time periods on the nights of 31 July and 1 August when only partial counts of 7,281 and 6,582 least cisco were made. On 29 July the trap was left open between 02:00h and 08:00h. Few fish were believed to have passed during this time. On 30 July, between 22:30h and 24:00h, 750 least cisco and 306 humpback whitefish were passed. On 31 July at 0:00h counts were suspended due to the stress on the 1000's of fish trying to enter the downstream trap. No estimate of missed fish was made for the 0:00h – 08:30h time period. The day's count of 7,281 was made between 19:30h and 24:00h. Again, on 31 July between 22:00h and 24:00h, a large pulse of fish emigrating resulted in 4,859 least cisco dip netted from the trap. On 1 August, the crew struggled between 0:00h and 0:200h to dip net and identify an additional 3,495 least cisco. Crowding around the boat gate and surges against the weir by hundreds of least cisco entering the downstream trap simultaneously necessitated opening the trap and lowering the boat gate. An estimated 2,500 least cisco were passed in 10 minutes. Smaller emigration peaks occurred on 23 August, and 13 September. Each peak was characterized by a large diel pulse after dark

2003–Migration movements of 187 least cisco into the lake occurred primarily in May with < 15% entering in late September and < 6% in October (Figure 3; Appendix 3). In five pulses beginning in June and extending into September and early October 15,134 least cisco left the lake (Figure 3).

Length-frequency distributions–Fork lengths from 92 least cisco sampled in 2001 ranged from 120 to 390 mm and averaged 301 mm (Figure 14). In 2002, lengths from a sample of 1,803 ranged from 120 to 450 mm, with a mean of 334 mm. In 2003, lengths from a sample of 1,098 ranged from 130 to 440 mm, with a mean of 326 mm. The 2003 sample exhibited a uni-modal distribution with the largest group in the 310 mm size class. A KS test of cumulative length frequencies indicated a significant difference between the 2002 and 2003 collections, ($P < 0.001$, D=0.122).

Length-weight relationships for male and female least cisco showed an allometric pattern with weight increasing at a faster rate than length (Figure 6). Length (L) and weight (W) relationships for least cisco collected at Whitefish Lake are described by the equation:

$Log_{10}\ W = -5.3085 + 3.1511\ (Log_{10} L),\ r^2 = 0.833,$

Otolith chemistry–Otolith Sr distribution was evaluated along core to margin transects for 10 least cisco, collected in Whitefish Lake. Strontium concentration graphs from nine least cisco were consistent with those of known amphidromous or anadromous fish. The graphs contained greater overall variability than known freshwater resident fish and precipitous peaks of Sr concentration characteristic of known amphidromous or anadromous species (Figures 7, 8). The Sr concentration graph from one least cisco contained levels similar to known freshwater resident fish. This fish was tentatively classified as a freshwater resident. These data indicate that a majority of the least cisco spent a portion of their lives in marine environments prior to being sampled in Whitefish Lake.

Otolith age–A sample of 97 least cisco ranged from age 1 to 14 years and averaged 6 years (Figure 11). Age at length analysis for least cisco indicated growth slowed after age 3, and the largest fish was not the oldest.

Maturity investigations–Least cisco GSI percentages increased with each emigration sample between 2 May and 17 October 2003 (Figure 9). However, large least cisco with a GSI $\leq$ 5% were sampled in September and October at the same time as fish with a GSI $\geq$ 12%. When GSI values were plotted against length, 300 mm was the minimum estimated size at maturity, approximately age 3 (Figure 11).

Whitefish Subsistence Harvest

In late July, subsistence users began harvesting whitefish in Whitefish Lake. Maximum monthly harvests were recorded in September for broad whitefish, and October for humpback whitefish and least cisco (Table 2). In-lake subsistence harvests occur primarily within a 0.25 to 0.5 km of both inlet and outlet, which accounted for 21% and 79% of the harvest, respectively. Traditional harvest methods consisted of attaching a gill net between two poles pounded into the lake bottom parallel to the lakeshore. Depths at the harvest sites were generally 1 to 1.5 m with net lead lines resting on the bottom. In 2003, lengths of nets were either estimated or verified. The legal limit for nets fished in Whitefish Lake is 15 fathoms or 27.4 meters yet 57% of the nets were longer than the legal limit and 75% of the fish were harvested with the use of these longer nets.

TABLE 2.–Subsistence harvest by month and species from Whitefish Lake, 2003.

Species	Month				
	June	July	August	September	October
Broad Whitefish	0	2	60	48	33
Humpback Whitefish	0	3	315	124	639
Least Cisco	0	0	15	78	32

CPUE–Daily CPUE ranged from 0.6 to 12.6 for broad whitefish, 0.9 to 126 for humpback whitefish, and 1.0 to 52 for least cisco. Most of the broad and humpback whitefish were harvested using nets from 110 to 146 mm (Figure 15). The highest CPUE were in September for broad whitefish and least cisco and in October for humpback whitefish.

Subsistence harvests checked during 2001-2003 included 272 broad whitefish, 1,637 humpback whitefish, and 148 least cisco. Effort in 2001 was not estimated and effort in 2002 consisted of approximately 48 nets set between 1 August and 7 October. Information collected in 2003 included fish caught, net lengths, and mesh size from 44 nets fished between 16 August and 16 October. Subsistence harvest within Whitefish Lake during 2003 totaled 143 and an additional 22 broad whitefish were collected for samples by the crew. By comparison, 254 broad whitefish emigrated through the weir during this same time. All 254 fish were tagged. A total of 1,081 humpback whitefish were harvested and 27,822 emigrated for a harvest rate of 4%. A low number of 125 least cisco were harvested while 15,134 were enumerated as they passed out of the lake for a harvest rate of only 0.8%. Overall, broad whitefish comprised less than 1% of the total enumerated whitefish leaving the lake in 2003, but made up 12% of the total fish harvest. Humpback whitefish comprised 65% of the enumerated fish and 79% of the harvest and, least cisco comprised 34% of the enumeration and only 9% of the harvest.

A KS test of the equality of lengths of broad and humpback whitefish and least cisco leaving Whitefish Lake in 2001-2003 versus subsistence harvests, suggests a harvest bias towards the largest of all three species (Figure 16). The test compared lengths from 292 out-migrant weir samples and 241 subsistence caught broad whitefish ($P < 0.01$, $D=0.147$). Humpback whitefish comparisons consisted of 16,424 weir samples collected between 2001and 2003, and 1,637 harvested by subsistence users ($P < 0.01$, $D=0.333$). Least cisco comparisons consisted of 2,993 weir samples collected between 2001 and 2003, and 148 subsistence samples ($P < 0.01$, $D=0.204$).

Movements and Harvest Areas–Fish were tagged in each of the three years of weir operations (Table 3). During heavy passage, approximately every 5th or 10th fish was tagged. Due to water clarity, most fish were netted out of the trap for species identification and tag information. Only five broad whitefish tagged emigrating in 2002 were recaptured emigrating in 2003. One broad whitefish leaving in July 2002 left a month earlier, June of 2003. Three of the four broad whitefish tagged in September left within two days of the 2002 emigration date, while one left more than two months earlier, in July (Figure 17).

TABLE 3.–Whitefish tagged by species and year, Whitefish Lake 2001-2003.

Year	Broad Whitefish	Humpback Whitefish	Least Cisco
2001	9	147	67
2002	31	2,431	1,860
2003	283	10,147	1,042
Total	323	12,725	2,969
Known subsistence harvest of tagged whitefish 2001-2003	24	58	3

Recaptures of humpback whitefish indicates a fidelity to the lake as a feeding area. Fish tagged in 2001 and 2002 leaving the lake were recaptured leaving the lake in 2002 and 2003. Some humpback whitefish switched emigration timing between years. For example, 14 of the 147 humpback whitefish tagged emigrating in the fall of 2001 were recaptured leaving in 2002. Twelve of these 14 emigrated 14 weeks earlier than 2001. In 2003 we recaptured 18 of the 147 humpback whitefish tagged in 2001 as they emigrated. Nine remained fall emigrants, one switched to a spring emigration, and eight were summer emigrants. Inter-year recapture data was available for 650 humpback whitefish tagged emigrating in 2002 and recaptured emigrating in 2003. Approximately 54% moved out of the lake at approximately the same time both years. In 2002, 14% of those humpback whitefish moved ≥ 2 statistical weeks early, while 19% delayed their emigration date ≥ 8 or more statistical weeks (Figure 17).

Seventy-four least cisco tagged emigrating in 2002 were recaptured emigrating in 2003. The majority emigrated in 2003, ± 2 weeks of the same statistical week they were tagged in 2002. Five of the tagged fish left ≥ 8 weeks later and two out-migrated ≤ 4 weeks earlier than in 2002 (Figure 17).

Whitefish tagged in Whitefish Lake were harvested by subsistence fishers in several locations outside of the lake. Broad whitefish were harvested at the confluence of Whitefish Lake Creek and the Kuskokwim River, Birch Tree Crossing, and the confluence of the Stony River, ranging in distance from 15 to 292 rkm (Table 3, Figure 18). Tags were returned from seven harvested humpback whitefish. One humpback whitefish was harvested 82 rkm downriver near the village of Tuluksak and another 619 rkm up river at the village of Medfra. Other humpback whitefish were harvested 50 rkm upriver near Birch Tree Crossing. Tag returns of least cisco indicated movements downstream to Tuluksak and one up the Kuskokwim River 229 rkm at Red Devil.

Other species

2002–Five species other than whitefish entered the lake including 198 northern pike, 65 longnose suckers *Catostomous catostomous*, six coho salmon *Oncorhynchus kitsutch*, one sockeye salmon *O. nerka*, and one chum salmon, *O. keta*. Weir counts of other fish leaving the lake included 156 northern pike, 120 longnose suckers, and one chum salmon (Appendix 2).

2003–Other species entering the lake included 248 northern pike, 48 longnose suckers, 264 coho salmon, and one chum salmon. Other fish leaving the lake included two inconnu, one round whitefish *Prosopium cylindracium,* 99 northern pike, 162 longnose suckers and 150 adult coho salmon. Some coregonids may have been hybrids and were listed with other unidentified coregonids (Appendix 2).

Discussion

Population assessment using a weir on Whitefish Lake was difficult, yet effective at understanding whitefish abundance and migration timing. Unexpected large numbers of emigrant whitefish in July 2002 coupled with turbid waters exceeded the crew's ability to monitor all fish passage. During September 2002, high wind events uprooted aquatic vegetation that clogged the weir and caused scouring, breaching the weir. In the spring of 2003, after the weir was installed, ice coming out of the lake curtailed complete counts during a one-week period.

We confirmed previous work (R. Baxter, ADFG, unpublished data) that broad whitefish, humpback whitefish and least cisco do not use these shallow tundra lakes during the winter probably due to low dissolved oxygen levels. Their seasonal usage begins early in the spring, entering these shallow tundra lakes as increasing flows lift the ice. Both the Kuskokwim River and Whitefish Lake still have ice cover at this time. Early arrival confirms the important role these lakes play in the ecology of whitefish. Access to shallow lakes, such as Whitefish Lake, during the spring and summer appears to be critical in the life history of these species.

Broad Whitefish

The majority of the broad whitefish migrating into Whitefish Lake occurred prior to the installation of the weir in 2002 or 2003. Only the end of the broad whitefish immigration was monitored, even with weir operations beginning 2 May 2003. This was the earliest the weir could be installed. It occurred when the Kuskokwim River was still frozen and the lake was 90% ice covered. Throughout the summer, very few whitefish entered or left the lake.

The majority of the broad whitefish began leaving Whitefish Lake the last week of September as water temperatures decreased to around 2ºC. Emigrant numbers dropped off as water temperatures rose from the low of 2ºC to 10ºC on 3 October. Emigrant numbers again increased as water temperatures fell to 3ºC during the period of 3-17 October. Spawning is known to occur close to freeze up or shortly after (Alt 1976; Chang-Kue and Jessop 1997). Decreasing temperatures in September and October probably incites broad whitefish to begin their spawning migrations. Tag returns indicated some broad whitefish had not emigrated by 17 October when the weir was removed. Alt (1972) found that broad whitefish spawn in the Kuskokwim River between late October and early November. The migration distance of 900 km to a known spawning ground in the upper Kuskokwim River (Alt 1972) would suggest that the majority of the broad whitefish in Whitefish Lake should have emigrated by 17 October when the weir was removed and water temperatures were low.

Maturity data suggest some broad whitefish were mature non-consecutive year spawners. A larger sample size is needed to confirm the percentage of non-consecutive year spawners.

The majority of the broad whitefish using Whitefish Lake were mature. Eighty four percent were ≥ 500 mm, larger than the minimum length at maturity of 380 mm for males and 470 mm for females. Only 2% were ≤ 400 mm and lengths of 500 mm corresponded to age 4. By comparison, size and maturity for broad whitefish in the Selawik River population was approximately eight years and 445 mm (Brown 2004) and five to seven years and 400-460 mm in the upper Kuskokwim River (Alt 1976).

Broad whitefish in Whitefish Lake were large compared to other populations with a mean of 534 mm, a mode of 560mm and a range of 270 mm to 650 mm. Samples of broad whitefish taken near Horseshoe Bend on the Mackenzie River in 1993 ranged in size from 405 to 643 mm, with a mode of 500 mm (Babaluk et al. 2001). In Kukjuktuk Creek, emigration in 1979 consisted of 73,813 broad whitefish greater than 200 mm. Approximately 3% were longer than 475 mm and none larger than 600 mm (Chang-Kue and Jessop 1992). Mean length of broad whitefish sampled from Travaillant Lake, a tributary lake to the lower Mackenzie River, was 453 mm and ≤ 10% were ≥ 500 mm (Harris et al. 2004). Lengths found in the Selawik River population ranged from 275 to 560 mm with a median length of 456 mm (Brown 2004) smaller than the median length of 550 in Whitefish Lake. Baxter (R. Baxter, ADFG, unpublished data) sampled 777 broad whitefish from the Kuskokwim River and tundra lakes below Bethel using experimental gill nets. Lengths ranged from 90 to 650 mm, with a mode of 420 mm. Broad whitefish between 400 and 500 mm comprised 76% of the sample and only 3% were $\geq$ 500 mm. Samples from the Holitna River ranged from 360 to 560 mm (Alt 1976).

Differences in length composition between lower Kuskokwim River locations and Whitefish Lake suggest broad whitefish enter the lake to feed after rearing in the lower river. This is consistent with our otolith analysis, which indicated the majority of the broad whitefish are amphidromous.

The maximum otolith age for broad whitefish sampled from Whitefish Lake was 20 years, which was younger than other sampled populations. Broad whitefish sampled in the Mackenzie River reached 27 years (Babaluk et al. 2001). Brown (2004) found broad whitefish sampled in the Selawik River attained ages of 27 years. Samples from Travaillant Lake, a population believed to be potamadromous were mainly in the 10-20 year range but one sampled fish reached age 31 (Harris and Howland 2004). Our sampling method to collect fish from each size category for age analysis represents the range of ages present, but not the composition of the population by age class, as the oldest fish were not the largest broad whitefish specimens. A large sample was not collected because of the small population found in Whitefish Lake.

The population estimate for broad whitefish in Whitefish Lake was 417 $\pm$ 137. This small population estimate is corroborated by harvest numbers and local knowledge that substantially fewer fish now reside in the lake. Others living on the Kuskokwim River have voiced their concern that the broad whitefish populations have been reduced and now are only a fraction of historical numbers. For example, 30 to 40 years ago broad whitefish comprised 90% of the subsistence harvests in the lakes near Tuntutuliak in the lower Kuskokwim River drainage whereas now they only comprise 10% of the harvest (R. Enoch, Tuntutuliak, personal communications).

