VALIDATION OF AGING TECHNIQUES FOR LARGEMOUTH BASS AND CHANNEL CATFISH IN CENTRAL TEXAS FARM PONDS.

by

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ABSTRACT

A study was conducted to determine the accuracy and validity of age determination methods for largemouth bass, *Micropterus salmoides*, and channel catfish, *Ictalurus punctatus*, in central Texas farm ponds. Each pond selected for this study had been stocked only once with largemouth bass and/or channel catfish. Ages of fishes collected ranged from one through four years of age at the time of collection.

Fish ages determined by the aging methods were compared to fish ages established by stocking dates. Overall accuracy of age determinations made by these methods was 94% for largemouth bass and 77% for channel catfish. Accuracy of aging generally decreased as fishes became older. Indefinite annuli and supernumerary marks were found on the scales of the largemouth bass and on the tin spines of the Channel catfish, but a majority of these marks could be correctly identified.

The scale and fin spine aging methods were further validated by determining the approximate time and the regularity of annulus formation. Annulus formation was found to occur from late February to mid-March for juvenile largemouth bass and from late March to early May for juvenile channel catfish. Regularity of annulus formation was indicated when total lengths were found to increase as the number of annuli found on the scales or fin spines increased, and when the calculated total lengths of fishes were found to agree with empirical total lengths of fishes at that age.

INTRODUCTION

Growth rates of fishes are extremely responsive to the environment, thus, growth will be less under unfavorable conditions than under favorable conditions. Growth rate data are therefore very useful as indicators of existing conditions in various bodies of water and have considerable value in fisheries management practices.

Most growth estimates are dependent upon accurate age determinations made from bony parts of the fish body. In past studies, age determinations of scaled species of fish were usually made from scales (Van Oosten, 1923, 1929; Hile, 1941; Sprugel, 1954; and Regier, 1962), while age determinations of unscaled species of fish were made from vertebrae or fin spines (Appleget and Smith, 1950; Sneed, 1950; and Marzolf, 1955). Other bony parts of the fish body such as fin rays (Boyko, 1950) and otoliths (Adams, 1942) have also been used for age determination.

Sculpturing of the outer surface of the scale or the banding of the fin spine or other bones reflects the growth of a fish at various stages of its life. Age determinations from scales, or other bony parts of the fish body, are based on accurate interpretation of annual marks (annuli), which are usually caused by changes in the growth rate of the fish as the seasons change from winter to spring, and of supernumerary marks (checks or false annuli), which are usually caused by irregular changes in the growth rate during the year. Validation of the aging method is necessary to insure that accurate age determinations are being made in a given area for a given species.

Van Oosten (1923, 1929) presented a summary of early literature on the development of the scale method of aging fish, and based validity of the scale method on the following assumptions: that scales remain constant in number and identity throughout the life of the fish; that a constant ratio is maintained between the annual increase in linear dimension of a scale and the annual increase in body length, throughout the life of the fish; and that the annuli are formed yearly and at the same time each year. He found these conditions to be valid and, therefore, the scale method sound in its basic theory. But situations in which annuli are not formed each year or where supernumerary marks may be formed are not unusual. Carlander (1956) states, "the real problem is not usually where annuli are formed but whether they are correctly interpreted by the biologist".

Validity and accuracy of the scale method of fish aging has been determined in past studies by the use of various criteria. Hile (1941) established validity of the annulus as a

