Precision of Scales and Dorsal Spines for Estimating Age of Common Carp

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ABSTRACT

We examined precision in age estimates from common carp (*Cyprinus carpio*) scales and dorsal spines sampled from 28 Iowa lakes (N = 501 individual fish). Exact agreement between two readers was 28.5% for scales and 90.6% for dorsal spines. Agreement of scale ages between readers was poor across the distribution of assigned ages. Agreement of dorsal spine ages increased to 95.8% after a joint examination conducted to assess reasons for disagreements. Age estimates from scales were as much as eight years less and seven years greater than ages estimated from dorsal spines, and discrepancies occurred in young as well as old fish.

INTRODUCTION

The common carp (*Cyprinus carpio*) is an important species throughout much of the world. Common carp is native to Europe where it is a popular sport fish (Panek 1987); however, it has been introduced into systems around the world. While many introduced populations provide some recreational and commercial value, they are generally considered a nuisance due to aquatic habitat destruction and water quality degradation (e.g., increased turbidity, nutrient resuspension, decreased abundance of vegetation; Crivelli 1983, Lougheed et al. 1998, Miller and Crowl 2006). Due to the negative effects of common carp on aquatic systems, increasing effort is being expended in North America to regulate their abundance, generally with the intention of minimizing their impact on water quality and other aquatic organisms (e.g., vegetation, fish, invertebrates, waterfowl). However, information is often needed on common carp age and growth to facilitate successful management of the species.

Age estimation is important for gaining insight into the ecology and management of fishes. Estimates of age are a fundamental component in population assessments and often provide the foundation for estimating other dynamic rate functions (e.g., recruitment, mortality; Ricker 1975, DeVries and Frie 1996, Campana 2001). A variety of structures have been used to estimate age of common carp including scales, sagittae and asteriscus otoliths, opercles, dorsal spines, pectoral fin rays, vertebrae, and even eye lenses, with little agreement between studies on which structures provide the highest accuracy and precision (Carlton and Jackson 1968, Lubinski et al. 1984, Brown et al. 2004, Phelps et al., in press). For example, McConnell (1952) reported that opercles were easier to read and required less processing time than scales. In contrast, Lubinski et al. (1984) found that scales provided more precise age estimates than opercles, dorsal spines, and sagittal otoliths; however, the authors recommended the use of sectioned dorsal spines when scales were unreadable. A recent study examined accuracy and precision of pectoral fin rays, vertebrae, scales, and opercles compared to otoliths and found that pectoral fin rays provided the greatest concordance with otoliths ages (Phelps et al. in press). Because age and growth of fishes reflect a diverse suite of biological, chemical, and physical factors occurring in a system, precision among structures may be system or region specific. Therefore, the purpose of this study was to assess the precision in age estimates of common carp in Iowa lakes using dorsal spines and scales.

METHODS AND MATERIALS

Common carp were sampled from 28 lakes in Iowa using DC-boat electrofishing and modified-fyke nets during 2001-2004 (Table 1). Fish were measured to the nearest 2.5 mm (total length), and dorsal spines and scales were collected from each individual. Scales were removed from the area posterior to the pectoral fin and ventral to the lateral line. Dorsal spines were removed from fish by cutting the spine at the surface of the body. Scales and dorsal spines were allowed to air dry in envelopes. After drying, lateral line and regenerated scales were removed from samples. Remaining scales were cleaned with water, pressed onto acetate slides, and read using a microfiche reader. Dorsal spines were sectioned using a rotary saw, sanded with 600-grit sandpaper, and examined at 8-56 magnification with transmitted light.

Ages were estimated for each structure by two readers. Each structure was aged independently and without knowledge of fish length, date of capture, and age estimates

Table 1. Lake surface area (hectares), sample size (N), and total length (mm) statistics of fish samples for age estimation from 28 Iowa lakes, 2001-2004.

