Hard Structure Aging Precision and Length-At-Age Data from Two Northern Leatherside Chub Populations

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Abstract

Northern leatherside chub *Lepidomeda copei* are an imperiled cyprinid fish native to the upper Snake River and upper Bear River basins in Utah and Wyoming. Age and growth rates have been documented for only a few populations and the precision of scale and otolith age estimates have never been described for the species. In this study, we describe the precision of scale and otolith derived age estimates for the northern leatherside chub. We also document scale-derived estimates of age and growth rates of two populations, Ham's Fork, Wyoming and Yellow Creek, Utah. Ages determined using scales agreed with those determined using otoliths in 70.8% of fish and agreement declined with age. Scale derived age estimates were on average younger than otolith derived estimates. The maximum age of the fish collected from Ham's Fork and Yellow Creek was three years. At the end of the growing season, captured age 1, 2, and 3 fish had an average (range) total length of 86 (73-100), 105 (99-115), and 124 (100-135) mm, in Yellow Creek and 86 (63-96), 99 (89-117), and 112 (100-123) mm in Ham's Fork. Growth rates did not differ between sexes in Ham's Fork, but females in Yellow Creek tended to grow faster than males. The data from our study increases our understanding of age and growth rates in northern leatherside chub and how these parameters vary among populations.

Key Words: Northern Leatherside Chub, Otolith, scale aging, back-calculation, Ham's Fork, Yellow Creek.

Introduction

Northern leatherside chub *Lepidomeda* (syn. *Gila, Snyderichthys*) copei, are increasingly rare cyprinids, native to the upper Snake River and upper Bear River in the Bonneville Basin of Utah and Wyoming (Sigler and Sigler 1987; Wheeler 1997; Blakney et al. 2014). Based on molecular (Johnson and Jordan 2000), morphological, and life history differences (Belk et al. 2005), northern leatherside chub were taxonomically separated from the southern Bonneville Basin ecotype by Johnson et al. (2004), who separated the southern leatherside chub into a new species, *Lepidomeda aliciae*. Relative to historic distributions, northern leatherside chub are declining due to introduction of non-native fish, habitat alterations, and dewatering of historical habitats (Walser et al. 1999; Wilson and Belk 2001; Belk and Johnson 2007). From a state and federal wildlife management perspective, northern leatherside chub are considered a species of special concern and are at risk of becoming threatened or endangered.

The biology and life history of northern leatherside chub had not been well studied until the 1990's. Sigler and Sigler (1996) noted that leatherside chub spawn from June to August in waters from 15 to 20°C. Johnson et al. (1995) found that gonadosomatic indices peaked in May for *L. aliciae* and fecundity, based on ova counts, averaged 1,813 eggs/female. Fecundity was correlated with the size of the female, ranging from 938 eggs for a 67 mm (standard length) female to 2,573 eggs for a 92 mm female that weighed 14.6 g (Johnson et al. 1995). Females may begin spawning at age 2 at 65-85 mm standard length and multiple spawns per year may occur (Johnson et al. 1995; Bartley et al. 2012). Johnson et al. (1995) determined that southern leatherside chub can reach a maximum age of 8 years. Maximum length is about 152 mm (Sigler and Sigler 1996). Females prefer small cobble as a spawning substrate (Billman et al. 2008a). Early life history characteristics, e.g., egg size, time to hatch and swim-up, have been described by Billman et al. (2008a). Temperatures of 26.8°C led to significant egg mortality compared to 18.4-24.6°C (Bartley et al. 2012). For juvenile northern leatherside chub, critical thermal maximum (CTM) and upper incipient lethal temperature (UILT) tests indicated CTM values were 29.6 to 35.0°C and UILT was 26.5 to 30.2°C (Billman et al. 2008b) and optimal temperature for growth was about 23°C (Billman et al. 2008b). Field observations have noted preferred velocities of 2.5-4.5 cm sec-1 and water depths of 25-65 cm (Wilson and Belk 2001). Lateral habitats such as off-channel pools and backwaters are important refuges from main channel predators (Walser et al. 1999). A diet study (Bell and Belk 2004) sampling adult fish >65 mm indicated that a broad array of prey were consumed; aquatic and terrestrial insects were especially favored, but crustaceans (Amphipoda and Isopoda) and gastropods were also consumed at some sites.