The reduction of broad whitefish in Whitefish Lake may be the result of several factors. First, a harvest bias exists at Whitefish Lake, and probably other places in the Kuskokwim River. Broad whitefish are a preferred food fish and people are known to travel from Bethel to fish Whitefish Lake. Large mesh nets and nets longer than the legal limit are used to target larger whitefish including broad whitefish. Less than 1% of the whitefish leaving Whitefish Lake were broad whitefish yet, they comprised almost 12% of the harvest which was approximately 22% of the estimated population. Second, emigration occurs in the fall, and peaks over a relatively short time period which is targeted by the subsistence fishery. Tag returns from 2001 to 2003 indicated broad whitefish were also harvested in several other Kuskokwim River locations. Third, anecdotal information suggested that during Kuskokwim River commercial salmon fishing periods, broad whitefish were caught regularly as by-catch. Baxter (R. Baxter, ADFG, unpublished data) noted that whitefish sales in Bethel stores in the late 1960's and early 1970's came primarily from the by-catch in the salmon fishery. Numbers of broad whitefish in the by-catch have gradually decreased and fewer are currently caught than in the past (James Charles 2005, personal communication, Tuntatuliak, Alaska). The directed harvest for large whitefish, broad whitefish in particular, and by-catch in the Kuskokwim River salmon fishery over the past four or five decades may have reduced the broad whitefish population. This in turn may have reduced or eliminated the buffering capacity of the population to withstand environmental fluctuations. R. Baxter in 1975 (ADFG, unpublished data) also noted that the Johnson, Eek and Kinak rivers, Alaska and Whitefish Lake were some of the systems he felt were experiencing problems from over fishing. Fourth, periods of low recruitment coupled with high levels of harvest pressure over past decades in the Kuskokwim drainage may not allow the population to recover. Fluctuating year class strengths of broad whitefish have been monitored along the Arctic coast (Gallaway et al. 1997). Numbers of this lightly exploited population fell five fold between 1982 and 1987. This was followed by a rebuilding period to 1991 and a subsequent reduction again in 1992. Variations in year class strength have also been noted on the Selawik River (Brown 2004), and in humpback whitefish and least cisco in the Chatanika River, Alaska (Fleming 1996). Fifth, environmental factors in Whitefish Lake may have changed. Climate records indicate that the period from 1949 to 1975 was substantially colder in Bethel than the period from 1977 to 2003 (Alaska Climate Research Center). An increase in temperatures occurred after 1977, with a 3.2^{o}C average rise in spring temperatures and a 2^{o}C average annual rise in temperature. These warmer temperatures have probably changed some environmental conditions in Whitefish Lake and the lower Kuskokwim River. This may be critical for some life history stage of broad whitefish that are found at their southernmost distribution in the Kuskokwim River. Baxter’s comments about the abundance of broad whitefish occurred prior to this environmental shift and the by-catch in the commercial fisheries that occurred during the 1970’s and early 1980’s (R. Baxter, ADFG, unpublished data).

Risks are associated with continuing the current heavy harvest pressure on the small number of broad whitefish in Whitefish Lake. If the Whitefish Lake population was larger and emigration occurred over a longer period, the risk would be lower, similar to humpback whitefish. Pressure on broad whitefish remains high because catch rates for humpback whitefish remain high.

Humpback Whitefish

Differences in numbers of humpback whitefish migrating into and out of Whitefish Lake in 2003 indicate that the majority entered the lake prior to 1 May. Our winter oxygen data from the lake in March indicated a very low winter oxygen level. This may require fish to leave sometime after the end of October. The number of fish counted entering the lake verses those leaving indicated that the majority would have had to migrate prior to ice-out. However, small numbers of humpback whitefish continued to enter the lake throughout the summer. More than 50% of the humpback whitefish emigration occurred in one large pulse in 2002, but was distributed over approximately five pulses in 2003 (Figure 3). In both years more than 50% of the humpback whitefish emigration occurred before August and prior to the subsistence fishery. Fleming (1996) found that humpback whitefish arrived in pulses on the Chatanika River spawning grounds. Our data would support that type of movement as smaller emigration pulses of humpback whitefish occurred from the end of August to the end of September in both 2002 and 2003. Emigration pulses of humpback whitefish from Whitefish Lake coincided with increases of whitefish caught at the salmon fish wheels operated near Kalskag (J. Pawluk ADFG, personal communication). This may indicate that they are joining humpback whitefish from other areas in the drainage as they migrate to spawning locations.

Humpback whitefish also switched emigration timing between years. Some switching may result from additional forage time needed to restore fat reserves depleted during the previous fall migration and spawning. Both robust and skinny fish were noted in the samples.

The majority of humpback whitefish using Whitefish Lake were large, mature fish. Of the sampled humpback whitefish 97% were ≥ 350 mm the minimum size at maturity. Fleming (1996) found humpback whitefish matured at 323 mm but considered 450 mm the size when all humpback whitefish were mature in the Chatanika River. Alt (1979) sampled humpback whitefish in 12 coastal and interior rivers and three lakes in Alaska noting that maturity was first reached between 310 and 360 mm. Humpback whitefish sampled in Highpower Creek at the headwaters of the Kuskokwim drainage were mature at 396 mm, or age 5 (Alt 1979). In the Chatanika River, Clark and Bernard (1988) determined humpback whitefish were mostly mature at age 7. Northern populations of humpback whitefish along the Arctic coast, where the growing season is shorter, begin to mature later at age 10 and reach 100% maturity at age 14 (Moulton et al. 1997). Based on otolith ages and GSI indices, humpback whitefish may mature as early as age 4 in Whitefish Lake.

Some humpback whitefish that use Whitefish Lake are mature, non-consecutive year spawners. This non-consecutive spawning of mature whitefish has been observed in Canada and Alaska (Morin et al. 1982; Bond and Erickson 1985; Moulton et al. 1997). Alt (1979) observed humpback whitefish spawning between 18 September and 15 October in the Chatanika River when water temperatures ranged from 0º to 3ºC. Spawning tubercles were noted on fish leaving Whitefish Lake the first week of September, so fish examined during October should be easily identified as non-consecutive spawners or mature spawners. Fleming (1996) considered 450 mm the size when all humpback whitefish were mature on the Chatanika River. He also checked humpback whitefish for sexual maturity between 26 and 30 September and found that by gently stripping fish to express sex products he could not determine the sex of up to 36% of the humpback greater than 450 mm. Spawning condition and presence of tubercles were collected from 424 humpback whitefish harvested near the inlet of Whitefish Lake between 1 and 16 October. Spawning tubercles were developed in 87% of males and 78% of the females. All fish were examined for sex by using a gentle stripping action on the abdomen, and 87% of the males and 79% of the females were mature. Fish that were not classified as mature and those without spawning tubercles were distributed throughout all sampled sizes. These fish were classified as either immature or non-consecutive.

Emigration counts of 31,858 in 2002 and 27,822 in 2003 were considered to represent the majority of the humpback whitefish using Whitefish Lake. Two factors were considered in this conclusion. First, spawning occurs at the end of September or the beginning of October when temperatures are around 0-3ºC. Second, spawning tubercles were first noted on fish leaving the lake the first week of September indicating a physical change beginning in mature fish migrating to spawning grounds. Therefore, most fish should have emigrated if they were going to spawn in other tributaries of the Kuskokwim River. These estimates do not include fish that may have spawned in Ophir Creek a tributary to Whitefish Lake or those not counted during large pulses of least cisco at the end of July and the beginning of August of 2002.

Ophir Creek, is considered a possible spawning area based upon the following. First, Ophir Creek is known as a traditional location to harvest whitefish during the fall and early winter (G.

Morgan, Kalskag, Alaska, personal communication). Whitefish are harvested using nets near the mouth of the creek during late September. They are also harvested in the first 100 meters of the creek with spears. This occurs when the ice is thick enough for winter travel. Whitefish prior to this time were not seen in creek surveys. Second, large humpback whitefish were harvested in spawning condition between 1 and 17 October near Ophir Creek. These factors indicate that some humpback whitefish might spawn in the inlet creek. A lacustrine or riverine life history type may explain why small young-of-the-year fish were not noted in emigrations. Young-of-the-year fish from this spawning population may spend summers in the lake and winters in the inlet creek. Micro-chemical analysis of otoliths from these would confirm this life history type.

The average length of humpback whitefish sampled in Whitefish Lake was approximately 416 mm, large compared to other populations. Fish > 400 mm comprised 70% of the population and only 3% were ≤ 350 mm. The median length of 420 mm was longer than the median length of 395mm found in the Selawik River (Brown 2004). By comparison, lengths from 665 humpback whitefish sampled from the Kutukhun River, a Kuskokwim tributary below Bethel, averaged 365 mm. Humpback whitefish ≥ 400 mm and ≤ 350 mm comprised 25% and 40% of the sample, respectively (R. Baxter, ADFG, unpublished data). Based on lengths, humpback whitefish probably enter Whitefish Lake when they are approximately age 4-6 years. This recruitment to the Whitefish Lake fishery is consistent with otolith analysis that indicates humpback whitefish are amphidromous.

Consistent with work in other areas, the humpback whitefish in Whitefish Lake are long lived reaching a maximum sampled age of 29 years. Brown (2004) found ages of humpback whitefish in the Selawik River ranged up to 27 years. The largest specimens were not the oldest in the collection.

Harvest pressure on humpback whitefish appears to be low and accounted for ≤ 5% of the 27,822 fish emigration in 2003. Humpback whitefish leave the lake throughout the summer and fall, with up to 50% emigrating prior to the onset of the subsistence fishery. Lake fidelity and the fact that some humpback whitefish switch emigration timing between years removes a portion from successive years of harvest pressure.

Due to the short duration of this study we were unable to detect trends in recruitment. Additional otolith work would be necessary to detect recruitment gaps. However, other Alaska populations appear to be highly variable. Humpback whitefish in the Chatanika River were found to have experienced several years of low recruitment (Fleming (1996, 1997, 1999). Pre-recruit year classes of humpback whitefish (ages 1-6), which were not fully vulnerable to his sampling gear on the spawning grounds represented between 21% and 27% of the sampled population for several years. Better recruitment was found in 1997 when these ages represented 47% of the sample. Brown (2004) also noted periodic patterns of what appeared to be a lack of recruitment for several age classes in both broad and hump back whitefish.

Least Cisco

The difference in numbers between the migration into and out of Whitefish Lake indicated that the majority of the least cisco moved into the lake prior to the weir being operated. Counts of fish entering the lake constituted < 1% of the fish leaving the lake in 2003. Least cisco continued throughout the summer to enter in small numbers. More than 50% of the least cisco emigration occurred in one large pulse in 2002. Emigration occurred in five pulses in 2003, and more than 50% of the least cisco emigration occurred before August. Large emigrations of least cisco have also been recorded prior to the middle of August in Kukjuktuk Creek, an Arctic coastal watershed east of the McKenzie River (Chang-Kue and Jessop 1992). Emigration pulses of least cisco from Whitefish Lake coincided with increases of whitefish caught at the fish wheels operated near Kalskag (J. Pawluk, ADFG, personal communication).

Whitefish Lake is used by large mature least cisco foraging during the summer months. More than half of the sample was larger than 300 mm, the minimum size of maturity which corresponded to ages 3 or 4. Samples taken from the Lower Kuskokwim River were also mature at 300 mm (R. Baxter, ADFG, unpublished data). In the Chatanika River, Clark and Bernard (1988) determined least cisco were mature at age 4. Moulton et al. (1997) found 50% of the female least cisco in Dease Inlet on the Beaufort Sea reached maturity by age 8 as opposed to age 3 or 4 in Whitefish Lake.

Least cisco in Whitefish Lake ranged from 120 to 450 mm and were similar in size to other populations. Least cisco collected from the Yukon-Kuskokwim Delta prior to 1975 ranged between 250 and 470 mm (R. Baxter, ADFG, unpublished data) and collections from Kukjuktuk Creek in Canada ranged between 100 and 470 mm (Chang-Kue and Jessop 1992).

GSI data indicates that some least cisco that use Whitefish Lake are mature, non-consecutive year spawners. Mature-sized non-consecutive spawning least cisco have also been observed in Canada (Morin et al. 1982; Bond and Erickson 1985; Moulton et al. 1997). On the Arctic coast, approximately 50% of the least cisco judged mature, spawned that year in Dease Inlet on the Beaufort Sea (Moulton et al. 1997).

Emigration counts of 26,043 in 2002 and 15,134 in 2003 were considered to represent the majority of the least cisco using Whitefish Lake. Factors considered in this conclusion were that spawning occurs near the end of September or beginning of October when temperatures dropped near freezing and emigration counts decreased as the season progressed.

Least cisco also switched emigration timing between years. Some switching may result from additional forage time needed to restore fat reserves depleted during the previous fall migration and spawning.

Least cisco attained a maximum age of 14 years in Whitefish Lake. These ages were similar to those found by Brown (2004) in the Yukon River where the maximum-recorded age was 16 years. However, least cisco up to age 25 or almost twice as old, were recorded by Moulton (1997) from samples taken in Dease Inlet. The largest least cisco in Whitefish was not the oldest.

Harvest pressure on least cisco using Whitefish Lake appears to be minimal with a known harvest of only 0.8% of the 15,134 emigrants. In addition, subsistence users did not appear to be targeting this species in Whitefish Lake. Tag returns from 2001 to 2003 indicated that least cisco were harvested in several locations outside of the lake. Least cisco left the lake throughout the summer and fall. Approximately 50% emigrated prior to the onset of the subsistence fishery.

Due to the short duration of this study we were unable to detect trends in recruitment of least cisco into Whitefish Lake. Additional otolith aging would be necessary to detect past gaps in recruitment. Other Alaska populations however, appear to be highly variable. Fleming (1996, 1997, 1999), working with spawning populations of least cisco in the Chatanika River, found that they experienced several years of low recruitment. Age 3 least cisco comprised only 5% of the Chatanika River population in 1997, compared to an average 22% over nine previous years (1986-1994).

Conclusions and Recommendations

Whitefish Lake is primarily a foraging lake for broad whitefish, humpback whitefish and least cisco based upon age and length, migration patterns, maturity and life history traits The lake may consist of multiple spawning stocks, thus, the risk of over fishing is considered minimal for humpback whitefish and least cisco that migrate from the lake to spawn. However, mature humpback whitefish that congregate at the mouth of Ophir Creek in September may spawn in Ophir Creek and have a different life history trait than other emigrants. These humpback whitefish may be vulnerable to over fishing because timing of the fishery occurs when fish are congregated near the mouth of Ophir Creek. Based upon these findings, our focus has shifted to locating spawning aggregates in the Kuskokwim River.

Harvest monitoring in Whitefish Lake should be continued on a periodic basis because it is a major subsistence harvest fishery with specific gear regulations. The small population of broad whitefish utilizing Whitefish Lake is at risk of over exploitation and the legal net length of 15 fathoms needs to be enforced.

Kuskokwim River whitefish which were once thought of as an inexhaustible resource may be suffering from harvest pressure. An estimate of annual non-salmon harvest by species should be completed annually on the Kuskokwim River. This could be accomplished similar to the State's catch calendar used for recording subsistence salmon harvests. Areas sampled by Baxter in the late 1960's and early 1970's should be re-sampled to detect if a shift in species composition has occurred. Population assessments may indicate additional regulations are required such as time and area to protect spawning broad and humpback whitefish. Changes in future management and regulations will require stakeholder participation and acceptance.

Future studies that delineate critical spawning habitat will be important. These areas once delineated can be protected from resource extraction activities and be sampled to monitor the Kuskokwim River populations.

