Annual Report, FIS 05-403

Life history and essential habitats of humpback whitefish in Lake Clark National Park, Kvichak River watershed, Alaska

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June Tracey of Nondalton fishes through the ice for humpback whitefish using a traditional hook and line. Whitefish are the second most important subsistence fish in the region.

December 2006

INTRODUCTION

Rationale

Many rural residents of the Kvichak River watershed (Figure 1) practice a subsistence lifestyle, harvesting much of their annual food supply from local wild animals and plants. Sockeye salmon are their primary subsistence resource and total annual subsistence harvests since 1985 range from 33,000 to 87,000 fish that provide 132,000 to 348,000 pounds of food (Westing et al. 2006, Morris 1986).

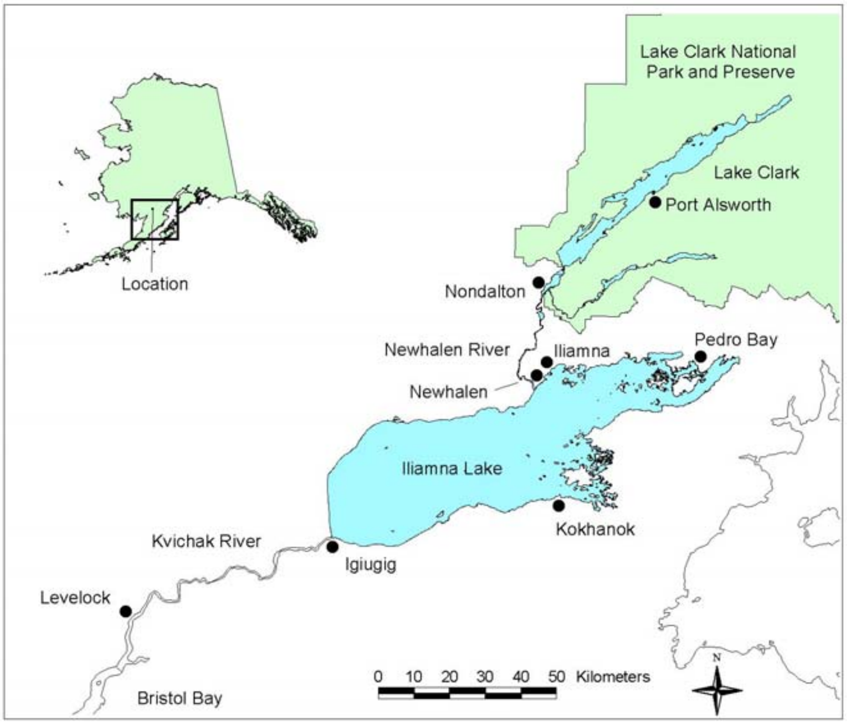

Figure 1. Kvichak River watershed, Alaska; communities are indicated by dots.

In contrast to the sockeye salmon resource, which is available July – August, non-salmon fish provide year-round local subsistence opportunities; 70 – 100% of Kvichak River watershed households annually harvest 18,000 to 50,000 usable pounds of non-salmon fish (Table 74; Krieg et al. 2005) with humpback whitefish (*Coregonus pidschian*) being their primary target (Figure 2). About 75% of households in the community of Nondalton (Figure 1) participate in the harvest of humpback whitefish in areas within and adjacent to Lake Clark National Park and Preserve (Morris 1986, Stickman et al. 2003), a federal subsistence conservation unit. Humpback whitefish are also important in the Lake Iliamna area, supplying the largest freshwater fish harvest in the community of Igiugig (Figure 1) and providing food for residents of the region through a resource exchange network among villages (Morris 1986, Fall et al. 1996).

Figure 2. George Koktelash Sr. of Nondalton displays a humpback whitefish he harvested spring of 2005.

Subsistence fishers in the Kvichak River watershed began reporting declines in their annual fall harvests of humpback whitefish in 1999 (D. Salmon, Igiugig, personal communication). Recent surveys show total whitefish subsistence harvests in the Kvichak River watershed dropped from about 13,000 fish per year in the mid-1990s to 1,000 fish per year in the early 2000s (Figure 3; Krieg et al. 2005). The reasons for the reduced harvest remain unclear as catch-per-unit-effort data are lacking.

A lack of basic biological information on humpback whitefish in Lake Clark, as well as in the greater Kvichak River watershed, hinders assessment of this species' status and their reported decline. The importance of this species to subsistence users in the region led the Bristol Bay Regional Advisory Council, the Federal Office of Subsistence Management, and the National Park Service to prioritize humpback whitefish in Lake Clark National Park and Preserve as a study topic for the Fisheries Resource Monitoring Program.