Length-at-age data are useful for understanding the general life history of fish, obtaining information about growth rates, and leading to an understanding of annual recruitment, mortality rates of age cohorts, and of the age structure of fish populations (Summerfelt and Hall 1987). Age of fishes can be estimated using a number of hard structures including scales, otoliths, fin rays, cleithra, and opercular bones (DeVries and Frie 1996). Otoliths provide the most accurate estimate of age for most species (DeVries and Frie 1996), but one disadvantage to the use of otoliths is that they require fish to be sacrificed whereas the use of scales is non-lethal. Quist et al. (2007) compared the precision of hard structures used to estimate cyprinid age in the Upper Colorado River Basin and found ~45% agreement between estimates derived using scales and otoliths. Agreement varied with species and was up to 92% for the two chub species included in their study (creek chub *Semotilus atromaculatus* and rountail chub *Gila robusta*). Previous studies with leatherside chub have used otoliths (Johnson et al. 1995) and no studies have evaluated the agreement between scales and otoliths for the species. Limited age and growth rate information is available for leatherside chub. Johnson et al. (1995) noted that the standard lengths for *L. aliciae* ranged from 38-100 mm for 1- to 8-year-old fish and that age- 2 fish were about 58 mm. Belk et al. (2005) noted that northern leatherside chub from one population were about 15% shorter than individuals from a southern leatherside population. The objectives of this paper are to first summarize the scale/otolith aging agreement from a sample of 24 northern leatherside chub and summarize length-at-age data obtained from two northern leatherside chub populations, one from Wyoming, and the other from Utah.

Methods

Aging Agreement Study

Backpack electroshockers (Smith-Root LR-24, Vancouver, Washington) were used to collect northern leatherside chub from two streams; Hayden Fork (Summit County, Utah; 40°51'24" N, 110°50'24"W; collected August 2, 2009) and Deadman Creek (Summit County, Utah; 40°53'35" N, 110°46'54"W; collected June 25, 2010). These fish were used as part of a captive breeding program and individuals from both populations were mixed in indoor holding tanks where temperature and photoperiod were manipulated seasonally to mimic natural conditions. Mortalities (N = 29) among these brood fish were collected and frozen between 2011 and 2013. No necropsies were performed to determine the cause of death. Frozen fish were later thawed, weighed, measured, and saggital otoliths and scales were removed. The scales and otoliths were stored dry. Scales were taken from the left-side of the fish in the region directly below the dorsal fin but above the lateral line. Otoliths were mounted to microscope slides and ground to a thin section that included the nucleus using fine-grit sandpaper. During grinding, the otoliths were regularly viewed under a microscope to ensure that no annuli were lost. The otolith with the most visible annuli from each fish was retained for this study and the other otolith was discarded. Each structure (scale vs. otolith) was aged either two or three times by an experienced reader by viewing the otoliths under a microscope at 100X magnification or by projecting scale images using a microfiche reader (Micro Design 175A). A third reading was only performed when the ages from the first two readings on a structure did not agree.

Age and Growth Rate Determintion from Ham's Fork and Yellow Creek

Leatherside chub were collected using backpack electrofishing units (Smith-Root LR-24, Vancouver, Washington) from a variety of habitats (i.e., pools, riffles, and runs) from two populations; Ham's Fork (Lincoln County, Wyoming; 42° 8'55" N, 110°44'44"W) and Yellow Creek (Summit County, Utah; 40° 59'31" N, 111°1'34"W; collection location downstream of where fish for aging agreement study were collected). The Ham's Fork fish were collected on September 19, 2014 and the Yellow Creek fish were collected on October 7, 2014. The fish were transported to the Fisheries Experiment Station (FES; Utah Division of Wildlife Resources, Logan, Utah) in a 100 L cooler filled with 50-60 L of FES water. An air bubbler was placed into the cooler and oxygen was provided to the fish at 1-2 L/min.

The leatherside chub were originally collected for a captive breeding program, but high mortality occurred both in transit (Yellow Creek only; likely due to chemical disinfectant residuals) and after arrival (both populations; due to "ich" *Ichthyophthirius multifiliis* outbreak) to FES. Dead fish were collected for the first 28 d after arrival and were frozen for later examination. We decided to opportunistically use the dead fish to derive length-at-age data from each population. The total length, weight, and sex of each fish was determined. Scales were also removed and aged using the same procedures described previously for the aging precision study. Scales were selected in favor of otoliths for aging because time and funding constraints prevented us from being able to mount and section otoliths. Measurements to each annulus (based on the consensus age from the 2 or 3 scale readings) were made using a ruler and fish length at the time of formation of each annulus was made through back-calculation via the Fraser-Lee Method (DeVries and Frie 1996). The intercept parameter was estimated as 6.5 mm based on total length measurements made on the day of hatch for captive reared northern leatherside chub (Wagner, personal observation). A fish was removed from analysis if two of the age estimates did not agree after three readings (5.7% of fish removed). In total, 31 fish from Ham's Fork and 37 fish from Yellow Creek were retained for analysis. Growth rates (mm/day) were estimated using these data for each fish by age group (0 to 1, 1 to 2, 2 to 3 yrs) by calculating the difference in back-calculated length between years and dividing by 365 days.

