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ESTIMATING AGES OF UTAH CHUBS BY USE OF PECTORAL FIN RAYS, OTOLITHS, AND SCALES

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ABSTRACT.—Utah chub *Gila atraria* is native to the Upper Snake River system in Wyoming and Idaho and to the Lake Bonneville Basin in Utah and southeastern Idaho. However, the Utah chub has been introduced into many other waterbodies in the western United States, where it competes with ecologically and economically important species. The objectives of this study were to evaluate between-reader precision and reader confidence in age estimates obtained from pectoral fin rays, lapilli (otoliths), asterisci (otoliths), and scales for Utah chubs collected from Henrys Lake, Idaho. Lapilli have been previously shown to provide accurate age estimates for Utah chubs; therefore, we sought to compare age estimates from fin rays, asterisci, and scales to those from lapilli. The between-reader coefficient of variation (CV) in age estimates was lowest and the percent of exact reader agreement (PA-0) was highest for pectoral fin rays (CV = 4.7, PA-0 = 74%), followed by scales (CV = 10.3, PA-0 = 52.3%), lapilli (CV = 11.6, PA-0 = 48.2%), and asterisci (CV = 13.0, PA-0 = 41.7%). Consensus age estimates from pectoral fin rays showed high concordance with consensus age estimates from lapilli. Our results indicate that pectoral fin rays provide the most precise age estimates for Utah chub. Pectoral fin rays are easily collected and processed and also provide age estimates without requiring fish sacrifice.

RESUMEN.—El pez bagre de Utah (*Gila atraria*) es nativo del sistema superior del río Snake en Wyoming e Idaho, y de la cuenca del lago Bonneville en Utah y del sureste de Idaho. Sin embargo, el pez bagre de Utah se ha introducido en muchas otros cuerpos de agua en el oeste de Estados Unidos, donde compite con especies de importancia ecológica y económica. Los objetivos de este estudio fueron evaluar la precisión entre lectores y la confianza entre las distintas formas de estimar la edad de los bagres de Utah colectados en Henrys Lake, Idaho. Estas estimaciones pueden ser obtenidas a través de los rayos de las aletas pectorales, los otolitos de lapilli, los otolitos asteriscos y las escamas. Se ha mostrado que los otolitos de lapilli proporcionan estimaciones exactas de la edad de los bagres de Utah; por lo tanto, también se buscó comparar las estimaciones de edad de los rayos de la aleta, los otolitos asteriscos y las escamas de los otolitos de lapilli. El coeficiente de variación entre lectores (CV) en las estimaciones de edad fue el más bajo y el porcentaje de congruencia entre lectores (PA-0) fue mayor en los rayos de las aletas pectorales (CV = 4.7; PA-0 = 74%), seguido por las escamas (CV = 10.3; PA-0 = 52.3%), los otolitos de lapilli (CV = 11.6; PA-0 = 48.2%) y otolitos asteriscos (CV = 13.0; PA-0 = 41.7%). Las estimaciones de edad por medio de los rayos de la aleta pectoral mostraron alta concordancia con las estimaciones de edad de los otolitos de lapilli. Nuestros resultados indican que los rayos de la aleta pectoral proporcionan las estimaciones de edad más precisas de los bagres de Utah. Los rayos de las aletas pectorales también proporcionan estimaciones de edad sin requerir el sacrificio de peces y son fácilmente colectados y procesados.

Utah chub *Gila atraria* is native to the Upper Snake River system of Wyoming and Idaho and to the Lake Bonneville Basin in Utah and southeastern Idaho (Page and Burr 1991). However, Utah chub has been introduced to many other waterbodies throughout the western United States. This species is often considered a nuisance as it is not sought by anglers (Graham 1961). In addition, Utah chub populations often reach high densities and compete with native fishes, some of which are important sport fishes like cutthroat trout *Oncorhynchus clarkii* and rainbow trout *O. mykiss* (Sigler and Miller 1963, Winters and Budy 2015). Thus, understanding the dynamics of Utah chub populations is essential to making well-informed management decisions.