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Foster. Wayne Morgan the natural resource director of KNA hired personnel, and purchased equipment and supplies for weir operations. KNA provided personnel to work at the weir. Carlton Morgan, Kevin Peltola, George Morgan, Rodney Sakar, and Glen Kameroff, all KNA employees, were instrumental in running the camp. Other U.S. Fish and Wildlife Service technicians working at the camp included Joe Cadeaux, Kelly Harbin, Dan Pascucci, Laurie Stafford, and others. Numerous ideas were discussed with Dr. Jeffrey Bromaghin on mark recapture methods to estimate the fish populations. Thanks to the entire Yukon Delta National Wildlife Refuge staff for their continuing support.

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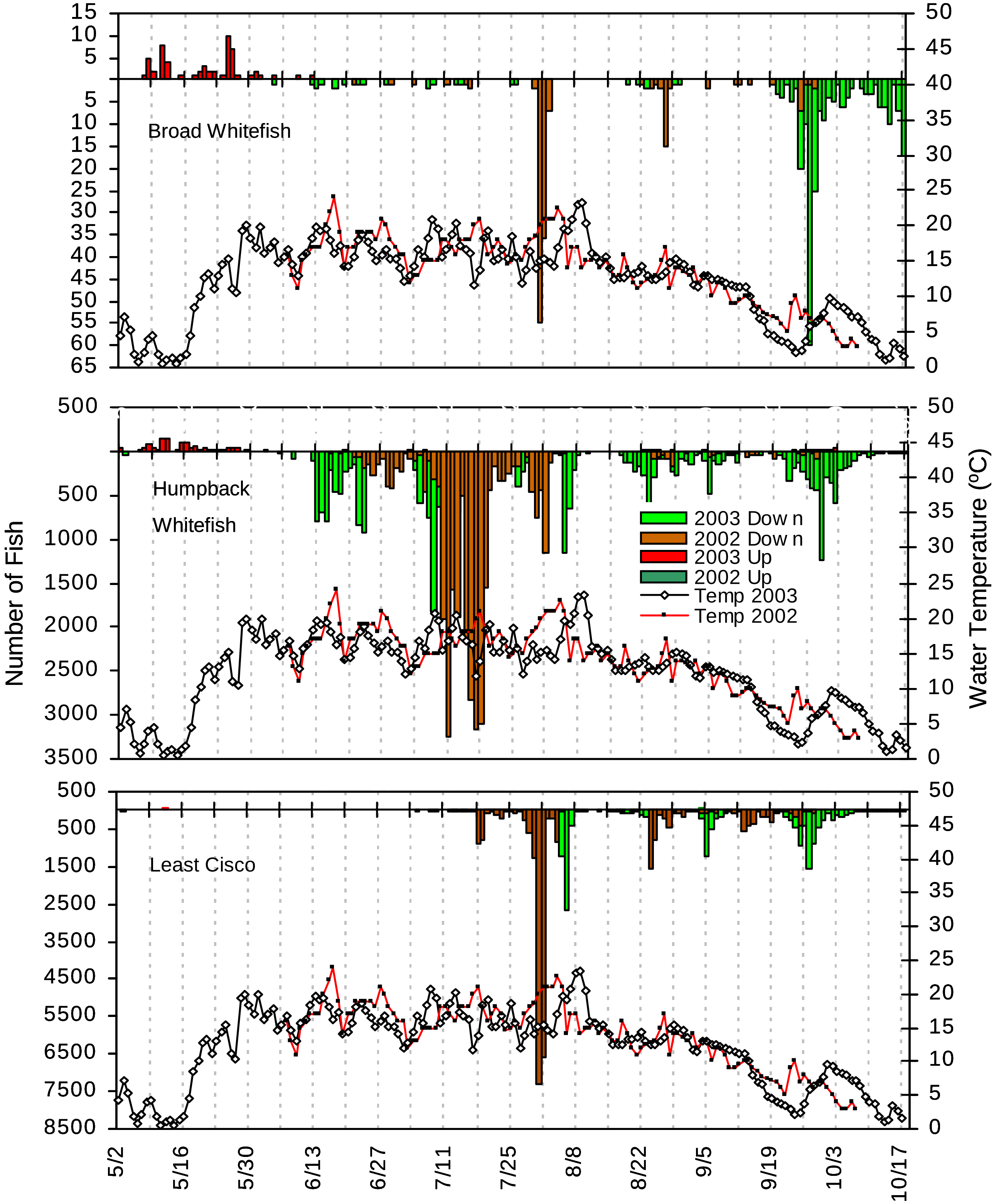

FIGURE 3.–Broad and humpback whitefish and least cisco immigration (upper bars) and emigration (lower bars) counts at the Whitefish Lake weir in 2002 and 2003. Counts in 2002 did not start until 16 June. Temperatures were recorded at the outlet of the lake.

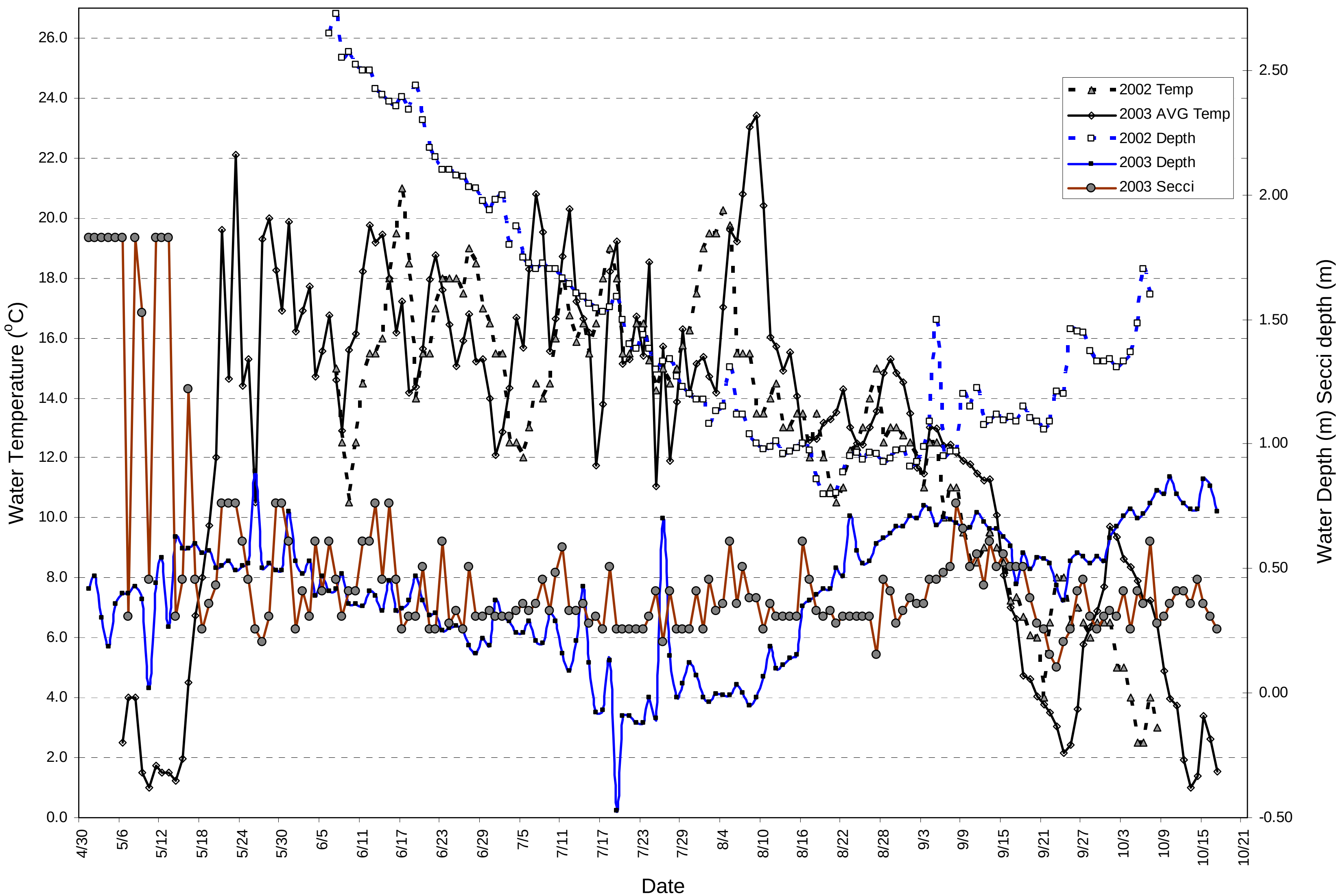

FIGURE 4.–Temperature, relative stage height and water clarity (secchi disk) data, from Whitefish Lake, 2002 and 2003.

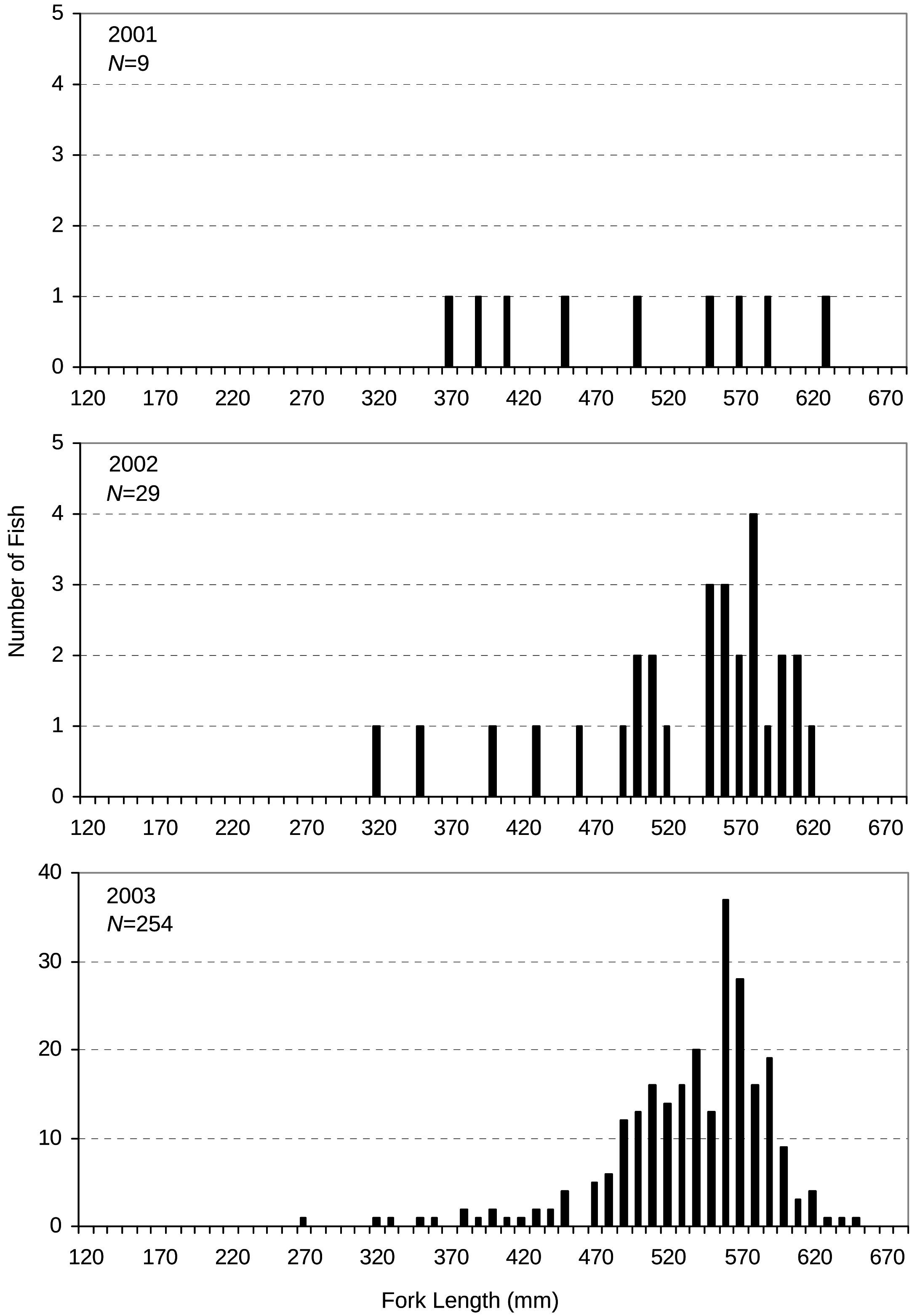

FIGURE 5.–Length composition of broad whitefish sampled at Whitefish Lake weir, 2001, 2002, and 2003.

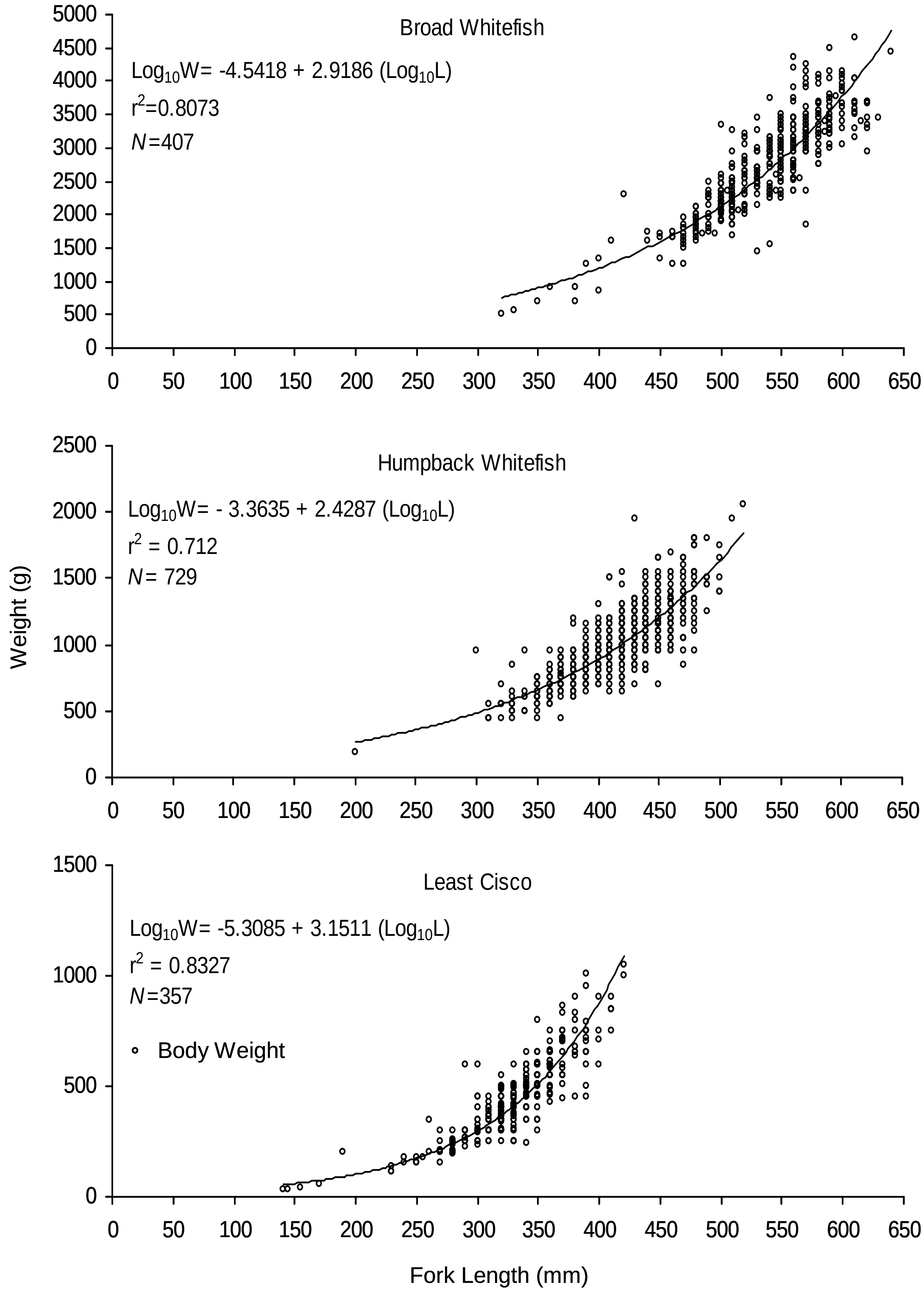

FIGURE 6.–Relationship of length to weight of broad and humpback whitefish and least cisco sampled at Whitefish Lake 2001-2003.