The mortality of fish from the Yellow Creek population was non-selective and the average weights (total length not measured) of surviving fish was similar to the dead fish evaluated in the study ($P = 0.78$, t = 0.78, df = 13). The mortality of Ham's Fork fish was size selective towards larger individuals ($P < 0.05$ for both total length and weight comparisons with surviving fish). Even though larger fish are over-represented in our sample from Ham's Fork we have chosen to include the data because the leatherside chub is a species that has been considered for listing as either Threatened or Endangered. In our opinion, the presentation of the data from this population could be beneficial for the conservation of the species. The fish fed poorly after the ich outbreak, and it is assumed minimal growth occurred after the fish were brought to FES. Weight data was excluded from analysis because it is probable that the fish lost weight after collection and that weights at the time of death were not representative of the time of collection.

Results

Aging Agreement Study

The scales and otoliths collected from each fish (n =29) were read twice and a third reading was used to determine a consensus age from each aging structure when the first two age estimates were not the same. The first two readings agreed for 18 fish (62%) when scales were read and 26 fish (90%) when otoliths were read. These data indicate that for northern leatherside chub that otoliths are easier to age and provide greater inter-reading precision than scales.

We could not derive a consensus age estimate (i.e., the same age was estimated twice after three readings) from the scales from five fish whereas we were able to derive consensus age estimates for all fish using otoliths. The five fish where we could not derive a consensus age estimate using scales were removed from analyses comparing age estimates derived using scales with those derived using otoliths. The ages derived using scales and otoliths were the same for 17 out of the 24 fish (70.8%) included in this analysis and the median age for both aging structures was 4 yrs. There was a tendency, however, for scale derived ages to be younger than those derived using otoliths and for agreement to decrease with age (Table 1). The oldest scale-derived age estimate was 5 yrs but ages up to 7 yrs were estimated using otoliths. The otolith derived age was older in every case where the ages from the two structures did not agree.

Age and Growth Rate Determination from Ham's Fork and Yellow Creek

From Ham's Fork we collected a total of 19 females (63%), 10 males (34%), and two small fish (3%) that had undeveloped gonads (Table 2). We collected 13 females (35%), 23 males (63%), and 1 undeveloped fish (3%) from Yellow Creek (Table 2). Length-

Table 1. Two-way table showing the number of northern leatherside chub that were aged to a particular age using scales when the otolith derived ages for the same fish are as given in the left-hand column. For example, there were 10 fish that had an otolith derived age estimate of 4 yrs. When scales were used to age the same fish, three of the fish were determined to be age-3 and the remaining seven individuals were estimated to be age-4.

	Scale Age Estimate (Yrs)								
Age Derived Using Otolith (Yrs)	0	1	2	3	4	5	6	7	Total
0	1								1
1		4							4
2									0
3				1					1
4				3	7				10
5					2	4			6
6						1			1
7						1			1
Total	1	4	0	4	9	6	0	0	24

Table 2. Mean total length at capture (mm) of northern leatherside chub collected from Yellow Creek and Ham's Fork from each of three age classes that were determined using scale samples. Annulus formation occurs in the spring and fish were collected in the fall; the fish had one additional growing season than suggested by the age (indicated by the "+"). Data are separated by sex (undetermined represents fish whose sex could not be determined using visual gonad examination). The number of fish collected (N) and range of total lengths for each category are reported.

		All Fish			Male			Female			Undetermined		
Source	Age	N	Mean (mm)		N	Mean (mm)	Range (mm)	N	Mean (mm)	Range (mm)	N	Mean(mm)	Range (mm)
Yellow Creek	1+	20	86	73-100	16	87	73-100	4	83	74-95			
	2+	12	105	99-115	6	102	99-105	6	109	102-115			
	3+	3	124	110-135	1	110		2	131	127-135			
Ham's Fork	1+	5	86	63-96	1	87		3	93	87-96	1	63	
	2+	17	99	89-117	9	98	91-104	7	102	95-117	1	89	
	3+	6	112	100-123				6	112	100-123			

at-age computed via back-calculation did not vary between sexes in Ham's Fork ($F_{1,52} = 1.24$, $P = 0.27$) but females in Yellow Creek had significantly longer lengths-at-age ($F_{1,47} = 5.04$, $P = 0.03$) than males (Fig. 1). Daily growth rates in both populations ranged from 0.061 to 0.125 mm/d among 1 to 3 year-old fish (Table 3). Growth rates decreased with age (both populations, $P < 0.01$), but did not vary between sexes (both $P > 0.11$), and there was no significant sex × age interaction (both $P > 0.89$).