Age and growth data provide biologists with the information needed to understand dynamic rate functions (i.e., mortality, growth, recruitment), which are used to inform management decisions (Ricker 1975). Examination of hard structures (i.e., otoliths, fin rays, and scales) is the most common technique for estimating age of fishes, and obtaining reliable age estimates is dependent on the selection of the best structure (Quist et al. 2012). A number of factors should be considered when selecting the most appropriate hard structure for estimating ages of fish. First and foremost

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is whether a particular structure has been validated (i.e., accuracy) and whether the structure provides precise age estimates (e.g., between- and within-reader precision). Other characteristics to consider include ease of collection and processing and whether or not fish can be sacrificed. Precision in age estimates from lapilli (otoliths) and other hard structures from Utah chubs is unknown. Thus, the objectives of this study were to evaluate between-reader precision and reader confidence in age estimates obtained from pectoral fin rays, lapilli, asterisci (otoliths), and scales for Utah chubs collected from Henrys Lake, Idaho. Annulus formation in the lapillus otolith has been validated for Utah chub (Johnson and Belk 2004), but examining the lapillus requires sacrificing the fish, performing the difficult otolith removal procedure, and spending extensive processing time in the laboratory. Therefore, we sought to compare age estimates from fin rays, asterisci, and scales to those from lapilli to determine which structure provides the most precise age estimation for Utah chub.

METHODS

This study was conducted using Utah chubs sampled from Henrys Lake. Utah chubs were illegally introduced into Henrys Lake and were first sampled in 1993 (Gamblin et al. 2001). Since that time, they have increased in abundance. Henrys Lake is located in northern Fremont County in east central Idaho, approximately 29 km west of Yellowstone National Park. A dam was constructed in 1924 on Henrys Lake to increase storage capacity for downstream irrigation. The dam increased the total surface area of the lake to 2630 ha, with a mean depth of 4 m. The lake is approximately 6.4 km long and 3.2 km wide. The outlet of Henrys Lake joins Big Springs Creek to form the headwaters of Henrys Fork of the Snake River (Schoby et al. 2013). The lake supports one of western North America's premier trophy fisheries for Yellowstone cutthroat trout *Oncorhynchus clarkii bouvieri* and hybrid trout (Yellowstone cutthroat trout *O. c. bouvieri* × rainbow trout *O. mykiss*), along with a popular fishery for brook trout *Salvelinus fontinalis.*

Utah chubs were collected from Henrys Lake in September and October of 2014 using 6 experimental gill nets (46 m long × 2 m deep; panels of 2-cm, 2.5-cm, 3-cm, 4-cm, 5-cm, and 6-cm bar-measure mesh). Nets were set at dusk and fished overnight. All fish were measured to the nearest millimeter (total length), assigned an identification number, and frozen for later processing. Lapilli, asterisci, pectoral fin rays, and scales were removed from each individual approximately 3 weeks after sampling. Otoliths were removed, cleaned of tissue, and placed in microcentrifuge tubes to dry. The left leading pectoral fin ray was removed from each individual by cutting as close to the pelvic girdle as possible, following methods of Koch et al. (2008). Approximately 10–15 scales were removed from the area immediately posterior to the pectoral fin on the left side of each individual. Fin rays and scales were placed into paper coin envelopes and allowed to air dry before further processing.

After drying, fin rays and otoliths were embedded in epoxy following Koch and Quist (2007). A thin section (approximately 0.3 mm thick) was cut from the base of the pectoral fin ray with a low-speed saw (Buehler Inc., Lake Bluff, IL). Thin transverse sections (approximately 0.2 mm thick) that included the nucleus were cut from each otolith. Sections were polished and viewed by using a dissecting microscope under transmitted light and then evaluated with an image analysis system (Image-Pro Plus, Media Cybernetics, Rockville, MD). At least 8 scales from each fish were placed onto acetate slides and pressed using a roller press. Acetate slides with scale impressions were then read using a microfiche reader.

