Transactions of the American Fisheries Society 117:301–307, 1988

Growth and Longevity of the Cui-ui and Longevity of Other Catostomids and Cyprinids in Western North America

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Abstract.—Annulus formation on opercula of the cui-ui *Chasmistes cujus* in Pyramid Lake, Nevada, was validated over an 8-year interval. Many fish were old, as old as 41 years of age. As many as three annuli were hidden (covered by supporting bone) in older fish. Growth was rapid during the first 10 years, slow from 10 to 20 years, and extremely slow or nil after 20 years. Age and growth were strongly correlated for about the first 10 years of life, but less so when fish became sexually mature. Examination of opercula of 15 additional species of large catostomids and cyprinids of western North America revealed that they were older than had previously been thought.

Recent validation (Scoppettone et al. 1986) of the longevity of the cui-ui *Chasmistes cujus*, an endangered catostomid endemic to Pyramid Lake, Nevada, indicates that this longevity is two to three times that found by Koch (1972) and Sigler et al. (1985) for this species. This finding supports increasing discoveries of age underestimation and overlooked longevity among fishes (Beamish and McFarlane 1987). The primary source of age discrepancy has been scales used without adequate validation of annuli (Beamish and McFarlane 1983). The western North American fish fauna includes numerous large catostomids and cyprinids such as the cui-ui, and it is conceivable that many of these may have longer life spans than previously believed.

Beamish and McFarlane (1983) used fin ray sections to demonstrate a greater longevity for white suckers *Catostomus commersoni* than had been known from scale analysis. This method proved unsuccessful for older cui-uis (Scoppettone et al. 1986). Otoliths were more reliable than opercles for aging razorback suckers *Xyrauchen texanus*, but age estimations from the two structures were not markedly different (McCarthy and Minckley 1987). Scoppettone et al. (1986) were able to validate the use of opercle bones to age cui-uis. The adult population of this species was composed of only a few year classes, two of which (1969 and 1950) predominated. Annulus validation was accomplished by following this sparse cui-ui year-class structure through time. The use of opercles may give further insight into catostomid and cyprinid ages when aging from scales does not appear reliable. Thus, cui-ui aging with opercula may serve as a model for aging some temperate zone catostomids and cyprinids.

This paper develops in greater detail the age and growth data of Scoppettone et al. (1986) by adding to the completeness of validation, describing hidden and false annuli, comparing aging with opercula versus aging with scales, and developing growth curves for males and females. I also use aging based on cui-ui opercula to suggest that other western North American catostomids and cyprinids have unrecognized longevity.

Methods

Opercula were prepared for viewing by boiling away the flesh or (with preserved museum specimens) by scraping it away with a scalpel. Annuli were identified by the method described by Casselman (1974) for subcleithra. Transparent bone was assumed to have the greatest calcium concentration and to have been accumulated in the winter months. Opaque bone was assumed to have a higher concentration of proteinaceous material and to have been accumulated during the summer. The annulus was defined as the region in which the outer edge of the transparent bone abutted the inner region of the opaque zone. By examining cui-ui opercula collected at various times of the year, I determined time of annulus and false annulus formations. To enumerate hidden annuli, I used a dremel tool to grind away the fenestrated reinforcement bone associated with growth and expansion of the hyomandibular socket. I contrasted ages determined from scales against ages determined from opercula for individual fish to illustrate the inaccuracy of the former method. Scales were taken from the left side of the fish, below the dorsal fin and above the lateral line, and were read in the manner described by Tesch (1971).