Discussion

Information on age and growth rates can help provide information that is needed to help conserve imperiled species such as the northern leatherside chub. Various hard structures can be used to derive these parameters and it is often desirable to use structures that can be collected non-lethally. Similar to other studies (e.g., Marwitz and Hubert 1995; Isermann et al. 2003; Quist et al. 2007), we found that estimates derived using both scales and otoliths are precise in younger fish, but that scale derived ages are younger than otolith derived ages in older fish (DeVries and Frie 1996). The aging agreement that we observed for scales and otoliths was similar to what has been observed in other species including white crappie *Pomoxis annularus* (Hammers and Miranda 1991), creek chub and roundtail chub (Quist et al. 2007), and bluegill *Lepomis macrochirus* (Hoxmeier et al. 2001). No information comparing the precision of scale and otolith age estimates for leatherside chub is available in the literature and other studies that have aged the leatherside chub (e.g., Johnson et al. 1995) used otoliths. The actual age of the fish included in our sample is not known; thus, the accuracy of the use of scales and otoliths for estimating the age of northern leatherside chub is not known. Based on data available for

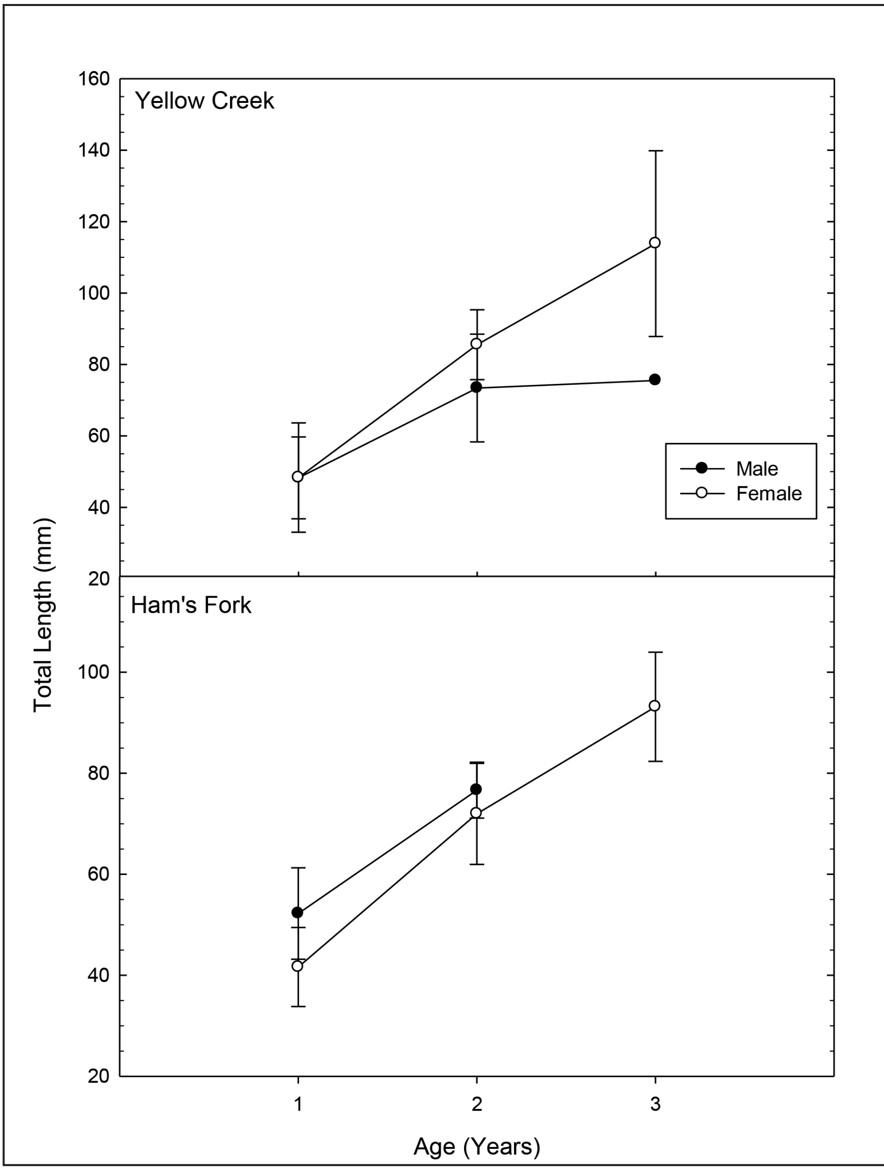

Figure 1. Average back-calculated lengths-at-age for male (closed circles) and female (open circles) northern leatherside chub collected from Yellow Creek (top panel) and Ham's Fork (bottom panel). Error bars represent ± 1 SD of the mean.

other species (DeVries and Frie 1996), it is likely that otoliths are more accurate than scales for the leatherside chub but our data suggests that scales are good substitutes when fish cannot be sacrificed.

Our study is the first to document the length-at-age and growth rates of northern leatherside chub in Ham's Fork and Yellow Creek. On average, the length at the time of capture was approximately 40 mm longer than back-calculated lengths-at-age and this difference can be attributed to the lengths being back-calculated to the beginning of the growing season (DeVries and Frie 1996) whereas the fish were collected at the end of the growing season. The growth rates we calculated were greater than those reported by Belk et al. (2005) based on common garden experiments for both northern leatherside chub from Sulfur Creek,

Table 3. Average daily growth rates (mm/d; with SD in parentheses) for northern leatherside chub from Yellow Creek and Ham's Fork. Data are based on back-calculation performed using scale samples.

Source	Age	All Fish (mm/d)	Male (mm/d)	Female (mm/d)	Undetermined (mm/d)
Yellow Creek	1	0.111 (0.040)	0.114 (0.032)	0.115 (0.042)	
	2	0.080 (0.015)	0.074 (0.012)	0.085 (0.017)	
	3	0.069 (0.008)	0.061	0.074 (0.004)	
