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Stock Characteristics of Humpback Whitefish and Least Cisco in the Chatanika River, Alaska

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ABSTRACT. Overharvest of humpback whitefish (*Coregonus pidschian*) and least cisco (*C. sardinella*) in the Chatanika River, Alaska, during the late 1980s led to collapsed stocks and closure of the fishery. We evaluated the stock characteristics of these two species to determine the extent of recovery. A total of 3207 humpback whitefish and 2766 least cisco were captured during their fall spawning migration in 2008. Humpback whitefish ranged from 188 to 583 mm in fork length (FL) and encompassed ages 5 to 29 years, while least cisco ranged from 215 to 425 mm in FL and their ages ranged from 3 to 14 years. Patterns in growth and length-at-age were similar for both species, and annual mortality rates were 31% for humpback whitefish (age 11 and older) and 44% for least cisco (age 9 and older). Population attributes were within the ranges observed for other North American stocks of humpback whitefish and least cisco. Although the humpback whitefish in the Chatanika River have stock attributes that are consistent with low exploitation and this species appears to have recovered, the least cisco in the river still exhibit many attributes that suggest the cisco stock has not fully recovered. The results of this study indicate that the current allowable harvest limit of 2000 whitefish is cautious and appears to be sustainable.

Key words: humpback whitefish, *Coregonus pidschian*, least cisco, *Coregonus sardinella*, size structure, age structure, growth, mortality rate

RÉSUMÉ. Vers la fin des années 1980, la pêche excessive du corégone à bosse (*Coregonus pidschian*) et de la cisco sardinelle (*C. sardinella*) dans la rivière Chatanika, en Alaska, a entraîné l’évidement des stocks et la fermeture du lieu de pêche. Nous avons évalué les caractéristiques des stocks de ces deux espèces afin de déterminer l’ampleur de leur rétablissement. Au total, 3 207 corégones à bosse et 2 766 ciscos sardinelles ont été capturés pendant leur frai de migration automnale en 2008. La longueur à la fourche du corégone à bosse variait entre 188 et 583 mm pour des âges allant de 5 à 29 ans, tandis que la longueur à la fourche de la cisco sardinelle variait entre 215 et 425 mm pour des âges allant de 3 à 14 ans. Les tendances de croissance et de longueur selon l’âge étaient semblables dans le cas des deux espèces, et les taux de mortalité annuels se chiffraient à 31 % dans le cas des corégones à bosse (âgés de 11 ou plus) et de 44 % pour les ciscos sardinelles (âgées de 9 ans et plus). Les caractéristiques de l’ensemble de la population se trouvaient dans les limites observées pour d’autres stocks nord-américains de corégones à bosse et de ciscos sardinelles. Bien que les caractéristiques du stock de corégone à bosse de la rivière Chatanika soient conformes à une faible exploitation et bien que cette espèce semble s’être rétablie, la cisco sardinelle de cette rivière affiche toujours de nombreuses caractéristiques qui laissent entendre que ce stock ne s’est pas encore complètement rétabli. Les résultats de cette étude indiquent que la limite actuelle de 2 000 qui est imposée quant à la pêche du corégone à bosse est prudente et semble durable.

Mots clés : corégone à bosse, *Coregonus pidschian*, cisco sardinelle, *Coregonus sardinella*, structure par taille, structure par âge, croissance, taux de mortalité

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INTRODUCTION

Whitefishes (*Coregonus* spp.) are found throughout the interior of Alaska and support subsistence, personal-use, and recreational fisheries (Fechhelm et al., 1999; Fleming, 1999; Adams et al., 2005). Two of the many species of whitefish in Alaska, humpback whitefish (*Coregonus pidschian*) and least cisco (*C. sardinella*), commonly coexist in large rivers and are managed similarly because of their comparable life-history strategies. For example, both whitefish species broadcast spawn over gravel substrates in flowing water during fall months (Scott and Crossman, 1973; Alt, 1979). Humpback whitefish and least cisco are iteroparous, although there seems to be variability between spawning events (Reist and Bond, 1988; Lambert and Dodson, 1990; Brown, 2006). Both species exhibit a wide variety of

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life-history patterns, including freshwater-migratory, anadromous-migratory, and non-migratory strategies (Reist and Bond, 1988; Brown et al., 2007; Harper et al., 2007).