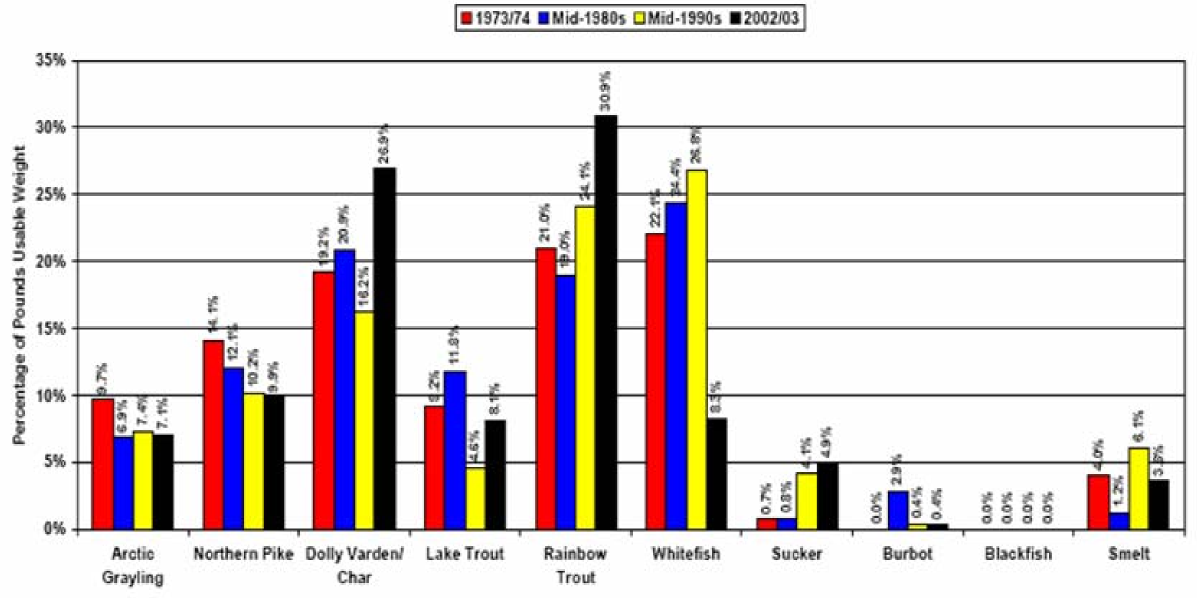

Figure 3. Percent composition of the total non-salmon freshwater fish subsistence harvest in the Kvichak River watershed (graph from Krieg et al. 2005). Note the large decline in whitefish harvest from the mid-1990s to early 2000s.

Related Life History Studies

Recorded age at maturity in Alaskan humpback whitefish populations ranges from 4 – 10 years, depending on geographic location (Alt and Kogl 1973, Alt 1979), although this information is lacking for populations in the Bristol Bay area. Humpback whitefish spawn during fall in littoral areas of lakes and rivers (Anras et al. 1999, Brown et al. 2002). They are broadcast spawners, casting gametes into the water where embryos eventually settle in the gravel to develop and hatch the following spring.

Lacustrine (lake resident), river resident, allacustrine (move between lakes and rivers), and anadromous (move between salt- and freshwater; spawn in freshwater) ecotypes of adult humpback whitefish are found in Alaska and Canada (Alt 1979, Morrow 1980, Bond and Erickson 1985, Reist and Bond 1988, Fleming 1996 and 1999). Multiple ecotypes of humpback whitefish may exist in the same watershed, indicating wide plasticity in life history behavior. For example, in the Chatanika River, humpback whitefish either reside exclusively in riverine habitats or migrate between lake and river habitats (Fleming 1996). Brown et al. (2002) observed that upper Tanana River humpback whitefish reside in lakes during spring and early summer (feeding habitat), riverine habitats during mid summer to late fall (spawning habitat), and either lake or river habitats during winter (overwintering habitat).

Based on strontium distribution in otoliths, Brown (2006) documented the presence of anadromous humpback whitefish in the Yukon, Koyukuk, and Tanana Rivers up to 1,700 km from the ocean. The Kvichak River watershed, which includes Lake Clark, contains an extensive system of lakes, rivers, ponds, and streams with waters ranging from glacially influenced and turbid to clear. Such habitat diversity may support multiple ecotypes of humpback whitefish, including anadromous forms, although this remains unverified. Two studies in the Lake Clark watershed, a field survey by Russell (1980) and a subsistence user survey by Stickman et al. (2003), documented the presence of humpback whitefish in Lake Clark, the Chulitna River, Pickerel Lakes, and Little Lake Clark, although some confusion was apparent in differentiating among whitefish species (Stickman et al. 2003).

In our study, we provide information on Lake Clark humpback whitefish biology that will both allow resource managers to better understand this species and help in developing stock status and trends projects.

OBJECTIVES

1) Determine basic life history characteristics of Lake Clark National Park humpback whitefish populations including age and size, age at maturity, fecundity, and anadromy.

2) Determine seasonal migration patterns and habitat use of Lake Clark National Park humpback whitefish populations.

METHODS

Study Site

The Lake Clark watershed (60° 01’ N, 154° 45’ W) drains an area of about 7,620 km^2 and is part of the greater Kvichak River watershed in southwest Alaska (Figure 1). Lake Clark is the sixth largest lake in Alaska with a surface area of 267 km^2, length of 66 km, width of 5 km, and an average depth of 103 m, and a maximum depth of 322 m (Anderson 1969, Wilkens 2002). Glaciers, steep mountains, glacial rivers, and high precipitation (average 203 cm annually) characterize the upper watershed; lowland tundra, small mountains, clear and stained streams, and low precipitation (average 64 cm annually) characterize the lower watershed (Jones and Fahl 1994, Brabets 2002). Six primary tributaries feed Lake Clark, with glacier-fed tributaries contributing about half the annual water budget and up to a million tons of suspended sediment annually (Brabets 2002). High suspended sediment inputs result in reduced water clarity, which impedes visual fish surveys.

