PROCEDURES FOR AGE DETERMINATION AND GROWTH RATE CALCULATIONS OF FLATHEAD CATFISH

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Abstract: Cross-sections cut from the articulating process (AP) of pectoral spines were used to determine age and back-calculate growth of 370 flathead catfish *(Pylodictis olivaris)* from 2 Oklahoma reservoirs. The accuracy of this method was validated by the following: agreement between the number of annuli and known age of 16 fish; 1 new annulus formed in the pectoral spines of fish tagged in 1970 and recaptured in 1971; agreement between calculated length increments and known length increases of tagged fish; and agreement between assigned age and length frequencies of young fish. Pectoral AP sections were superior to dorsal AP sections for age determinations. Sole use of sections from the distal end of the basal recess of pectoral spines would have resulted in underestimation of age by 1 to 5 years in fish of 3 to 13 years of age.

Proc. Ann. Conf. S.E. Assoc. Fish & Wildl. Agencies 34:253-262

Accurate age determination and back-calculation of growth is usually necessary for population analysis and knowledgeable management of a fish species. Although valid methods for age determination are known for many species, a method validated for one species should not be assumed accurate for other species until it has been tested. During studies begun in 1967, commonly used methods for age determination of flathead catfish caused underestimation of age for fish older than age 2.

The use of cross-sections cut from the distal end of the basal recess (BR sections) of pectoral spines for age and growth determinations has been validated for channel catfish, *Ictalurus punctatus* (Sneed 1951, Marzolf 1955, Prentice and Whiteside 1975), but not for flathead catfish. The central lumen found in BR sections of flathead catfish enlarges with growth of the pectoral spine, causing resorption of the surrounding bone tissue containing the earliest annuli (Muncy 1957, Langemeier 1965, Mayhew 1969, Hesse et al. 1976).

The main purpose of this paper is to describe the use of cross-sections cut from the articulating process (AP sections) of the pectoral spine for age determination and back-calculation of growth of the flathead catfish. Also ages determined from AP sections of dorsal spines and BR sections of pectoral spines were compared to ages previously determined from pectoral AP sections.

Sincere appreciation is extended to R. C. Summerfelt and M. D. Clady, past and current personnel of the Oklahoma Cooperative Fishery Research Unit; and students of Oklahoma State University for their assistance during this study.

Financial support was provided through the auspices of the Oklahoma Cooperative Fishery Research Unit by the Oklahoma Department of Wildlife Conservation, Zoology Department of Oklahoma State University, U.S. Fish and Wildlife Service and former Bureau of Commercial Fisheries.

METHODS

Collection of Materials

Pectoral and dorsal spines were removed intact from flathead catfish collected in 1967-1972 from Lake Carl Blackwell, Oklahoma and in 1971 and 1972 from Boomer Lake, Oklahoma. The age of fish from Boomer Lake was known because the lake had no flathead catfish in 1967 when hatchery-reared young-of-the-year were stocked by the Oklahoma Department of Wildlife Conservation. Fish were collected mainly with experimental gill nets with bar mesh sizes ranging from 64-127 mm, but snaglines, electrofishing, rotenone and barrel traps were also used (Turner 1977).

Total length was measured to the nearest millimeter. Weight was determined either to the nearest 0.1 kg or gram. Sex was determined either by dissection or examination of the genital area (Turner and Summerfelt 1971). Most flathead catfish which were not autopsied, were tagged with 2 types of tags (Summerfelt and Turner 1973). Fish were sexed, weighed and measured each time they were captured.