Since the 1970s, the Chatanika River, located near Fairbanks in the interior of Alaska, has supported a prolific and popular recreational spear fishery for humpback whitefish and least cisco during their fall spawning migration. Exploitation of these two whitefish species, reported only as whitefish (with no distinction between species), remained under 10 000 fish annually during the 1970s and early 1980s. In 1987, the harvest reached its highest level (more than 25 000 whitefish), which prompted concern about overfishing among Alaska Department of Fish and Game fisheries biologists (Timmons, 1991; Fleming, 1994, 1996). Because of these concerns, a management plan that restricted harvest was adopted in 1992; however, a 1994 population assessment indicated that least cisco abundance was too low, and the spear fishery was closed (A. Brase, pers. comm. 2008). Stock assessments in the years after the closure (Fleming, 1994, 1996, 1997, 1999) indicated that stocks of both species were still depressed, and the fishery remained closed. Because of high angler interest, the spear fishery was reopened in 2007 on a restricted basis: 100 permits were issued, with an allowed harvest of 10 whitefish (any species) per permit. The spear fishery remains open on that basis, and 200 permits have been issued annually with a limit of 10 whitefish (any species) per permit (Brase, 2008; Brase and Baker, 2011). Species-specific restrictions are not possible because humpback whitefish and least cisco, as well as round whitefish (*Prosopium cylindraceum*) and the occasional broad whitefish (*Coregonus nasus*), often occupy the same areas in the river concurrently, and it is difficult to distinguish among species while spear fishing.

Alaska Department of Fish and Game population abundance estimates in 2008 (Wuttig, 2009) and model simulation results of spear fishing harvest impacts on humpback whitefish and least cisco abundance (Edenfield, 2009) suggest that an annual allowable harvest of 2000 whitefish is currently sustainable in the Chatanika River. However, since the last formal stock assessment was in 1998 (Fleming, 1999), a thorough examination of the current stock structure is needed to determine whether the harvest regulations are sufficiently restrictive.

The objective of the present research was to assess the stock characteristics of humpback whitefish and least cisco during their spawning migration in the Chatanika River. We expected that stock structure (i.e., size and age structure, age-at-maturity, growth, and mortality rates) of these two species would be comparable to the historical stock structure before the collapse of the fishery. Currently, there is interest in sustaining a viable personal-use fishery, but we lack the necessary population information. It is hoped that this study will enhance our understanding of humpback whitefish and least cisco stocks throughout their Arctic distribution, emphasizing the interior of Alaska and the Chatanika River.

METHODS

Study Site

The Chatanika River, Alaska, is formed in the White Mountains by the convergence of Faith, McManus, and Smith creeks, approximately 80 km northeast of Fairbanks. The river flows southwest for 275 river kilometers (rkm), ending where it joins the Tolovana River in Minto Flats. The portion of the Chatanika River that falls within the study area is shown in Figure 1. Up to this point, the river has primarily large gravel and cobble substrates with riffle, pool, and cut-bank habitats. After entering Minto Flats, it becomes a slower stream, with primarily sandy substrate and stable banks. Anadromous Chinook salmon (*Oncorhynchus tshawytscha*), chum salmon (*O. keta*), and Arctic lamprey (*Lethenteron camtschaticum*) spawn in the river in summer, while potamodromous humpback whitefish and least cisco migrate from Minto Flats to the river and spawn in fall. Resident fishes in the river include round whitefish, Arctic grayling (*Thymallus arcticus*), northern pike (*Esox lucius*), burbot (*Lota lota*), longnose sucker (*Catostomus catostomus*), slimy sculpin (*Cottus cognatus*), and Alaskan brook lamprey (*Lethenteron alaskense*). Potamodromous inconnu (*Stenodus leucichthys*) and broad whitefish are also occasionally observed in the Chatanika River.

Field Collections

Humpback whitefish and least cisco were collected between 26 August and 3 October 2008 using direct-current (DC) boat electrofishing (Coffelt Model VVP-15 electroshocker, 30-Hz pulsed DC). Electrofishing was conducted in 20-minute runs in the downstream direction encompassing a 70-km section of the Chatanika River downstream of the Elliot Highway Bridge, as described in Fleming (1994) and Wuttig (2009). All captured whitefish were identified and measured for fork length (FL) to the nearest 1 mm. A random subsample of 218 humpback whitefish and 341 least cisco was selected, with a goal of 5–10 fish of each species per 10 mm length category. Subsampled individuals were sexed and euthanized for extraction of both sagittal otoliths. All otoliths were rinsed in water, rubbed clean to remove the otolithic membrane, placed in vials, and dried for at least seven days.

