VALIDATION OF AGING TECHNIQUES FOR LARGEMOUTH BASS, *MICROPTERUS SALMOIDES*, AND CHANNEL CATFISH, *ICTALURUS PUNCTATUS*, IN CENTRAL TEXAS FARM PONDS

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Growth rates of fish are extremely responsive to the environment, and because of this, growth may be less when conditions are unfavorable than that which occurs 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 and measurements made to successive year marks. 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 conditions: that scales remain constant in number and identity throughout the life of the fish; that the annual increment in the length (or some other dimension which must be used) of the scale maintains, throughout the life of the fish, a constant ratio with the annual increment in body length; 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 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 persistently strongly or weakly represented in collections of successive years. Lagler (1952) suggested validation of the scale method by the criteria listed above by Hile, augmented by direct comparison of the age of a fish estimated by the scale method to the actual age of the fish and 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 the comparison of ages estimated by the scale method to 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 studies established validity of the scale method by determining the annual character 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 identifying 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 is in question for fish from southern latitudes (Prather, 1967). Age and growth studies have not been a regular part of fisheries management practices in Texas because of the difficulties in reading scales. 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.

CHAPTER II

METHODS AND MATERIALS

Study Area and Methods

Largemouth bass and channel catfish were collected from seven farm ponds located in the blackland soil region of the Texan Biotic Province (Blair, 1950). Ponds selected for this study had no other bodies of water in their drainage areas. 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 and 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 was a research pond located at the Aquatic Station, Southwest Texas State University, San Marcos, Texas. Ponds F, G, H, and I were farm ponds used principally for livestock watering and were situated in uncultivated pasture land in Caldwell, Guadalupe, and Hays counties. Ponds were selected principally on the basis of soil region and stocking dates. The selection of ponds located in the same soil region and the same biotic province should minimize the variations in the environmental conditions of the ponds and

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	Largemouth Bass	1971	1	0.04	1.5
B	Hays	Channel Catfish	1971	1	0.04	1.5
C*	Hays	Largemouth Bass	1971	1	0.04	1.5
D*	Hays	Channel Catfish	1971	1	0.04	1.5
E	Hays	Largemouth Bass	1970	2	0.44	2.1
F	Caldwell	Channel Catfish	1970	2	0.30	5.2
G	Caldwell	Largemouth Bass	1969	3	0.61	4.9
		Channel Catfish	1968	4		
H	Guadalupe	Channel Catfish	1969	3	0.81	4.6
I	Hays	Largemouth Bass	1968	4	2.14	5.2
		Channel Catfish	1967	5		

*Ponds used only for determination of time of annulus formation.

the variations in fish growth among these ponds. Selecting ponds which had been stocked only one time assisted in determining the accurate ages of fishes collected. Additional information for each pond is given in Table 1.

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. An attempt was made to collect at least 30 stocked channel catfish from ponds B, F, G, and H. A total of 108 largemouth bass and 107 channel catfish were collected to represent age classes I through IV. The assumption is made that fish growth had ceased, or reached its slowest rate by late winter, thus the margins of scales and fin spines of fishes collected in late winter represented the last annulus. In fishes collected in early spring the last annulus and new spring growth cound 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 fish collected, washed with water to remove excess slime, and placed in a scale envelope. 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 near the base that insured the inclusion of the distal portion of the basal groove and was placed in a scale envelope. The inclusion of the distal portion of the basal groove insured 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, location, and collection date were recorded for each fish on scale 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). Cross sections of spines, located at the distal end of the basal groove, used in spine age analysis were prepared by a 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. An attempt was made to collect scale samples from five largemouth bass and spine samples from 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 time from the first observation of a newly formed annulus until all fish in a sample possessed newly formed annuli was designated the approximate time 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 were based, is caused by changes in fish growth rate during the year (Lagler, 1952; and Chugunova, 1963). Changes in rate of growth are usually caused by changes in environmental conditions. 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 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 by widely spaced circuli distally (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 the most important 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 by narrowly spaced circuli distally

(Sprugel, 1954; Regier, 1962; and Chugunova, 1963), (2) crowded circuli, usually two or three, projecting 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 any of the characteristics of supernumerary marks were labeled as supernumerary marks. Marks on fin spine cross sections were identified as annuli when they were distinct and appeared in all fields of the section concentric with the edge, and as supernumerary marks when 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 each appropriate scale impression or spine section. Age analysis was then carried out in a random order. Therefore, age determinations were made 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 two readings for each individual. 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 fishes in ponds A, B, E, F, G and H were determined by this method.