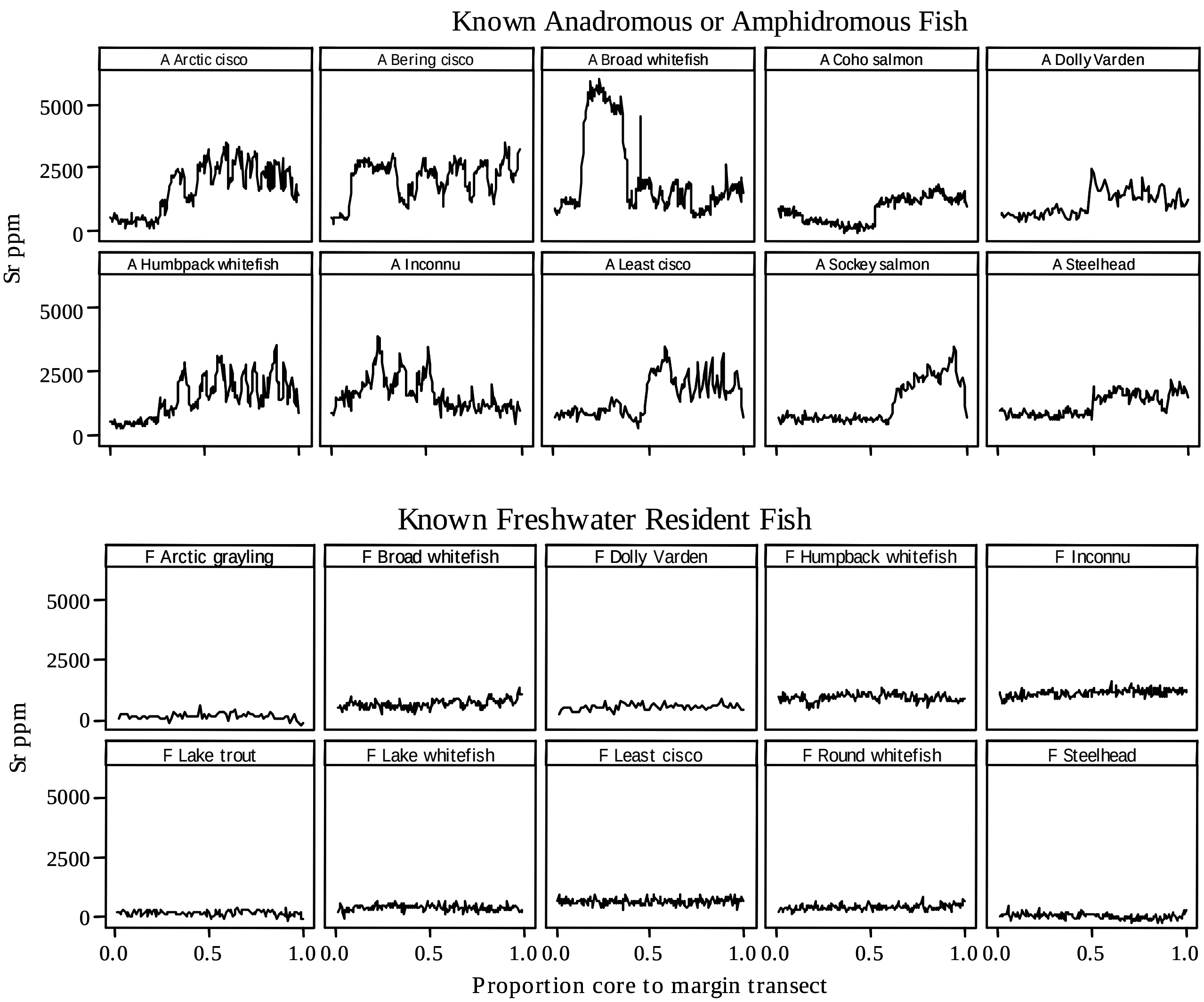

FIGURE 7.–Graphs of otolith Sr distribution along core to margin transects of 10 known anadromous or amphidromous fish (top two rows) and 10 known freshwater resident fish (bottom two rows) presented to aid in classifying samples of broad whitefish, humpback whitefish and least cisco captured in Whitefish Lake with unknown life histories.

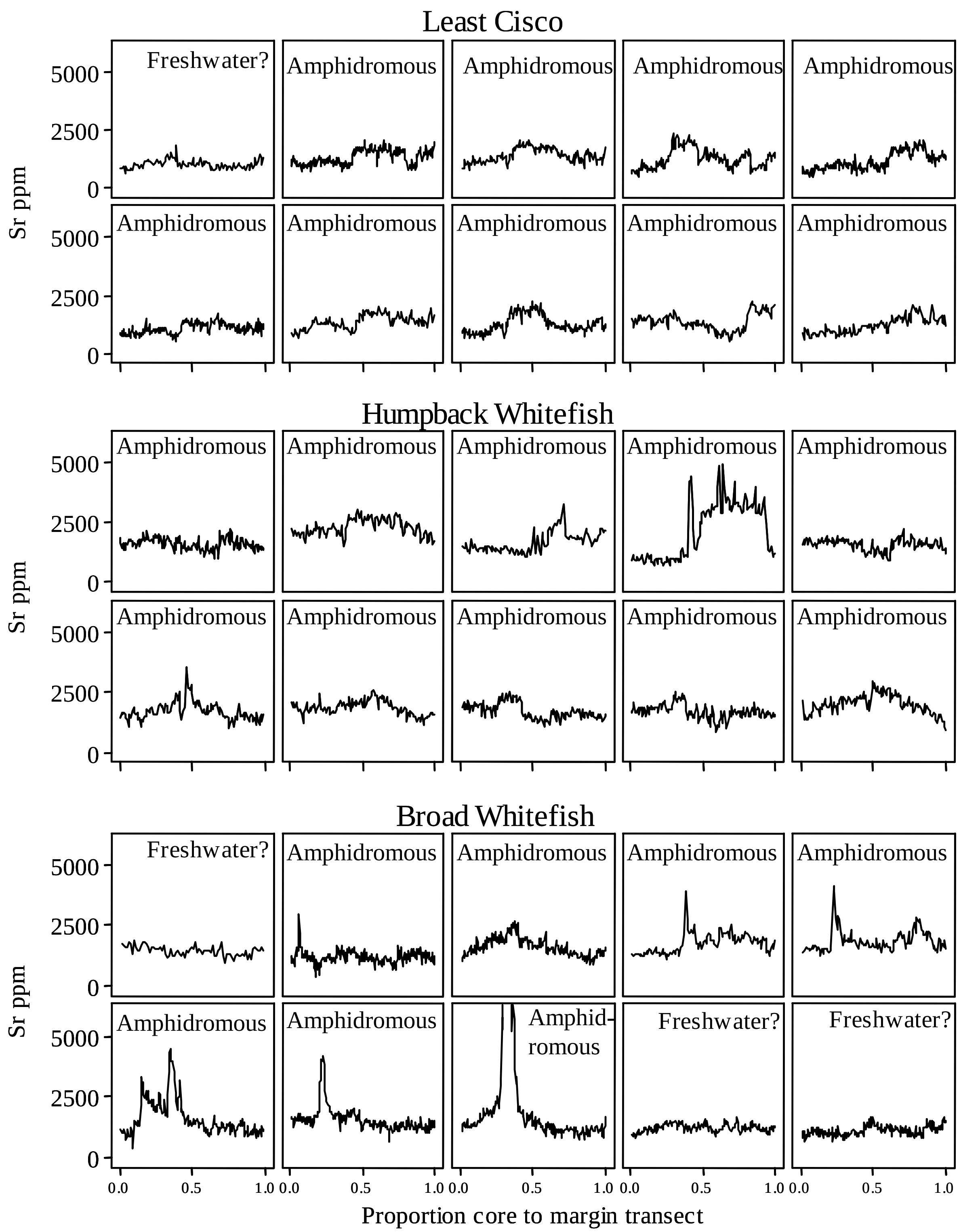

FIGURE 8.–Graphs of otolith Sr distribution along core to margin transects from 10 samples each of least cisco (top two rows), humpback whitefish (middle two rows), and broad whitefish (bottom two rows) from Whitefish Lake.

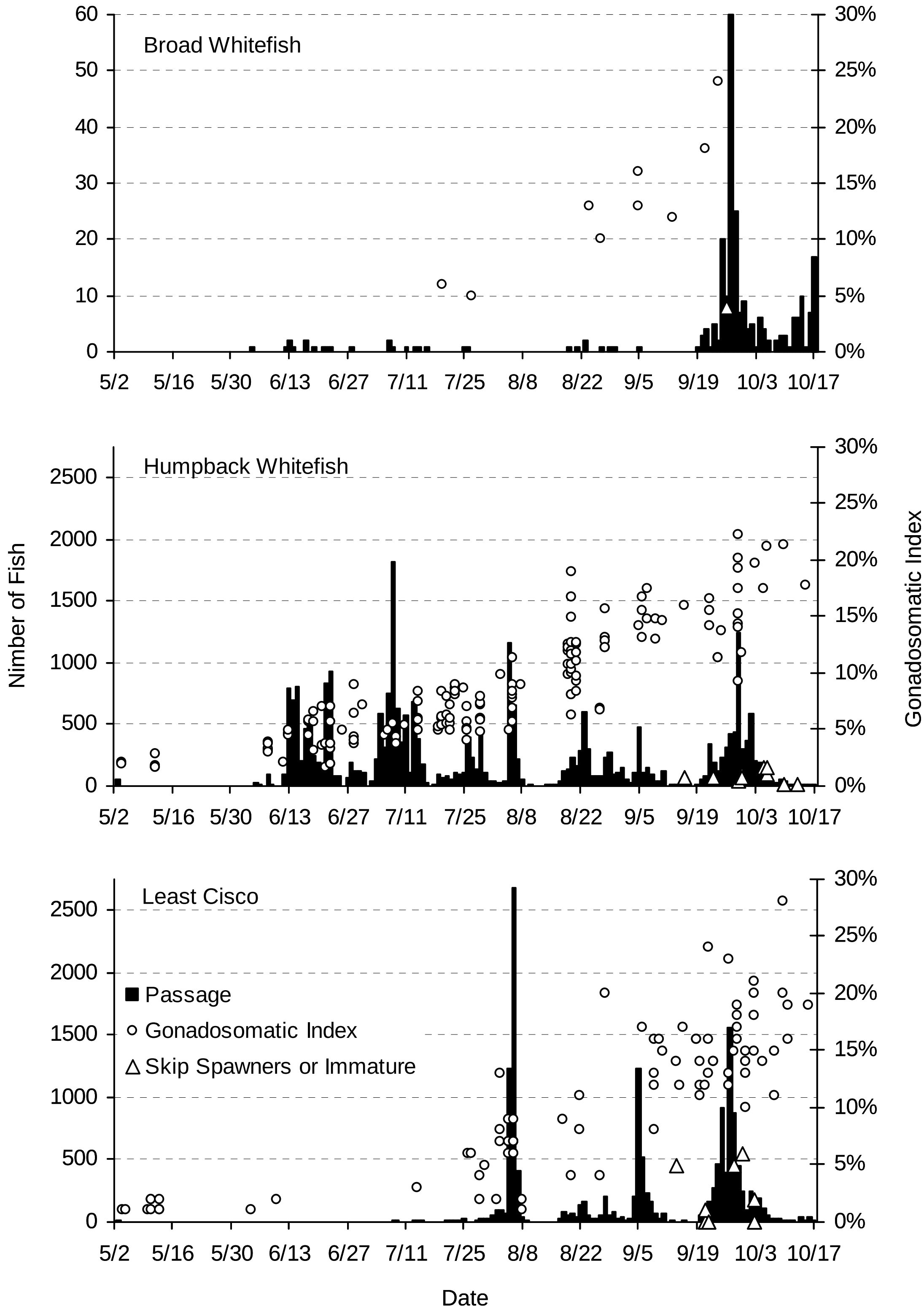

FIGURE 9.–Relationship of gonadosomatic index to passage for broad and humpback whitefish and least cisco, sampled at Whitefish Lake.

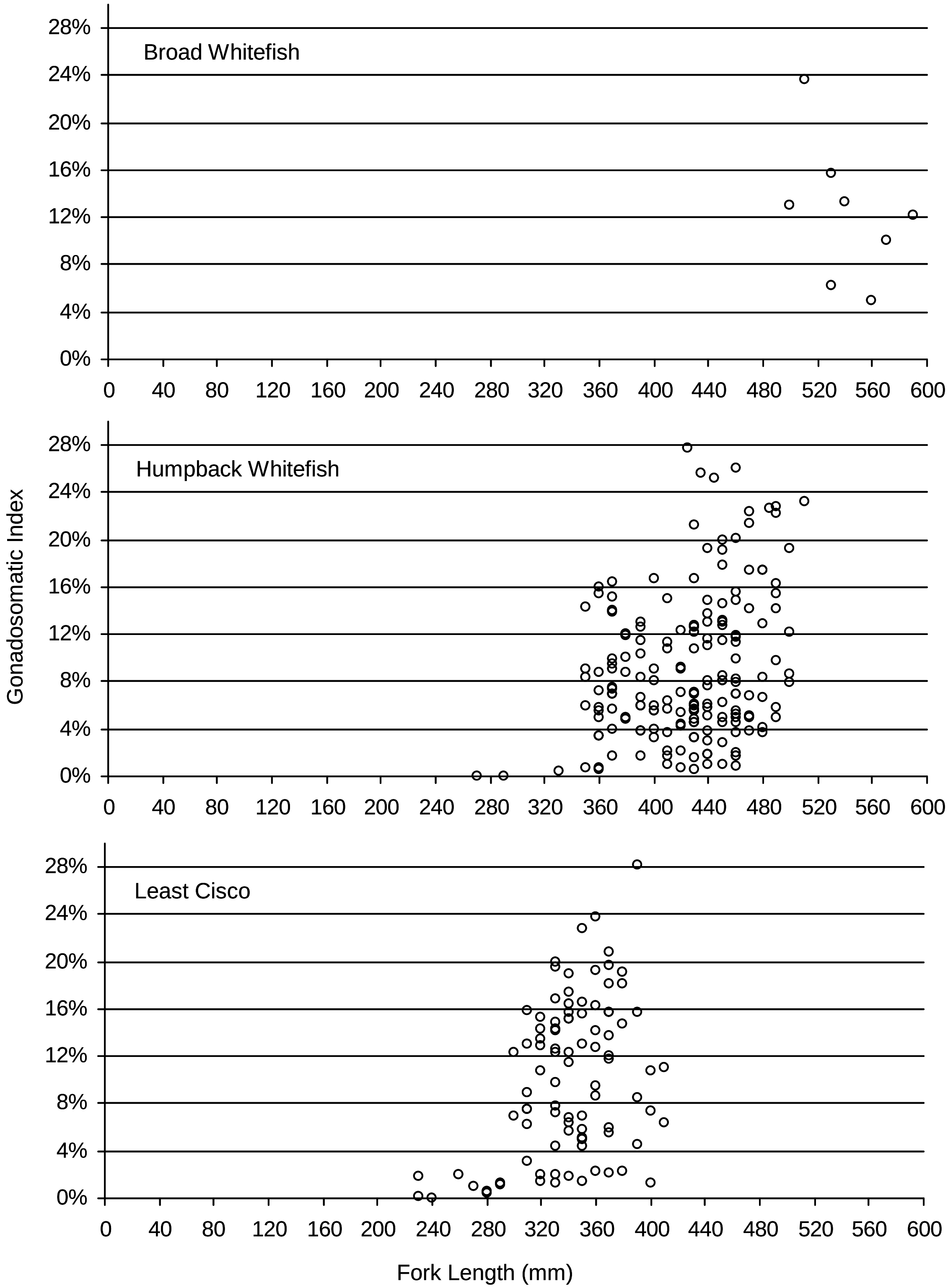

FIGURE 10.–Relationship of gonadosomatic index to length of broad and humpback whitefish and least cisco, Whitefish Lake.