Preparation of Cross-sections

Spines were sectioned with fine-toothed saw blades, 22 mm in diameter and 0.10 or 0.15 mm in thickness, on an instrument similar to one described by Witt (1961). Water was applied with an eye dropper to spines while cutting cross-sections to retard curling and scorching due to friction. A series of 3 to 6 cross-sections, 0.5 to 1.0 mm in thickness, were cut from the articulating process of pectoral spines (Fig. 1A) for age determination and radii measurements. Both surfaces of AP sections were examined to insure that the surface having the greatest radius for the first annulus was used. A drop of 50 percent isopropyl alcohol placed on the sections improved differentiation of the annuli. Three sections were also cut from the distal end of the basal recess of pectoral spines (Fig. 1B) to determine the number of annuli missing because of lumen enlargement. For dorsal spines, a series of 5 to 10 cross-sections, 0.3 to 0.5 mm in thickness, were cut from between the basal recess and basal foramen (Fig. 1C). Dorsal spines of known-age fish from Boomer Lake were sectioned with a low speed saw (Buehler Limited, Isomet Model 11-1180) using a diamond wafering blade (Number 11-4244). On dorsal spines of known-age fish, cross-sections were cut from both the articulating process (Fig. 1C) and the distal end of the basal recess (Fig. 1D).

Determination and Measurement of Annuli

Cross sections examined under reflected light had broad white zones alternating with narrow dark rings. The narrow dark rings seen under reflected light were considered year marks if they were distinct and occurred in all quadrants of cross-sections which normally had easily read annuli.

Year marks in AP sections of pectoral spines were apparent in only the anterior and posterior quadrants (Fig. 1A). Year marks on dorsal AP sections, which were used to check ages determined from pectoral AP sections, were more ovoid and continuous (Fig. 1C), but the first 1 or 2 annuli were often obscured by deterioration of the innermost bone deposits.

False annuli were observed in fish in age-groups 2 and older. These marks were recognized as false annuli by their fainter appearance and irregular spacing. After the fourth or fifth annulus, false annuli were often more distinct, but were identified as false annuli because of their typical location just distal to the more obvious true annuli; these false annuli often were "halo-like" in appearance.

The number of annuli observed in AP sections of pectoral and dorsal spines was compared to the known age of flathead catfish collected from Boomer Lake. Also, the number of new annuli formed by tagged fish from Lake Carl Blackwell was determined by comparing BR cross-sections from the right and left pectoral spines which were removed at tagging and on recapture, respectively.

Radii of spine cross-sections were measured with an ocular micrometer in a binocular dissecting microscope at magnifications of 20X and 30X for pectoral and dorsal sections, respectively. For pectoral AP sections, spine radius was measured from the midpoint of the innermost annulus to the tip of the lobe with the most distinct annular markings.