Channel catfish do not usually reproduce in farm ponds (Swingle and Smith, 1947; and Lewis, 1950). However, channel catfish apparently reproduced in Pond I and since it was impossible to accurately determine the age of these fish, channel catfish data from this pond were omitted from the study.

In ponds where reproduction occurred after stocking it was necessary to employ methods of separating the stocked fishes from their offspring before utilizing them in validation of aging techniques. For example, largemouth bass reproduction occurred in ponds G and I which necessitated separating stocked bass 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. 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). However, since overlap of age group distributions was evident 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.

Fish growth in a body of water varies from year to year due to varying environmental conditions. Variations in fish growth are recorded in the growth patterns on the scales of the fish in that body of water. Therefore, the stocked fish in each pond in this study should exhibit scale growth patterns which are different from the scale growth patterns 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. Any fish not shown to be a stocked fish by all three methods was eliminated from the known age category.

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 mid-anterior 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 regression equation used to calculate the body-scale and body-spine relationships were as follows:

$$\underline{L} = \underline{a} + \underline{bS},$$

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

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

CHAPTER III

RESULTS AND DISCUSSION

Known Age Fishes

Separations of largemouth bass, collected from ponds G and I, into different year classes based on length frequencies (Figures 1 and 2) was in good agreement with separations based on Harding's (1949) probability paper method (Figures 1 and 2). These two methods were used in conjunction with the scale growth pattern method to ultimately separate the stocked fish from their offspring.

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 (Figure 3) than occurred on scales of other fish (Figure 4) 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 (Figure 5) than occurred on the scales of other fish (Figure 6) collected from Pond I. Only the 19 fish from Pond G and the 24 fish from Pond I which were indicated by all three methods to be the stocked fish, with a known age determined by the stocking date of the pond, were used in the validation