Sockeye salmon are a known food resource for more than 40 different species of animals (Willson et al. 1998), including humpback whitefish. Sockeye salmon are an important cyclical resource to the Lake Clark National Park ecosystem. Escapements have shown an increasing trend since 2000 and have ranged from 200,000 to more than 700,000 sockeye salmon (Woody 2004, Young and Woody 2006, National Park Service, unpublished data).

Life History

Capture Methods

We tested various capture methods in 2005 including seines, hook (#12) and line, gillnets with uniform and variable mesh sizes, fyke nets, minnow traps, and hoop nets. Sampling was conducted over a randomly selected range of available fish habitats and primarily in littoral areas (<10 m) due to gear constraints. Based on input from local subsistence fishers, fish eggs were used to pre-bait sampling areas and to bait traps in an effort to attract whitefish to gear. Fishing with seines and hook and line was conducted during daylight hours, while 24 hr sets were made with gillnets, fyke nets, minnow traps, and hoop nets. We used an ACCESS database to document sampling locations, general habitat type and humpback whitefish captures (Appendix I).

Size and Age

Each captured humpback whitefish was measured (total and fork length) and weighed, and three scales were collected for age estimates. Additionally, about 100 humpback whitefish over a range of sizes were sacrificed to obtain otoliths (ear bones) for age estimates. We later compared ages estimated from both scales and otoliths from the same individuals. We hoped that similar estimates would be obtained from both structures, or that a correctable bias was found, so that captured humpback whitefish would not have to be sacrificed to obtain age data. Otolith aging criteria followed Mills and Beamish (1980), Chilton and Beamish (1982), and Howland et al. (2004). Scale aging followed Howland et al. (2004). All otoliths and scales were aged twice.

Verification of Anadromy

Ten otoliths were selected across sample sites to determine whether Lake Clark humpback whitefish were anadromous. We tested for anadromy by analyzing strontium (Sr) concentrations in otoliths (Figure 4). This method has been used for humpback whitefish collected from the upper Tanana River drainage (Brown 2006). It is based on the documented influence of salinity on the chemical composition of fish otoliths (Fowler et al. 1995a and b; Mugiya and Tanaka 1995; Secor et al. 1995; Farrell and Campana 1996), and studies on salmonid otoliths that showed a significant rise in Sr concentration when fish experience a change from freshwater to 6.3 ppm salinity (Zimmerman and Reeves 2000 and 2002).

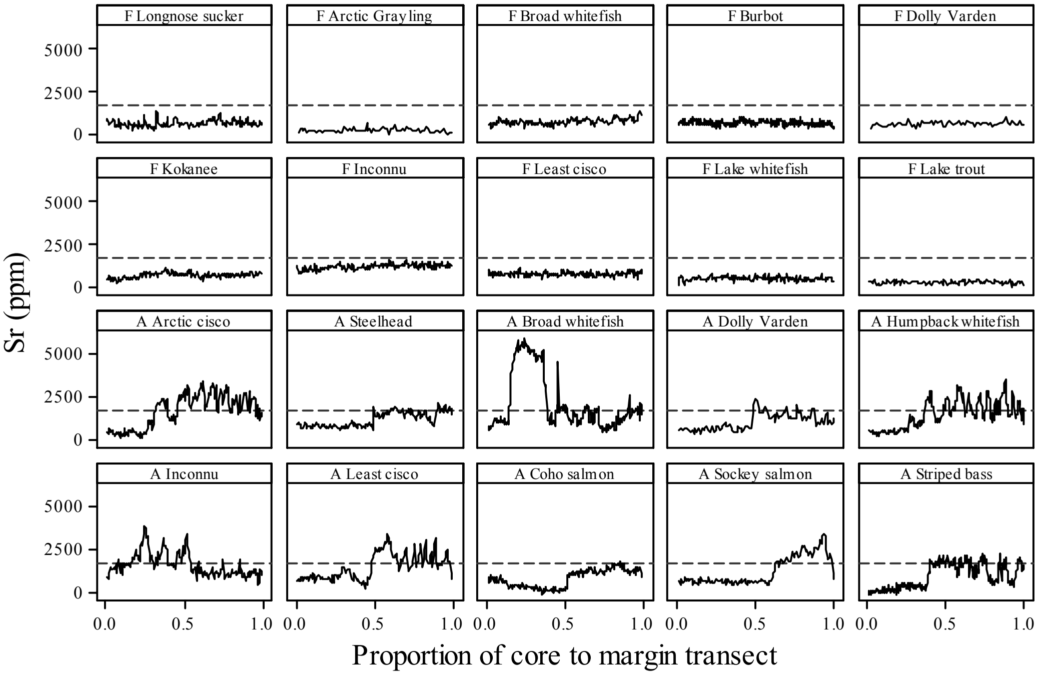

Figure 4. Strontium (Sr) concentration as a proportion of otolith core to margin transects for a selection of known freshwater resident (top 2 rows, F species) and anadromous (bottom 2 rows, A species) fish species. Horizontal dashed lines are at the 1,700 ppm position. Freshwater fish do not usually exceed this value, while anadromous fish do (From Brown 2006).

