Precision of Scales and Pectoral Fin Rays for Estimating Age of Highfin Carpsucker, Quillback Carpsucker, and River Carpsucker

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ABSTRACT

We examined between-reader precision of age estimates of scales and pectoral fin rays for 123 highfin carpsuckers (*Carpiodes velifer*), 174 quillback carpsuckers (*C. cyprinus*), and 135 river carpsuckers (*C. carpio*). Precision of age estimates was assessed through measures of agreement, the coefficient of variation (CV), and a confidence rating. Exact agreement between readers was higher for fin rays (highfin carpsucker = 82.1%; quillback carpsucker = 75.9%; river carpsucker = 77.0%) than scales (highfin carpsucker = 69.5%, quillback carpsucker = 68.9%; river carpsucker = 71.1%). In addition, CV was lower for fin rays (highfin carpsucker = 2.28; quillback carpsucker = 2.43; river carpsucker = 2.90) than scales (highfin carpsucker = 2.95; quillback carpsucker = 3.00; river carpsucker = 3.46). Fin rays were also assigned a higher confidence rating (i.e., mean readability, 0-3 with 3 being high; highfin carpsucker = 2.22; quillback carpsucker = 1.95; river carpsucker = 1.92) than scales (highfin carpsucker = 1.53; quillback carpsucker = 1.51; river carpsucker = 1.68).

INTRODUCTION

The highfin carpsucker (*Carpiodes velifer*), quillback carpsucker (*C. cyprinus*), and river carpsucker (*C. carpio*) are native species common throughout central North America. Highfin carpsucker and quillback carpsucker are listed by Kansas and Illinois as species of greatest conservation need (Becker 2005, Wasson et al. 2005). In Iowa, the status of river carpsucker and quillback carpsucker is considered to be stable; however, the status of the highfin carpsucker is unknown (Zohrer 2006).

Throughout their distribution, carpsuckers have experienced the same changes to habitat that have caused 68 of the 144 native fish species of Iowa to be identified as species of greatest conservation need (Zohrer 2006). Increased agricultural land use is typically associated with declines in fish assemblage diversity and biomass (Walser and Bart 1999, Karr et al. 1985), and agriculture has altered over 80% of the land in Iowa (Natural Resources Conservation Service 2000). Changes to the watersheds of rivers have been shown to have many affects on fish assemblages caused by changes in habitat (from increased sedimentation), temperature (from the removal of stream side vegetation), the macroinvertebrate community, and egg and larval fish survival (Morgan et al. 1983, Cooper 1987, Holopainen and Huttunen 1992). Because *Carpiodes* spp. are typically a major component of lotic fish assemblages, additional information on their population dynamics is needed to better understand the ecology of large river systems.

The ability to obtain precise estimates of age is fundamental to the estimation of dynamic rate functions such as mortality and recruitment. Traditionally, a variety of structures have been used to estimate the age of fishes (i.e., scales, otoliths, dorsal spines, pectoral fin rays, opercles), but the structure that provides the greatest accuracy and precision often varies among species and geographic location (DeVries and Frie 1996, Jackson et al. 2007). Given the importance of age and growth information, determining the best structure for aging should be a high priority.

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The age and growth of river carpsuckers have been studied using scales (Buchholz 1957, Al-Rawi 1965, Morris 1965); however, most studies have reported difficulty in using scales. A more recent study by Bratten et al. (1999) evaluated the use of the second dorsal fin ray as an alternative aging structure. They found that the percentage of exact agreement was only slightly higher for fin rays (71%) than scales (68%), and despite the previous concerns with the use of scales for aging river carpsuckers, the authors concluded that river carpsucker scales should be used for fish less than 400 mm in length and fin rays for fish longer than 400 mm. In contrast to river carpsuckers, aging of highfin carpsuckers and quillback carpsuckers has been largely ignored.

Pectoral fin rays have become an increasingly common structure for estimating the age of fish (Metcalf 2005, Maceina et al. 2007, Quist et al. 2007). Pectoral fin rays can be removed non-lethally, which is particularly important when working with rare or threatened species. The processing time of fin rays is substantially less than that of otoliths (Isermann et al. 2003). Fin rays also provide more precise age estimates than scales for several species such as common carp (*Cyprinus carpio*) and white sucker (*Catostomus commersonii*; Jackson et al. 2007, Quist et al. 2007). In addition, fin rays provide age estimates that are very similar to age estimates from otoliths for a variety of fish species, including Pacific cod (*Gadus macrocephalus*), Atlantic sturgeon (*Acipenser oxyrinchus*), walleye (*Sander vitreus*), rainbow smelt (*Osmerus mordax*), and several catostomid species (Beamish 1981, Stevenson and Secor 1999, Isermann et al. 2003, Quist et al. 2007, Walsh et al. 2008). The objective of this study was to evaluate precision of age estimates from pectoral fin rays and scales for highfin carpsucker, quillback carpsucker, and river carpsucker.