Annulus validation consisted of following the addition of new annuli on two predominant year classes of cui-ui (1969 and 1950) collected from the spawning population in 1978 and 1982–1986. Using the method of annulus identification described by Casselman (1974), I found that there were only the 1969 and 1950 year classes in my first collection of cui-ui opercles made in 1982. I reasoned that these two year classes were marker cohorts (young and old), and that annuli could be verified for both in succeeding years. Cui-ui opercula collected by U.S. Fish and Wildlife Service personnel during the 1978 spawning season were used for initial annulus verification. Further verification in years subsequent to 1982 showed that an additional well-defined annulus was added each year from 1983 through 1986. Fish collected in 1978 were gillnetted from the spring prespawning aggregation near the mouth of the Truckee River, Pyramid Lake's only perennial tributary. These fish subsequently died in the cui-ui hatchery, located on the west side of Pyramid Lake. Cui-uis used in 1982–1986 were those that died on their spawning migration up the Truckee River. Most had either been dropped on land by white pelicans *Pelecanus erythrorhynchos* or had been killed as a result of the physical handling required to lift them around the 12-m-high Marble Bluff Dam. Several older fish (30+) were found floating in the river, dead of no apparent cause.

Due to the initial paucity of year and age-classes, Scoppettone et al. (1986) constructed cui-ui growth curves by back-calculating fish size from opercula. However, by the time of this study there was an increase in cui-ui spawner year-class diversity as younger adults entered the run. Also, juveniles of 60–360 mm fork length were collected during systematic gillnetting by Pyramid Lake Paiute tribal biologists, and were seined along the shoreline. In previous cui-ui age–growth studies, juveniles had been unavailable (Koch 1972; Sigler et al. 1985; Scoppettone et al. 1986). For this study, I had 19 year classes representing 28 ages. This enabled me to develop composite growth curves by plotting ascribed age against fork length. I used least-squares regression to find the equations that best fit the data, and quasi-Newton minimization to find the coefficients (Winer 1971). Separate curves were developed for males and females. Sex could not be readily determined for fish less than 6 years of age so I used the same group of juveniles for the female and male curves. I achieved the best fit by combining two separate curves for each sex—the first to fit the first growth period (0–10 years) and the second to fit the two remaining growth periods (>10 years).

To examine the longevity of other western North American catostomids and cyprinids, I aged opercula (Casselman 1974) of 15 species of fish that were obtained from museums, collected by me, or donated by various persons.

Results

Age Validation

Age validation of the two year classes of cui-ui (1969 and 1950) identified and followed by Scoppettone et al. (1986) was extended to span 8 years (1978–1986). In the first collection, made in spring 1978, only four year classes occurred. Of these, most were from the 1969 and 1950 year classes and thus were 9 and 28 years old, respectively (Figure 1). The next collection was made in spring 1982, and was again represented only by the 1969 and 1950 year classes, which were then 13 and 32 years old, respectively. By 1986, the 1969 and 1950 year classes were 17 and 36 years old, respectively, proving that ages up to 36 years were valid. In 1986, an increased number of year classes entered the spawning migration and the dominance of the 1969 year class dropped to 70% from more than 85% in the four preceding years. Fish of the 1950 year class made up less than 5% of the fish that died during the upstream migrations in 1982–1986.

Hidden and False Annuli

Correct aging by the opercle method requires determining the number of annuli hidden (covered by support bone) immediately ventrad of the hyomandibular socket. In cui-ui, the number of hidden annuli (0–3) was a function of age and of opercle size and shape. Generally no annuli were hidden in fish less than 6 years old; one was hidden in most 6-year-olds (Figure 2). Among fish older than 6 years, more annuli were in females than in males (Figure 2). For example, among 9-year-olds, two annuli were hidden in about 50% of the females but in only 20% of the males. ("Aberrant" percentages of hidden annuli for 11- and 12-year-old females probably are due to small sample sizes.)

The few false annuli encountered occurred only in the first 6 years of life, and appeared to form in late summer or early fall. They were generally peculiar to a given year class, such as the 1950 year class, and served as a secondary means of cohort identification (Scoppettone et al. 1986).