Otoliths selected for microchemical analyses were prepared and interpreted by R. Brown (U.S. Fish and Wildlife Service, Fairbanks) following methods he had used previously (Brown 2000). Each otolith was polished on a lapidary wheel with 1 μm diamond abrasive and coated with a thin layer of conductive carbon in preparation for microprobe analysis. Microchemical analysis of otoliths was accomplished using a wavelength-dispersive electron microprobe capable of precise and accurate measurement of otolith Sr concentration (Campana et al. 1997). The technology functions by bombarding points on a sample surface with a focused beam of electrons. Atoms within the material are ionized by the electron beam and emit x-rays unique to each element. Spectrometers are tuned to count the x-rays from elements of interest, in this case, Sr. X-ray counts at each sample point are proportional to the elemental concentration in the material (Potts 1987, Reed 1997, Goldstein et al. 2003).

Sr x-ray counts were collected from a series of points from a core (early life) to margin (just prior to death) transect for each otolith. Sr x-ray counts collected for 25 s at each point were converted to estimates of Sr ppm concentration based on a regression equation relating the two measures, similar to the process described by Howland et al. (2004). Quantitative procedures were conducted on over 800 sample points from each otolith and then were compared to Sr otolith transects from other freshwater, diadromous, and marine species (Figure 4).

RESULTS

Capture Techniques

The most effective capture techniques for humpback whitefish in Lake Clark were seines and gillnets. Seining in shallow (<5 m) areas, baited with preserved salmon eggs, yielded the best catches. In rocky areas, where seining was not feasible, constantly monitored variable mesh gillnets were successfully used, but resulted in higher mortality to captured fishes. Ice fishing during early spring in Sixmile Lake with a single egg on a #12 hook attached to a hand line was another effective, but much less efficient method, and one that is commonly used by subsistence fishers.

Juvenile humpback whitefish (age 0 to 3) were mostly captured by seine in shallow (<3 m) areas of both Chulitna Bay and Long Lake, whereas individuals older than age 4 were captured across a wider range of habitat types including shallow (≤ 2m) small (<6 km long) tributary lakes with abundant aquatic plants (Long and Pickeral Lakes) and deep large fjord lakes (Little Lake Clark; Figure 5). Humpback whitefish were easily observed and captured in the Newhalen River and Chulitna Bay at subsistence salmon processing sites.

Size and Age

A total of 809 humpback whitefish were sampled during 2005, and 649 of those were categorized as juveniles (≤ 4 years old). Total lengths of sampled fish ranged between 95 and 584 mm (Figure 6) with 454 individuals measuring less than 119 mm.

Estimated ages ranged from age 0 to 27. Ages estimated from paired otolith and scale samples (N=110) were usually similar for individuals with total lengths between 82 to ≤ 230 mm, but differed, sometimes dramatically, for individuals longer than 400 mm (Figure 7). In general, estimated otolith ages were greater than estimated scale ages for the same individual (Figure 8), and less variation was observed between two readings of the same otolith (SD = 0.24) than between two readings of the same scale (SD = 0.87).

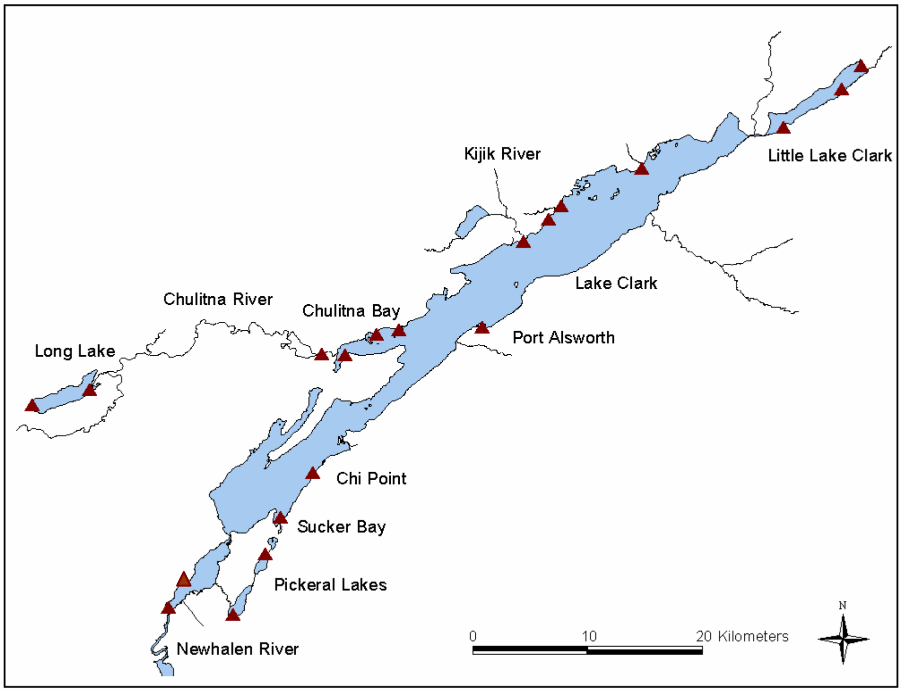

Figure 5. Sample sites (red triangles) fished for humpback whitefish, Lake Clark drainage, 2005. Pickerel Lake system tributaries were also sampled.