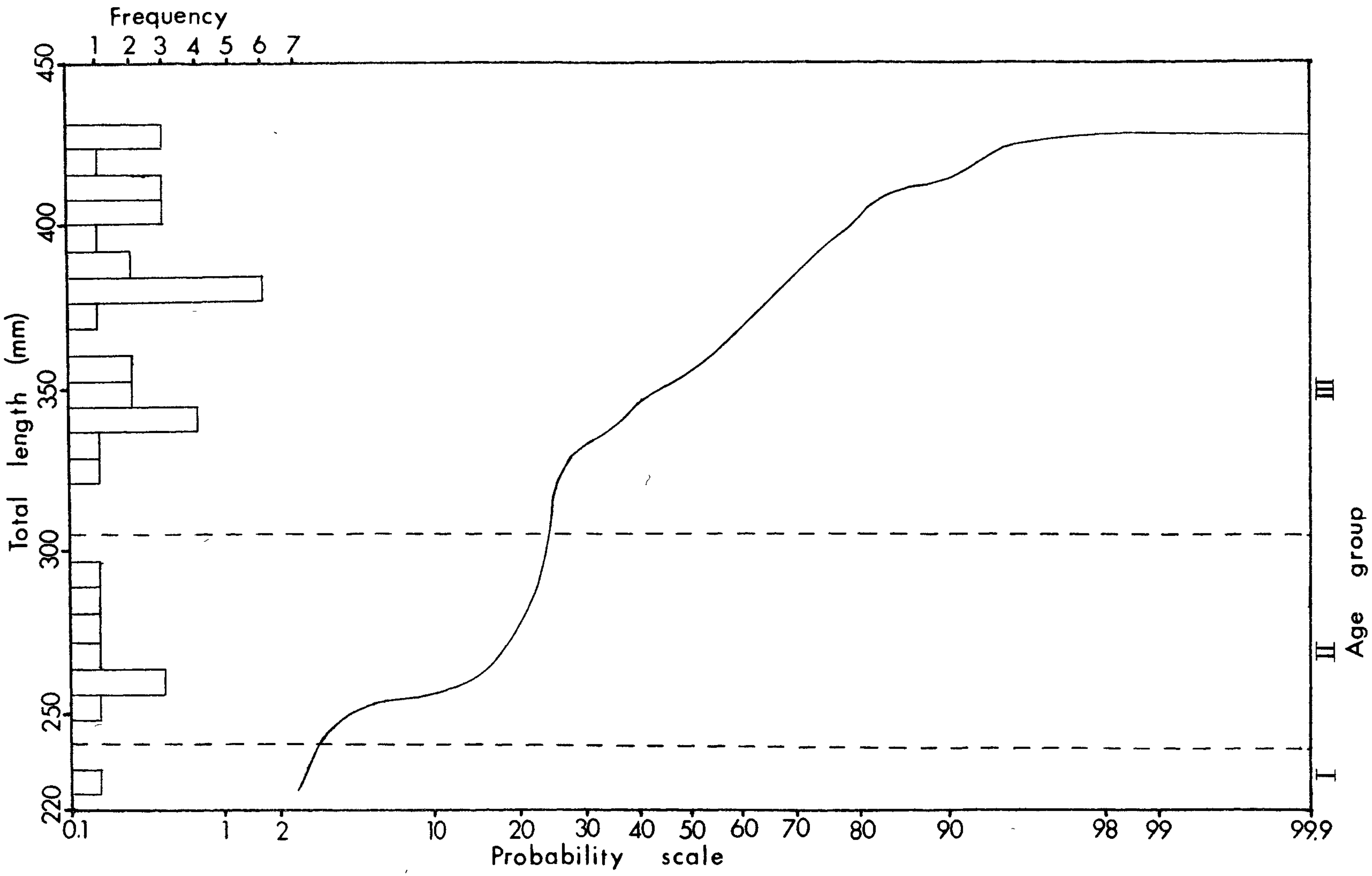

FIGURE 1.--Length frequencies and age group separations based on Harding's (1949) probability paper method for largemouth bass collected from Pond G.