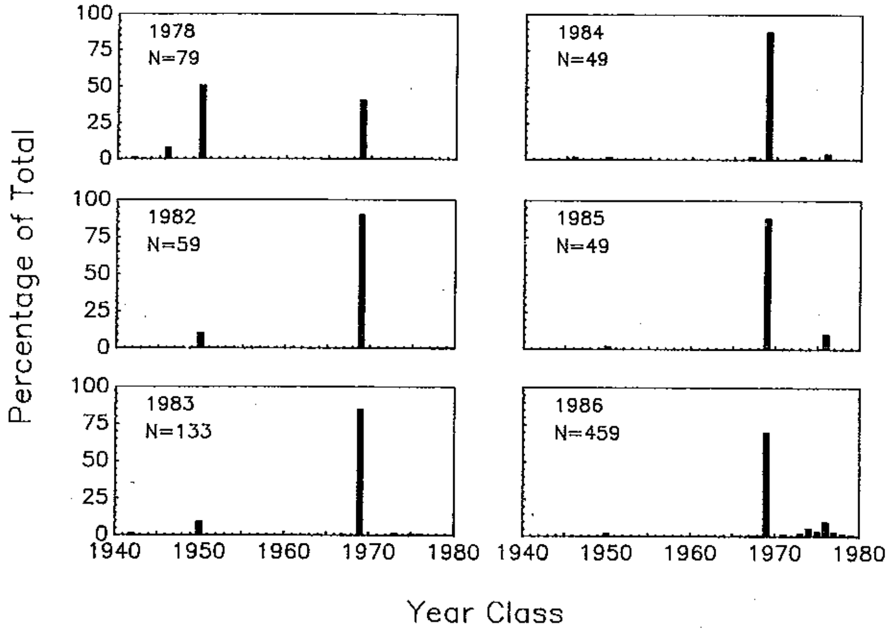

FIGURE 1.—Year-class structure of cui-uis gill netted from the 1978 prespawning aggregation in Pyramid Lake, Nevada, and collected dead during the 1982–1986 spawning migrations.

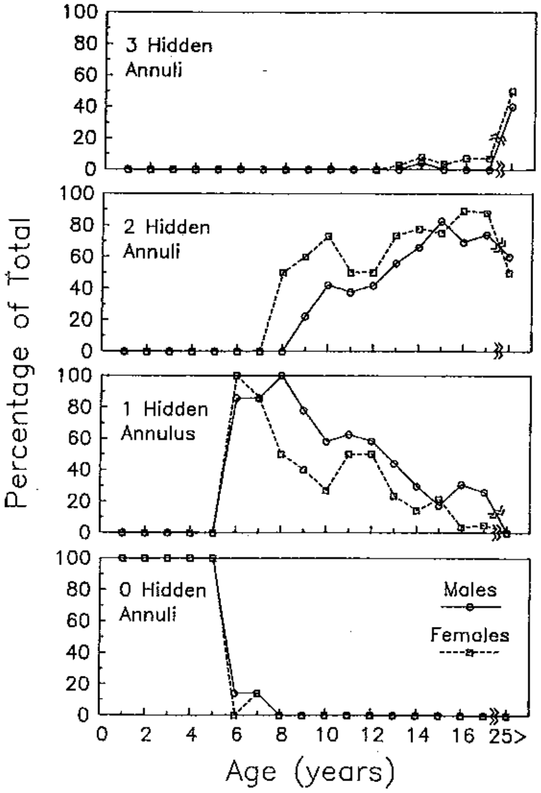

FIGURE 2.—Percent of cui-uis with 0–3 hidden annuli by age for males and females in Pyramid Lake, Nevada, 1978 and 1982–1986.

Opercular versus Scale Ages

Scales "annuli" account for only a fraction of the actual age of older cui-uis. For example, our oldest opercular-aged fish was 41 but was aged as 11 from scales (Figure 3). Scales became unreliable for aging about the time when fish became sexually mature. The youngest cui-uis in the spawning run were 6 years old, but there was evidence that some fish spawned for the first time at 9 or 10 years of age and some as late as 12 years. Among older fish (≥28 years), the age determined from scales ranged from 7 to 12 years—about the age at which cui-uis begin to reproduce.