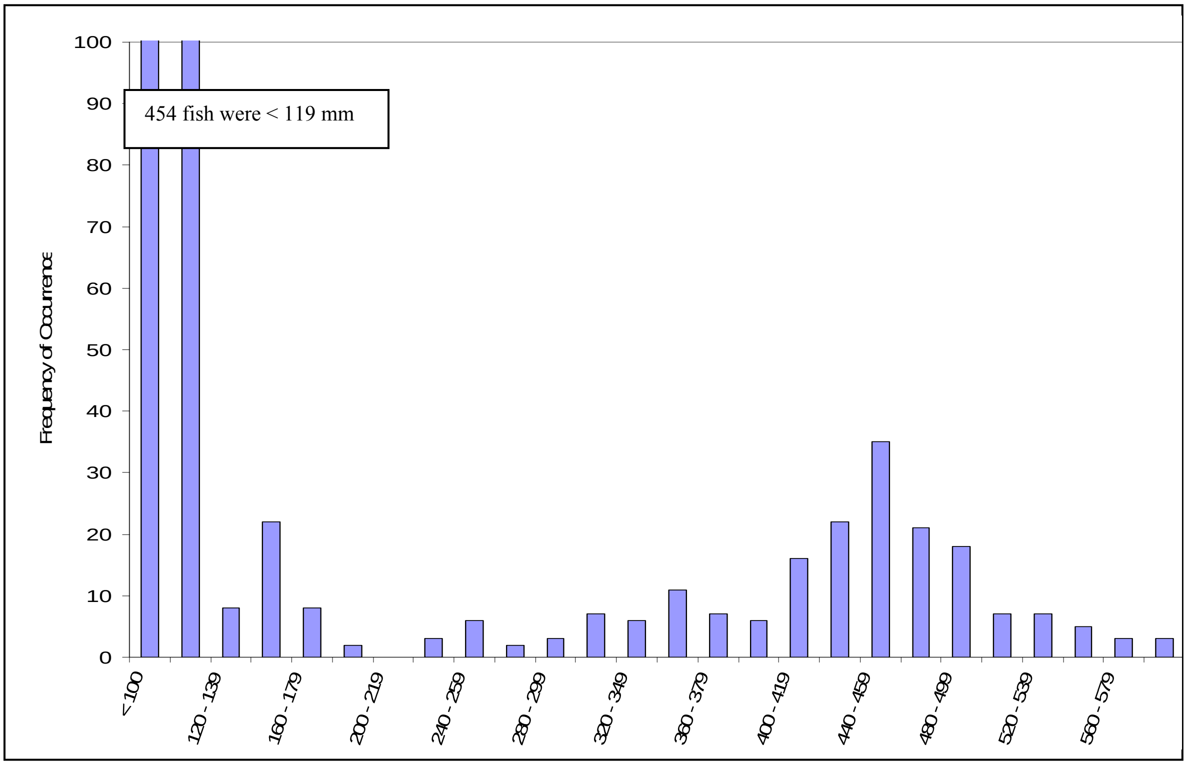

Figure 6. Size frequency distribution for Lake Clark humpback whitefish sampled in 2005.