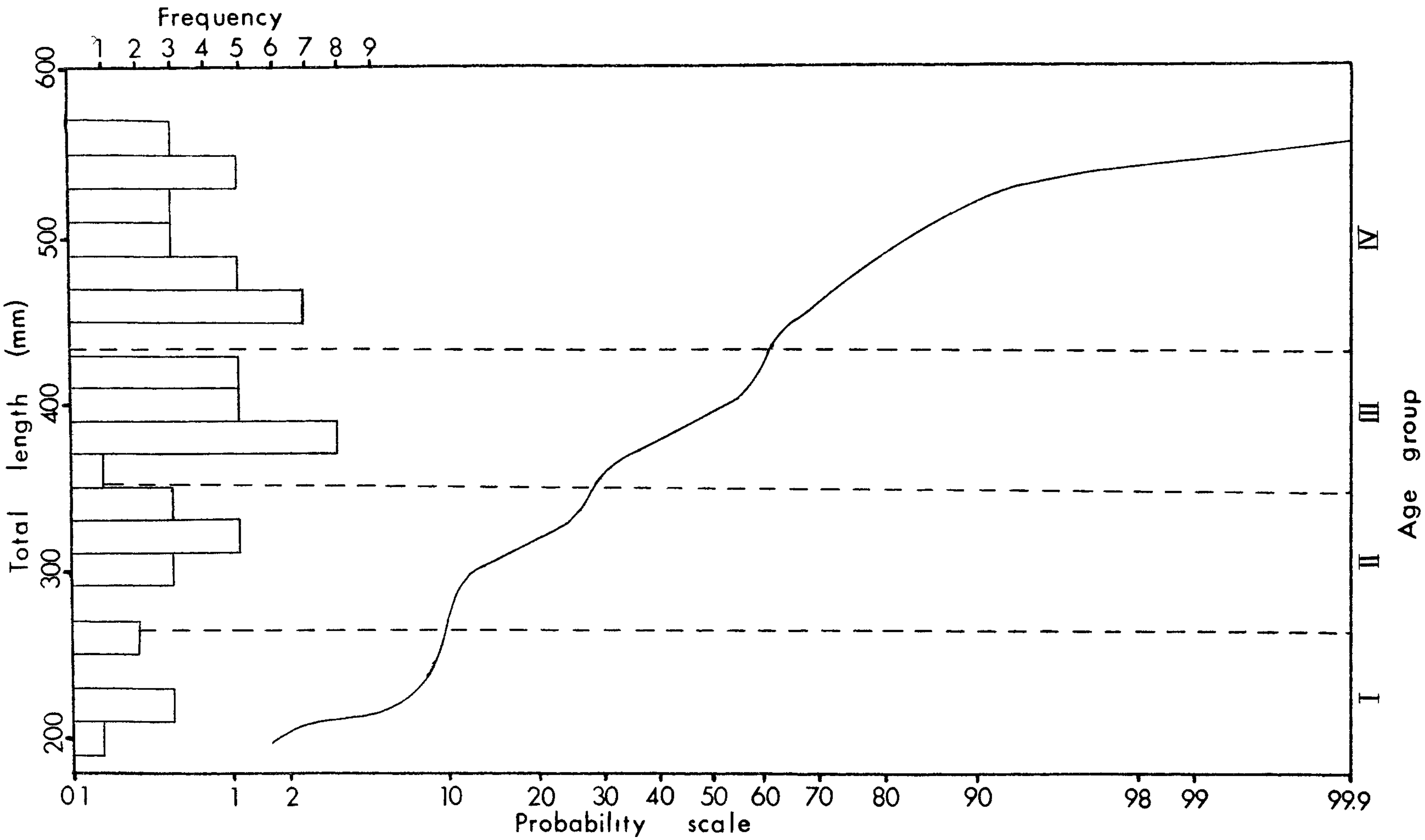

FIGURE 2.--Length frequencies and age group separations based on Harding's (1949) probability paper method for largemouth bass collected from Pond I.