Growth

The relative spacing of opercular annuli indicated that most older cui-uis had three distinct growth periods. Growth was rapid during the first 9–10 years of life, slower at ages 11–20, and very slow or virtually nil thereafter (Figure 4).

The capture of many juveniles in the mid-1980s and the additional collections of adults made available fish of 28 ages between 1 and 41 years by 1986, including a complete annual series from ages 1 to 17. From these, I developed separate growth curves for males and females (Figure 5). Because of gaps in the age series, I was unable to develop separate curves for both of the latter two growth periods.

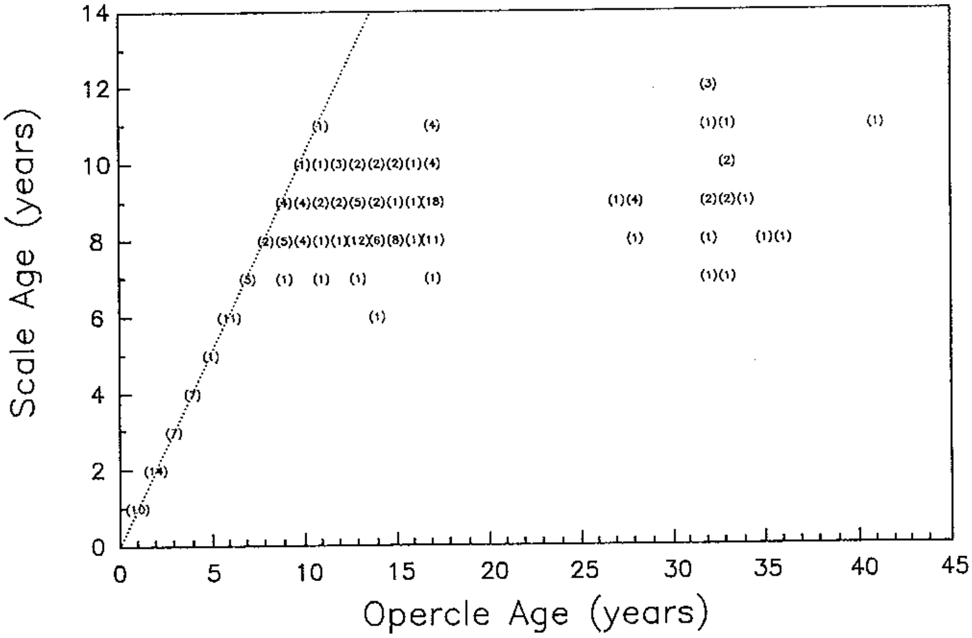

FIGURE 3.—Opercle age versus scale age for 174 cui-uis (numbers of fish are in parentheses).

Curves for both sexes were steepest for 0–10-year-old fish, and much flatter for older fish (especially for males). Curves were similar to those developed by Scoppettone et al. (1986) by back-calculation from opercular measurements. Variation between the two curve sets may be partly due to differences in the sample base: 2 year classes (1969 and 1950) for the earlier study, 19 for the present one. The correlation between age and growth rate was high for the first 10 years of life ($r = 0.988$ for females and 0.989 for males), but declined thereafter (to 0.626 for females and to 0.426 for males—perhaps partly because the sample size for older males was relatively small).

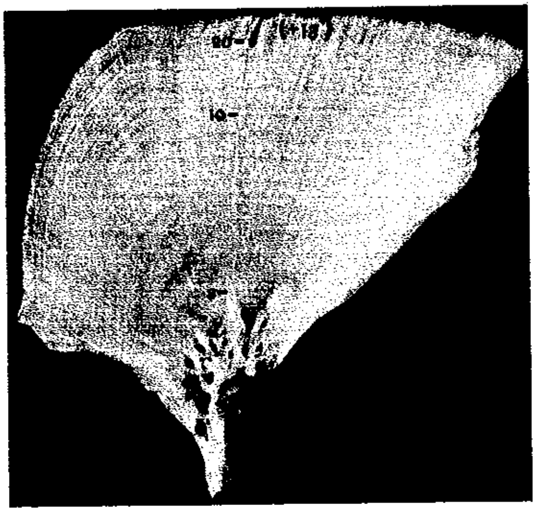

FIGURE 4.—Operculum from a 33-year-old cui-ui, showing three growth periods. The numbers 3, 10, and 20 are numbered annuli. The +13 represents 13 years beyond the 20th annulus.