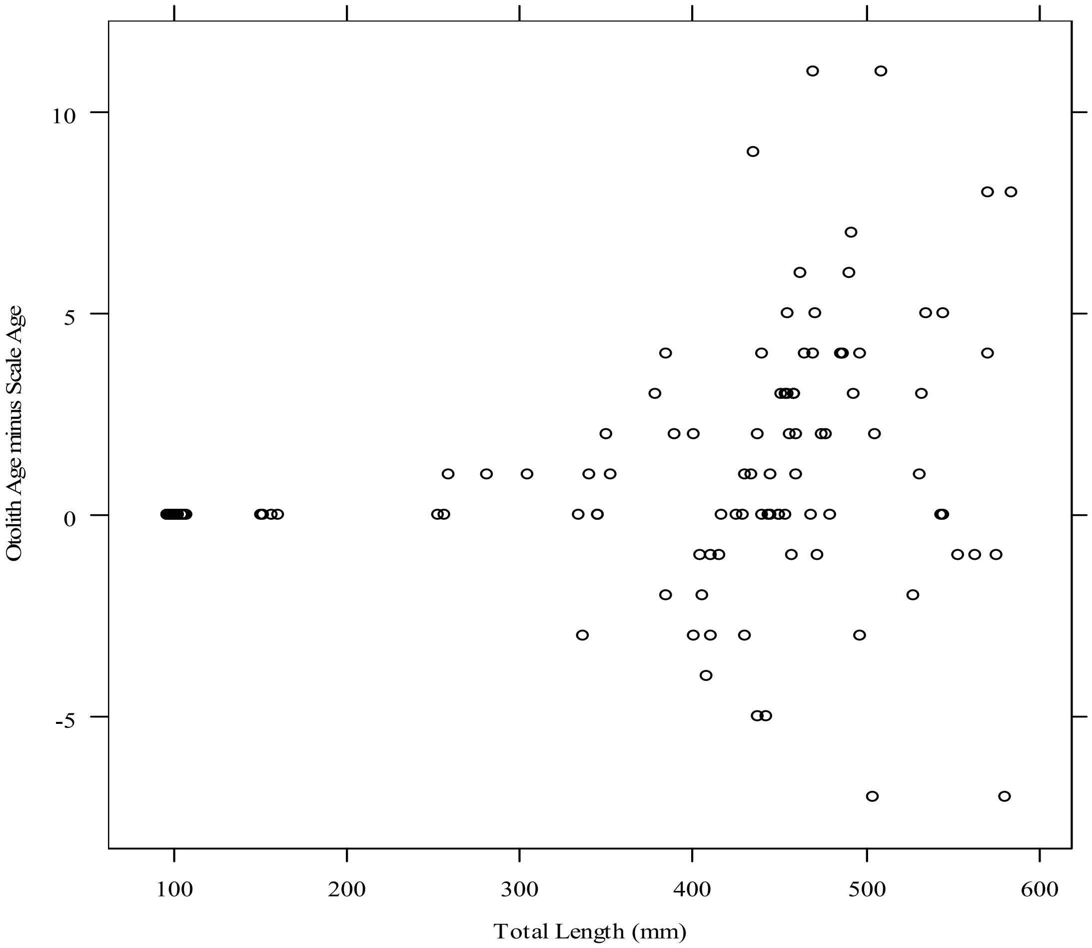

Figure 7. Differences in estimated ages from otoliths and scales by length for humpback whitefish, Lake Clark, 2005. Deviations above 0 indicated that the otolith age was older than the corresponding scale age.

The differences in age estimates between otoliths and scales produced different von Bertalanffy growth equations (Figure 9) giving different maximum length estimates: otolith $L\infty$ = 507 (95% confidence interval 488, 531); scale $L\infty$ =562 (confidence interval 533,600).

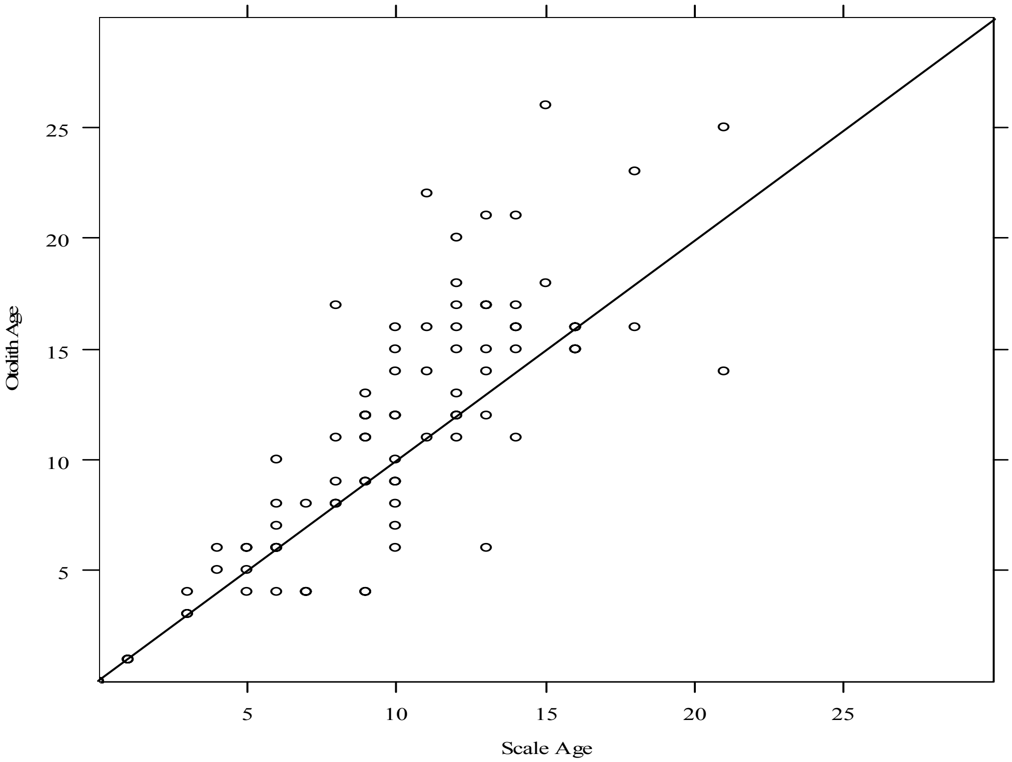

Figure 8. Age estimates from otoliths versus scales. The points left of the 1-1 diagonal indicate that for most humpback whitefish the otolith age exceeded the scale age.