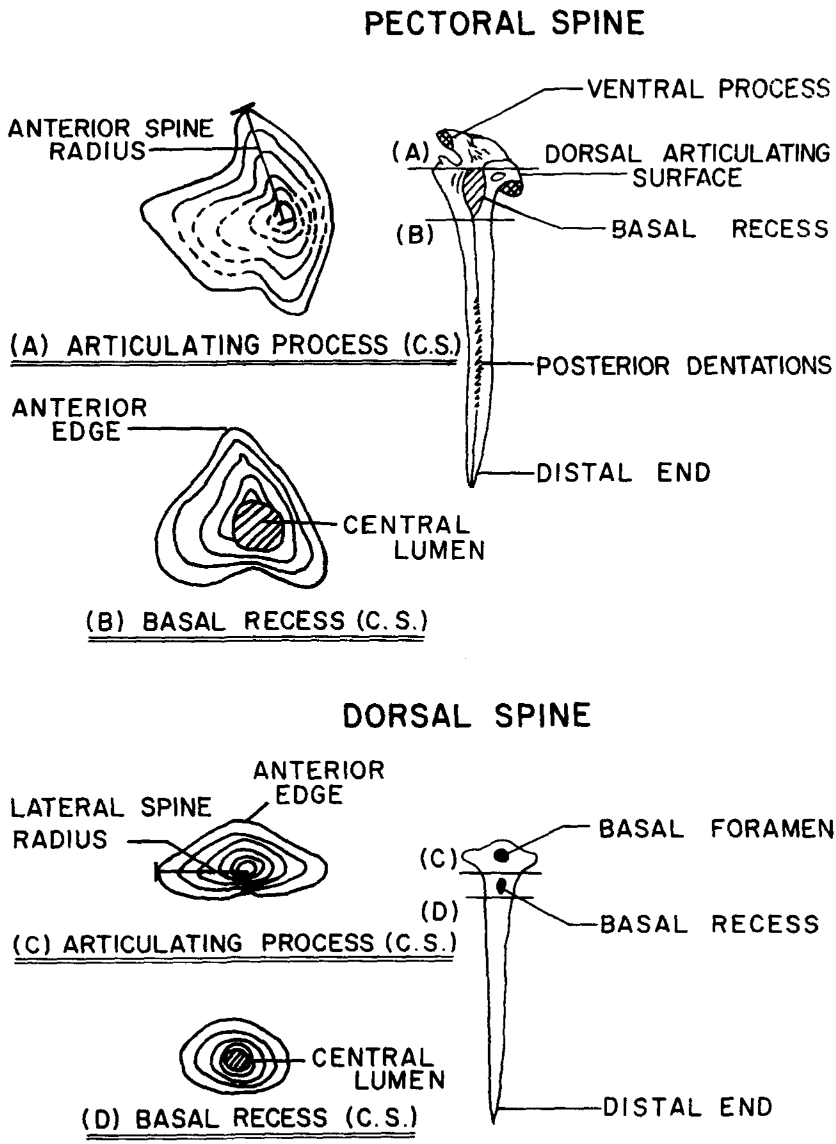

Fig. 1. Posterior views of the pectoral and dorsal spines showing the points of sectioning and the corresponding cross-sections used in age and growth determinations.

Usually the extension of the anterior edge of the pectoral spine into the dorsal articulating surface (Fig. 1A) was most readable. Because annuli were discernible in only the anterior and posterior quadrants of pectoral AP sections, the midpoint of the innermost annulus was estimated by eye. A relatively constant reference point for measurements was obtained by using the section having the greatest radius for the first annulus.

Back-calculation of Growth

Linear and curvilinear regressions were computed between total length and total spine radius measurements of pectoral AP sections of all 192 fish in the 1967-1968 sample using the following equations: $Y = a + bX$ and $Y = a + bX + cX^2$ where Y was total length in millimeters, X was spine radius measurement in ocular units (X20) and a, b, and c were constants. Regressions also were calculated using mean total lengths and mean spine radii of fish in 50-mm length classes. Because the second degree equation failed to cause a statistically significant reduction in variance, the y-intercept of the most appropriate linear regression was used to compute mean lengths at annulus formation by the Lee Method (Tesch 1971). Ages were given in arabic numbers as recommended by Ricker (1975).

RESULTS

Validation of Age Determination Method

Five annuli were found in AP sections of both pectoral and dorsal spines of 4 flathead catfish from Boomer Lake, which had been initially stocked with fry 5 years earlier. Four annuli were seen in either pectoral or dorsal AP sections from 11 of 12 known-age fish collected 4 years after stocking; the first annulus could not be seen in either pectoral or dorsal AP sections on the other age-4 fish.

The third, fourth and fifth annuli of known-age fish from Boomer Lake were more distinct and much farther apart than the first 2 annuli. Because of the small size of age-1 fish and greater thickness of pectoral AP sections cut with the high speed saw, the innermost (first) annulus was often visible on only 1 pectoral AP section. In contrast, the relatively smaller diameter of dorsal spines and the superior sectioning capability of the low speed saw used subsequently on dorsal spines made it possible to cut several dorsal AP sections which contained the first annulus.

Six flathead catfish from Lake Carl Blackwell, which were tagged in 1970 and recaptured in 1971, had formed one new annulus between tagging and recapture. As the distal portion of the left pectoral spine had been removed when these fish were tagged in 1970, the number of outermost annuli could be compared between BR sections of the left and right pectoral spines.