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year mark by the following criteria: (1) fish assigned to the same age group had similar lengths; (2) agreement was found between the age of small fish as estimated from length-frequency distributions and from scale examination; (3) lengths of young fish, calculated from scale markings of older fish, agreed with the actual lengths of fish at that age at the time of capture; (4) calculated growth histories for different age groups and different year classes agreed in showing good and poor growth in certain calendar years; and (5) certain year classes were consistently strongly or weakly represented in collections of successive years. Lagler (1952) suggested validation of the scale method by the above criteria, augmented by direct comparison of the age of a fish, as estimated by the scale method, with the actual age of the fish, as well as by determination of the time of year of annulus formation. Cooper (1951), Alvord (1954), Cable (1956), Judy (1961), Prather (1967), Burnet (1969), and others determined validity of the scale method by comparing ages estimated by the scale method to the actual ages of fishes. Certain of the criteria proposed by Hile (1941) have been used to determine the validity of the scale method by various researchers: Butler and Smith (1949) used criteria 1 and 4; Hooper (1949) utilized criteria 1 and 2; Appleget and Smith (1950) used criteria 2, 3, 4, and 5 in combination with a comparison of fish age estimated by the scale method to actual fish age; and Sneed (1950) used criterion 1 in combinations with a comparison of fish age estimated by the scale method to actual fish age. Other workers established validity of the scale method by studying annulus characteristics and time of year of annulus formation (Berg and Grinnaldi, 1967; and Mathews and Williams, 1972). Accuracy and validity of the scale method have been increased by the presentation of criteria for distinguishing annuli from supernumerary marks on scales and bones (Sprugel, 1954; Marzolf, 1955; Van Oosten, 1957; Regier, 1962; and Chugunova, 1963).

Few age and growth studies have been conducted in the Gulf Coast States (Smith and Swingle, 1940; Brown, 1960; and Prather, 1967), and the accuracy of age determinations for fish from southern states is questionable (Prather, 1967). Age and growth studies have not been a regular part of fisheries management practices in Texas because of difficulties in the reading of scales. Consequently, the main objective of this study is to validate aging methods which could be used in age and growth studies for largemouth bass, *Micropterus salmoides,* and channel catfish, *Ictalurus punctatus,* in central Texas.

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STUDY AND MATERIALS

Study Area and Methods

The seven farm ponds used in the study were all selected from the Blackland Prarie soil district of the Texan Biotic Province (Blair, 1950) so as to minimize extraneous variations in fish growth due to environmental variations between ponds. All ponds selected were recently constructed and there were no other bodies of water in their watersheds. Ponds were stocked with fingerling largemouth bass at a rate of 185 to 247 per surface hectare, and with fingerling channel catfish at a rate of about 247 per surface hectare. The ponds were stocked only once thereby facillitating accurate age determinations for captured fishes. Fishing pressure was non-existent or light before sampling for this study. Ponds A, B, C, and D (Table 1) were research ponds located at the San Marcos State Fish Hatchery, San Marcos, Texas. Pond E (Table 1) was a research pond located at the Aquatic Station, Southwest Texas State University, San Marcos, Texas. Ponds F, G, H, and I (Table 1) were farm ponds used principally for livestock watering and were situated in uncultivated pasture land in Caldwell, Guadalupe, and Hays counties.

Table 1. Descriptions and locations of farm ponds used in this study.

Pond	Location (county)	Species stocked	Year Stocked	Age of stocked fish at capture (years)	Size	
					Surface area (ha)	Max. depth (m)
A	Hays	LMB[2]	1971	1	0.04	1.5
B	Hays	CC[2]	1971	1	0.04	1.5
C[1]	Hays	LMB	1971	1	0.04	1.5
D[1]	Hays	CC	1971	1	0.04	1.5
E	Hays	LMB	1970	2	0.44	2.1
F	Caldwell	CC	1970	2	0.30	5.2
G	Caldwell	LMB	1969	3	0.61	4.9
		CC	1968	4		
H	Guadalupe	CC	1969	3	0.81	4.6
I	Hays	LMB	1968	4	2.14	5.2
		CC	1967	5		

[1]Ponds used only for determination of time of annulus formation.

[2]LMB = Largemouth bass, CC = Channel catfish.

The fishes were collected from February to May 1972 with seines, gill nets, barrel traps, electrofishing gear, and hook and line. The greatest part of the sampling effort was selective for the larger fishes in each farm pond in an attempt to collect the stocked fishes rather than their progeny. A total of 108 largemouth bass and 107 channel catfish were collected to represent age classes I through IV. It was assumed that fish growth had ceased, or had reached its slowest rate, by late winter, and thus, that the margins of scales and fin spines of fishes collected in late winter represented the last annulus. A temperature of 6 C, recorded in ponds C and D on January 29, 1972 was sufficiently low to stop fish growth according to Berg and Grinnaldi (1967). In fishes collected in early spring, the last annulus and new spring growth could be identified.