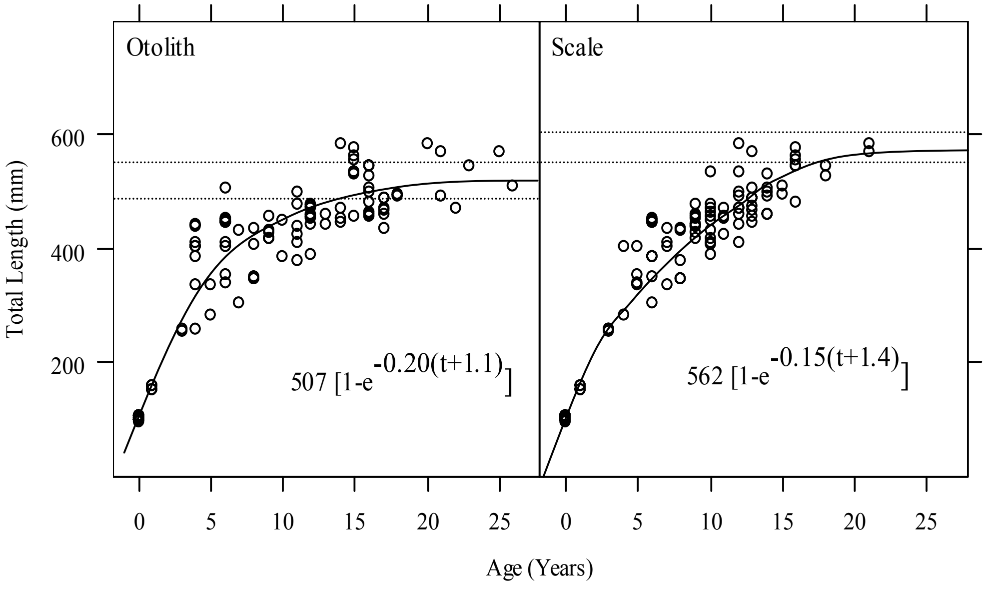

Figure 9. Von Bertalanffy growth equations for age estimates from otoliths and scales. Equations result in different maximum length estimates: otolith $L\infty = 507$ (95% confidence interval 488, 531); scale $L\infty =562$ (confidence interval 533,600).

Verification of Anadromy

No definitive spikes in Sr concentrations above 1,700 ppm were observed for the 10 Lake Clark humpback whitefish otoliths analyzed, although four fish (05-108, 05-122, 05-127, and 05-152) had values that were near or at this level (Figure 10). Also, most individuals exhibited greater variation in Sr concentrations in comparison to values for freshwater fishes examined in another study (Figure 4).

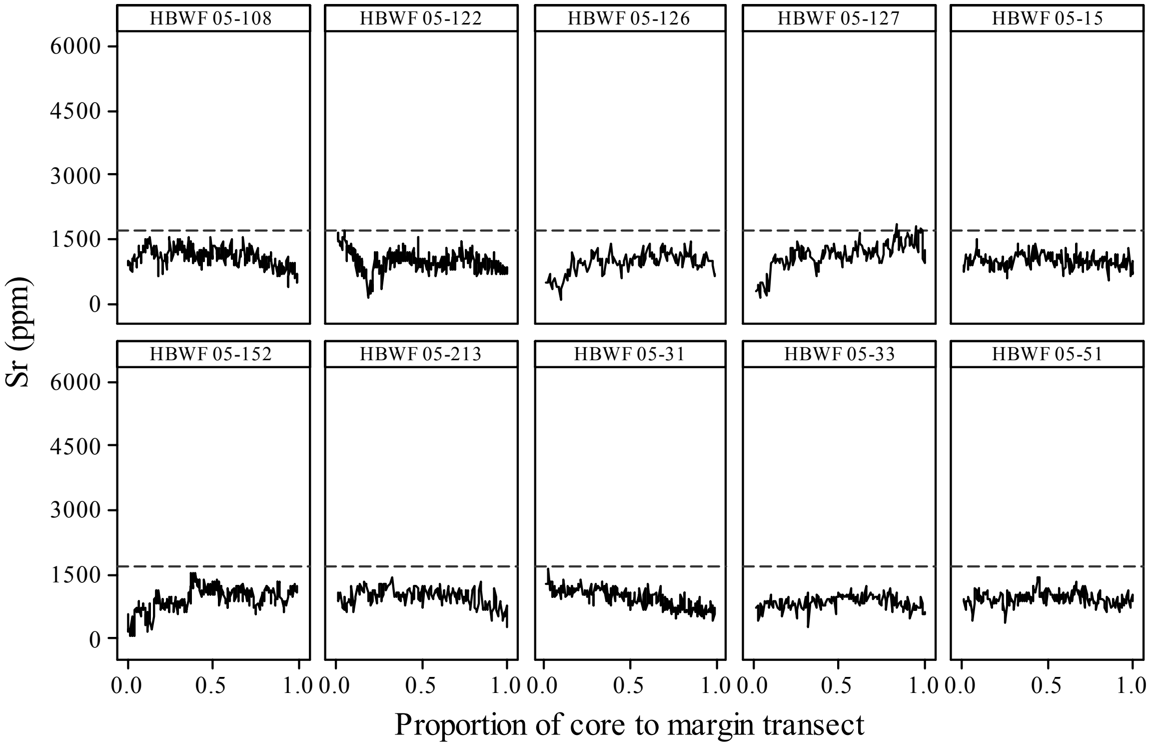

Figure 10. Strontium (Sr) concentration as a proportion of otolith core to margin transects for 10 Lake Clark humpback whitefish. No definitive spikes of Sr concentration are apparent suggesting these fish migrated to marine habitats; however, it is possible that fish 05-108, 05-122, 05-127, or 05-152 did because of the greater variation here when compared to non-anadromous fish (e.g. Figure 4). Another explanation for the variation may be vertical movements of whitefish in Lake Clark.

DISCUSSION

Although humpback whitefish are the second most important subsistence fish species harvested in the Kvichak River watershed, few data are available to assist managers in evaluating a reported recent decline in this species' abundance. Initial research on humpback whitefish in Lake Clark National Park began in 2005, and indicates they are both attracted to and derive nutrients from anadromous sockeye salmon. We capitalized on this behavior and were able to easily sample humpback whitefish with seines and gillnets in areas baited with salmon eggs. Ice fishing was also found to be a viable, but slow capture method.

Similar to results obtained from Canadian studies of lake whitefish (Barnes and Power 1984), our age estimates of humpback whitefish were the same from both scales and otoliths for the first three years of life, after which, age estimates from these two structures began to vary. The difficultly in obtaining accurate age estimates suggests an age validation study would be useful to this and other similar studies. In Lake Clark this could be accomplished by marking and recapturing humpback whitefish of various sizes in a small system such as the Pickeral Lakes, assuming they exhibit site fidelity and that a wide range of ages could be marked.