Presumptive annuli on each structure were enumerated independently by 2 readers. Reader 1 had extensive experience using hard structures to estimate ages of fishes. Reader 2 was relatively inexperienced, but received training prior to this study. Readers were not informed of fish lengths and prior age estimates. After both readers had assigned a presumptive age estimate to each structure, estimates were compared. Estimates differing between readers were reexamined and a consensus age was assigned. If a consensus age was not reached, the structure was removed from further analyses. Readers also assigned a confidence rating to their age estimate for

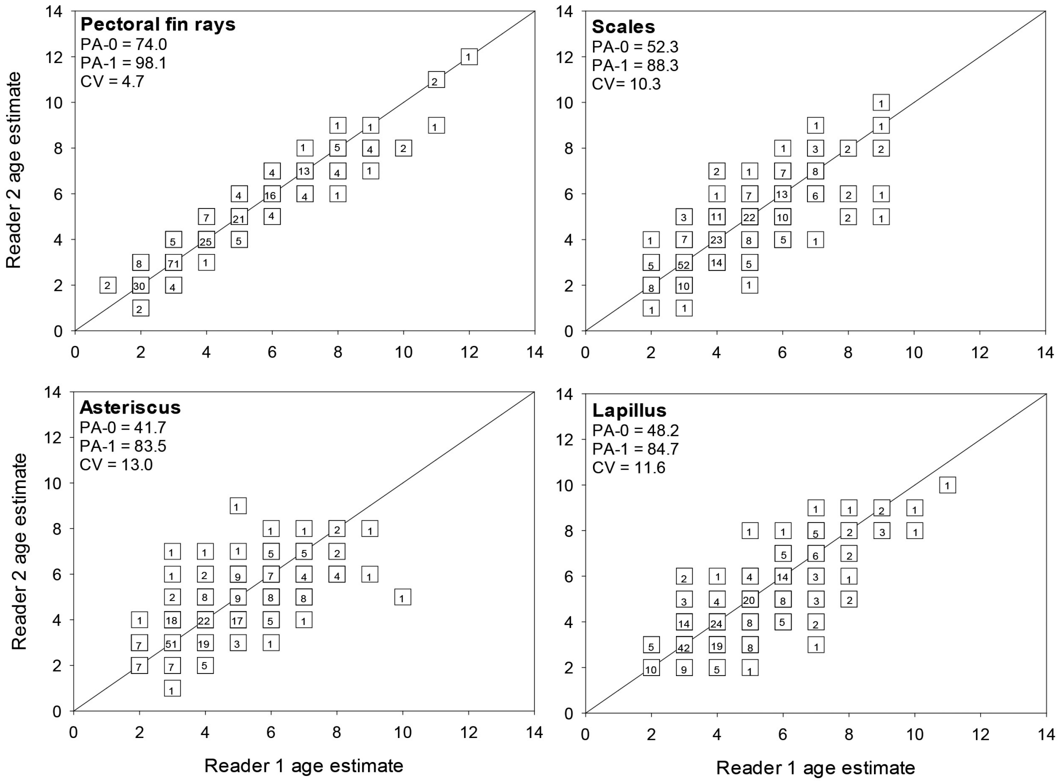

Fig. 1. Age-bias plots for ages (years) assigned to pectoral fin rays, scales, lapilli (otoliths), and asterisci (otoliths) from Utah Chub sampled from Henry's Lake, Idaho, in 2014. Precision between readers is indicated as percent exact agreement (PA-0), percent agreement within 1 year (PA-1), and mean coefficient of variation (CV). Numbers within boxes correspond to the number of observations at each point. The solid line represents the 1:1 relationship.

each structure as a measure of readability (Fitzgerald et al. 1997, Koch et al. 2008, Spiegel et al. 2010). Confidence ratings were integers between 0 (no confidence) and 3 (complete confidence) as described in Spiegel et al. (2010).

Consensus ages for all structures were plotted against one another and linear regressions were used to determine relationships among age estimates. Plots were constructed to evaluate and compare precision between structures and readers. Percent exact reader agreement and percent agreement within 1 year were calculated for all structures. The coefficient of variation (CV = [standard deviation/mean] × 100) was calculated and used as another measure of precision (Campana et al. 1995). The CV was estimated for each individual fish and structure and then averaged across fish to provide an estimate of between-reader precision by structure.

RESULTS

In total, 258 Utah chubs were sampled. Of the 258 fish sampled, pectoral fin rays were collected from all fish, scales from 256 individuals, lapilli from 255 individuals, and asterisci from 254 individuals. Fish varied in length from 138 mm to 332 mm ($\bar{x}$ = 222 mm, SD 43). Consensus age estimates varied from 1 to 12 years for pectoral fin rays, 2 to 10 years for scales, 2 to 11 years for lapilli, and 2 to 10 years for asterisci.