Laboratory Analyses

Otoliths were ground through the nucleus using a Hi-Tech Diamond wheel (Good Baer Services LLC, Ventura, California), creating a flat plane that included the nucleus. The ground otolith was mounted on a glass slide using Crystal Bond 509 (Structure Probe, Inc., West Chester, Pennsylvania) and reground until only a small section containing the nucleus remained. Otoliths were sliced into thin sections (200–400 μm) using an Ingram Model 65C

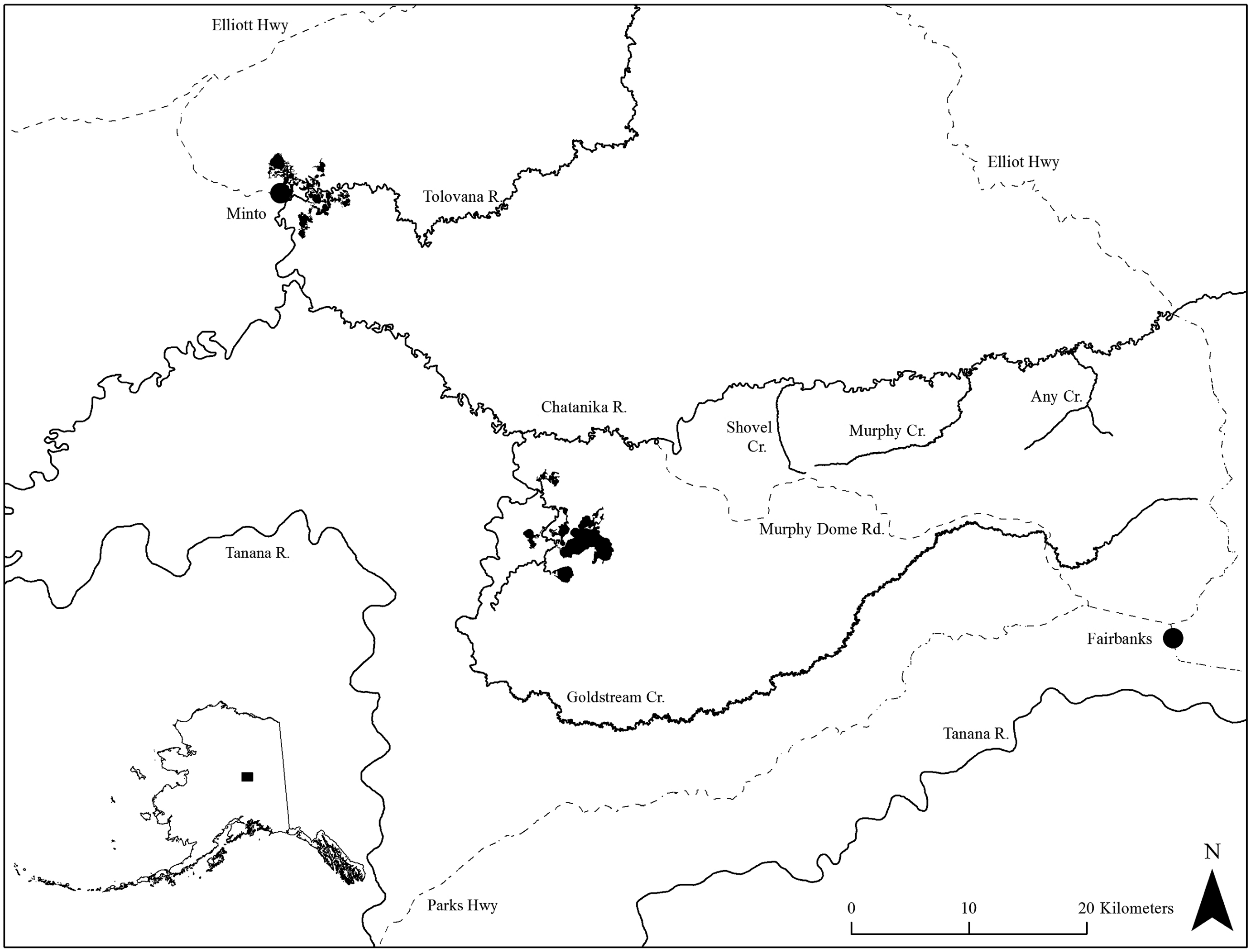

FIG. 1. Map of the Chatanika River near Fairbanks, Alaska.

thin-sectioning saw (Ward's Natural Science, Rochester, New York), and the sections were examined at 50× magnification using a Leica compound stereoscope (Leica Microsystems, Wetzlar, Germany). For age determinations, two viewers examined the same image of each otolith thin section independently; if their estimates were different, they re-examined the same structure together to reach a consensus. An age-length key was developed by calculating the percentage of fish in each age and length class from the subsampled population and extrapolating these data to the expected number of fish in each age and length class for the entire spawning population (Edenfield, 2009).