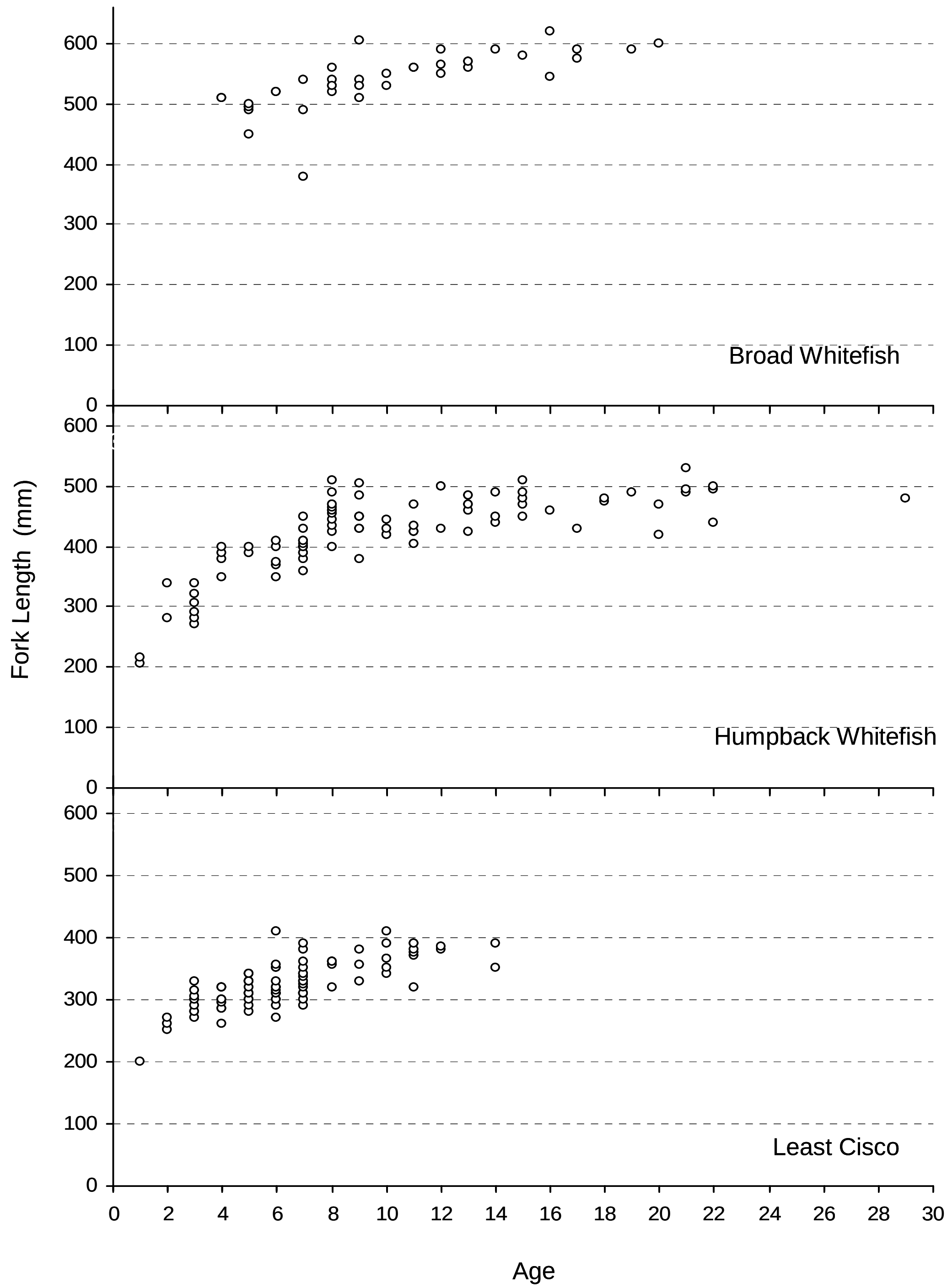

FIGURE 11.–Length at age for broad and humpback whitefish and least cisco from Whitefish Lake, 2001-2002.

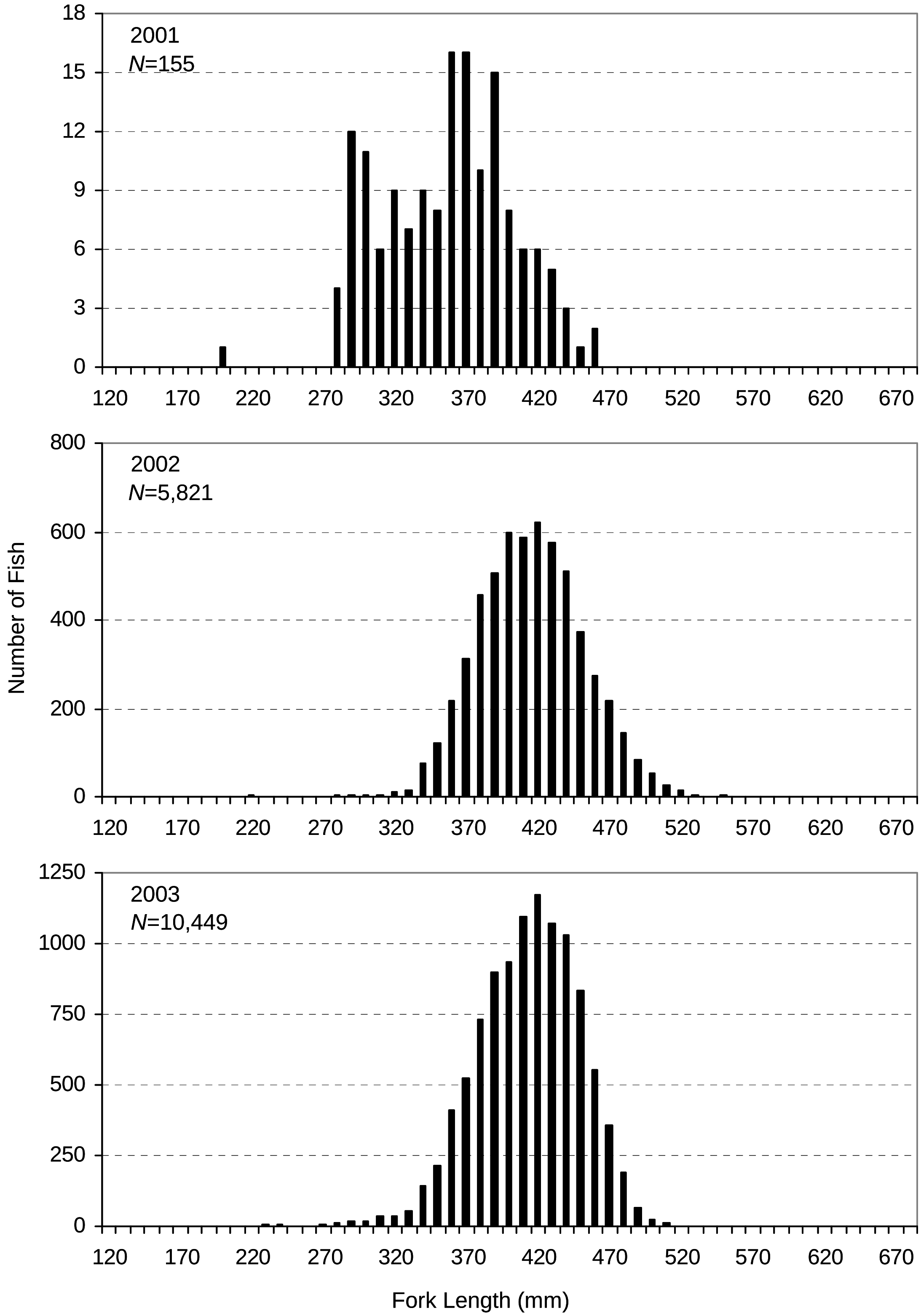

FIGURE 12.–Length composition of humpback whitefish sampled at Whitefish Lake weir, 2001, 2002, and 2003.

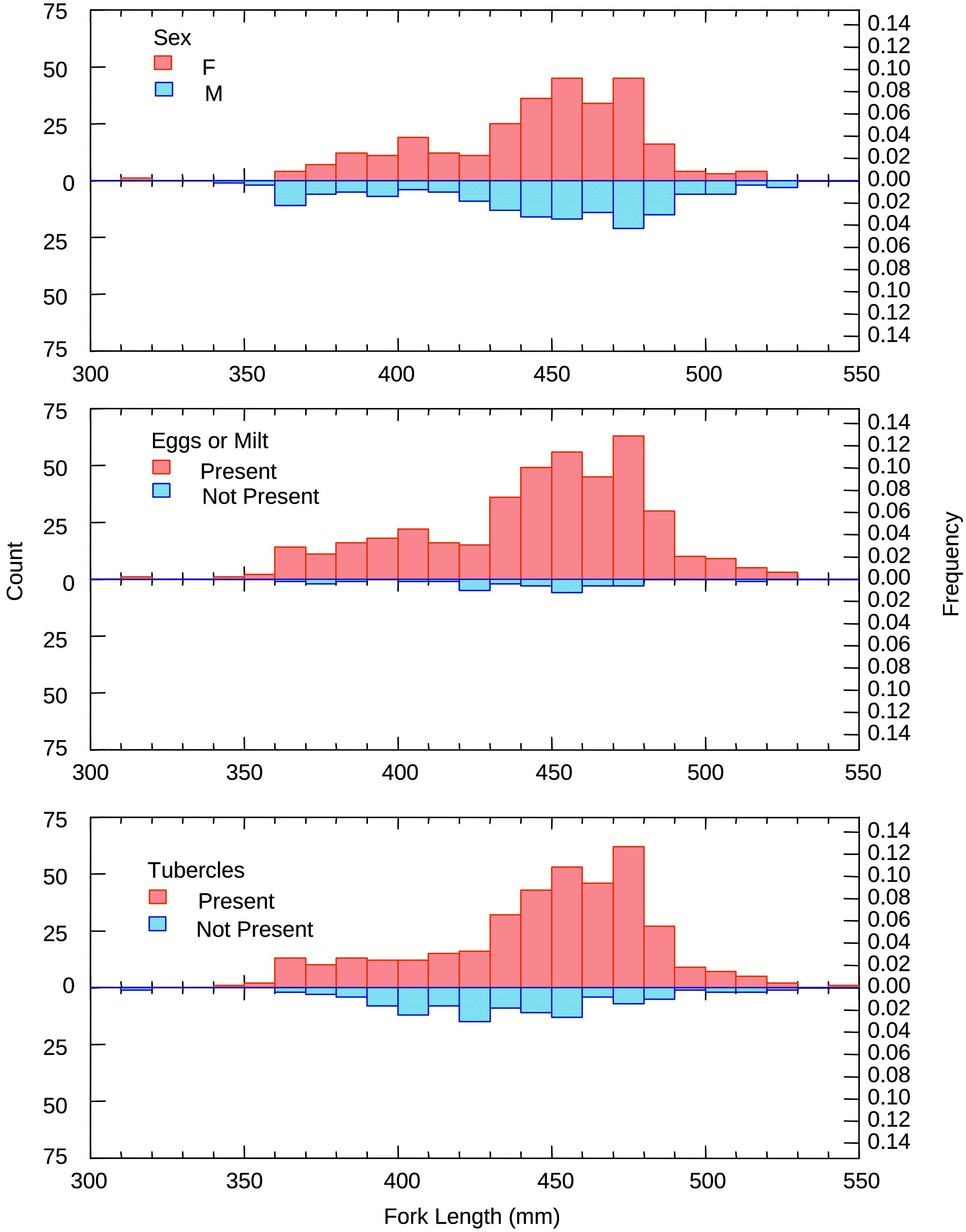

FIGURE 13.–Sex, maturity index, and presence of spawning tubercles of humpback whitefish harvested near Ophir Creek, the primary inlet of Whitefish Lake between October 1 and 16, 2003.

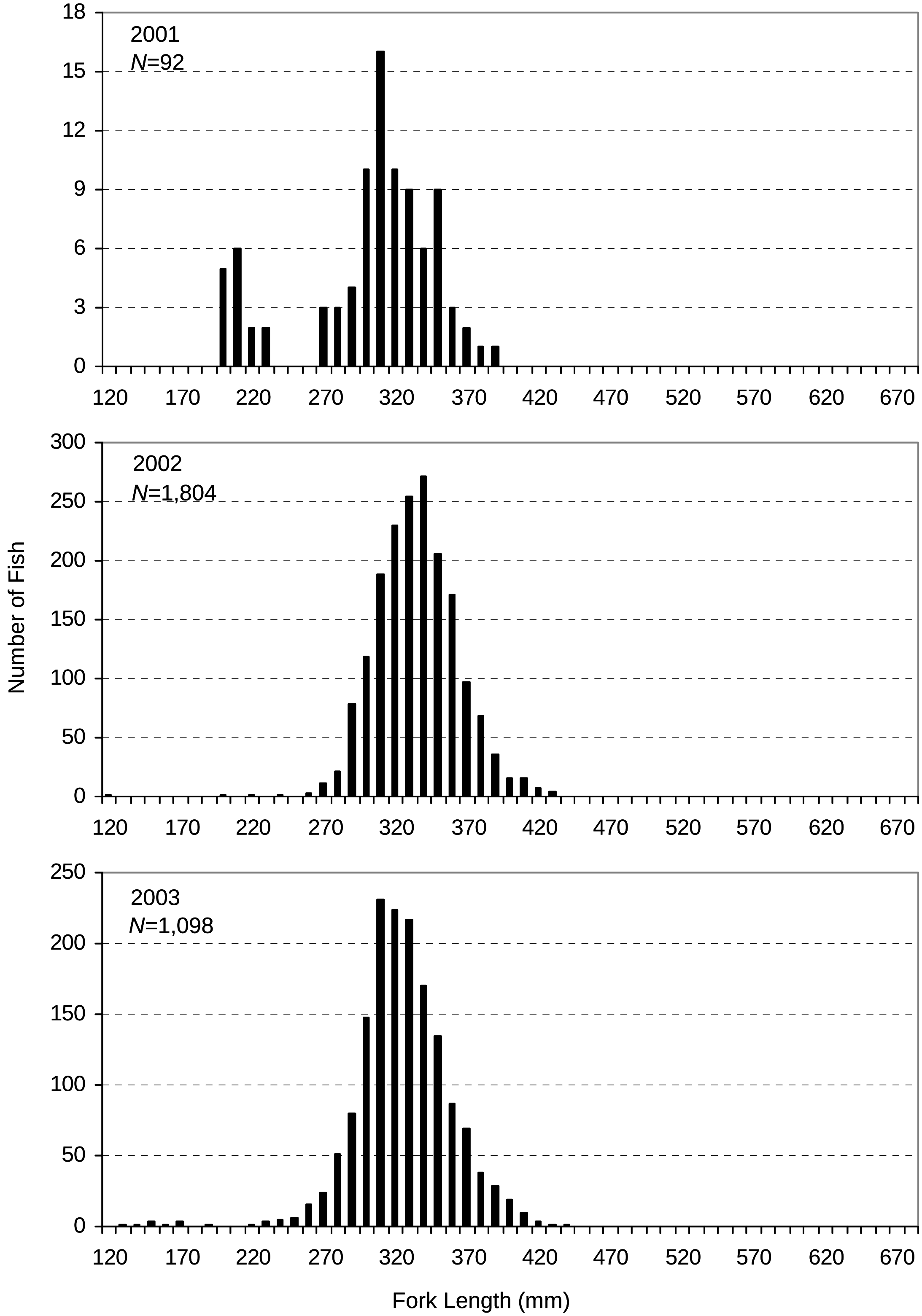

FIGURE 14.–Length composition of least cisco samples passing the Whitefish Lake weir, 2001, 2002, and 2003.