Percent exact agreement was highest for pectoral fin rays and lowest for asterisci (Fig. 1). Percent exact agreement was 74% for pectoral fin rays, 52% for scales, 48% for lapilli, and 41% for asterisci. Percent agreement within 1 year (PA-1) was highest for pectoral fin rays (PA-1 = 98.1%), followed by scales (PA-1 = 88.3%), lapilli (PA-1 = 84.7%), and asterisci (PA-1 = 83.5%). Between-reader coefficient of

TABLE 1. Percent confidence ratings for reader 1 and reader 2 for pectoral fin rays, scales, lapilli (otoliths), and asterisci (otoliths) from Utah chubs collected from Henrys Lake, Idaho, in 2014. The number of fish with each rating is provided in parentheses.

	Confidence rating			
Structure/reader	0	1	2	3
Fin rays				
Reader 1	0 (0)	9 (22)	67 (173)	24 (63)
Reader 2	0 (0)	3 (8)	59 (152)	38 (98)
Scales				
Reader 1	0 (1)	43 (110)	54 (137)	3 (8)
Reader 2	0 (0)	67 (172)	32 (83)	0 (0)
Lapilli				
Reader 1	11 (29)	43 (109)	41 (105)	4 (11)
Reader 2	18 (45)	66 (169)	16 (41)	0 (0)
Asterisci				
Reader 1	18 (45)	74 (189)	8 (19)	0 (0)
Reader 2	63 (159)	35 (90)	2 (5)	0 (0)

variation (CV) was lowest for pectoral fin rays (CV = 4.7), followed by scales (CV = 10.3), lapilli (CV = 11.6), and asterisci (CV = 13.0). Readers were most confident in age estimates from pectoral fin rays and were least confident in age estimates from asterisci (Table 1). Mean reader confidence was 2.3 (SE 0.1) for pectoral fin rays, 1.5 (SE 0.1) for scales, 1.2 (SE 0.2) for lapilli, and 0.7 (SE 0.3) for asterisci.

The between-reader CV was lowest for pectoral fin rays and highest for asterisci and lapilli (Fig. 1). Concordance was high between readers for age estimates from pectoral fin rays. Consensus age estimates from pectoral fin rays showed high concordance with consensus age estimates from lapilli (Fig. 2). In comparison to lapilli, scales and asterisci overestimated age for younger ages and underestimated age for older ages.

DISCUSSION

Natural resource agencies are often interested in controlling introduced Utah Chub populations. As such, understanding the population rate functions of Utah chub is critical for evaluating options and making management decisions. Otoliths are generally considered the most accurate hard structure for estimating age for many species, but the accuracy of each hard structure can vary across species