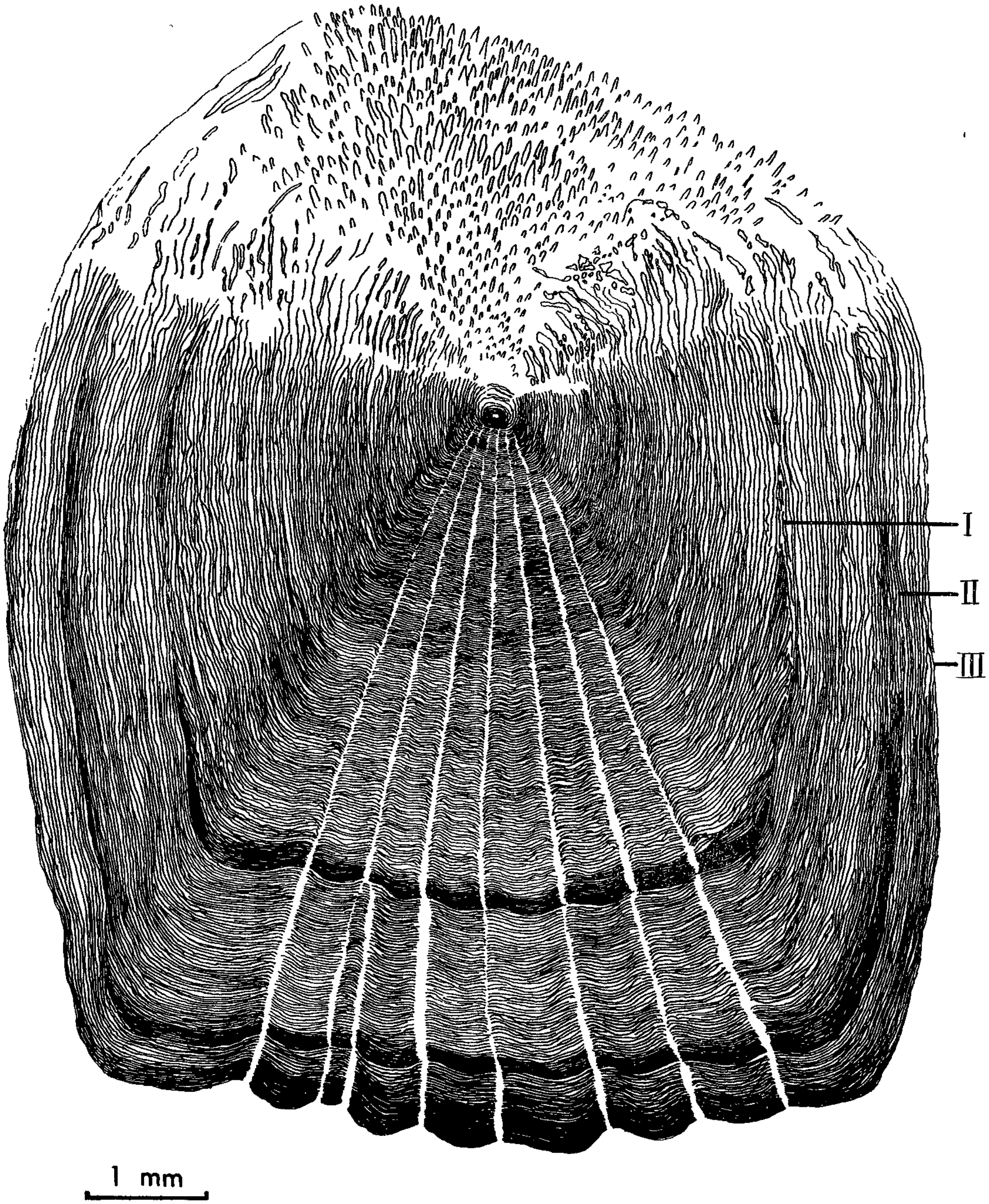

FIGURE 3.--Scale of a 3-year-old largemouth bass collected from Pond G, with annuli indicated by Roman numerals.