Table 1. Criteria used to assign confidence ratings to scales and fin rays from *Carpiodes* spp. collected from four Iowa rivers, 2009

Confidence rating	Guidelines for assigning confidence ratings
	Scales
0	Disagreement between scales > 2 yrs. Most annuli lack cutting over. Annuli do not exhibit tightly spaced rings. Checks present.
1	Disagreement between scales < 2 yrs. Some annuli exhibit cutting over. Checks present.
2	Diagreement between scales maximum of 1 yr. Cutting over apparent on many annuli.
3	No disagreement between scales. Cutting over present for majority of annuli. Annuli exhibit tightly packed rings and easy to identify.
	Fin rays
0	Focus highly eroded. Most annular rings hard to identify. Wide or double rings apparent. Error may be ≥ 2 yrs.
1	Focus slightly eroded. Checks present. Majority of annulI easily identified but may have double rings. Error likely < 2 yrs.
2	Focus intact. Most annular rings well defined. Minimal checks present. Error within 1 yr.
3	Focus intact. Annular rings well defined.

METHODS

River carpsucker (135), highfin carpsucker (123), and quillback carpsucker (174) were collected by electrofishing from four non-wadeable rivers in Iowa, the Boone, North Raccoon, Shell Rock, and Wapsipinicon. Fish were measured to the nearest mm and weighed to the nearest gram. The left marginal pectoral fin ray was removed by cutting just proximal to the articulation point where the fin ray joined the body wall and then separated from the rest of the fin (Koch et al. 2008). Approximately 10-15 scales were removed from the area just posterior to the insertion of the pectoral fin. Fin rays and scales were placed into paper envelopes and allowed to air dry.

After drying, fin rays were mounted in epoxy using the methods described in Koch and Quist (2007). Fin rays were cut into 1.0 mm sections using a Buehler Isomet low speed saw (Buehler Inc., Lake Bluff, Illinois). Sections were taken from the proximal end of the spine, as this area of the fin ray has been shown to provide the highest quality sections and greatest precision among readers for other fish species (Sneed 1951; Koch and Quist 2008). Sections were evaluated microscopically and aged with the aid of image analysis software. At least eight scales from each fish were pressed onto acetate slides (40 mm wide × 70 mm long × 1 mm thick). Scale impressions were evaluated using a microfiche reader at 44× magnification.

Two readers independently aged the fin rays and scales once. Readers assigned ages to structures without knowledge of age estimates of the other structure or age estimates of the other reader. Precision between readers for scales and fin rays was assessed by plotting the age estimates from reader 1 against the age estimates of reader 2 and by examining the proximity of the mean age with 95% confidence intervals to the equivalence line (Campana et al. 1995). Percentages of exact agreement and agreement within one year were calculated for each structure to evaluate precision of age estimates between-readers. The coefficient of variation (CV) was calculated for each individual fish and aging structure and then averaged to estimate between-reader precision for each structure. A paired *t*-test was used to estimate whether age estimates differed between fin rays and scales (Campana et al. 1995).

In addition to aging the structures, a confidence rating (i.e., readability) was assigned to each age estimated for a structure based on a 0 to 3 scale that was similar to the one used by Fitzgerald et al. (1997) and Koch and Quist (2008). For structures rated 0, the reader had no confidence in the age they assigned, while structures assigned a rating of 3 were considered to exhibit a clear age. Previous uses of confidence ratings have relied on ratings that lack clear criteria, and higher ratings have not always been correlated with increased precision of age estimates (Fitzgerald et al. 1997). To increase the consistency of confidence ratings within and among readers, we developed guiding criteria for the assignment of ratings (Table 1). A *t*-test was used to determine if mean confidence ratings assigned to scales and pectoral fin rays differed. Results from all *t*-tests were considered significant at $\alpha = 0.05$.