A sample of four or more scales was taken from a key region from each largemouth bass collected (except for a few of the smaller specimens) and washed with water to remove excess slime. The key region was designated as the area two to three scale rows below the lateral line at the tip of the left pectoral fin. The left pectoral fin spine was clipped from each channel catfish at a point sufficiently near the spine base as to include the distal portion of the basal groove, thereby insuring that no annuli would be omitted when the spine was cross sectioned (Sneed, 1950; and Marzolf, 1955). Total length to the nearest millimeter, weight to the nearest gram, and collection date and location were recorded for each fish on the scale and spine envelopes at the time of collection.

Scale impressions used in the scale age analysis were made on cellulose acetate strips with a roller press as described by Smith (1954). Spines were sectioned at the distal end of the basal groove, following the decalcification and cutting technique described by Wahtela and Owen (1970). These sections were mounted on standard glass microscope slides with permount histological mounting medium. Scale impressions and spine sections were examined under 60X magnification with a microprojector similar to that described by Van Oosten, Deason, and Jobes (1934).

Fingerling largemouth bass and channel catfish were stocked separately in ponds C and D at the San Marcos State Fish Hatchery to determine the time of annulus formation. Scale or spine samples were collected from usually five largemouth bass and usually five channel catfish at irregular intervals from September through May. Only five individuals were sampled at each collection date because of the limited number of fish available in each pond. The interval between the earliest collection with an individual having a newly formed annulus and the earliest collection in which the entire sample possessed newly formed annuli was designated as the approximate time of year of annulus formation. Water temperature just below the surface was obtained at each sampling date with a standard 110 C laboratory thermometer.

Age Determinations by Scale and Fin Spine Methods

The sculpturing of the outer surface of the scale or the banding of the fin spine or other bones, upon which age determinations are based, is related to changes in fish growth rate during the year (Lagler, 1952; and Chugunova, 1963). Fish growth is usually rapid in the summer, decreases in the fall, and is slowest, or absent, in the winter (Berg and Grinnaldi, 1967). As fish growth continues, small, concentric ridges, or rings, called circuli (also described as sclerites by Chugunova, 1963) are formed on the scale (Lagler, 1952). When fish growth is rapid the circuli are spaced widely, and when growth is slow the circuli are spaced closely (Van Oosten, 1923). Changes in fish growth rate also cause bands on spines or other bones due to layering as the bone grows. Broad layers, deposited during periods of rapid growth, alternate with narrow layers, deposited during periods of slow or interrupted growth (Chugunova, 1963). The annulus is located at the transition from slow winter growth to fast spring growth (Van Oosten, 1923; Chugunova, 1963; and Berg and Grinnaldi, 1967), and can usually be identified by characteristic changes in the spacing of the circuli or the layering of the bone tissue of the spine. However, supernumerary marks, which require careful study to be properly identified since they resemble annuli, are sometimes formed (Carlander, 1956).

In this study, an annulus is defined as the first complete circulus formed on scales or the outside edge of the narrow winter band on spines upon the resumption of rapid spring growth. Criteria for the identification of annuli on scales in this study were: (1) a scale mark preceded by narrowly spaced circuli and followed distally by widely spaced circuli (Cooper, 1951; Lagler, 1952; Alvord, 1954; and Carlander, 1961), (2) anastomoses, or "cutting over" of circuli on the lateral fields of the scale (Cooper, 1951; Lagler, 1952; Carlander, 1961; Carlander and Whitney, 1961; and Chugunova, 1963), and (3) a gap or wide space between circuli (Carlander, 1961; Carlander and Whitney, 1961; and Chugunova, 1963). The first two criteria were considered to be the most useful in annulus identification but all criteria involved some subjectivity. Criteria for identification of supernumerary marks on scales in this study were: (1) a scale mark preceded by a zone of widely spaced circuli and followed distally by narrowly spaced circuli (Sprugel, 1954; Regier, 1962; and Chugunova, 1963), (2) crowded circuli, usually two or three, projected into a zone of widely spaced circuli (crowded circuli did not fit the regular pattern of scale growth and appeared confusing) (Chugunova, 1963), (3) lack of extreme anastomoses of circuli and incomplete extension of the mark in all fields of the scale (Regier, 1962), (4) circuli continuous through the mark (Regier, 1962), and (5) circuli discontinuous distal to the mark (Regier, 1962). Scale marks which exhibited at least one of the characteristics of supernumerary marks were identified as supernumerary marks. Marks on fin spine cross sections were identified as annuli if they were distinct and appeared in all fields of the section concentric with the edge, or as supernumerary marks if they were incomplete or indistinct (Appleget and Smith, 1950; Marzolf, 1955; and Chugunova, 1963).