Comparative Value of Pectoral and Dorsal Spine Cross-sections

Pectoral AP sections were superior to dorsal AP sections for determining age of a sample of flathead catfish from Lake Carl Blackwell. Degenerative changes in the innermost bone tissue of dorsal spines caused the first, and sometimes second, annulus to be obscured in dorsal AP sections of age-5 and older fish; it was also more difficult to discern the most recently-formed annuli in dorsal AP sections than in pectoral AP sections of age-6 and older fish (Turner 1977). In contrast, pectoral and dorsal AP sections were equally good for determining the age of known age-4 and age-5 fish from Boomer Lake.

Unless checked against pectoral AP sections, the use of pectoral BR sections would have caused the age of flathead catfish from Lake Carl Blackwell to be underestimated by 1 to 5 years in fish of 3 to 13 years of age (Table 1). More annuli were missing from pectoral BR sections when the spine lumen was located anterior to its normal position (Fig. 1B). The converse was true when the lumen was located more posteriorly than normal. Pectoral BR sections from known age-4 and age-5 fish from Boomer Lake were missing the first 1 or 2 annuli because of enlargement of the spine lumen (Table 1).

Back calculation of growth

The relationship between total length and spine radius of pectoral AP sections for 192 fish collected in 1967 and 1968 was adequately described by the equation,

$$Y = 75.64 + 4.389\,X \quad (R^2 = 0.86)$$

Table 1. Percentages by age group of flathead catfish captured in Lake Carl Blackwell and Boomer Lake, which were missing 1 or more annuli from cross-sections cut from the distal end of the basal recess of pectoral spines.

Age group	Number of fish	Percentage of fish missing annulus indicated				
		1st	2nd	3rd	4th	5th
			Lake Carl Blackwell			
3	10	60				
4	18	78	6			
5	45	96	31			
6	57	98	65	5		
7	49	100	55	8		
8	30	100	60	7	3	
9	34	100	88	21		
10	27	100	100	22	4	
11	18	100	100	61	6	6
12	8	100	88	75		
13	11	100	100	55	36	9
14	4	100	100	50		
15	3	100	100	67		
16	1	100	100	100		
17	1	100	100	100		
21	1	100	100	100	100	
			Boomer Lake			
4	12	100	18			
5	4	100	24			

where Y = *total length in millimeters and* X = *spine radius in ocular units* (1 *unit* = 0.038 mm) (Fig. 2). When the 75.6 mm intercept was used to back-calculate lengths at annulus formation for fish collected in 1968, mean calculated lengths at ages 1-3 were greater than the mean lengths at capture of fish in age groups 1-3 (Turner 1977). These errors resulted from using the y-intercept of 75.6 mm which was computed from a biased sample; 84 percent of the 192 fish in this sample were from 500 to 800 mm, TL. In order to determine a more realistic relationship between length and spine radius, a linear regression was *computed from the mean lengths and mean pectoral spine radii of fish in 16 50-mm length* classes. The equation:

$$Y = 11.03 + 4.9277\ X\ \text{(Fig. 2)}$$

described a body-spine relationship which was weighted equally for length and spine radius measurements of fish in all length classes collected.

When the intercept of 11.0 mm was used to back-calculate growth for fish from Lake Carl Blackwell in 1967 and 1968, mean calculated lengths compared well with empirical lengths of the next youngest age group at time of capture (Table 2). The empirical length of fish in age-group 5 was greater than the calculated length of fish at age 6 because only the