RESULTS

Highfin carpsucker varied in total length from 220 to 423 mm, river carpsucker varied from 170 to 441 mm, and quillback carpsucker varied from 187 to 480 mm. Examination of the age bias plots (Fig. 1) indicated that readers did not consistently overestimate or underestimate ages for fin rays and scales collected from the studied species. Precision between readers tended to be low for scales, indicating greater variation in age estimates between readers for scales than for fin rays. Precision of both scales and fin rays decreased as age increased. Exact agreement in age estimates between readers was higher for fin rays than scales for highfin carpsucker (fin ray = 82.1%; scale = 69.5%), quillback carpsucker (fin ray = 75.9%; scale = 68.9%) and river carpsuckers (fin ray = 77.0%; scales = 71.1%; Table 2).

Exact agreement between fin rays and scales was lowest for highfin carpsucker (33.1%), which was the only species that exhibited a significant difference in age between fin rays and scales ($P < 0.0001$; Table 3). Age estimates from scales of highfin carpsuckers were generally one-three years less than those from fin rays. For all of the species, there was no significant difference between the ages assigned to fin rays between the readers. In addition, a high percentage of age estimates between readers for fin rays were within one year. Age estimates within one year between readers was higher for fin rays (highfin

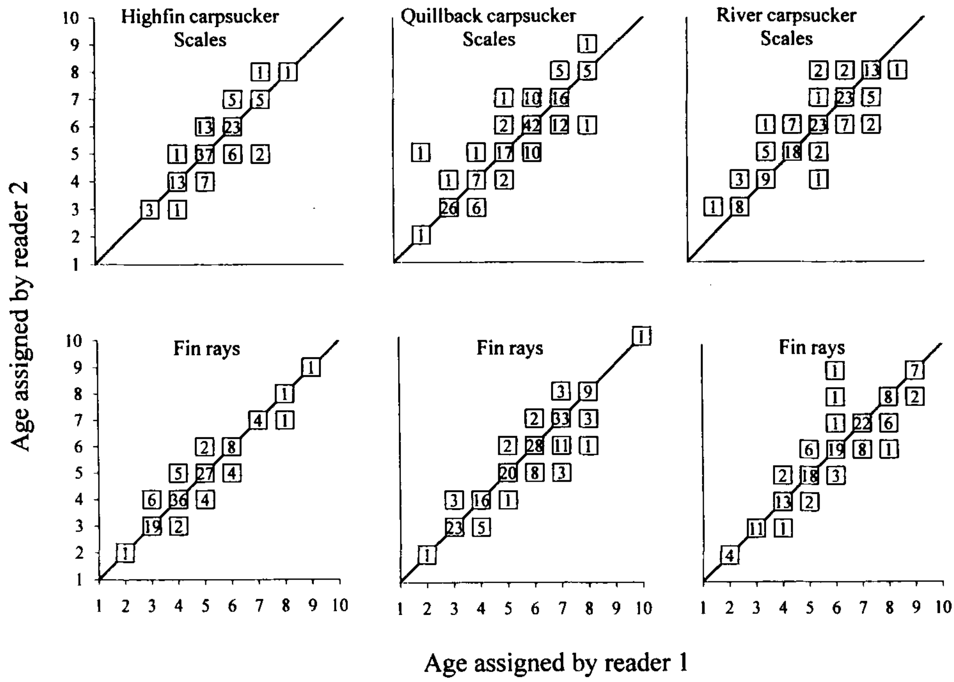

Figure 1. Age bias plots comparing agreement between readers for highfin carpsucker, quillback carpsucker and river carpsucker for pectoral fin rays and scales sampled from Iowa rivers, 2009. Diagonal lines represent exact agreement between readers. Numbers in squares represent the number of fish at each age.

Table 2. Precision in age estimates between two readers for pectoral fin rays and scales obtained from *Carpiodes* spp. collected from Iowa rivers, 2009.

Species Structure	Percentage of exact agreement	Percentage of agreement within 1 yr.	Coefficient of variaton (%)	Mean confidence rating
Highfin carpsucker				
Scale	69.5	93.3	2.95	1.53
Fin ray	82.1	100.0	2.28	2.22
Quillback carpsucker				
Scale	68.9	94.8	3.00	1.51
Fin ray	75.9	97.7	2.43	1.95
River carpsucker				
Scale	71.1	95.5	3.46	1.68
Fin ray	77.0	98.5	2.90	1.92

carpsucker = 100.0%; quillback carpsucker = 97.7%; river carpsucker = 98.5%) than for scales (highfin carpsucker = 93.3%; quillback carpsucker = 94.8%; river carpsucker = 95.5%; Table 3). Fin rays also had a lower mean between reader CV than scales (Table 4). However, within-reader exact agreement between fin rays and scales was less than 50% for all species and both readers (Table 4).