Data recorded for each fish at capture were cross-referenced to the corresponding scale impression or spine section. Age analysis was then carried out in a random order without knowledge of the true age or size of the fish from which the scale or spine came. Scale impressions and spine sections were read and reread repeatedly until there was agreement between any two readings for each specimen. Such repeated readings may increase the accuracy of age interpretations according to Carlander (1956).

Establishment of Fish Ages

A given species was stocked in a pond on only a single date. Thus, if the species did not reproduce in that pond, the age of all fish collected was the same and was determined by the time elapsed between stocking and collecting. The ages of channel catfish in ponds B, F, G and H and of largemouth bass in ponds A and E were determined by this method.

Channel catfish do not usually reproduce in farm ponds (Swingle and Smith, 1947; and Lewis, 1950) but apparently reproduced in Pond I. The data from these fish were omitted from the study since it was impossible to be confident that the stocked fish were being accurately separated from their offspring.

Largemouth bass reproduction occurred in ponds G and I which necessitated separating stocked fish from their offspring to be sure that fish used from these two ponds were of known age. Length frequency distribution data from each pond were used to separate fish into year classes (Figure 1 and 2). Age group separations made by length frequencies were then compared to age group separations made by plotting length frequency data on probability paper as proposed by Harding (1949) (Figures 1 and 2). However, since there was some indication of overlap of age group distributions using these methods, and since sample sizes were small, it was necessary to more clearly separate the stocked largemouth bass from their offspring by looking at scale growth patterns.

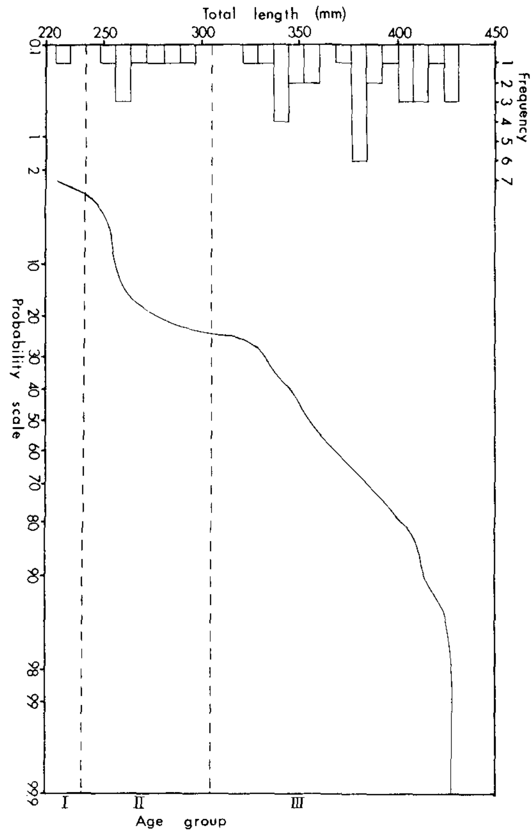

Figure 1. Length frequencies and age group separations based on Harding's (1949) probability paper method for largemouth bass collected from Pond G.