Determination of sexual maturity of humpback whitefish and least cisco was based on visual inspection of the gonads. Female fish were considered immature if they had eggs that were small and yolkless, and males, if they had testes present only as ducts. Females were considered mature if the ovaries appeared to be ready for the upcoming spawning period or if there were signs of spawning in previous years (i.e., developed eggs from a previous spawning event present in the peritoneal cavity; Thompson and Davies, 1976). Males were considered mature if the testes were more developed than ducts and showed signs of distal growth (Thompson and Davies, 1976).

Data Analyses

The fork length and age-at-capture data derived from the age-length key were used to create a von Bertalanffy growth relationship using SAS Version 9.2 (SAS Institute, Inc., Cary, North Carolina). From the fitted growth curve:

$$l_t = L_\infty(1-e^{-K(t-t_o)}),$$

where l_t was fish fork length at a given time (age), values were estimated for the maximum theoretical fork length (L_∞), Brody growth coefficient, (K), and the time period when length is equal to 0 mm (t_0) for the von Bertalanffy growth model.

Annual mortality (A) was estimated using Heincke's method (Ricker, 1975). Humpback whitefish and least cisco were large enough to be caught by the sampling gear at ages

11 and 9, respectively. Total annual mortality (A) was estimated as:

$$A = n_0/N,$$

where n_0 was the number of fish at the age of recruitment to the sampling gear and N was the number of fish in all age classes recruited to the sampling gear. This method required only the youngest age class large enough to be caught by the sampling gear to be aged accurately, reducing the reliance of the mortality estimate on accurate age assignment among older age classes. This approach is the most appropriate mortality rate estimator because of the difficulty associated with accurately aging long-lived fishes, such as whitefishes (Ricker, 1975).

Statistical analyses were conducted using SigmaStat Version 3.5 (Systat Software, Inc., Point Richmond, California), and all statistical tests were considered significant at the $\alpha = 0.05$ level. Parametric tests were used when applicable, but non-parametric tests were used if assumptions of normality and equal variances were violated. Differences between the age structures of male and female humpback whitefish and least cisco were compared using chi-square tests.

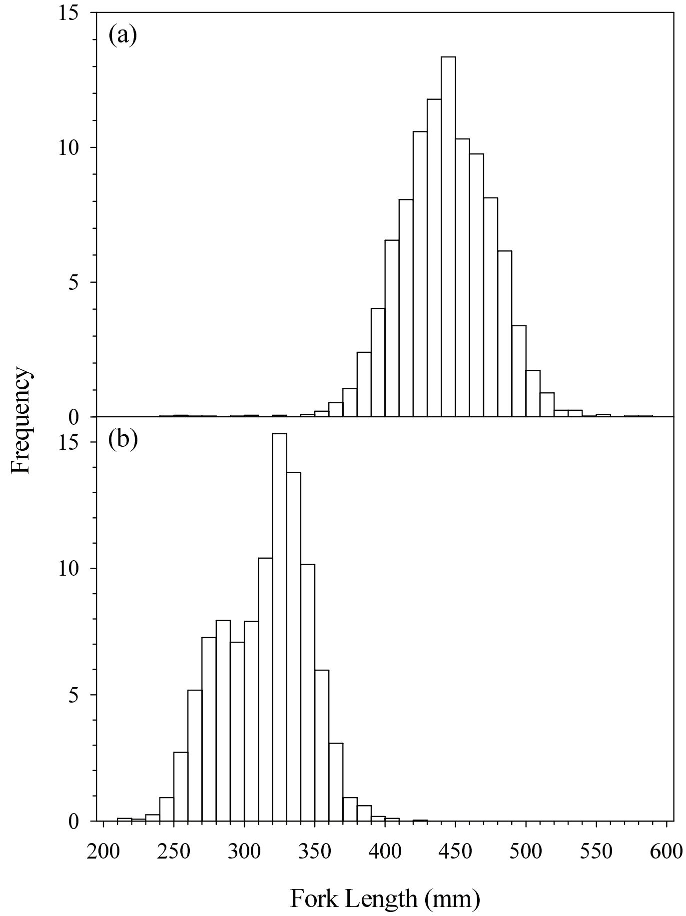

FIG. 2. Length-frequency distributions (both sexes combined) for (a) humpback whitefish and (b) least cisco in the Chatanika River in 2008.

RESULTS

A total of 3207 humpback whitefish and 2766 least cisco were captured from the Chatanika River. Humpback whitefish FL (both sexes combined) ranged from 188 to 583 mm, with a mean and median of 445 mm (Fig. 2). Thirty-five percent of the fish occurred in the 420 to 450 mm category. Least cisco FL (both sexes combined) ranged from 215 to 425 mm, with a mean of 316 mm and a median of 321 mm (Fig. 2). Forty percent of the least cisco occurred within the 320–350 mm range. The sex ratios (males to females) of subsampled fish were 52:48 for humpback whitefish and 59:41 for least cisco.