The mean confidence rating was significantly higher for fin rays in all three species ($P < 0.001$; Table 2). Additionally, as confidence rating for a structure increased, between reader agreement also increased (Table 4). For example, exact agreement of fin rays from highfin carpsucker rated 1, 2, and 3 was 61.1, 76.3, and 93.5% respectively. Similarly, percent agreement increased for scales as confidence ratings increased.

Table 3. Within-reader exact agreement (%) of age estimates between scales and fin rays for *Carpiodes* spp. collected from four Iowa rivers, 2009.

	Highfn carpsucker	Quillback carpsucker	River carpsucker
Reader 1	33.1	48.9	43.0
Reader 2	34.7	46.0	43.0

DISCUSSION

Previous attempts at aging *Carpiodes* spp. have primarily focused on the use of scales (Buchholz 1957, Al-Rawi 1965, Morris 1965, Woodward and Wissing 1976). The authors of these studies indicated that obtaining age estimates from scales was often difficult due to a lack of "cutting over" at annulus formation or impossible because the scales were unreadable. In addition, previous studies of aging *Carpiodes* spp. had questionable ages due to the high prevalence of false annuli. Water level fluctuations, changes in water temperature, starvation, and low dissolved oxygen can all cause scales to develop false annuli (Wyel and Booth 1999). The frequent occurrence of false annuli in the scales of carpsuckers may be reflective of the constantly changing environment of river systems. In contrast to scales, calcified structures such as otoliths and fin rays have been shown to be less susceptible to the formation of false annuli during periods of stress (Marshall and Parker 1982, Campana 1983).

Many of the studies that have examined the use of scales for estimating ages have shown that precision in age estimates varies greatly among species. For instance, scales provide precise ages for several centrachid species, including largemouth bass (*Micropterus salmoides*) (Long and Fisher 2001) and bluegills (*Lepomis macrochirus*) (Reiger 1962); however, scales also underestimate the age of fish (Erickson 1983, Isermann et al. 2003). Although the current study cannot evaluate accuracy of age estimates, percentage of agreement between readers for scales (i.e., 65-70%) was similar to values previous reported for river carpsuckers in the Des Moines River (Morris 1965) and in the Missouri River (Bratten et al. 1999). These authors stated that obtaining age estimates from scales was often difficult and that a high percentage of scales (~10%) was unreadable. Both readers in the current study noted that reading scales from many of the fish was difficult and that precision would likely have been less if fewer scale impressions had been made. Often, only one or two out of 8-12 scale impressions were used for age estimation.

Similar to scales, previous research has shown that the accuracy and precision of age estimates from fin rays tend to vary between species. For instance, fin rays did not provide precise or accurate age estimates of pallid sturgeon (*Scaphirhynchus albus*) (Hurley et al. 2004) and white sturgeon (*A. transmontanus*) (Rien and Beamesderfer 1994). However, fin rays had higher precision and more accurate age estimates than otoliths in rainbow smelt (Walsh et al. 2008). Quist et al. (2007) found that age estimates were similar between fin rays and otoliths for bluehead sucker (*Catostomus discobolus*), flannelmouth sucker (*C. latipinnis*), and white sucker (*C. commersonii*). Additionally, the scales of these same catastomid species provided age estimates that were substantially less than those obtained from fin rays and otoliths (Quist et al. 2007). In the current study, pectoral fin rays typically had a higher age estimate than scales. Most importantly, pectoral fin rays had the highest percentage of agreement, highest confidence ratings, and the lowest CVs for all three species.

Although there have been several previous attempts at aging carpsuckers (including the current study), no study has validated the age assignments or growth estimates. Pectoral fin rays provide a more precise estimate of age than scales and would be a good choice for a future validation study. Fin rays also have the added benefit of not requiring the killing of fish in areas where population status is unknown or declining. Based on this research, we recommend that researchers use pectoral fin rays for aging carpsuckers.

Table 4. Number (N) and percentage (%) of between-reader exact agreement at different confidence ratings for scales and pectoral fin rays for *Carpiodes* spp. collected from four Iowa rivers, 2009.

Species	Confidence rating	Scales		Pectoral fin rays	
		N	%	N	%
Highfin carpsucker	0	3	66.6	0	0
	1	54	63.0	18	61.1
	2	54	79.6	59	76.3
	3	7	85.7	46	93.5
Quillback carpsucker	0	10	50.0	1	100
	1	90	60.0	55	65.5
	2	44	72.7	68	77.9
	3	25	96.0	50	88.0
River carpsucker	0	3	33.3	0	0
	1	55	71.0	46	65.2
	2	58	69.0	54	77.8
	3	19	73.6	35	85.7

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