Fish growth rates in a body of water vary from year to year due to varying environmental conditions. Therefore, the stocked fish in each pond in this study should exhibit scale growth patterns which are different from those of their offspring. A tentative separation of the stocked bass from their offspring in ponds G and I was made by noting differences in the scale growth patterns of the different age groups, as determined by the number of annuli. Fish tentatively shown to be stocked fish by the scale growth pattern method were then compared to those fish which were tentatively shown to be stocked fish by the length frequency and probability paper methods. In Pond G, 19 of the 26 fish indicated to be stocked fish by length frequency and probability paper methods exhibited wider growth bands on their scales from the focus to the first annulus than occurred on scales of other fish collected from Pond G. In Pond I, 24 of the 26 fish indicated to be stocked fish by length frequency and probability paper methods exhibited wider growth bands on their scales from the first to the second annulus than occured on the scales of other fish collected from Pond I. Only the 19 fish from Pond G and the 24 from Pond I which were indicated by all three methods to be the stocked fish were used in the validation analyses, while the remaining fish were considered to be offspring of the stocked fish or of questionable age.

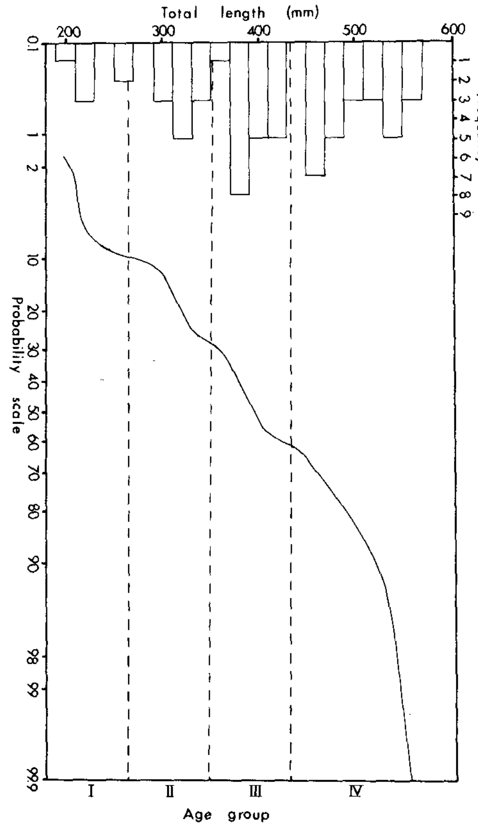

Figure 2. Length frequencies and age group separations based on Harding's (1949) probability paper method for largemouth bass collected from Pond I.

Statistical Methods

The positions of the focus, the annuli, and the margin of each scale were marked on strips of paper and used for back calculation of length at each year of life by a nomograph method described by Carlander and Smith (1944). All measurements of the scales were made along the midanterior field. The positions of the center of the lumen, the annuli, and the edge of each spine section were also recorded on strips of paper and used with the nomograph method. All measurements of spine sections were made along the posterior radii.

The nomograph method requires the use of a regression line based upon total lengths and corresponding total scale or total spine measurements for fishes at the time of capture (Butler and Smith, 1949; Sneed, 1950; Sprugel, 1954; Whitney and Carlander, 1956; and Carlander and Whitney, 1961). Since total lengths of fish were derived from scale or spine measurements, the scale or spine measurements were used as the independent variable in establishing body-scale or body-spine relationships (Winsor, 1946; and Whitney and Carlander, 1956). Total lengths and scale or spine measurements from 108 largemouth bass and 107 channel catfish were used to fit regression lines by the least squares method. Rectilinear body-scale and body-spine relationships were assumed since sample sizes were small (Carlander, 1956; and

Whitney and Carlander, 1956). Therefore, back-calculated fish lengths based on the relationships were considered approximate. The Lee Method used to calculate the body-scale and body-spine relationships was as follows:

$$L = a + bS,$$

where L is the total body length of fish in millimeters, S is either the anterior scale radius measurement in centimeters (X60) for largemouth bass, or posterior spine radius measurement in centimeters (X60) for channel catfish, a is the Y intercept, and b is the slope.

Mean empirical total lengths and mean empirical scale or spine measurements of largemouth bass and channel catfish were plotted at fixed 25 millimeter increments of total scale or spine measurements along the calculated regression lines as a visual goodness of fit test (Whitney and Carlander, 1956).