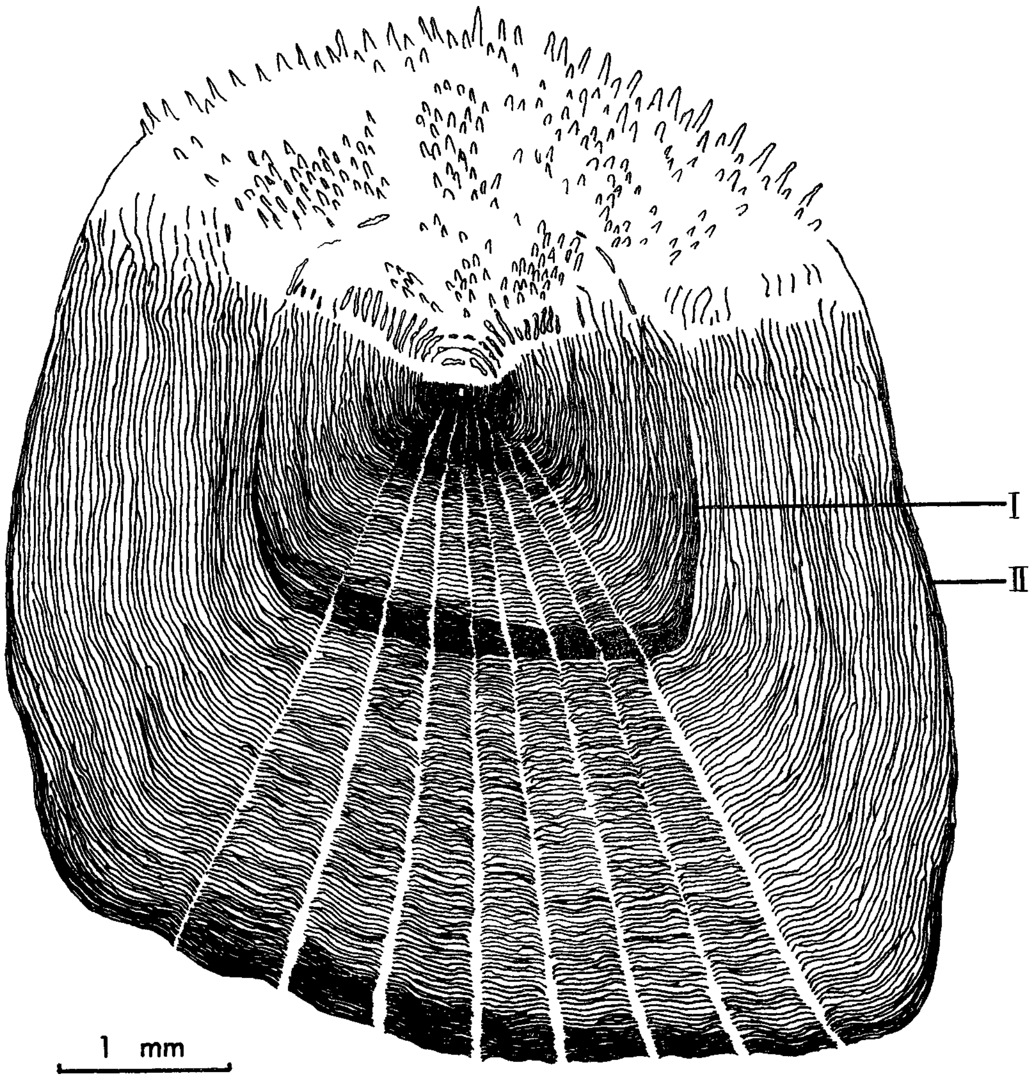

FIGURE 4.--Scale of a 2-year-old largemouth bass collected from Pond G, with annuli indicated by Roman numerals.

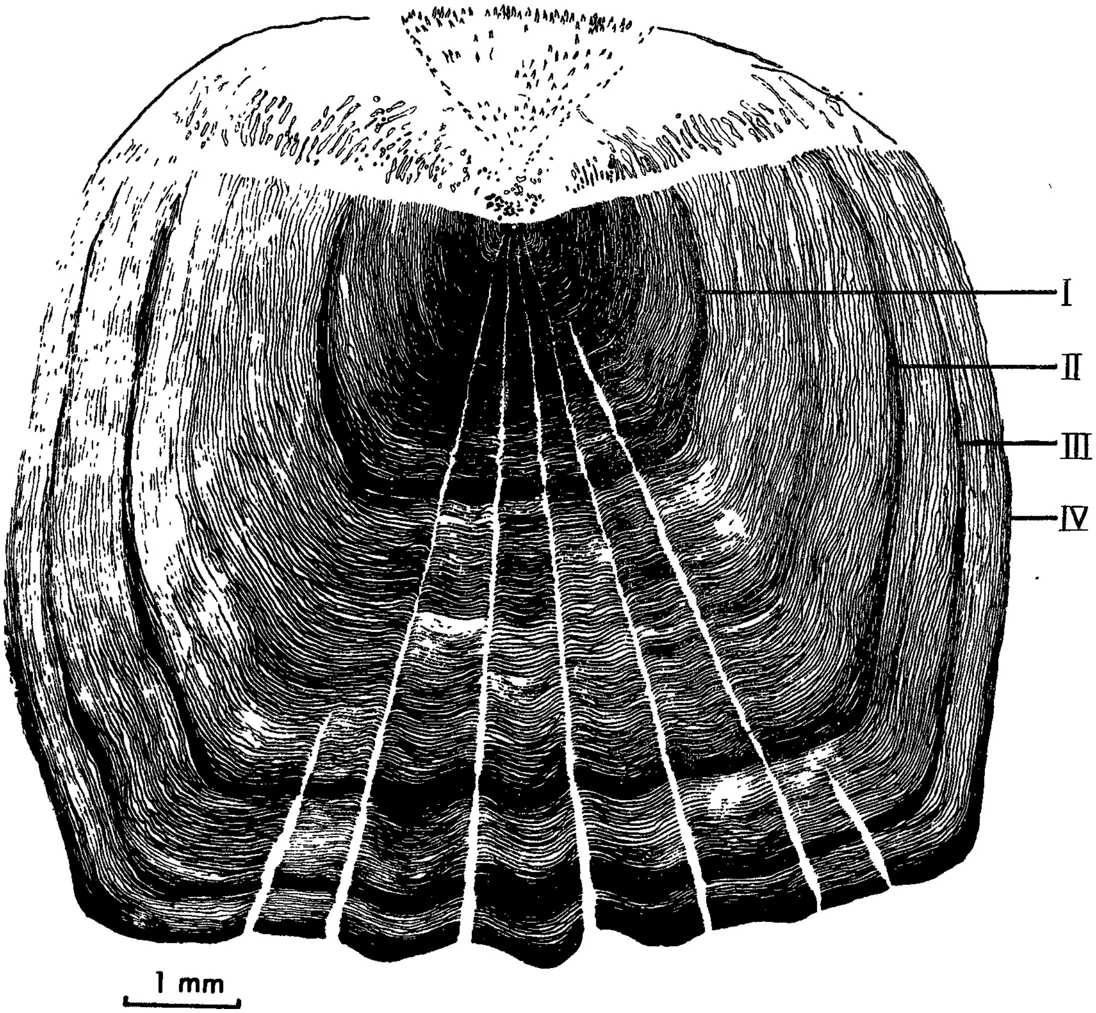

FIGURE 5.--Scale of a 4-year-old largemouth bass collected from Pond I, with annuli indicated by Roman numerals.