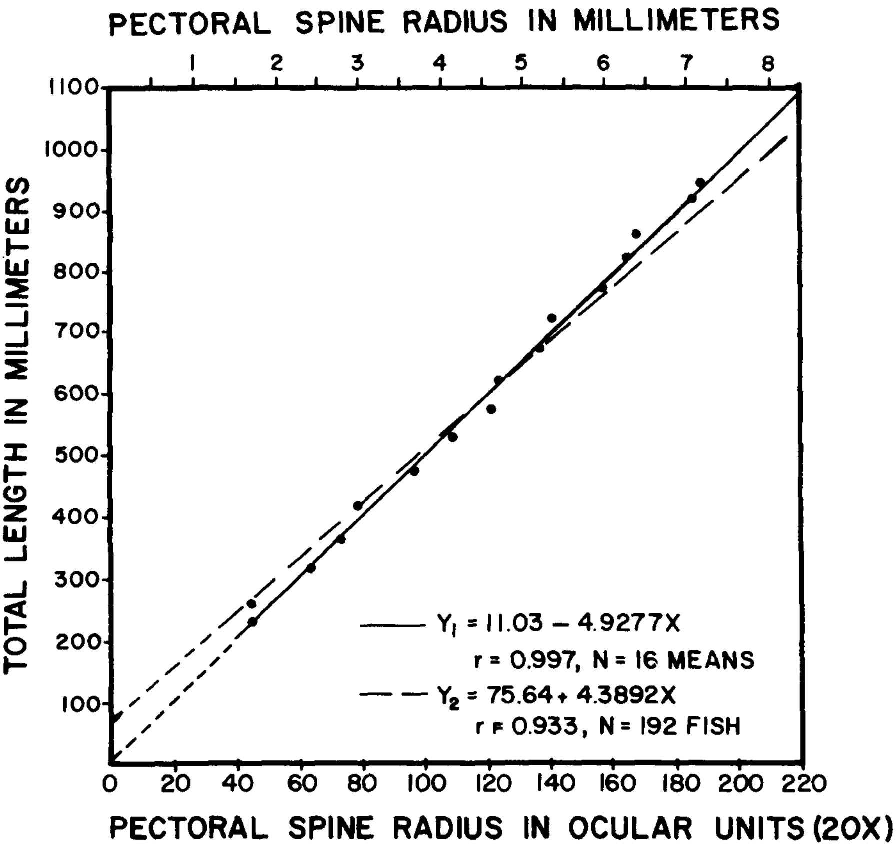

Fig. 2. Total length—pectoral spine radius relationships calculated from means of length classes (Y_1) and from all 192 flathead catfish (Y_2) collected from Lake Carl Blackwell in 1967-1968. Points represent mean spine radii and mean total lengths of fish in 50-mm length classes.

largest age-5 fish were vulnerable to the smallest mesh size (76 mm) of gill nets which was effective in catching flathead catfish in 1967 and 1968 (Turner 1977); thus both length at capture and lengths at annuli were positively biased for fish in age-group 5.

Calculated lengths at the same ages were similar for fish in 1967 and 1968 (Table 2). The largest discrepancies between years were for the lower calculated lengths and lengths at capture for fish at ages 6-9 in 1967. In 1967, most fish were collected in 76-mm mesh of gill nets, whereas the largest mesh size used in 1968 was 127 mm. As 76-mm mesh seldom caught flathead catfish >700 mm, larger, more rapidly-growing fish in age groups 7 and older were under represented in fish collections in 1967. There was good agreement in mean calculated lengths of fish at ages 1-4 in 1967 and 1968 and the empirical lengths of fish in these age groups which were also aged by modes in length-frequency distributions (Turner 1977).

The accuracy of back-calculated lengths was evaluated by comparing the length increases of tagged flathead catfish with the calculated growth increments of fish collected in 1968. The mean growth rates of 2 males and 8 females, which were tagged in 1968 and

Table 2. Empirical and calculated total length in millimeters of flathead catfish collected from Lake Carl Blackwell in 1967 and 1968.