RESULTS AND DISCUSSION

Accuracy of Age Determinations by the Scale and Fin Spine Methods

Although criteria have been presented to distinguish annuli from supernumerary marks, there were instances in this study where scale or spine readings were questionable due to interpretation of some marks. Age analysis results (Table 2) show that, although agreement of two readings was obtained with the first two readings for a majority of the largemouth bass (66%) and channel catfish (74%), many fishes required a third reading and a few fishes required a fourth reading. The necessity for reading the 37 largemouth bass scales more than twice in order to obtain agreement of two readings was attributed to the great detail in scale sculpturing and the possibility of confusion in scale age analysis. For example, slight anastomoses of circuli on the lateral field of a scale or an isolated space between two circuli did not necessarily identify an annulus, although these characteristics contributed to annulus identification. Identification of annuli and supernumerary marks on spines was based on distinctness and appearance of a mark in all fields of the spine section and required little subjectivity. However, due to the spine softening technique used for preparation of spine cross sections, some of the marks on the spine sections (16 in age class II and 6 in age class III) faded after a period of about two months. This introduced subjectivity into spine age analysis and was the major reason that more than two readings of these spines were required to reach agreement of two readings.

Table 2. Number of largemouth bass scale readings and number of channel catfish spine readings needed to get agreement of two readings.

Known age group	Number collected	Number of individuals with agreement of two readings by:		
		2nd reading	3rd reading	4th reading
		Largemouth Bass		
I	30	26	4	0
II	35	23	11	1
III	19	9	8	2
IV	24	13	8	3
Total	108	71	31	6
		Channel catfish		
I	30	29	1	0
II	30	16	13	1
III	11	8	3	0
IV	36	26	9	1
Total	107	79	26	2

Table 3. Supernumerary marks found on scales from largemouth bass collected from ponds A, E, G, and I and supernumerary marks found on fin spines from channel catfish collected from ponds B, F, G, and H.

Known age groups	Number of individuals	Number of supernumerary marks	Locations[1]
		Largemouth bass	
I	30	14	0+
II	35	15	0+
		6	I+
III	19	6	0+
		7	I+
		2	II+
IV	24	9	0+
		12	I+
		4	II+
		3	III+
Total	108	78	
		Channel catfish	
I	30	2	0+
II	30	2	0+
		1	I+
III	11	0	--
IV	36	1	0+
Total	107	6	

Numbers and locations of supernumerary marks found during scale and spine age analyses are shown in Table 3. Spines from 107 channel catfish exhibited a total of six supernumerary marks and scales from 108 largemouth bass exhibited a total of 78 supernumerary marks. The supernumerary marks seemed to occur mostly in the first and second years of life.

Accuracy of the age determinations by the scale method compared to the established ages of the fishes is shown as "percent correct" in Table 4. In channel catfish, low accuracy of age determinations in age groups II and III probably resulted from increased difficulty in interpreting the faded marks on spine sections of these two groups. Of the seven largemouth bass which were incorrectly aged, five were assigned ages too old (overaged) and two were assigned ages too young (underaged). Of the 25 channel catfish that were incorrectly aged, 12 were overaged and 13 were underaged.

From this study it was apparent that indifinite annuli and supernumerary marks were often formed on the scales of largemouth bass and on the spines of channel catfish although a large majority of the individuals could be aged with a high degree of accuracy, especially in the first years of life. The observed errors in aging fishes were due to lack of annulus formation, or to misinterpretation of a supernumerary mark as an annulus, or to misinterpretation of an annulus as a supernumerary mark.

[1]Locations of the supernumerary marks on the scales or fin spines are denoted as follows: 0+ means the mark was found before the first annulus, I+ means the mark was found between the first and second annuli, II+ means the mark was found between the second and third annuli, and III+ means the mark was found between the third and fourth annuli.

Table 4. Accuracy of age determinations from largemouth bass scale readings and channel catfish spine readings.

Known age group	Number collected	Number aged correctly	Percent correct
		Largemouth bass	
I	30	30	100
II	35	32	91
III	19	16	84
IV	24	23	96
Total	108	101	94
		Channel catfish	
I	30	30	100
II	30	22	73
III	11	9	82
IV	36	21	58
Total	107	82	77

Validity of the Scale and Fin Spine Methods

To validly use the scale method for age determinations of fishes, it is necessary to determine the approximate time of year of annulus formation and the regularity of annulus formation each year for each species (Hile, 1941; Sprugel, 1954; Berg and Grinnaldi, 1967; and Mathews and Williams, 1972). On February 24 new annuli were being formed in some of the juvenile largemouth bass previously stocked in Pond C, and newly formed annuli were found on all individuals sampled from that pond on March 19, May 4, and May 17 (Table 5). On March 29 a new annulus was observed on one juvenile channel catfish previously stocked in Pond D, and newly formed annuli were present on all individuals sampled on May 10 (Table 5). Therefore, the approximate time of year of annulus formation in these juvenile fishes was designated as late February to mid-March for largemouth bass and as late March to early May for channel catfish.