			Length			
Lake	Surface area	N	Mean	SD	Min	Max
Avenue of the Saints	16	3	579	38	538	615
Badger	17	38	478	74	290	699
Beeds	40	5	648	36	594	688
Clear	1,485	73	594	147	295	841
Crystal	107	22	450	86	203	650
Diamond	39	6	587	124	460	744
George Wyth	18	4	544	61	455	597
Green Castle	6	5	605	20	589	638
Hawthorn	75	1	638	*a*	638	638
Indian	20	2	678	15	665	688
Little River	305	41	531	79	419	704
Little Spirit	245	22	660	119	356	828
Lost Island	466	18	516	74	439	782
Lower Pine	23	27	645	48	536	724
Manawa	297	18	526	198	231	800
Meyer	14	7	579	53	503	648
Mill Creek	12	23	406	53	269	579
Ottumwa	29	28	429	64	267	546
Pleasant Creek	169	7	724	33	683	759
Rathbun	4,381	10	417	33	373	467
Silver—Palo Alto	262	42	589	84	368	699
Spring	20	28	610	84	472	803
Thayer	6	13	442	99	345	599
Three Fires	38	27	544	48	452	660
Three Mile	323	1	373	*a*	373	373
Upper Gar	15	20	511	99	333	665
Upper Pine	34	8	638	66	531	765
Volga	53	2	401	28	381	419

[a] Not estimable

from the other reader or the other structure. Precision between readers and structures was evaluated using age-bias plots (Campana et al. 1995). Agreement of age estimates was assessed by calculating the percent agreement (i.e., exact agreement and within one year) in age estimates. Precision of age estimates between readers and structures was also measured using the coefficient of variation (CV; Campana et al. 1995). The CV was estimated for individual fish and then averaged. Percent agreement and CVs were calculated between structures (e.g., scales vs. dorsal spines for reader 1) and between readers (e.g., reader 1 vs. reader 2 for scales).

Following the independent aging of structures by both readers, dorsal spines were re-examined by both readers (i.e., jointly) to resolve differences in age estimates. The primary purpose for the second reading was to investigate patterns in disagreements. This same procedure was not conducted for scales.

RESULTS

We aged 501 fishes varying from 203 to 840 mm in total length (Table 1). Ages assigned to scales varied from 0 to 15 and dorsal spine ages varied from 0 to 18 between readers (Fig. 1). Reader 1 obtained higher agreement and a lower mean CV between structures than reader 2. Exact agreement between dorsal spine and scale age estimates was 32.7% for reader 1 and 22.0% for reader 2, while agreement in age estimates within one year was 65.5% for reader 1 and 41.7% for reader 2. In general, scale ages were lower than dorsal spine ages for both readers, but no consistent pattern was observed. Among lakes, exact agreement between structures varied from 0 to 100% for reader 1 and 0 to 75% for reader 2. Similarly, agreement within one year varied from 0 to 100% for both readers.

Precision of age estimates between readers was low for scales compared to dorsal spines (Fig. 2). Exact agreement of age estimates between readers was 28.5% for scales and 90.6% for dorsal spines, while age agreements within one year were 67.1% (scales) and 93.4% (dorsal spines). Agreement in scale ages varied considerably across the distribution of assigned ages. For instance, scales estimated to be age 6 by reader 1 were assigned scale ages varying from age 3 to age 10 by reader 2. Similarly, scales that were estimated to be age 6 by reader 2 were assigned scale ages from age 2 to age 12 by reader 1. When disagreements occurred with regard to scales, reader 2 generally assigned higher ages than reader 1 through age 4; whereas, reader 1 generally assigned higher ages than reader 2 for ages beyond age 4. Most disagreements in ages among dorsal spines arose after age 4, where reader 1 tended to assign higher ages than reader 2. Among lakes, exact agreement between readers varied from 0 to 100% for both structures. Agreement within one year varied from 0 to 100% for scales and from 33 to 100% for dorsal spines.

Of the 501 dorsal spines examined, readers disagreed on age for only 47 individuals and a consensus was reached for 20 of those fish during joint examination. Of those 20 fish, 50% of consensus ages agreed with the original estimate made by reader 2, while 30% of the consensus ages agreed with the original estimate made by reader 1, and the remaining 20% were assigned ages different from both readers' original estimate. This process increased percent agreement to 95.8% (exact) and 97.3% (within one year; Fig. 3). Readers were unable to agree upon age for 27 dorsal spines.