The age structure for humpback whitefish (both sexes combined) comprised 25 age classes (age range, 5 to 29), while that for least cisco (both sexes combined) had 12 age classes (age range, 3 to 14; Fig. 3). The youngest age at maturity for humpback whitefish was 6 years for males and 5 years for females, and the age at which 50% of fish had reached sexual maturity was estimated at 6 years for males and 7 years for females. For least cisco, the youngest age at maturity was 3 years for both sexes, and the age at which 50% of individuals had reached sexual maturity was 3 years for males and 5 years for females. Female humpback whitefish were represented in nearly all age classes, while male humpback whitefish were found more often in younger age classes (Fig. 3). A significant difference between the age compositions of male and female humpback whitefish was detected, with females represented more frequently in older age classes ($\chi^2 = 33.645$; $p = 0.029$). The least cisco age structure also had more males at younger ages (peak at age 4) and females in older age classes (peak at age 10; Fig. 3). A significant difference in age structure was also detected between male and female least cisco ($\chi^2 = 29.768$; $p = 0.002$), with males tending to be younger than females.

Length-at-age estimates for humpback whitefish indicated that they reached a mean fork length of 358 mm at age 5, the earliest age of maturity (Fig. 4). The theoretical maximum length (L_∞) of humpback whitefish was 509 mm, which corresponded to the mean length in the oldest age group collected during the study period (age 29; FL = 515 mm). For least cisco, the mean fork length of fish was 269 mm at age 3 (earliest age of maturity) and 385 mm at the oldest age collected (age 14). The latter figure corresponded to the von Bertalanffy growth estimate for the theoretical maximum fork length ($L_\infty = 376$ mm).

On the basis of Heincke's method, the annual mortality (A) for humpback whitefish age 11 and older was estimated to be 31.1% (95% CI = 28.8–33.2%). Similarly, the annual mortality (A) for least cisco age 9 and older was estimated to be 44.3% (95% CI = 42.7–46.9%).

DISCUSSION

The size structure of humpback whitefish in the Chatanika River was similar to length distributions after the

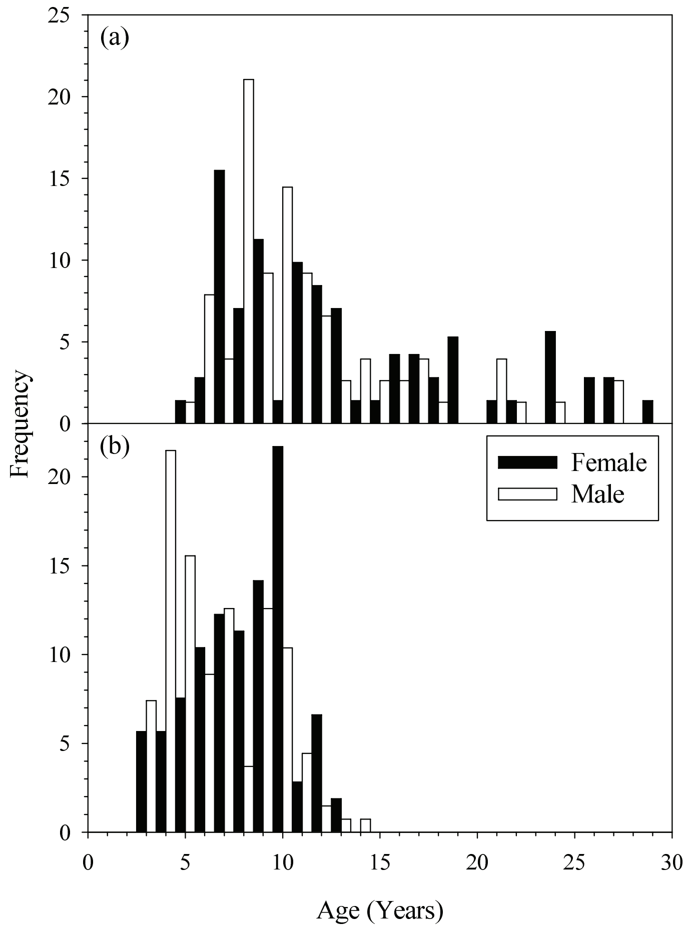

FIG. 3. Age-frequency distributions by sex for (a) humpback whitefish and (b) least cisco in the Chatanika River in 2008.