Age group	1967 No. of fish	1967 Mean length at capture	1967 Mean calculated length	1968 No. of fish	1968 Mean length at capture	1968 Mean calculated length
1	3	88[1]	61	5	76[1]	58
2	1	177	118	0	-	117
3	1	256	197	5	234	198
4	0	-	310	10	356	309
5	4	575	454	26	588	446
6	10	596	552	31	633	549
7	6	638	604	26	656	623
8	3	647	640	22	702	678
9	3	690	673	16	731	714
10	0	-	719	14	758	738
11	1	761	742	7	796	761
12				3	812	785
13				4	809	794
Total	32	-	-	169	-	-

[1]*Except for fish in age-group 1 (where age was estimated by the length frequency method),* age was determined by examination of spine cross-sections.

recaptured in 1969, were 3.6 and 2.5 mm/month (43 and 30 mm per year), respectively (Turner 1977). In comparison, the mean calculated length increments for males and females during their ninth year of life, which was the most comparable year of life to the mean lengths when tagged, were 43 and 35 mm per year, respectively (Turner 1977). Although sample sizes of tagged fish were small, the similarity between these 2 independent estimates of growth for both sexes gives credence to the method used to determine age and back-calculate growth.

The range and standard deviation of calculated lengths at a specific age increased after age 3 because of the period of accelerated growth which usually occurred in the fourth through seventh years of life (Fig. 3). The greatest differences between maximum and minimum lengths of individual fish at a specific age were at ages 4-8. The great variation in length at ages 4-8 was caused by variation in the period of rapid growth in fish of the same year class. In fast-growing fish, rapid growth started in the third or fourth year of life and had greater magnitude, whereas, slow-growing fish had relatively slow growth until the eighth and ninth years.

Growth of flathead catfish stocked in Boomer Lake was also highly variable. Total lengths of known age-4 fish collected in gill nets during August 1971 ranged from 516 to 715 mm, but an age-5 fish collected in June 1972 was only 465 mm. Back-calculated lengths of fish at annulus 3 and 4 ranged from 174 - 598 and 294 - 687 mm, respectively (Turner 1977).

DISCUSSION

Age and growth determined from pectoral AP sections were considered accurate in this