DISCUSSION

Scales are among the most commonly used structures for estimating age of fishes due to their ease of collection and rapid processing times (DeVries and Frie 1996). Scales have been shown to provide accurate and precise age estimates for some species, including largemouth bass (*Micropterus salmoides*; Prentice and Whiteside 1974, Long and Fisher 2001), black crappie (*Pomoxis nigromaculatus*; Kruse et al. 1993), and striped bass (*Morone saxatilis*; Welch et al. 1993). Although scales perform well for many species, several studies have reported that scales tend to underestimate fish age (e.g., Marwitz and Hubert 1995, Kocovsky and Carline 2000, Isermann et al. 2003). Some of the issues involved with determining age based on scales include indistinct annuli, regeneration, resorption, erosion, and the presence of "checks" (Casselman 1990, Graynoth 1996, Weyl and Booth 1999). Events such as handling, spawning, low dissolved oxygen, starvation, changes in water temperature, and water level fluctuations can lead to checks (Ottaway and Simkiss 1977, Weyl and Booth 1999). Both readers in our study reported difficulty identifying annuli on common carp scales regardless of age, due to the large number of apparent checks. Although both readers were as consistent as possible when aging scales, neither felt confident in scale-age estimates beyond age 1. Due to lack of confidence and the large number and magnitude of the discrepancies, we did not attempt to resolve age disagreements with scales. Because of the problems encountered estimating scale ages, understanding the performance of other structures for

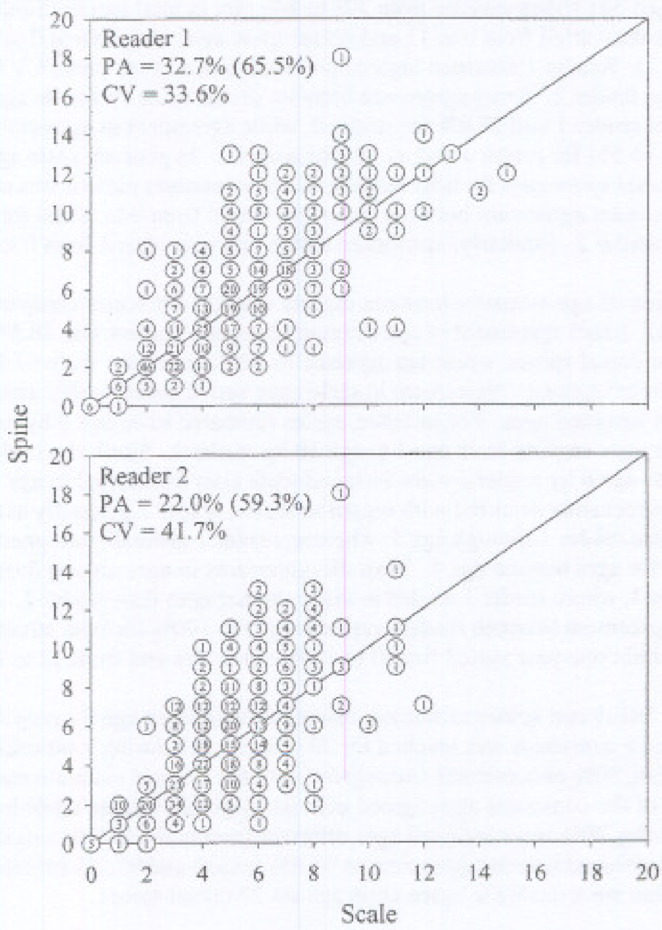

Figure 1. Age-bias plots of scales and dorsal spines used to age common carp ($N = 501$) sampled from 28 Iowa lakes, 2001-2004. Precision between structures for each reader was measured as percent exact agreement (PA; value outside of parentheses), percent agreement within one year (value inside of parentheses), and mean coefficient of variation (CV). Numbers in circles represent the number of common carp at each age.

aging common carp is critical for providing information necessary to manage this species.