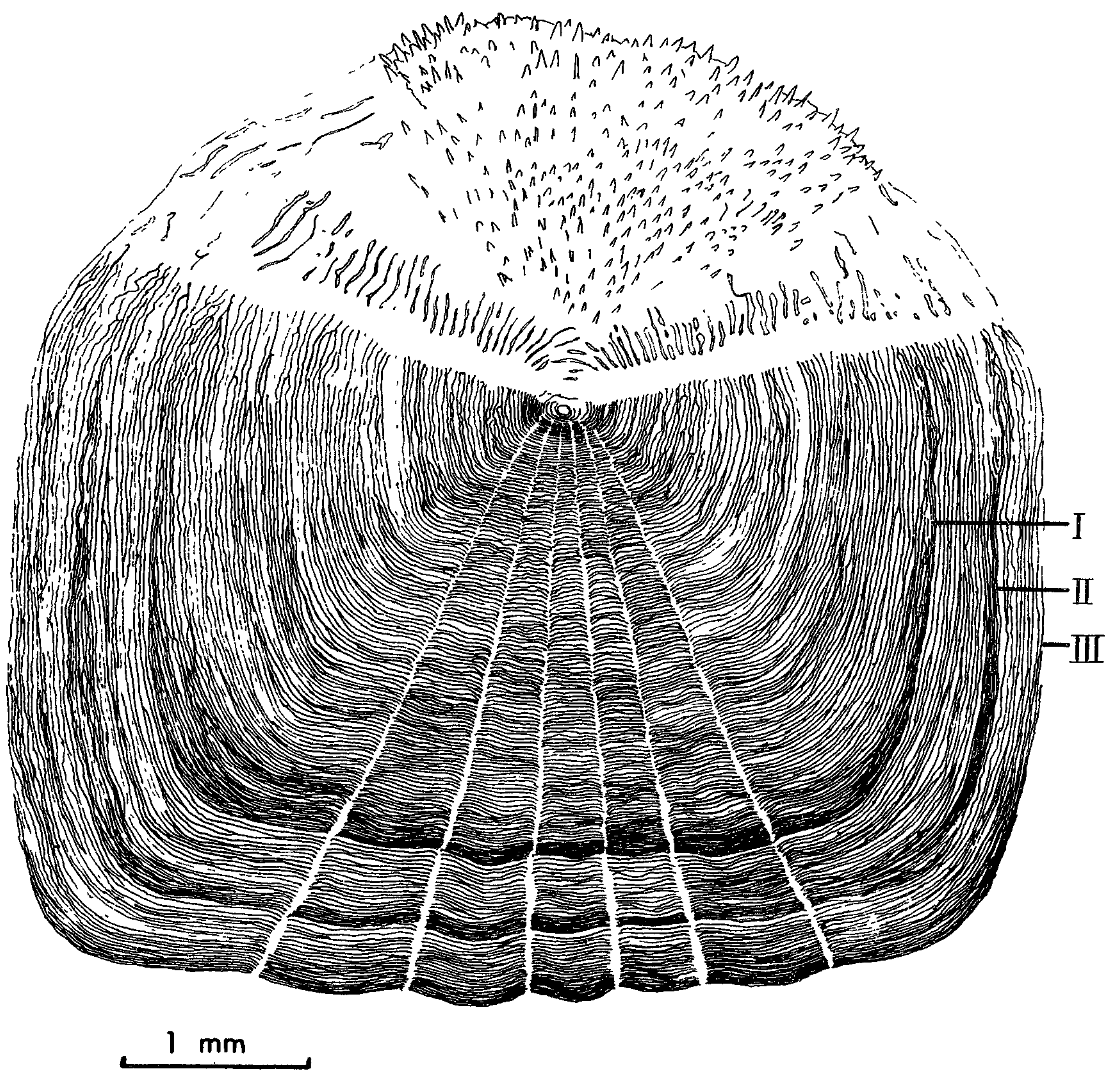

FIGURE 6.--Scale of a 3-year-old largemouth bass collected from Pond I, with annuli indicated by Roman numerals.

analyses. The other fish from Ponds G and I which were not indicated by all three methods to be the stocked fish were considered as offspring of the stocked fish or of questionable known age, therefore, they were not used in validation analyses.