Ham's Fork	1	0.106 (0.026)	0.125 (0.025)	0.096 (0.021)	0.096 (0.021)
	2	0.080 (0.023)	0.070 (0.022)	0.088 (0.021)	0.065
	3	0.0740 (0.028)		0.074 (0.030)	

Wyoming and southern leatherside chub from East Fork of the Sevier River, Utah (about 0.0045 mm/day for both populations). The growth rates that we calculated are less than those reported for young-of -the-year northern leatherside chub reared in captivity (0.2952 mm/day; Bartley et al. 2012). Belk et al. (2005) documented the occurrence of individuals that were up to four years-old from both populations and found that the length-at-age of southern leatherside chub was approximately 15% greater than found in northern leatherside chub.

In a separate study, Johnson et al. (1995) documented the age-structure and growth rates from southern leatherside chub from two tributaries to Utah Lake, Utah. The maximum age of the leatherside collected by Johnson et al. (1995) was 8 yrs. The ages reported by Johnson et al. (1995) were based on otoliths whereas we report ages that were derived using scales, which can have the tendency to underestimate age (DeVries and Frie 1996). No studies have reported aging agreement between scales and otoliths for leatherside chub but data from chub species from other genera indicate that agreement may be greater for chub than other species (Quist et al. 2007). Johnson et al. (1995) back-calculated growth rates using standard lengths rather than total lengths; thus, it is difficult to compare the growth rates in the populations they assessed against our populations. The oldest individuals collected in our study were age-3. Given a maximum age of about 8 years (Johnson et al. 1995), the data suggests that older age classes that should be present were not. So, this maximum age in both Yellow Creek and Ham's Fork suggests that most northern leatherside chub in these populations spawn only once or twice in their lifetimes. Further research would be needed to determine what factors (e.g., predation, disease, overwinter mortality) may be contributing to poor recruitment to the older age classes.

Our data from these two populations contributes additional knowledge concerning the growth rate and age structure of northern leatherside chub. We acknowledge that our sample size is small, but the northern leatherside chub is an imperiled species and our sample size is similar to other studies on the species (e.g., Johnson et al. 1995; Bell and Belk 2004; Belk et al. 2005). Our data from Ham's Fork indicates that fish from that population grow at a similar rate to other populations whereas fish from Yellow Creek appear to grow faster than individuals from other populations. Future studies should address why individuals from Yellow Creek grow faster than other populations and why older age classes of northern leatherside chub are not found in either population.

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