Fin rays and dorsal spines have been found to provide precise age estimates in many fish species including walleye pollock (*Theragra chalcogramma*), Pacific cod (*Gadus macrocephalus*), albacore (*Thunnus alalunga*), sturgeon (*Acipenser* spp.), and blue throat wrasse (*Notolabrus tetricus*; Beamish 1981, Stevenson and Secor 1999, Metcalf and Swearer 2005). Common carp have been aged using a variety of structures; however, few studies have evaluated the precision among age estimates using these structures. In the current study, scale ages agreed with less than 33% of dorsal spine ages and discrepancies were as much as nine years different for each reader. Scales had poor precision between readers, but exact agreement of dorsal spine ages between readers was 90.6% after the initial viewing. Spines are relatively easy to collect, process, and interpret and do not require sacrificing fish. The structures utilized in this study were collected in conjunction with a larger project investigating relationships among

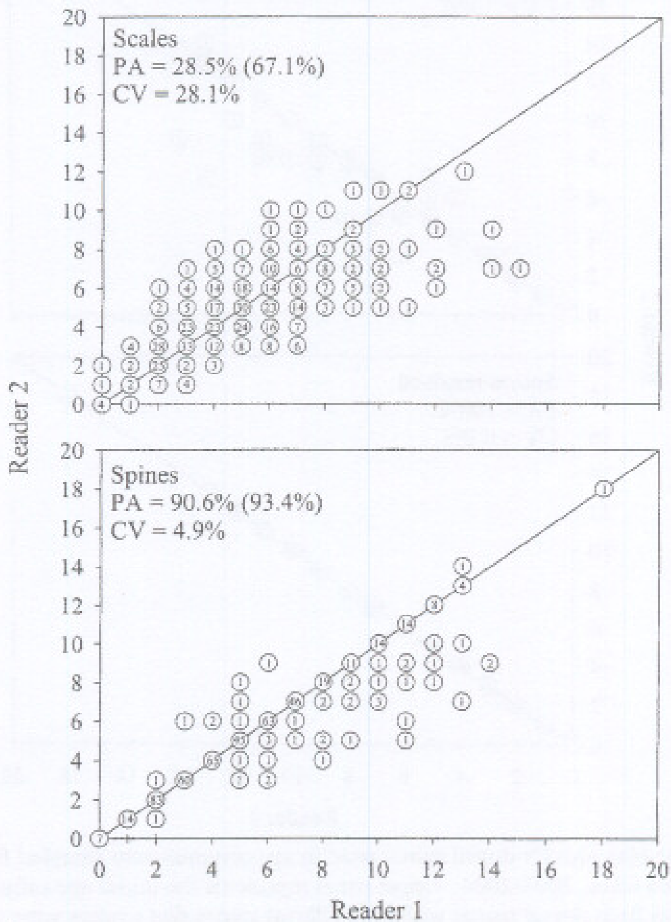

Figure 2. Age-bias plots for scales and dorsal spines used to age common carp ($N = 501$) sampled from 28 Iowa lakes, 2001-2004. Precision between readers for scales was measured as percent exact agreement (PA; value outside of parentheses), percent agreement within one year (value inside of parentheses), and mean coefficient of variation (CV). Numbers in circles represent the number of common carp at each age.

limnological conditions and fish communities in 132 Iowa lakes. Otolith collection was not in the protocol for that study and as such they were not available for analysis in this study. Whether or not dorsal spines provide accurate age estimates is unknown; however, the use of common carp dorsal spines for age estimation has been indirectly validated in Pathfinder Reservoir, Wyoming (Wichers 1976). Moreover, fin rays and spines have been shown to be as accurate as otoliths for some species (Beamish 1981, Cass and Beamish 1983, Chilton and Bilton 1986). For instance, Cass and Beamish (1983) used oxytetracycline to mark tagged lingcod (*Ophiodon elongatus*) and reported that fin rays of these tagged fish had formed annuli equal to the number of years at liberty. Several researchers have reported issues with expansion of the central lumen eroding early annuli in spines of *Ictalurus* spp. (Patton and Hubert 1996, Kwak et al.