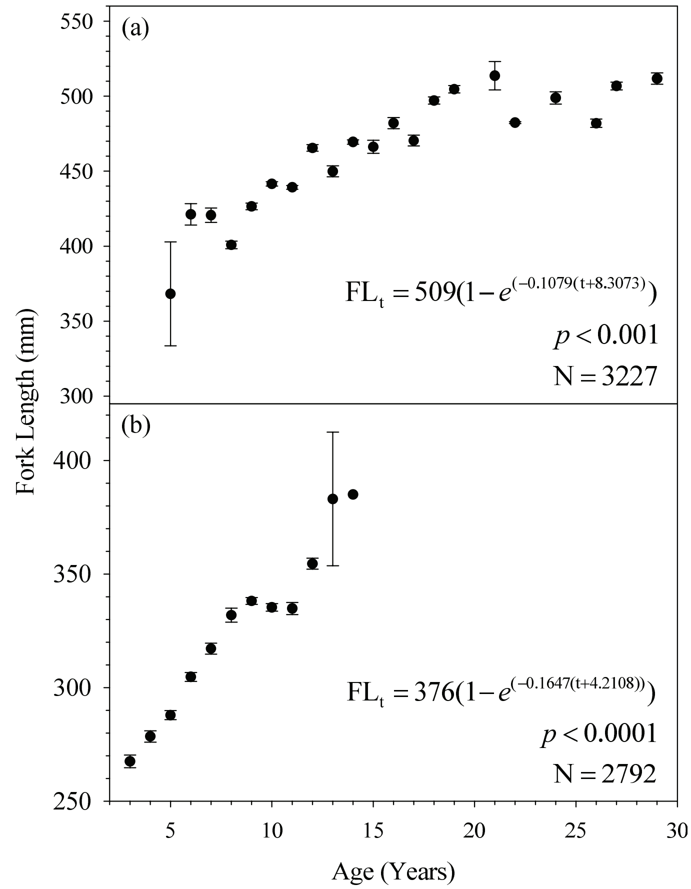

FIG. 4. Mean length at age and von Bertalanffy growth relationships for (a) humpback whitefish and (b) least cisco in the Chatanika River in 2008. Error bars represent 95% confidence interval for mean length-at-age values.

fishery was restricted in 1992. Thirty-five percent of the length-frequency distribution in 2008 was composed of fish that ranged from 420 to 450 mm. During the period of the restricted spear fishery, 42% (1992), 35% (1993), and 33% (1994) of fish occurred within this size range (Fleming, 1993, 1994, 1996, 1999). Prior to 1991, when the spear fishery was not restricted, humpback whitefish in the Chatanika River were smaller (range: 390 to 410 mm; Hallberg and Holmes, 1987; Halberg, 1988, 1989; Timmons, 1990). The mean length of humpback whitefish in the Chatanika River in 2008 (445 mm) was larger than mean lengths reported for other exploited stocks of this species in Alaska that were collected during their spawning migration in late summer or fall in the Kuskokwim River (range: 412 to 430 mm; Harper et al., 2008) and the upper Tanana River (range: 393 to 396 mm; Brown, 2006) or during summer foraging bouts in Whitefish Lake (range: 355 to 415 mm; Harper et al., 2007).

The size structure of least cisco in the Chatanika River, in contrast to that of humpback whitefish, was most similar to mean and median lengths of fish collected before the fishery was restricted. For example, the mean length of least cisco observed in 2008 (316 mm) was similar to FL estimates that were recorded when the spear fishery was active (1986: 313 mm; 1987 and 1988: 319 mm; Hallberg and Holmes, 1987; Timmons, 1990). However, during the restriction of the spear fishery, the median fork length of least cisco in the Chatanika River was longer (1992: 340 mm; 1995: 335 mm; 1998: 348 mm; Fleming, 1993, 1996, 1999) than the lengths we observed in 2008 (321 mm). Harper et al. (2007) observed that mean lengths of least cisco from Whitefish Lake collected during summer months ranged from 301 to 334 mm. Bond and Erickson (1985) reported fork lengths for least cisco in tundra lakes in the Northwest Territories during summer and fall months that ranged from 48 to 389 mm, with 83% of fish between 200 and 349 mm. Although Harper et al. (2007) and Bond and Erickson (1985) focused on feeding populations of least cisco populations in lakes, we included their results for comparison with fish in our study, which were on their spawning migration.