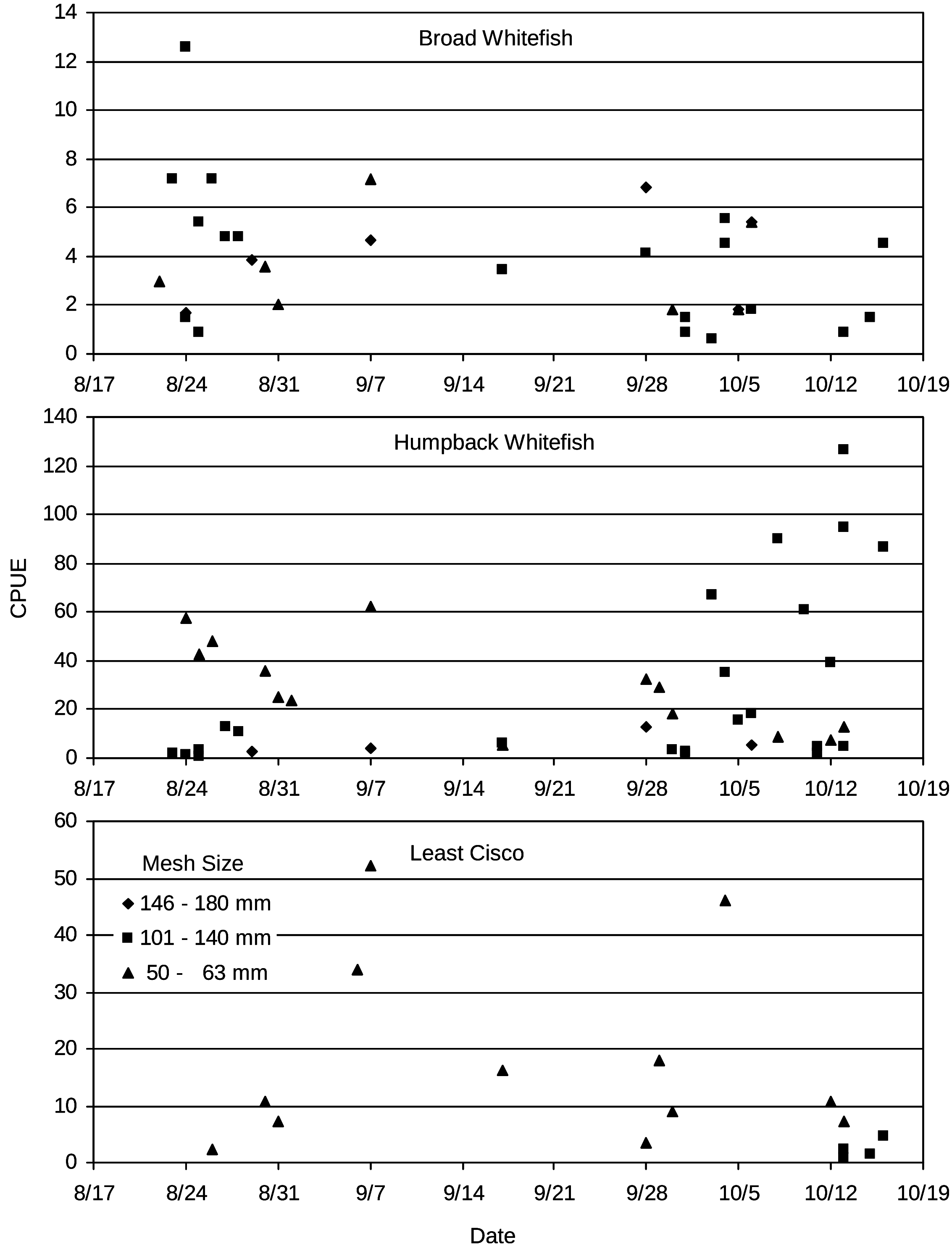

FIGURE 15.– Catch per Unit of Effort for broad and humpback whitefish and least cisco harvested in Whitefish Lake 2003. One unit of effort is equal to one net night, and 15 fathoms of net.

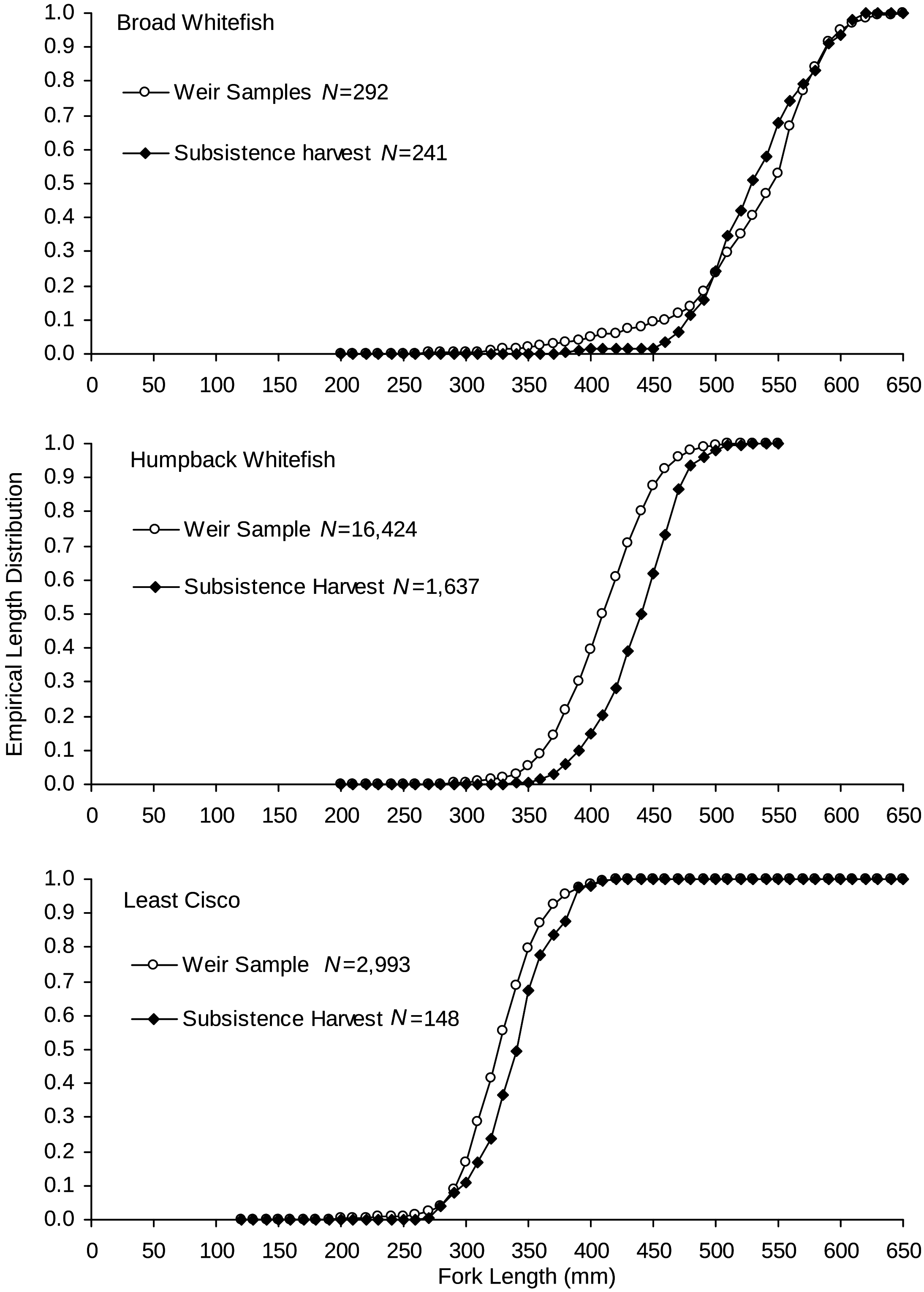

FIGURE 16.–Empirical length distributions of broad and humpback whitefish and least cisco sampled at the weir and from subsistence harvests, 2001-2003.

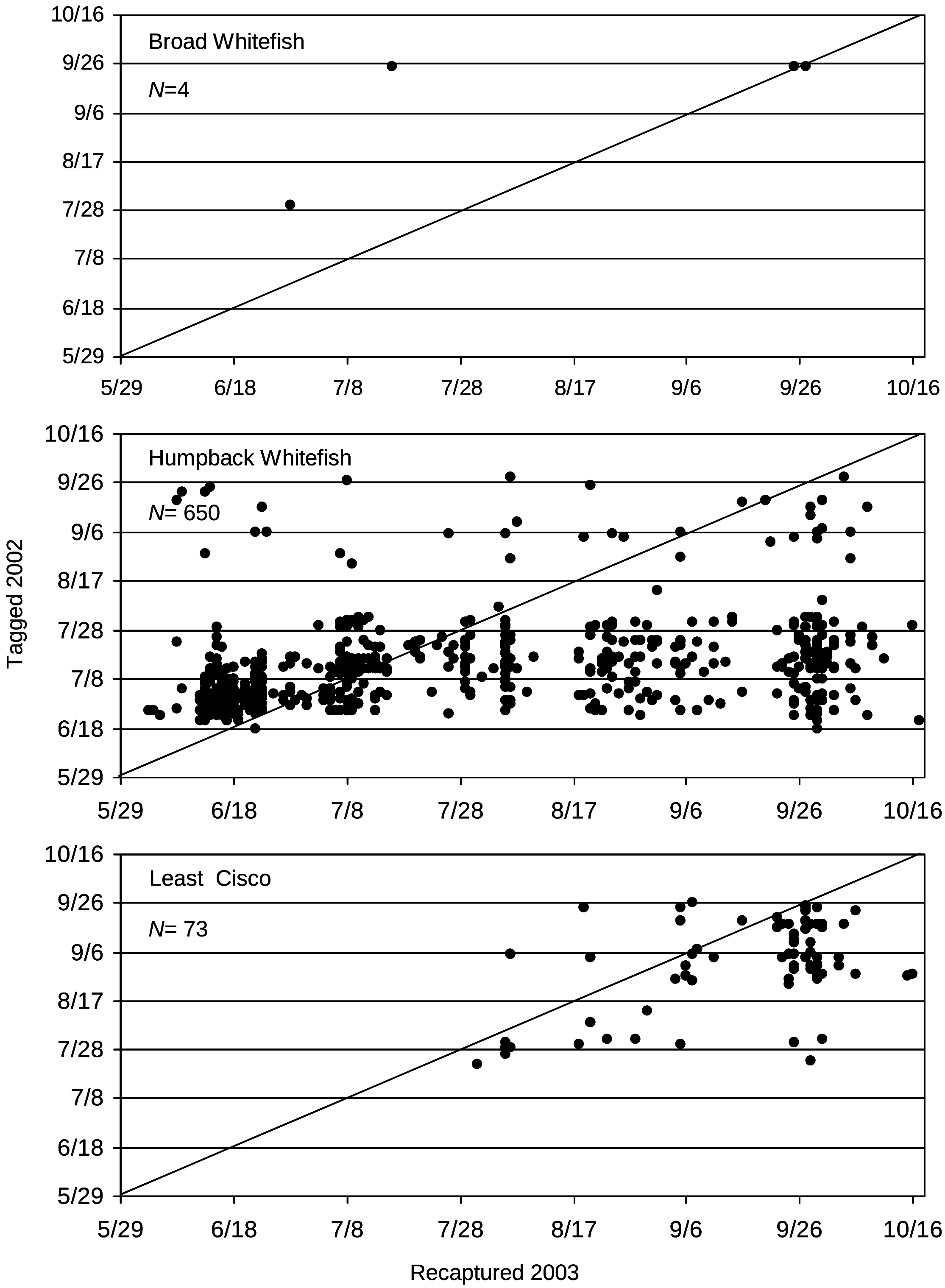

FIGURE 17.–Summary of tagged and recaptured broad and humpback whitefish, and least cisco emigrating from Whitefish Lake, 2002 and 2003. Fish tagged while emigrating during 2002 were recaptured while emigrating in 2003. Fish emigrating during the same week between years would fall on the diagonal.

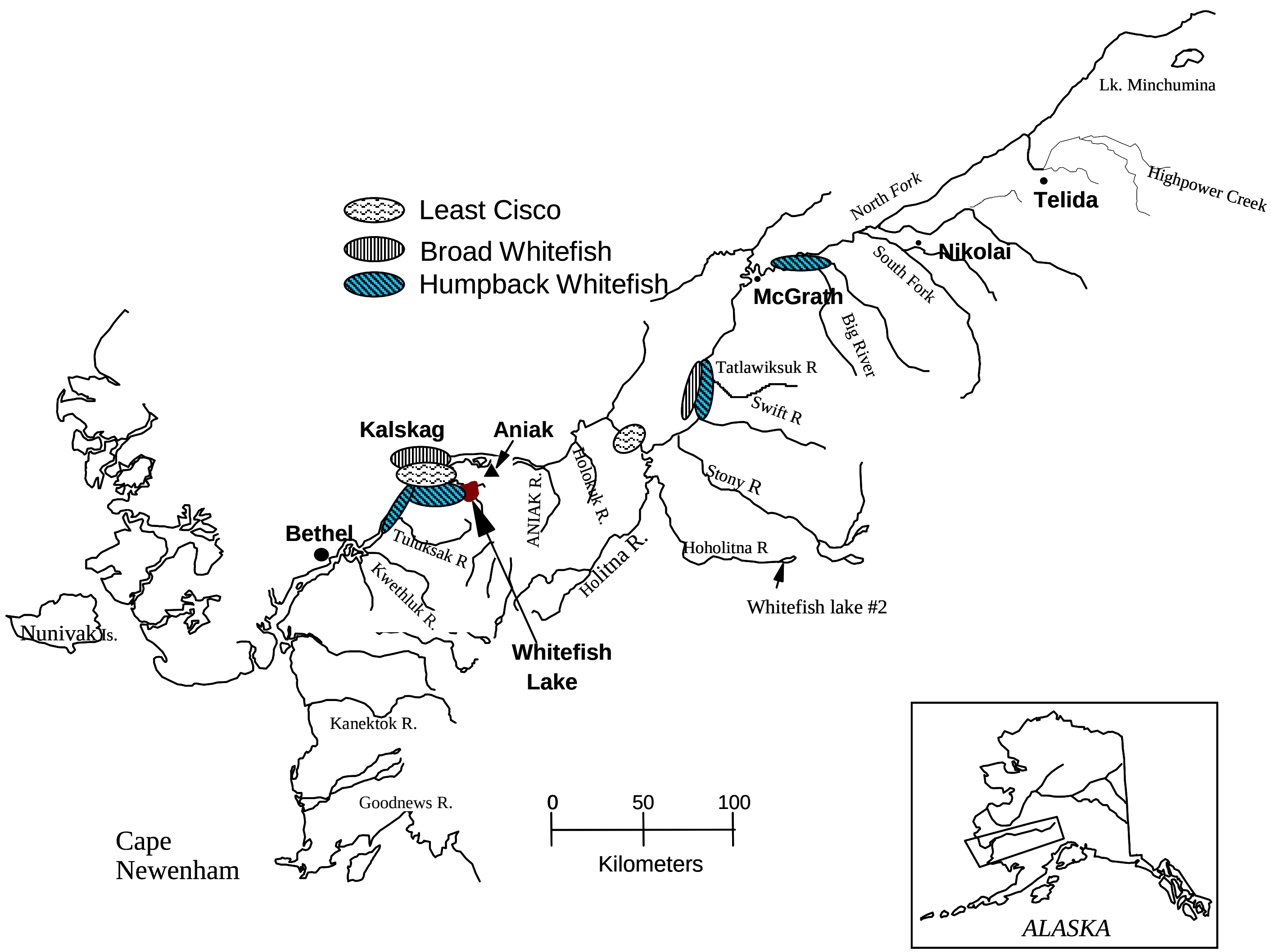

FIGURE 18.–Locations where broad and humpback whitefish and least cisco tagged in Whitefish Lake (2001-2003) have been harvested outside of the lake.