Size distribution for the population based on samples obtained from seines, variable mesh gillnets and hook and line fishing indicate a bimodal frequency distribution. This type of distribution is similar to that observed for other whitefish species and lake trout in Arctic systems of Canada (Power 1984). Our growth equations (Figure 8) indicate rapid growth until age 4 – 7, which is likely when individuals become sexually mature which would slow growth rates. The lack of individuals of intermediate sizes could be due to differences in year class strength, selection by the subsistence fishery or predators. After fish reach a size of ≥ 380 mm, predation likely declines and mortality in the population may stabilize at a low level for the rest of the life span.

The lack of a strong Sr spike in the 10 otoliths analyzed for anadromy suggests Lake Clark whitefish either remain in freshwater throughout their life, or that they use estuarine areas with very low salinities. The high variation observed in the Sr signal of some fish may be due to spending time in a low salinity estuary, extensive vertical movements within freshwater, or feeding on anadromous sockeye salmon carcasses and eggs. Further study is needed to tease out potential causal factors. The radio telemetry work planned for 2006 may allow us to determine whether some Lake Clark whitefish are anadromous.

ACKNOWLEDGEMENTS

This project was made possible by a grant from the Federal Office of Subsistence Management, U.S. Fish and Wildlife Service, logistical support from the friendly staff at Lake Clark National Park and Preserve; Bristol Bay Native Association Interns including Tim Dyasuk and Tatiana Askoak. Theresa Rickteroff assisted with whitefish sampling and the people of Nondalton gave invaluable advice on fishing and potential capture locations.

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Appendix I. Example of the humpback whitefish ACCESS database documenting sampling locations, general habitat type and whether humpback whitefish were captured in that habitat.

Sampling Locations Table

ID	Drainage	Water Body	Specific Location	Latitude	Longitude	Habitat Type	Humpback Whitefish?
1	Lake Clark	Sucker Bay	North Point	60.03452	-154.65990	Lacustrine	Yes
2	Lake Clark	Sucker Bay	West Shore	60.03352	-154.66391	Lacustrine	No
3	Lake Clark	Sucker Bay	East Shore	60.03424	-154.66122	Lacustrine	No
4	Sixmile Lake	Pickeral Lakes	Middle Pickeral Lake	60.00228	-154.68863	Lacustrine	Yes
5	Sixmile Lake	Pickeral Lakes	Lower Pickeral Lake	59.94745	-154.74532	Lacustrine	Yes
6	Sixmile Lake	Pickeral Lakes	Lower Lake Outlet	59.94700	-154.74000	Riverine	Yes
7	Sixmile Lake	Newhalen River	East Bank	59.94897	-154.85942	Riverine	Yes
8	Sixmile Lake	Newhalen River	West Bank	59.94374	-154.86653	Riverine	Yes
9	Chulitna River	Long Lake	West End	60.13332	-155.11555	Lacustrine	Yes
10	Chulitna River	Long Lake	East End	60.14605	-155.01315	Lacustrine	Yes
11	Little Lake Clark	Little Lake Clark	Outlet of Waterfall Stream	60.38381	-153.75661	Lacustrine	Yes
12	Little Lake Clark	Little Lake Clark	Outlet of Large Tributary	60.38635	-153.75560	Lacustrine	No
13	Little Lake Clark	Little Lake Clark	Outlet of Small Tributary	60.41901	-153.64772	Lacustrine	No
14	Little Lake Clark	Little Lake Clark	Head of Lake	60.44230	-153.61101	Lacustrine	No
15	Lake Clark	Chulitna Bay	Owl Bluff Island	60.20422	-154.45186	Lacustrine	Yes
16	Lake Clark	Chulitna Bay	Indian Point	60.18213	-154.54840	Lacustrine	Yes
17	Lake Clark	Chulitna Bay	North Shore	60.20245	-154.49315	Lacustrine	No
18	Lake Clark	Chi Point	Bill and Martha's	60.07444	-154.60583	Lacustrine	No
19	Lake Clark	Port	Hardenburg Bay	60.20316	-	Lacustrine	Yes

Sampling Locations Table

ID	Drainage	Water Body	Specific Location	Latitude	Longitude	Habitat Type	Humpback Whitefish?
		Alsworth			154.30487		
20	Lake Clark	Chulitna Bay	Indian Point Island	60.18042	-154.55276	Lacustrine	Yes
21	Lake Clark	Chulitna Bay	West End	60.18205	-154.58353	Lacustrine	Yes
23	Chulitna River	Chulitna River	Lower	60.18205	-154.58353	Riverine	No
24	Lake Clark	Lake Clark	Mouth of Kijik River	60.28427	-154.22836	Lacustrine	Yes
25	Lake Clark	Lake Clark	Priest Rock	60.30828	-154.17600	Lacustrine	No
26	Lake Clark	Lake Clark	Island near Hammond's	60.00000	-154.00000	Lacustrine	No
27	Lake Clark	Lake Clark	Mouth of Portage Creek	60.35029	-154.01547	Lacustrine	No
28	Lake Clark	Kijik Lake	Outlet	60.30790	-154.29328	Riverine	No