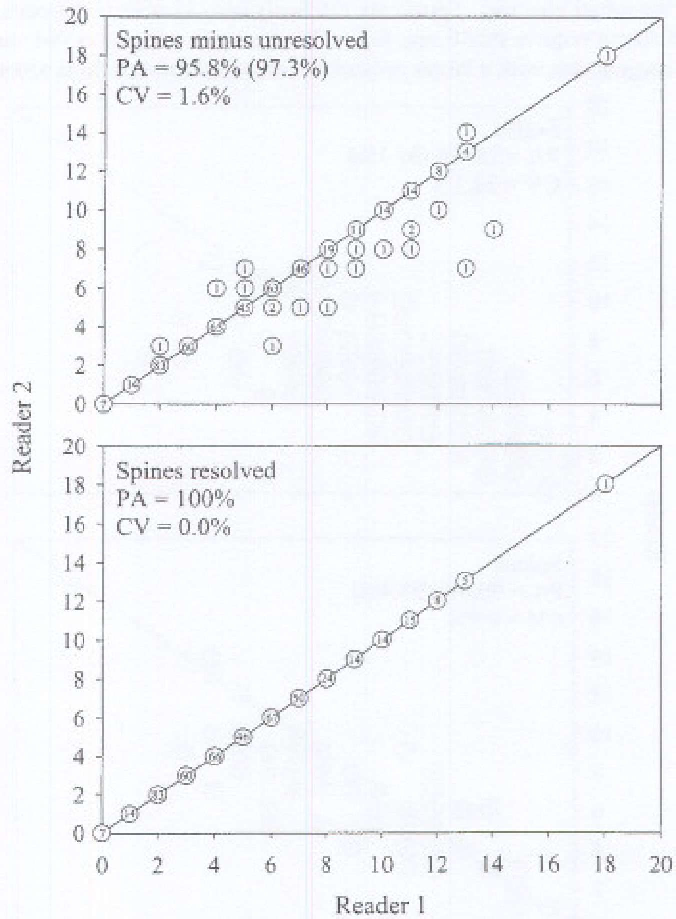

Figure 3. Age-bias plot for dorsal spines used to age common carp sampled from 28 Iowa lakes, 2001-2004. Upper panel represents the initial age estimates (N = 474) from dorsal spines without 27 dorsal spines that readers were unable to resolve during a joint-viewing. Lower panel represents the final distribution of ages following resolution of age disagreements. Precision between readers for dorsal spines was measured as percent exact agreement (PA; value outside of parentheses), percent agreement within one year (value inside of parentheses), and mean coefficient of variation (CV). Numbers in circles represent the number of common carp at each age.

2006), but this phenomenon was not observed in our study. Only 47 disagreements occurred of the 501 dorsal spines examined, and consensus was reached on 20 of those fish during joint examination. Of the 27 dorsal spines that were in disagreement, 48% were from two lakes (Ottumwa and Silver lakes). Nearly all disagreements were due to the presence of double annuli (48.9%) or indistinct annuli (27.7%). Double or false annuli have been observed in aging structures (e.g., spines, scales, otoliths) of several fish species including walleye (*Sander vitreus*), Atlantic sturgeon (*Acipenser oxyrinchus*), and jackass morwong (*Nemadactylus macropterus*; Smith 1982, Stevenson and Secor 1999, Kocovsky and Carline 2000).

Successful management of non-native species requires understanding their population dynamics, which is partially dependent on obtaining accurate and precise estimates of age (Ricker 1975, DeVries and Frie 1996, Campana 2001, Isermann et al. 2003). Several issues must be considered when selecting structures for age estimation including accuracy, precision, processing time, and lethality. Our results suggest that dorsal spines offer precise estimates of age and minimal processing time while providing the benefit of not requiring the sacrificing of fish. While loss of non-native fish like common carp may not be an issue, dorsal spine analysis requires less collection and processing time than lethal structures.

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