APPENDIX 1.–Daily passage of whitefish and other species migrating into and out of Whitefish Lake 2001.

	Daily Upstream Passage							Daily Downstream Passage						
Date	Broad Whitefish	Humpback Whitefish	Least Cisco	Northern Pike	Longnose Sucker	Unidentified Coregonids	Coho Salmon	Broad Whitefish	Humpback Whitefish	Least Cisco	Northern Pike	Longnose Sucker	Unidentified Coregonids	Coho Salmon
09/21	0	0	0	2	0	0	0	0	0	0	0	0	0	0
09/22	0	0	0	0	0	0	0	0	2	0	0	0	0	0
09/23	0	1	0	0	0	0	0	1	11	1	0	0	0	0
09/24	0	0	0	1	0	0	0	0	0	2	0	0	0	0
09/25	0	0	0	0	0	0	0	0	4	7	0	0	0	0
09/26	0	0	0	0	0	0	0	1	19	2	1	0	0	0
09/27	0	0	0	0	0	0	0	0	6	4	0	0	0	0
09/28	0	0	0	0	0	0	0	0	2	1	0	0	0	0
09/29	0	0	0	1	0	0	0	0	3	5	0	0	0	0
09/30	1	0	0	0	0	0	0	1	7	3	0	1	0	1
10/01	0	0	1	0	0	0	0	0	6	3	0	0	0	0
10/02	0	1	0	0	0	0	0	0	1	0	0	0	0	0
10/03	0	0	0	0	0	0	0	0	1	1	1	0	0	0
10/04	0	0	1	0	0	0	0	0	7	2	0	0	0	0
10/05	0	0	0	2	0	0	0	0	21	10	0	0	0	0
10/06	0	0	0	2	0	0	0	0	22	15	0	0	0	0
10/07	0	0	0	0	0	0	0	0	23	14	0	0	0	0
10/08	0	0	0	0	0	0	0	1	8	7	0	0	0	0
10/09	1	1	0	0	0	0	0	1	6	5	0	0	0	0
10/10	0	0	0	0	0	0	0	3	6	9	3	0	0	0
10/11	0	1	0	0	0	0	0	1	0	1	2	2	0	0
Totals:	2	4	2	8	0	0	0	9	155	92	7	3	0	1

Appendix 2.–Daily passage of whitefish and other species migrating into and out of Whitefish Lake, 2002.

	Daily Upstream Passage							Daily Downstream Passage						
Date	Broad Whitefish	Humpback Whitefish	Least Cisco	Northern Pike	Longnose Sucker	Unidentified Coregonids	Coho Salmon	Broad Whitefish	Humpback Whitefish	Least Cisco	Northern Pike	Longnose Sucker	Unidentified Coregonids	Coho Salmon
06/16	0	1	0	6	0	0	0	0	16	0	1	1	0	0
06/17	0	2	0	2	1	0	0	0	4	0	3	0	0	0
06/18	0	0	1	0	0	0	0	0	26	0	0	1	0	0
06/19	1	0	1	1	1	0	0	0	5	0	0	1	0	0
06/20	0	1	1	3	6	0	0	0	1	0	0	0	0	0
06/21	0	2	0	3	1	0	0	1	63	0	0	3	0	0
06/22	0	0	0	4	0	0	0	0	63	1	1	0	0	0
06/23	0	0	0	11	0	0	0	0	189	0	1	1	0	0
06/24	1	0	0	13	1	0	0	0	152	0	8	4	0	0
06/25	0	2	0	18	2	0	0	0	270	0	10	1	0	0
06/26	0	2	0	6	0	0	0	0	156	0	5	0	0	0
06/27	0	1	0	11	0	0	0	0	88	0	10	0	0	0
06/28	0	1	0	8	0	0	0	0	404	1	8	0	0	0
06/29	0	4	0	6	2	0	0	1	411	0	6	0	0	0
06/30	0	1	0	5	1	0	0	0	200	1	3	1	0	0
07/01	0	0	0	5	1	0	0	0	230	0	3	0	0	0
07/02	0	0	0	0	0	0	0	0	28	0	3	2	0	0
07/03	1	10	5	9	1	0	0	0	89	0	0	0	0	0
07/04	0	0	0	6	0	0	0	1	104	0	1	0	0	0
07/05	0	4	15	11	1	0	0	0	50	1	0	0	0	0
07/06	0	11	10	4	0	0	0	0	468	1	1	0	0	0
07/07[a]	0	0	0	4	0	0	0	0	114	0	0	0	0	0
07/08	0	2	1	8	0	0	0	0	319	0	3	0	0	0
7/9[b]	0	1	2	3	0	0	0	0	405	0	5	0	0	0
7/10[c]	0	0	0	5	0	0	0	0	1,900	0	2	1	0	0
7/11[d]	0	7	0	6	0	0	0	1	3,242	2	5	0	0	0
07/12	0	0	0	3	0	0	0	0	1,564	8	10	0	0	0
07/13	0	0	0	1	0	0	0	0	1,894	7	4	0	0	0
07/14	0	0	0	2	0	0	0	0	510	0	0	0	0	0
07/15	0	4	0	1	1	0	0	1	2,134	6	1	0	0	0

APPENDIX 2.–Daily passage 2002 (page 2 of 4)

	Daily Upstream Passage							Daily Downstream Passage						
Date	Broad Whitefish	Humpback Whitefish	Least Cisco	Northern Pike	Longnose Sucker	Unidentified Coregonids	Coho Salmon	Broad Whitefish	Humpback Whitefish	Least Cisco	Northern Pike	Longnose Sucker	Unidentified Coregonids	Coho Salmon
07/16	0	0	0	0	0	0	0	2	2,833	25	18	0	0	0
07/17	0	0	0	2	0	0	0	0	3,165	33	1	0	0	0
07/18	0	0	0	0	0	0	0	0	3,111	866	10	0	0	0
07/19	0	0	0	0	0	0	0	0	1,550	778	1	0	0	0
07/20	0	0	0	0	0	0	0	0	451	55	2	8	0	0
07/21	0	0	0	0	0	0	0	0	168	3	0	1	0	0
07/22	0	0	2	0	0	0	0	0	341	121	1	4	0	0
07/23	0	0	1	1	0	0	0	0	346	196	3	6	0	0
07/24	0	3	1	0	0	0	0	0	252	40	0	0	0	0
07/25	0	0	0	0	0	0	0	0	176	22	1	3	0	0
07/26	0	0	0	0	0	0	0	0	177	62	1	4	0	0
07/27	0	0	0	1	0	0	0	0	4	21	0	0	0	0
07/28	0	0	2	1	1	0	0	0	72	244	0	1	0	0
7/29[e]	0	0	0	1	0	0	0	0	471	580	0	0	0	0
07/30	0	0	0	0	0	0	0	2	751	1,249	3	2	0	0
07/31[f]	0	0	0	0	0	0	0	55	436	7,281	2	0	0	0
08/01[g]	0	0	0	0	0	0	0	36	1,155	6,582	3	0	0	0
08/02	0	0	0	0	0	0	0	7	131	228	2	19	0	0
08/03	0	0	0	2	0	0	0	0	30	198	1	27	0	0
08/04	0	0	0	0	0	0	0	0	31	843	4	10	0	0
08/05	0	0	0	2	0	0	0	0	15	35	2	5	0	0
08/06	0	0	0	0	0	0	0	0	2	1	1	2	0	0
08/07	0	0	0	0	0	0	0	0	0	1	0	0	0	0
08/08	0	0	1	0	0	0	0	0	1	7	0	0	0	0
08/09	0	0	0	3	0	0	0	0	2	2	0	0	0	0
08/10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08/11	0	1	0	1	0	0	0	0	1	1	0	0	0	0
08/12	0	0	1	0	0	0	0	0	1	2	0	0	0	0
08/13	0	0	0	0	1	0	0	0	5	35	0	0	0	0
08/14	0	0	0	0	0	0	0	0	1	1	0	0	0	0
08/15	0	0	0	0	0	0	0	0	0	19	0	2	0	0

APPENDIX 2.–Daily passage 2002 (page 3 of 4)

	Daily Upstream Passage							Daily Downstream Passage						
Date	Broad Whitefish	Humpback Whitefish	Least Cisco	Northern Pike	Longnose Sucker	Unidentified Coregonids	Coho Salmon	Broad Whitefish	Humpback Whitefish	Least Cisco	Northern Pike	Longnose Sucker	Unidentified Coregonids	Coho Salmon
08/16	0	0	0	0	0	0	0	0	0	3	0	0	0	0
08/17	0	0	0	0	0	0	0	0	3	10	0	0	0	0
08/18	0	1	0	0	1	0	1	0	4	4	0	2	0	0
08/19	0	0	0	0	0	0	0	0	1	0	0	1	0	1
08/20	0	0	0	0	0	0	0	0	4	10	1	1	0	0
08/21	0	0	0	1	0	0	0	0	2	4	0	0	0	0
08/22	0	0	0	1	0	0	0	1	0	2	0	0	0	0
08/23	0	0	0	7	0	0	0	0	2	1	1	0	0	0
08/24	0	0	16	0	0	0	0	2	93	1,537	0	1	0	0
08/25	0	1	4	0	0	0	0	1	56	793	0	0	0	0
08/26	0	0	2	0	0	0	0	2	51	136	0	0	1	0
08/27	0	0	0	0	0	0	0	15	82	195	0	1	0	0
08/28	0	0	0	1	1	0	1	2	164	470	0	0	0	0
08/29	0	0	1	1	0	0	0	0	0	7	0	0	0	0
08/30	0	0	0	0	0	0	0	0	5	56	1	1	0	0
08/31	0	0	0	0	0	0	0	0	21	150	1	0	0	0
09/01	0	1	0	1	1	0	0	0	5	23	0	0	0	0
09/02	0	0	0	0	0	0	0	0	2	1	0	0	0	0
09/03	0	0	0	2	1	0	1	0	2	0	0	0	0	0
09/04	0	19	52	0	0	0	0	0	0	52	0	0	0	0
09/05	0	0	0	0	14	0	1	2	70	94	0	0	0	0
09/06	0	0	0	0	1	0	0	0	53	37	0	0	0	0
09/07	0	0	0	1	0	0	0	0	34	52	0	0	0	0
09/08	0	0	0	2	24	0	1	0	2	1	0	0	0	0
09/09	0	0	0	1	1	0	1	0	15	23	0	0	0	0
09/10	0	0	0	0	0	0	0	0	18	20	1	0	0	0
09/11	0	0	0	1	0	0	0	1	34	98	0	0	0	0
09/12	0	0	0	0	0	0	0	1	0	3	0	0	0	0
09/13	0	0	0	0	0	0	0	0	70	547	0	0	0	0
09/14	0	0	0	0	0	0	0	1	41	406	0	0	0	0
09/15	0	0	0	0	0	0	0	0	35	370	0	0	0	0

Appendix 2.–Daily passage 2002 (page 4 of 4)

	Daily Upstream Passage							Daily Downstream Passage						
Date	Broad Whitefish	Humpback Whitefish	Least Cisco	Northern Pike	Longnose Sucker	Unidentified Coregonids	Coho Salmon	Broad Whitefish	Humpback Whitefish	Least Cisco	Northern Pike	Longnose Sucker	Unidentified Coregonids	Coho Salmon
09/16	0	0	0	0	0	0	0	0	12	25	0	0	0	0
09/17	0	0	0	0	0	0	0	0	13	181	0	0	0	0
09/18	0	0	1	0	0	0	0	0	16	171	0	1	0	0
09/19	0	0	0	0	0	0	0	1	86	336	0	0	0	0
09/20	0	0	0	0	0	0	0	0	5	14	0	0	0	0
09/21	0	0	1	0	0	0	0	0	6	16	0	0	0	1
09/22	0	0	0	0	0	0	0	0	8	43	1	1	0	0
09/23	0	0	0	0	0	0	0	0	8	51	0	0	0	0
09/24	0	0	0	0	0	0	0	0	14	164	0	0	0	0
09/25	0	0	0	0	0	0	0	7	43	401	0	1	0	0
09/26[h]	0	0	0	0	0	0	0	1	6	15	0	0	0	0
09/27[h]	0	0	0	0	0	0	0	1	31	26	2	0	0	0
09/28[h]	0	0	0	0	0	0	0	2	90	88	2	0	0	0
Totals:	3	82	121	198	65	0	6	147	31,985	26,195	156	120	1	2

[a] Trap left open, no counts from 00:00 to 08:00 . The number of fish that passed is unknown, but large numbers of humpback whitefish were present upstream of the weir
[b] Trap open, no counts from 00:00-08:00h. Estimated 100-200 humpback in trap when opened.
[c] Trap open, no counts from 00:00-10:00h. Estimated 1,000- 2,000 humpback may have passed.
[c] Trap open, no counts from 00:00-10:00h.
[d] 1,255 humpback passed 00:00-01:00h. Trap open, no counts 02:20-09:00h
[e] 00:00-02:00h 302 least cisco, 156 humpbck whitefish. Trap open, no counts 02:00-08:00h, unknown passage.
[f] Trap open, no counts from 00:00-0830h. Counts at end of day, 19:30-22:00h 2,073 least cisco, 182 humpback whitefish passed. 22:00-24:00h, 4,859 least cisco, 159 humpback, 55 broad whitefish passed.
[g] 00:00-02:00h 3,445 least cisco, 522 humpback and 35 broad whitefish passed downstream. 22:30-24:00h, 2,834 least cisco and 449 humpback whitefish and one broad whitefish passed. 00:00-00:30 on 8-2-02, no fish movement, no fish seen behind weir.
[h] Weir not fish tight. Storm surge caused scouring beneth panels.

APPENDIX 3.–Daily passage of whitefish and other species migrating into and out of Whitefish Lake, 2003.