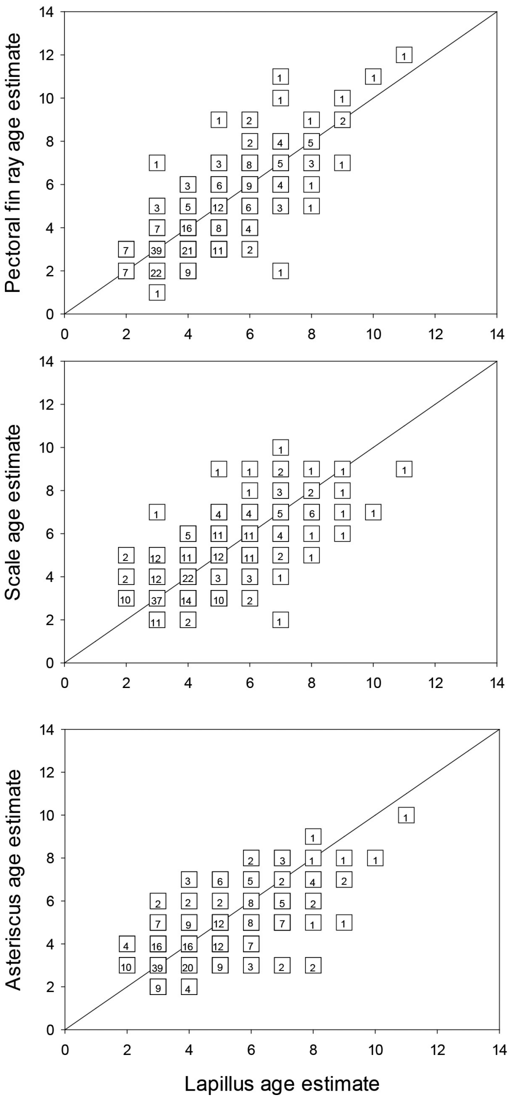

Fig. 2 (left column). Age-bias plots for consensus ages (years) assigned to pectoral fin rays, scales, and asterisci (otoliths). Numbers within boxes correspond to the number of observations at each point. The solid line represents the 1:1 relationship.

and geographic region (Quist et al. 2012). Although lapilli have been shown to provide accurate age estimates for Utah chubs (Johnson and Belk 2004), age estimates from other calcified structures have not been previously evaluated with regard to precision and concordance with lapilli.

Scales are commonly used to estimate fish ages, as they are quick and inexpensive to process and do not require sacrificing fish (Quist et al. 2012). Many studies have evaluated the accuracy and precision of scales (e.g., Boxrucker 1986, Kruse et al. 1993, Long and Fisher 2001). However, the accuracy and precision of age estimates from scales vary among species, and most studies have shown that scales provide inaccurate age estimates, particularly for older individuals and in populations with slow-growing individuals (e.g., Schramm and Doerzbacher 1985, Marwitz and Hubert 1995, Isermann et al. 2003). In our study, ages assigned to scales overestimated the ages of young fish and underestimated the ages of older fish in comparison to ages assigned to lapilli. Moreover, readers had low confidence in ages assigned to scales. This was often due to the presence of false and indistinct annuli.

Fin rays also provide a nonlethal alternative to use of otoliths. Much like the results from other hard structures, the accuracy and precision of age estimates from fin rays vary among taxa and systems. For instance, age estimates assigned to fin rays collected from pallid sturgeon *Scaphirhynchus albus* were inaccurate and imprecise (Hurley et al. 2004). In contrast, fin rays from Chinook salmon *Oncorhynchus tshawytscha* provided accurate and unbiased estimates of age (Copeland et al. 2007). Quist et al. (2007) found that fin rays collected from 5 species of catostomids and cyprinids in the upper Colorado River Basin of Wyoming provided age estimates nearly identical to those obtained from otoliths. Dorsal fin spines and pectoral fin rays have shown the highest precision between readers and the least amount of variation when estimating age of common carp *Cyprinus carpio* (Yates et al. 2016).

In our study, readers were least confident in ages assigned to asterisci. Both lapilli and asterisci had high CVs and low agreement between readers. Distinct annuli were often difficult to see in both otolith types, and various attempts were made to improve the clarity of the otoliths (immersion oil, polishing of the sections, lighting adjustments). Despite these attempts, lapilli and asterisci remained difficult to read. Asterisci and lapilli were also difficult to collect from fish and required the longest processing time. Processing methods for pectoral fin rays were similar to those for otoliths, but pectoral fin ray sections required little additional effort to improve clarity and were the easiest to read.

Our results suggest that pectoral fin rays provide the most precise age estimates for Utah chub. Pectoral fin rays had the highest exact reader agreement, the greatest agreement within 1 year, the lowest CV, and the highest confidence ratings of all the structures compared in this study. Age estimates obtained from pectoral fin rays were concordant with those from the lapillus otolith but were more precise. Pectoral fin rays were also the easiest structure to collect, process, and read, and they do not require sacrificing fish.

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LITERATURE CITED

BOXRUCKER, J. 1986. A comparison of the otolith and scale methods for aging white crappies in Oklahoma. North American Journal of Fisheries Management 6:122–125.

CAMPANA, S.E., M.C. ANNAND, AND J.I. MCMILLAN. 1995. Graphical and statistical methods for determining the consistency of age determinations. Transactions of the American Fisheries Society 124:131–138.

COPELAND, T., M.W. HYATT, AND J. JOHNSON. 2007. Comparison of methods used to age spring–summer chinook salmon in Idaho: validation and simulated effects on estimated age composition. North American Journal of Fisheries Management 27:1393–1401.