The age distribution of humpback whitefish collected in the Chatanika River was within the ranges reported for other stocks; however, the structures used to age this species varied from study to study. In our study, 59% of humpback whitefish were between ages 7 and 12 and only 34% of fish occurred in age classes 13 through 29. In Dease Inlet, Alaska, the age composition of humpback whitefish ranged from ages 5 through 24, with most fish captured between ages 9 and 12 (Moulton et al., 1997). Humpback whitefish in the upper Tanana River drainage were primarily between ages 3 and 9 (80%), with less than 5% of fish older than age 20 (maximum age = 26; Brown, 2006). These two studies used otoliths for aging purposes and focused on little to moderately exploited populations. In contrast, earlier studies of humpback whitefish collected from the Chatanika River, either during the years of high exploitation or during years of no exploitation after the collapse of the fishery, used scales for aging purposes. Consequently, these studies reported a predominantly younger age structure (ages 5–7 from 1986 to 1989; (Hallberg, 1988, 1989) and ages 8–9 from 1992 to 1996 (Fleming, 1993, 1994, 1996). Several studies have shown that compared to other structures used in aging, scales underestimate fish age, particularly for long-lived fishes such as whitefish (Power, 1978; Mills and Beamish, 1980; Muir et al., 2008a, b). As a result, it is possible that the age structure observed in 2008 was similar to that of post-harvest years in the Chatanika River. In any case, the age structure estimated during our study in the Chatanika River is similar to observations from systems where humpback whitefish were exploited at low to moderate levels (Moulton et al., 1997; Brown, 2006).

The age composition of least cisco in the Chatanika River, like that of humpback whitefish, was comparable to age ranges reported for other stocks of this species, and least cisco studies also showed variability in the structures they used to age fish. We estimate that the ages of least cisco in the Chatanika River currently range from 3 to 14 years. Moulton et al. (1997), using otoliths, found least cisco in Dease Inlet as old as 24 years, much older than the maximum age of fish observed in the Chatanika River in 2008. The age distribution observed in the Chatanika River was similar to that of exploited populations of least cisco migrating into and out of tundra lakes used as feeding and nursery areas in the Northwest Territories (Bond and Erickson, 1985), where ages ranged from 0 to 11. Although Bond and Erickson (1985) used scales to estimate the ages of least cisco, a large proportion (40%) of their fish were juveniles between ages 2 and 4 and thus were most likely aged accurately. These studies and our results suggest that the relatively young age structure estimated for least cisco in the Chatanika River may indicate that this stock has not fully recovered from the collapse of the fishery.

The age at sexual maturity of humpback whitefish and least cisco in the Chatanika River was within the ranges reported for other stocks. For humpback whitefish in our study, the youngest age at maturity and the age at which 50% of fish had reached maturity were age 6 for males and ages 5 and 7, respectively, for females. For least cisco, the youngest age at maturity was age 3 for both sexes, and 50% of fish had reached maturity at age 3 for males and age 5 for females. Clark and Bernard (1992) reported that humpback whitefish in the Chatanika River at the peak of the spear fishery were mature as early as age 5, while Harper et al. (2007) documented mature fish in Whitefish Lake as young as age 4. Mature least cisco have been documented as early as ages 3 and 4, regardless of sex, for other stocks in Alaska and the Northwest Territories (Bond and Erickson, 1985; Clark and Bernard, 1992; Harper et al., 2007). In contrast, Moulton et al. (1997) reported that in Dease Inlet, 50% of humpback whitefish had reached maturity at age 11 for males and age 14 for females, while the comparable ages for least cisco were age 8 for males and age 7 for females. However, the authors attributed the delayed age at maturity for these stocks to the particularly short annual growing season associated with the North Slope of Alaska along the Beaufort Sea coast.

Growth, and subsequently length-at-age, of humpback whitefish and least cisco in the Chatanika River in 2008 followed a pattern similar to those observed for other stocks of these two species in North America. In general, annual growth was greatest for early life stages and declined in older age classes, a change which can be attributed to the onset of reproductive maturity (Dupuis, 2010). Similarly, Chang-Kue and Jessop (1992) found that least cisco in the Northwest Territories grew rapidly until they reached reproductive maturity, after which their growth rate declined. In the present study, the von Bertalanffy growth model estimated the maximum theoretical fork length to be 509 mm for humpback whitefish and 375 mm for least cisco, which was within the range of maximum lengths reported in other studies (Brown, 2004, 2006; Harper et al., 2007, 2008). Because length-at-age is also dependent on accurate age estimation, it is difficult to compare fish growth among studies that employ different aging techniques.