Table 5. Time of annulus formation for juvenile largemouth bass in Pond C and channel catfish in Pond D.

Collection date	No. of fish collected	Water temp. (C)	No. of fish with *newly formed annuli* Largemouth bass	Channel catfish
1971				
Sept. 20	5	16.7	0	---
Sept. 20	5	16.7	---	0
Dec. 10	5	18.9	0	---
Dec. 10	5	18.9	---	0
1972				
Jan. 29	5	6.0	0	---
Jan. 29	5	6.0	---	0
Feb. 12	5	7.8	0	---
Feb. 24	5	16.7	1	---
Feb. 28	5	16.8	---	0
Mar. 7	5	15.0	---	0
Mar. 10	2	15.0	1	---
Mar. 19	5	11.1	5	---
Mar. 29	2	17.8	---	1
May 4	5	20.0	5	---
May 4	5	20.0	---	4
May 10	5	21.1	---	5
May 17	5	20.0	5	---

Table 6. Newly formed annuli found on scales and spines taken in age-determination collections.

Known age group	Number collected	Collection period (1972)	Number with new annuli	Percent with new annuli
		Largemouth bass		
I	30	May 4-May 17	28	93
II	35	Mar. 11-Mar. 15	23	66
III	19	Feb. 13-Mar. 28	1	5
IV	24	Mar. 19-Apr. 6	6	25
		Channel catfish		
I	30	May 4	26	87
II	30	Feb. 12-Mar. 29	2	7
III	11	Mar. 3-Apr. 10	2	18
IV	36	Feb. 30-Mar. 25	0	0

Some scales and spines from fishes which had been collected for the purpose of determining true age were observed to have newly formed annuli (Table 6). The time of year of annulus formation in the fishes collected for age determination from ponds A, B, E, F, G, H, and I (Table 6) corresponded with the time of year of annulus formation in the fishes collected to monitor time of year of annulus formation from ponds C and D (Table 5).

Support for the regularity of annulus formation could be found if the number of annuli found on scales or spines increased with the total body lengths of the fishes (Hile 1941; Butler and Smith, 1949; Hooper, 1949; Sneed, 1950; and Lagler, 1952). Table 7 indicates that as the number of annuli on scales of largemouth bass and on spines of channel catfish increased, the mean empirical total lengths of the fishes also increased. This suggested that scale and spine markings which were identified as annuli had been added systematically (Hile, 1941; and Hooper, 1949).

Table 7. Mean calculated total lengths at the end of each year of life and mean empirical total length of all age groups for largemouth bass and channel catfish.

Known age group	Number of individuals	Mean empirical total length (mm)	Calculated total lengths at each annulus (mm) 1	2	3	4
		Largemouth bass				
I	30	143	133			
II	32	275	149	266		
III	16	390	270	340	388	
IV	23	499	217	385	458	497
Total	101					
Average			179	321	429	497
		Channel catfish				
I	30	188	160			
II	22	348	179	338		
III	9	428	192	332	424	
IV	21	516	198	332	432	516
Total	82					
Average			178	333	429	516

To further support regularity of annulus formation, back-calculated total lengths of fishes at different ages were compared to empirical total lengths of fishes at that age. Back-calculated total lengths of fishes were obtained by use of body-scale or body-spine relationships derived by simple linear regression. The body-scale relationship for largemouth bass upon 108 fish (Figure 3) was defined by the formula,

$$L = -0.181 + 12.642\ S.$$

The body-spine relationship for channel catfish based upon 107 fish (Figure 4) was defined by the formula,

$$L = -70.853 + 29.574\ S.$$

When the mean empirical total lengths and mean empirical scale or spine measurements were plotted (Figures 3 and 4), a slight deviation from linearity was noticed in the upper extreme of both regression lines, but since the deviation was slight and since sample sizes used to determine the lines were small, the regression lines were considered to be adequate for the description of the body-scale and body-spine relationships for this study. Mean calculated total lengths of fishes at each annulus (Table 7) were found to agree closely with the total lengths of fishes of various ages at the time of capture.