	Daily Upstream Passage							Daily Downstream Passage						
Date	Broad Whitefish	Humpback Whitefish	Least Cisco	Northern Pike	Longnose Sucker	Unidentified Coregonids	Coho Salmon	Broad Whitefish	Humpback Whitefish	Least Cisco	Northern Pike	Longnose Sucker	Unidentified Coregonids	Coho Salmon
05/02	0	31	3	17	0	0	0	0	3	0	1	0	0	0
05/03	0	6	1	9	0	0	0	0	52	8	4	0	0	0
05/04	0	2	2	4	0	0	0	0	4	2	4	0	0	0
05/05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05/06	0	17	0	4	0	0	0	0	0	0	0	0	0	0
05/07	1	39	10	5	0	0	0	0	6	0	0	0	0	0
05/08	5	91	1	13	0	1	0	0	0	0	0	0	0	0
05/09	2	48	5	1	0	2	0	0	0	0	0	0	0	0
05/10	0	16	0	7	0	0	0	0	0	0	0	0	0	0
05/11	8	141	23	12	0	1	0	0	0	0	0	0	0	0
05/12	4	139	51	2	0	2	0	0	0	0	0	0	0	0
05/13	0	6	16	0	0	2	0	0	0	0	0	0	0	0
05/14	0	24	1	1	0	0	0	0	0	0	0	0	0	0
05/15	1	93	3	1	0	0	0	0	2	0	0	0	0	0
05/16	0	106	1	1	0	0	0	0	0	0	0	0	0	0
05/17	0	32	2	10	0	0	0	0	0	0	0	0	0	0
05/18	1	64	4	10	0	0	0	0	0	0	0	0	0	0
05/19	2	26	0	3	0	0	0	0	0	0	0	0	0	0
05/20	3	46	1	3	0	0	0	0	1	0	0	0	0	0
05/21	2	25	0	4	0	0	0	0	0	0	1	0	0	0
05/22	2	9	0	2	0	0	0	0	4	1	4	0	0	0
05/23	0	19	0	3	0	0	0	0	3	0	3	0	0	0
05/24	1	14	0	2	0	0	0	0	0	0	1	0	0	0
05/25	10	40	0	6	0	0	0	0	0	0	1	0	0	0
05/26	7	41	6	8	0	0	0	0	0	0	1	0	0	0
05/27	1	32	0	5	0	0	0	0	0	0	1	0	0	0
05/28	0	7	0	10	1	0	0	0	0	0	0	0	0	0
05/29	0	18	0	1	0	0	0	0	0	0	0	0	0	0
05/30	1	5	0	3	0	0	0	0	0	0	2	0	0	0
05/31	2	4	0	0	1	0	0	0	1	0	4	0	0	0

APPENDIX 3.–Daily passage 2003 (page2 of 6)

	Daily Upstream Passage							Daily Downstream Passage						
Date	Broad Whitefish	Humpback Whitefish	Least Cisco	Northern Pike	Longnose Sucker	Unidentified Coregonids	Coho Salmon	Broad Whitefish	Humpback Whitefish	Least Cisco	Northern Pike	Longnose Sucker	Unidentified Coregonids	Coho Salmon
06/01	1	6	0	2	2	0	0	0	0	0	0	0	0	0
06/02	0	14	0	4	9	0	0	0	2	0	1	0	0	0
06/03	0	1	0	2	0	0	0	0	4	0	3	0	0	0
06/04	1	0	0	1	0	0	0	1	6	0	1	0	0	0
06/05	0	0	0	5	9	0	0	0	21	0	0	0	0	0
06/06	0	1	0	2	1	0	0	0	7	0	0	0	0	0
06/07	0	1	0	0	0	0	0	0	5	0	0	0	0	0
06/08	0	3	0	0	9	0	0	0	92	0	0	0	0	0
06/09	1	0	0	6	2	0	0	0	10	0	4	0	0	0
06/10	0	0	0	1	0	0	0	0	0	0	1	0	0	0
06/11	0	2	0	0	2	0	0	0	1	0	0	0	0	0
06/12	1	0	0	1	0	0	0	1	98	0	3	0	0	0
06/13	0	1	0	1	0	0	0	2	793	2	3	0	0	0
06/14	0	0	0	1	0	0	0	1	701	1	0	0	0	0
06/15	0	1	0	4	0	0	0	0	807	1	2	4	0	0
06/16	0	1	0	2	0	0	0	0	206	0	3	0	0	0
06/17	0	5	0	0	2	0	0	2	468	0	1	2	0	0
06/18	0	0	0	0	0	0	0	0	489	0	1	0	0	0
06/19	0	9	0	6	0	0	0	1	242	0	2	0	0	0
06/20	0	1	0	3	3	0	0	0	192	0	0	1	0	0
06/21	0	0	0	5	1	0	0	1	153	0	0	0	1	0
06/22	0	5	0	2	4	0	0	1	840	1	0	7	1	0
06/23	0	0	0	3	0	0	0	1	929	1	4	0	0	0
06/24	0	1	0	2	0	0	0	0	83	0	0	0	0	0
06/25	0	0	0	1	0	0	0	0	83	0	0	0	0	0
06/26	0	0	0	0	0	0	0	0	2	0	0	0	0	0
06/27	0	0	0	1	0	0	0	0	74	0	1	0	0	0
06/28	0	4	0	1	0	0	0	1	195	0	3	0	0	0
06/29	0	5	0	3	0	0	0	0	123	0	0	0	0	0
06/30	0	0	0	0	0	0	0	0	122	0	2	0	0	0

APPENDIX 3.–Daily passage 2003 (page 3 of 6)

	Daily Upstream Passage							Daily Downstream Passage						
Date	Broad Whitefish	Humpback Whitefish	Least Cisco	Northern Pike	Longnose Sucker	Unidentified Coregonids	Coho Salmon	Broad Whitefish	Humpback Whitefish	Least Cisco	Northern Pike	Longnose Sucker	Unidentified Coregonids	Coho Salmon
07/01	0	0	0	0	0	0	0	0	115	0	0	1	0	0
07/02	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07/03	0	0	0	0	0	0	0	0	35	1	0	0	0	0
07/04	0	0	1	2	0	0	0	0	217	0	1	0	0	0
07/05	0	7	0	0	0	0	0	0	586	3	1	0	1	0
07/06	0	1	0	2	0	0	0	0	318	0	0	1	0	0
07/07	0	3	0	1	0	0	0	2	748	1	0	3	3	0
07/08	0	2	0	0	0	0	0	1	1,820	9	0	0	4	0
07/09	0	4	0	1	0	0	0	0	629	11	0	9	4	0
07/10	0	2	0	0	0	0	0	0	352	1	1	3	0	0
07/11	0	1	0	0	0	0	0	1	570	2	1	0	1	0
07/12	0	1	0	1	0	0	0	0	104	1	0	0	0	0
07/13	0	0	0	0	0	0	0	1	684	10	1	10	4	0
07/14	0	0	0	0	0	0	0	1	379	9	1	7	0	0
07/15	0	6	0	0	1	0	0	0	174	9	0	3	0	0
07/16	0	0	0	1	1	0	0	1	33	0	0	0	0	0
07/17	0	0	0	1	0	0	0	0	4	0	0	0	0	0
07/18	0	0	0	0	0	0	0	0	11	0	0	0	1	0
07/19	0	0	0	0	0	0	0	0	90	0	0	5	0	0
07/20	0	0	0	0	0	0	0	0	62	5	1	4	0	0
07/21	0	0	0	0	0	0	0	0	88	12	1	3	4	0
07/22	0	0	0	0	0	0	0	0	59	9	0	8	1	0
07/23	0	0	0	0	0	0	0	0	109	8	0	4	2	0
07/24	0	0	0	0	0	0	0	0	95	17	1	30	6	0
07/25	0	0	0	0	0	0	0	1	116	29	0	1	1	0
07/26	0	0	0	0	0	0	0	1	402	4	0	2	3	0
07/27	0	0	0	0	0	0	0	0	228	2	0	17	2	0
07/28	0	0	0	0	0	0	0	0	131	12	0	0	2	0
07/29	0	0	0	0	0	0	0	0	466	26	4	2	4	0
07/30	0	0	0	0	0	0	0	0	115	25	1	0	1	0
07/31	0	0	0	0	0	0	0	0	37	27	0	0	0	0

APPENDIX 3.–Daily passage 2003 (page 4 of 6)

	Daily Upstream Passage							Daily Downstream Passage						
Date	Broad Whitefish	Humpback Whitefish	Least Cisco	Northern Pike	Longnose Sucker	Unidentified Coregonids	Coho Salmon	Broad Whitefish	Humpback Whitefish	Least Cisco	Northern Pike	Longnose Sucker	Unidentified Coregonids	Coho Salmon
08/01	0	0	0	0	0	0	0	0	41	52	0	0	1	0
08/02	0	0	0	0	0	0	0	0	34	91	2	0	0	0
08/03	0	0	0	0	0	0	0	0	31	93	0	0	0	0
08/04	0	0	0	0	0	0	0	0	40	62	0	0	1	0
08/05	0	0	0	0	0	0	0	0	1,157	1,226	1	0	2	0
08/06	0	0	0	0	0	0	0	0	661	2,679	0	0	0	0
08/07	0	0	0	0	0	0	0	0	213	405	1	0	1	1
08/08	0	0	0	0	0	0	0	0	50	38	0	0	0	1
08/09	0	0	0	0	0	0	0	0	6	16	0	0	0	0
08/10	0	0	0	0	0	0	0	0	17	3	0	1	1	0
08/11	0	0	0	0	0	0	0	0	1	1	0	3	0	0
08/12	0	1	0	2	0	0	0	0	0	0	1	0	0	0
08/13	0	0	1	1	0	0	0	0	4	1	0	0	0	0
08/14	0	0	0	1	0	0	0	0	7	2	0	0	0	0
08/15	0	0	0	0	0	0	5	0	7	0	0	0	1	1
08/16	0	0	0	1	0	0	1	0	13	0	0	0	1	1
08/17	0	1	1	2	0	1	31	0	35	26	0	1	0	2
08/18	0	0	0	0	0	0	10	0	121	76	1	1	1	3
08/19	0	2	0	0	0	2	14	1	134	54	0	1	1	1
08/20	0	5	0	0	0	0	6	0	237	66	0	1	1	0
08/21	0	6	0	0	0	0	6	1	169	46	0	0	0	1
08/22	0	21	1	1	0	0	8	0	281	141	0	0	0	61
08/23	0	21	2	0	0	0	43	2	605	165	2	2	0	7
08/24	0	8	1	1	0	0	0	0	297	61	1	0	1	0
08/25	0	13	0	0	0	0	5	0	88	28	0	0	0	1
08/26	0	7	1	0	0	0	2	0	81	33	0	0	0	0
08/27	0	7	0	1	0	0	5	1	77	54	0	0	1	0
08/28	0	9	0	2	0	0	2	0	228	203	0	3	1	2
08/29	0	0	0	0	0	0	0	1	273	56	0	2	0	4
08/30	0	0	0	2	0	0	0	1	96	80	0	3	0	2
08/31	0	2	1	4	0	0	1	0	103	26	0	0	0	0

APPENDIX 3.–Daily passage 2003 (page 5 of 6)

	Daily Upstream Passage							Daily Downstream Passage						
Date	Broad Whitefish	Humpback Whitefish	Least Cisco	Northern Pike	Longnose Sucker	Unidentified Coregonids	Coho Salmon	Broad Whitefish	Humpback Whitefish	Least Cisco	Northern Pike	Longnose Sucker	Unidentified Coregonids	Coho Salmon
09/01	0	5	0	0	0	0	2	0	152	37	0	1	0	3
09/02	0	2	0	0	0	0	0	0	49	12	0	2	0	0
09/03	0	0	0	0	0	0	0	0	25	25	0	0	0	0
09/04	0	3	1	1	0	0	0	0	105	204	0	1	0	0
09/05	0	1	1	1	0	0	0	1	475	1,237	0	1	0	0
09/06	0	0	2	1	0	0	0	0	106	523	1	0	0	0
09/07	0	0	2	2	0	0	0	0	145	238	0	1	0	0
09/08	0	0	0	0	0	0	0	0	100	159	1	2	0	0
09/09	0	1	0	1	0	0	0	0	40	64	1	0	0	0
09/10	0	0	1	0	0	0	16	0	40	28	0	1	0	2
09/11	0	1	0	0	0	0	13	0	128	70	0	0	0	0
09/12	0	1	0	0	0	0	0	0	4	0	0	0	0	0
09/13	0	0	0	1	0	0	0	0	15	8	0	0	0	0
09/14	0	1	0	0	0	0	0	0	13	5	0	0	0	0
09/15	0	1	0	0	0	0	0	0	6	0	0	0	0	0
09/16	0	0	0	0	0	0	0	0	52	8	0	0	0	0
09/17	0	1	0	0	0	0	0	0	0	2	0	0	0	0
09/18	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09/19	0	0	0	1	0	0	0	1	17	4	0	0	0	0
09/20	0	2	0	0	0	0	0	3	50	52	0	0	0	0
09/21	0	3	0	0	0	0	0	4	79	39	0	0	1	0
09/22	0	4	0	0	0	0	0	1	337	163	0	0	0	0
09/23	0	12	5	0	0	0	0	5	192	279	0	0	0	0
09/24	0	2	1	2	0	0	0	2	118	460	1	0	0	0
09/25	0	15	4	0	0	0	0	20	231	923	0	2	2	0
09/26	0	17	4	0	0	0	0	10	312	403	0	0	2	0
09/27	0	9	5	1	0	0	0	60	425	1,561	0	0	12	0
09/28	0	14	8	1	0	0	37	25	436	870	2	2	3	5
09/29	0	12	0	0	0	0	21	7	1,241	447	0	1	3	9
09/30	0	16	2	0	0	0	17	9	306	248	1	1	0	0

APPENDIX 3.–Daily passage 2003 (page 6 of 6)

	Daily Upstream Passage								Daily Downstream Passage						
Date	Broad Whitefish	Humpback Whitefish	Least Cisco	Northern Pike	Longnose Sucker	Unidentified Coregonids	Coho Salmon		Broad Whitefish	Humpback Whitefish	Least Cisco	Northern Pike	Longnose Sucker	Unidentified Coregonids	Coho Salmon
10/1	0	8	1	0	0	0	1		4	364	94	2	1	2	5
10/2	0	33	2	1	0	1	2		5	584	246	1	0	3	4
10/3	0	4	0	0	0	0	1		1	210	126	1	0	0	1
10/4[a]	0	5	0	1	0	0	4		6	187	187	1	0	1	12
10/5	0	0	3	0	0	0	4		4	166	103	0	0	1	3
10/6	0	1	1	0	0	0	0		2	117	57	0	0	0	2
10/7[b]	0	0	1	0	0	0	3		0	46	21	0	0	1	2
10/8	0	1	0	0	0	0	1		2	30	17	0	0	0	4
10/9	0	1	1	0	0	0	0		3	59	29	0	1	0	2
10/10	0	0	0	0	0	0	1		3	39	17	0	0	0	3
10/11	0	3	1	0	0	0	0		1	17	9	0	0	0	0
10/12	0	1	2	0	0	0	2		6	18	20	0	0	0	0
10/13	0	0	0	0	0	0	0		6	11	5	1	0	0	2
10/14	0	0	0	1	0	0	0		10	14	35	0	0	0	0
10/15	0	2	0	0	0	0	0		1	15	16	1	0	0	3
10/16	0	0	0	0	0	0	0		7	20	35	0	0	0	0
10/17	0	2	0	0	0	0	0		17	18	14	0	0	0	0
Totals:	57	1,516	187	248	48	15	264	0	254	27,822	15,134	99	162	91	150

[a] One inconnu passed downstream.

[b] One chum passed upstream.