The estimated annual mortality rates in the Chatanika River in 2008 were 31% for humpback whitefish age 11 and older and 44% for least cisco age 9 and older. In 1993, when the spear fishery was still active, the annual mortality rates of these two species were 47% and 53% (Fleming, 1994). However, in 1994, after the fishery had closed, estimated annual mortality rate estimates were 15% for humpback whitefish and 58% for least cisco (Fleming, 1996). Fleming (1996) suggests that the high estimate of mortality for least cisco in 1994, when exploitation was low, could be due to the timing of sampling that year or to increased predation by northern pike that resulted in lower recruitment. It would appear that annual mortality rates of whitefish are highly variable and are specific to the population in question. For example, Brown (2006), using radio-telemetry data, estimated an annual mortality rate of 31% for humpback whitefish in the upper Tanana River drainage, where this species is the primary target of subsistence users. Scheerer and Taylor (1985) estimated that annual mortality rates of commercially exploited stocks of lake whitefish (*Coregonus clupeaformis*) in Lake Michigan ranged from 56% to 77%, while Ebener et al. (2010) estimated that natural mortality rates of commercially exploited lake whitefish in lakes Michigan and Huron ranged from 31% to 100%. Previous studies on lake whitefish populations in Canadian lakes reported annual mortality rates of 23% (range: 15–29%) for unexploited populations, 32% (range: 25–40%) for those with low exploitation, and 60% (range: 50–81%) for those with moderate to high levels of exploitation (Healey, 1975; Mills and Beamish, 1980; Mills et al., 2004).

One caveat in our study was that comparisons of stock attributes for humpback and least cisco in the Chatanika River to those reported in other studies must be interpreted judiciously because different methods and approaches were used to calculate these estimates. Beamish and McFarlane (1983) stressed the need for validation of aging structures for all fishes to standardize procedures and allow for meaningful comparisons among populations or stocks, but to date this validation has not been accomplished for humpback whitefish or least cisco. Therefore, age and associated growth and length-at-age comparisons of different stocks of these two species must be interpreted with caution until there has been a validation of aging techniques. Further, the analytical procedures for estimating mortality rates of whitefish stocks were not always similar among studies, and included the use of mark-recapture, age-structure, and radio-telemetry data. As a result, comparisons of mortality rates must also be interpreted with caution. Those included in our evaluation are intended to provide a means of contrasting our study with studies of exploited and unexploited stocks of whitefishes in other North American systems.

Unexploited fish stocks are typically characterized by high abundance, a low rate of annual mortality, a broad range of fish length and age classes, and low annual growth (Clady et al., 1975; Healey, 1975, 1980; Goedde and Coble, 1981; Mills et al., 2004). Our study indicates that humpback whitefish in the Chatanika River exhibit most of the attributes consistent with low exploitation or low mortality. Further, the stock structure for humpback whitefish collected in 2008 was similar to data collected before the collapse of the fishery and after its restriction and subsequent closure, which suggests that this species has recovered. In contrast, the least cisco in the Chatanika River, even though the current harvest level is low, exhibit many population attributes that suggest this stock has not fully recovered (e.g., small size at age, age composition skewed to younger fish). In fact, the population abundance estimate for least cisco in 2008 was the lowest on record (Wuttig, 2009). Our stock-attribute estimates for both species are within the range documented for other stocks throughout Alaska and northern Canada (Bond and Erickson, 1985; Fleming, 1993, 1994, 1996, 1997; Brown, 2004, 2006; Harper et al., 2007, 2008).

The results of our study, the Alaska Department of Fish and Game abundance estimates from 2008 (Wuttig, 2009), and model simulation results of spear fishing harvest impacts on humpback whitefish and least cisco abundance (Edenfield, 2009) indicate that the current allowable harvest of 2000 whitefish (any species) is cautious, but appears to be sustainable, at least over the short term. Although neither species is currently overexploited in the Chatanika River, least cisco does not appear to have recovered fully to pre-collapse abundance and stock-attribute levels. We recommend that stock assessments be conducted every three years to ensure that there are no negative changes in population structure and that the current level of harvest in the spear fishery is not detrimental to long-term viability. To facilitate these monitoring efforts, we also recommend that spear fishers report whitefish harvest by species to allow accurate accounting of species-specific harvest. Further, if these assessment and monitoring efforts indicate that stocks of either species, but particularly least cisco, are continuing to improve, it might be possible to allow cautious increases in the annual harvest level. Future research should aim to better our understanding of spawning periodicity and sample early life-history stages to provide comprehensive assessments of population abundance and recruitment. Standardized aging techniques and use of consistent methods are needed to improve assessments of age structure, growth, and mortality within and among populations. Such population data will provide managers with the tools necessary to develop appropriate fishery management strategies and monitor humpback whitefish and least cisco more accurately in relation to the spear-fishery harvest in the Chatanika River.

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