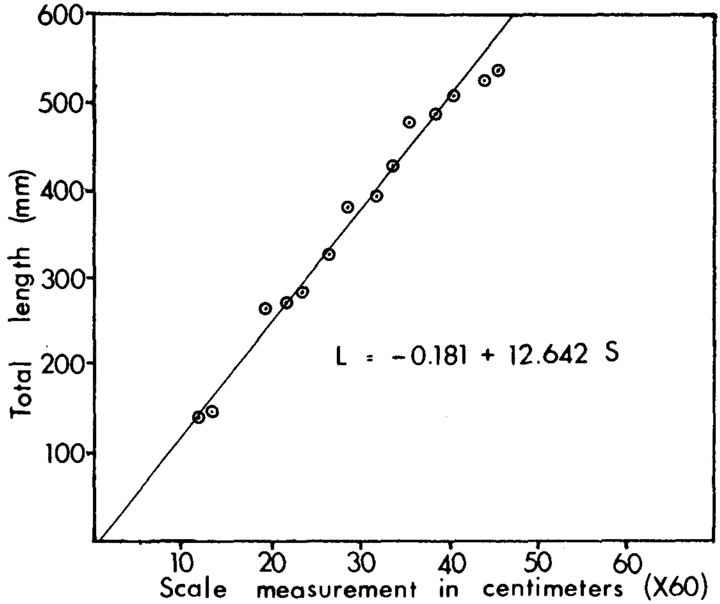

Figure 3. Body-scale relationship for largemouth bass from ponds A, E, G, and I.

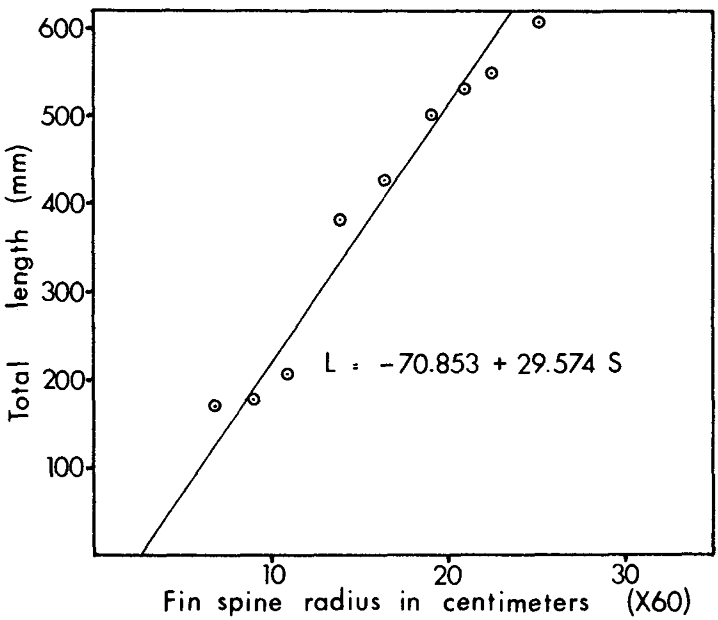

Figure 4. Body-spine relationship for channel catfish from ponds B, F, G, and H.

From this study it is apparent that criteria for the validation of age determination methods for these largemouth bass and channel catfish have been satisfied. Annulus formation occurred at approximately the same time of the year for largemouth bass from ponds A, C, E, G, and I and for channel catfish from ponds B, D, F, G, and H. Mean empirical total lengths increased with an increase in the number of annuli on the scales and spines, which suggests regularity of annulus formation. Finally, mean total lengths of fish of various ages, calculated from scale or spine measurements from older fish, were in close agreement with mean empirical total lengths of known age fish of the same age. This also suggests regularity of annulus formation.

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