Other Species

Examination of opercle bones suggested long life spans for other catostomids and cyprinids in the western USA (Table 1). Among fish I examined, catostomids were the longest-lived; a specimen of Lost River sucker was oldest (43 years), and a June sucker (42 years) and a cui-ui (41 years) were next oldest. The oldest cyprinid was a tui chub from Eagle Lake, California (32 years); the second oldest was a Colorado squawfish from the Colorado River (26 years).

Discussion

Two predominant year classes (1969 and 1950), separated by 18 years of virtually no recruitment and followed by a decade (1970s) of weak year classes, presented an unusual opportunity to validate annuli formation in cui-ui opercula. The disproportionate recruitment success is attributed to water diversion and the inability of cui-uis to reach spawning habitats in the Truckee River during

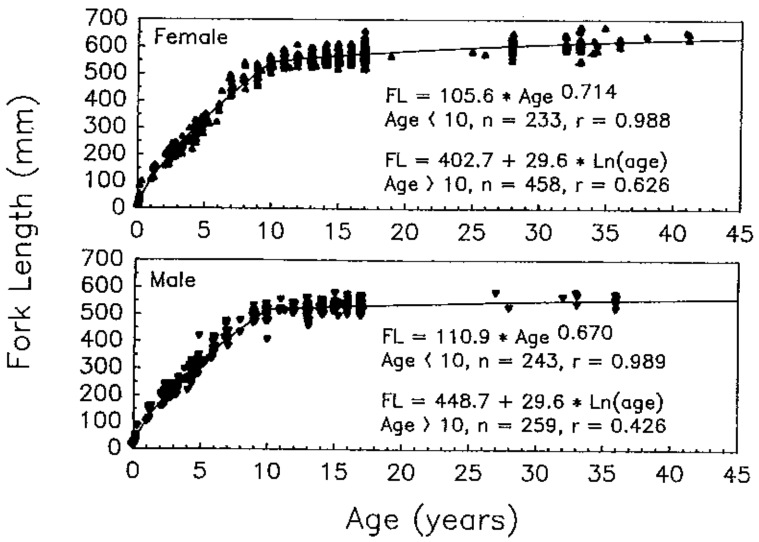

FIGURE 5.—Relationship of age to fork length for male and female cui-uis. Asterisks (*) in the equations denote multiplication; Ln denotes $\log_e$; n is sample size.

TABLE 1.—Maximum age and collection locality for 16 species of cyprinids and catostomids in the western USA.

Species	Number of fish	Length (mm) of oldest fish[a]	Maximum age (years)	Locality
		Cyprinidae		
Tui chub				
Gila bicolor	25	360 SL	32	Eagle Lake, California
Blue chub				
Gila coerulea	10	342 FL	17	Upper Klamath Lake, Oregon
Sacramento squawfish				
Ptychocheilus grandis	2	662 SL	16	Russian River, California
Colorado squawfish				
Ptychocheilus lucius	3	765 FL	26	Colorado River, Colorado
		Catostomidae		
Bluehead sucker				
Catostomus discobolus	61	396 FL	20	Green River, Utah
Flannelmouth sucker				
Catostomus latipinnis	30	530 FL	28	Green River, Utah
Lost River sucker				
Catostomus luxatus	194	743 FL	43	Upper Klamath Lake, Oregon
Largescale sucker				
Catostomus macrocheilus	6	476 FL	22	Lower Granite Reservoir, Washington
Sacramento sucker				
Catostomus occidentalis	28	560 FL	30	Crystal Springs, California
Klamath smallscale sucker				
Catostomus rimiculus	5	455 FL	15	Copco Reservoir California
Klamath largescale sucker				
Catostomus snyderi	21	461 FL	31	Upper Klamath Lake, Oregon
Tahoe sucker				
Catostomus tahoensis	195	572 FL	27	Pyramid Lake, Nevada
Shortnose sucker				
Chasmistes brevirostris	29	485 FL	33	Copco Reservoir, California
Cui-ui				
Chasmistes cujus	858	648 FL	41	Pyramid Lake, Nevada
June sucker				
Chasmistes liorus	20	522 FL	42	Utah Lake,Utah