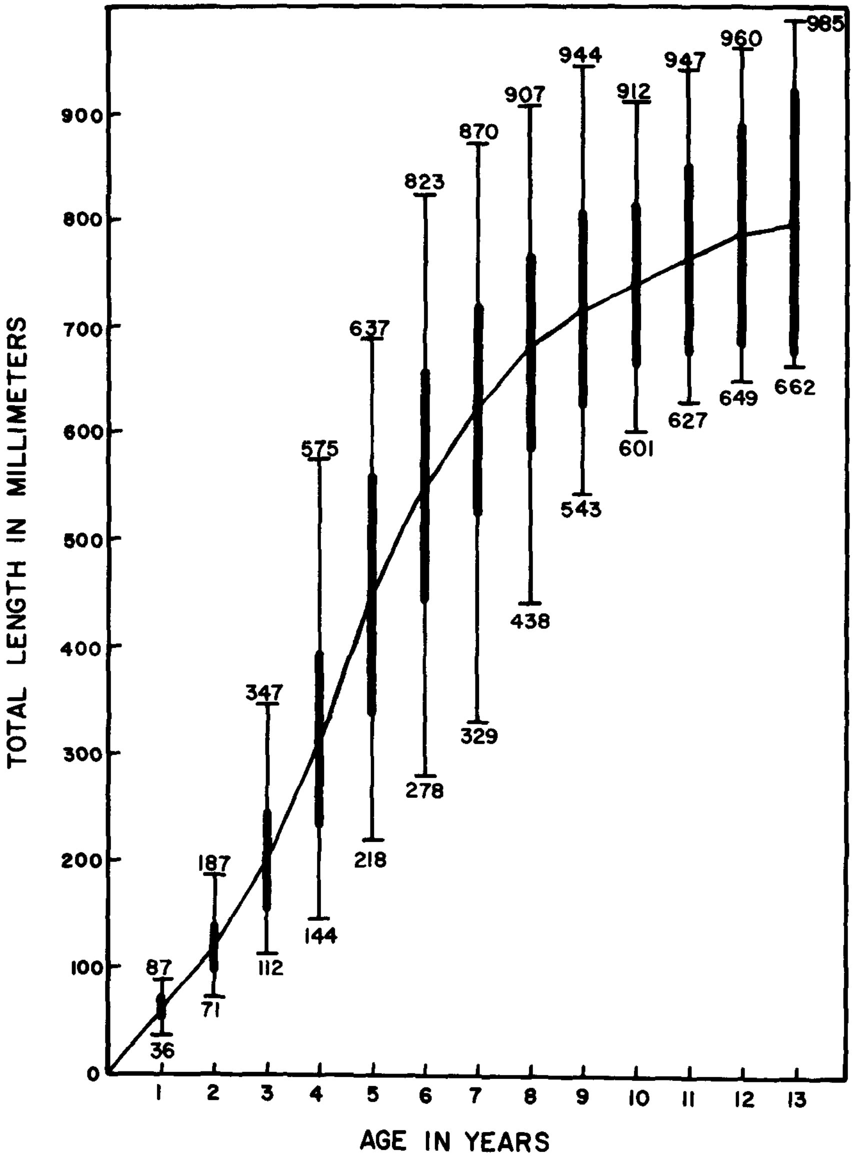

Fig. 3. Grand mean total lengths of flathead catfish collected from Lake Carl Blackwell in 1968. Thin vertical lines and numbers represent the range from maximum to minimum total lengths calculated for individual fish at each age; heavier vertical lines indicate ± one standard deviation from the calculated grand mean length.

study for the following reasons: (1) agreement between number of annuli and age of known-age fish, (2) only 1 annulus formed per year on pectoral spines of tagged fish, (3) known length increases of tagged fish were similar to growth calculated from annuli measurements of pectoral AP sections, (4) close agreement between assigned age and length frequencies of age-4 and younger fish, and (5) similarity of calculated growth histories.

Methods of age determination have been described and validated for *Ictalurus punctatus* (Appelget and Smith 1951, Sneed 1951, and Prentice and Whiteside 1975) and *Clarias gariepinus* (van der Waal and Schoonbee 1975). Marzolf (1955) recommended BR sections of the pectoral spine for age determinations, but noted that enlargement in the spine lumen caused the first annulus to be partially obscured. Hess et al. (1976) found the first annulus was completely missing in 69 to 100 percent of fish in age-groups 3-8. Loss of annuli in pectoral BR sections was more likely a problem for *Pylodictis olivaris* from Oklahoma reservoirs because of differences in the morphology and growth of pectoral spines and the larger average size of *P. olivaris* (Turner 1977).

The loss of annuli because of lumen enlargement in pectoral spines of *P. olivaris* was noted by Muncy (1957), Mayhew (1969) and Hesse et al. (1976). Although the use of BR sections from dorsal spines has been used to improve age of *P. olivaris* (Jenkins 1954, Layher 1976), the first annulus was missing in 15 of 16 known-age fish from Boomer Lake.

The age of age-5 and older flathead catfish from the Missouri River could be accurately determined only by comparing BR and AP sections of the pectoral spine (Langemeier 1965, Holz 1969). Ihm (1968) also used pectoral AP sections as an aid in distinguishing the outermost annuli of *I. punctatus* and *I. melas*. In my study, loss of the first annulus often occurred by age 3 and up to 4 additional annuli were lost in older fish. Loss of annuli because of lumen enlargement in pectoral BR sections has probably resulted in underestimation of the age of older flathead catfish in many reports. If so, growth rates of flathead catfish calculated from pectoral BR sections would be overestimated. Even the comparability in growth between different waters by the same worker could be affected if errors in age determination varied with growth rate.

Although Langemeier (1965) and Holz (1969) used pectoral AP sections to determine age of flathead catfish, they resorted back to pectoral BR sections for measurement of annuli for back calculations. These findings indicated that pectoral BR sections were undesirable for this purpose (Turner 1977).

In summary, a series of AP sections (0.3 to 0.5 mm in thickness) from both pectoral and dorsal spines permitted accurate age determination of flathead catfish. Measurements of annuli in pectoral AP sections were used to back calculate growth.

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