FITZGERALD, T.J., T.L. MARGENAU, AND F.A. COPES. 1997. Muskellunge scale interpretation: the question of aging accuracy. North American Journal of Fisheries Management 17:206–209.

GAMBLIN, M., T.J. HERRON, B.A. RICH, AND W.C. SCHRADER. 2001. Regional Fisheries Management Investigations Upper Snake Region. Report No. 02-44, Idaho Department of Fish and Game, Boise, ID.

GRAHAM, R.J. 1961. Biology of the Utah chub in Hebgen Lake, Montana. Transactions of the American Fisheries Society 90:269–276.

HURLEY, K.L., R.J. SHEEHAN, AND R.C. HEIDINGER. 2004. Accuracy and precision of age estimates for pallid sturgeon from pectoral fin rays. North American Journal of Fisheries Management 24:715–718.

ISERMANN, D.A., J.R. MEERBEEK, G.D. SCHOLTEN, AND D.W. WILLIS. 2003. Evaluation of three different structures used for walleye age estimation with emphasis on removal and processing times. North American Journal of Fisheries Management 23:625–631.

JOHNSON, J.B., AND M.C. BELK. 2004. Temperate Utah chub form valid otolith annuli in the absence of fluctuating temperature. Journal of Fish Biology 65: 293–298.

KOCH, J.D., AND M.C. QUIST. 2007. A technique for preparing fin rays and spines for age and growth analysis. North American Journal of Fisheries Management 27:782–784.

KOCH, J.D., W.J. SCHRECK, AND M.C. QUIST. 2008. Standardized removal and sectioning locations for shovelnose sturgeon fin rays. Fisheries Management and Ecology 15:139–145.

KRUSE, C.G., C.S. GUY, AND D.W. WILLIS. 1993. Comparison of otolith and scale age characteristics for black crappies collected from South Dakota waters. North American Journal of Fisheries Management 13:856–858.

LONG, J.M., AND W.L. FISHER. 2001. Precision and bias of largemouth, smallmouth, and spotted bass ages estimated from scales, whole otoliths, and sectioned otoliths. North American Journal of Fisheries Management 21:636–645.

MARWITZ, T.D., AND W.A. HUBERT. 1995. Precision of age estimates from different calcified structures. Prairie Naturalist 27:41–49.

PAGE, L.M., AND B.M. BURR. 1991. A field guide to freshwater fishes of North America north of Mexico. Houghton Mifflin, Boston, MA.

QUIST, M.C., Z.J. JACKSON, M.R. BOWER, AND W.A. HUBERT. 2007. Precision of hard structures used to estimate age of riverine catostomids and cyprinids in the Upper Colorado River basin. North American Journal of Fisheries Management 27:643–649.

QUIST, M.C., M.A. PEGG, AND D.R. DEVRIES. 2012. Age and growth. Pages 677–731 *in* A.V. Zale, D.L. Parrish, and T.M. Sutton, editors, Fisheries techniques. 3rd edition. American Fisheries Society, Bethesda, MD.

RICKER, W.L. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada Bulletin, Ottawa.

SCHOBY, G., B. HIGH, J. FRY, AND D. GARREN 2013. Fishery Management Annual Report, Upper Snake Region 2011. Report No. 13-117, Idaho Department of Fish and Game, Boise, ID.

SCHRAMM, H.L., JR., AND J.F. DOERZBACHER. 1985. Use of otoliths to age black crappie from Florida. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 36:95–105.

SIGLER, W.F., AND R.R. MILLER. 1963. Fishes of Utah. Utah Department of Game and Fish, Salt Lake City, UT.

SPIEGEL, J.R., M.C. QUIST, AND J.E. MORRIS. 2010. Precision of scales and pectoral fin rays for estimating age of highfin carpsucker, quillback carpsucker and river carpsucker. Journal of Freshwater Ecology 25:271–278.

WINTERS, L.K., AND P. BUDY. 2015. Exploring crowded trophic niche space in a novel reservoir fish assemblage: how many is too many? Transactions of the American Fisheries Society 144:1117–1128.

YATES, J.R., C.J. WATKINS, AND M.C. QUIST. 2016. Evaluation of hard structures used to estimate the age of common carp. Northwest Science 90:195–205.

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