[a] FL = fork length; SL = standard length.

most years (La Rivers 1962). Recruitment had been so infrequent or low that no juveniles less than 350 mm fork length had been captured between 1939 and 1981. After several high-water years in the 1980s, juveniles became relatively numerous and were readily captured (Scoppettone et al. 1986). From these and the two predominant year classes collected over six different years, along with several weak year classes from the 1970s, I was able to develop growth curves for both sexes by plotting age against fork length. In contrast, Scoppettone et al. (1986) had few age-groups to work with, and thus back-calculated growth rates from the opercle bone.

Ages of other species examined (Table 1) far surpass the longevities previously ascribed to these species. For example, my maximum age for tui chub is greater by a factor of 6 than the one reported by Moyle (1976). Judged by their opercula, these long-lived cyprinids and catostomids have growth curves similar to those of the cui-ui. There appears to be some point late in life at which growth virtually stops; such cessation of growth in fishes may be a source of age bias (Beamish and McFarlane 1987). Some 16-year-old cui-uis in my study, aged 9 or 10 by the scale method, were as large as or larger than others that were over 30 years old. The only consistent external age-related difference among cui-uis is the large head size of older fish (Scoppettone et al. 1986). The growth curve (Figure 5) showed continual growth with increasing age, but the data set was incomplete. If each of the three growth periods could have been fitted separately, there might be no correlation between age and growth in the third growth period, and the curve would be similar to that projected by Scoppettone et al. (1986)—a virtually straight line after 20 years of life. Similarly, lake whitefish *Coregonus clupeaformis* and sablefish *Anoplopoma fimbria* virtually stop growing in their latter years (Power 1978; Beamish and McFarlane 1987).

These findings of widespread longevity among western North American suckers and minnows means that perceptions of their life history patterns, and management of their populations, will be greatly altered. For example, the cui-ui was previously believed to be relatively short-lived (Koch 1972), and juveniles were reported to disappear mysteriously (Johnson 1958). In actuality, the species withstood an 18-year interval without successful recruitment to the population. Young cui-uis did not mysteriously disappear; in many years they simply did not exist. Similarly, the razorback sucker was thought to be a short-lived species that maintained a reproducing population in Lake Mohave along the lower Colorado River. It has recently been demonstrated that virtually no successful recruitment had occurred for 30 years, and that the population comprises old fish (Minckley 1983; McCarthy and Minckley 1987). The findings in my study indicate that many other North American catostomids and cyprinids are long-lived. Beamish and McFarlane (1983) suggested that misaging of long-lived fishes may have led to species mismanagement. This paper is intended to help avert this situation for North American catostomids and cyprinids.

Acknowledgments

The Pyramid Lake Fishery staff provided many of the juveniles and adult cui-uis. Other species were donated by Don Anglin, Craig Bienz, David Bennett, Gary Lee Johnson, Peter Moyle, Randy D. Radant, Mike Sevon, Jerry Smith, Thomas L. Taylor, Mark Warren, Russ Wickwire, Jeffery Ziller, and the California Academy of Sciences. I thank Peter Moyle and Jerry Smith for reviewing the manuscript and Mark Coleman for help with the scale reading.

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Received July 9, 1987