Accuracy of Age Determinations by the Scale and Fin Spine Methods

Although criteria have been presented to identify 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 (Tables 2 and 3) show that, although agreement of two readings was obtained with 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

TABLE 2.--Number of largemouth bass scale 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
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

TABLE 3.--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
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

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 six in age class III) faded after a period of about two months. This necessitated subjectivity in spine age analysis and was the major reason more than two readings of these spines were required to reach agreement of two readings.

Numbers and locations of supernumerary marks found during scale and spine age analyses are shown in Tables 4 and 5. 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 Tables 6 and 7. A general decrease in the accuracy of age determinations in older fishes was due to increased difficulty of interpretation of growth marks in older scales and spines. The accuracy of interpretation of supernumerary marks and annuli decreased in older fishes since annuli were laid down closer together in later years. In channel catfish, low accuracy of age determinations in age groups II and III probably resulted from

TABLE 4.--Supernumerary marks found on scales from largemouth bass collected from Ponds A, E, G, and I

Known age group	Number of individuals	Number of supernumerary marks	Locations*
I	30	14	O+
II	35	15	O+
		6	I+
III	19	6	O+
		7	I+
		2	II+
IV	24	9	O+
		12	I+
		4	II+
		3	III+
Total	108	78	

*Location of the supernumerary mark on the scale denoted: O+ 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 5.--Supernumerary marks found on fin spines from channel catfish collected from Ponds B, F, G, and H

Known age group	Number of individuals	Number of supernumerary marks	Locations*
I	30	2	O+
II	30	2	O+
		1	I+
III	11	0	--
IV	36	1	O+
Total	107	6	

*Location of the supernumerary mark on the fin spine denoted: O+ means the mark was found before the first annulus and I+ means the mark was found between the first and second annuli.

TABLE 6.--Accuracy of age determinations from largemouth bass scale examinations

Known age group	Number collected	Number aged correctly	Percent correct
I	30	30	100
II	35	32	91
III	19	16	84
IV	24	23	96
Total	108	101	94

TABLE 7.--Accuracy of age determinations from channel catfish fin spine examinations

Known age group	Number collected	Number aged correctly	Percent correct
I	30	30	100
II	30	22	73
III	11	9	82
IV	36	21	58
Total	107	82	77

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 indefinite 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 either 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.

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

TABLE 8.--Time of annulus formation for juvenile largemouth bass and channel catfish in Ponds C and D

Collection date	No. of fish collected	Water temp. (C)	No. of fish with newly formed annuli: Largemouth bass	No. of fish with newly formed annuli: 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	---

individuals sampled from that pond on March 19, May 4, and May 17 (Table 8). 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 8). The approximate time of annulus formation in these juvenile fishes was, therefore, designated as late February to mid-March for largemouth bass and late March to early May for channel catfish.

As scales and spines from fishes collected in ponds were examined to determine age, some individuals were observed to have newly formed annuli (Tables 9 and 10). Annulus formation time in the fishes collected for age determination for Ponds A, B, E, F, G, H, and I (Tables 9 and 10) corresponded with annulus formation time in the fishes collected to monitor time of annulus formation from Ponds C and D (Table 8).

A temperature of 6 C, recorded in Ponds C and D on January 29, 1972 (Table 8) was sufficiently low to stop fish growth according to Berg and Grinnaldi (1967).

To determine the regularity of annulus formation and add validity to the scale method, the total body lengths of fishes should increase as the number of annuli found on their scales or spines increase (Hile, 1941; Butler and Smith, 1949; Hooper, 1949; Sneed, 1950; and Lagler, 1952). As the number of annuli on scales of largemouth bass or on spines of

TABLE 9.--Largemouth bass with newly formed annuli in age determination collections from Ponds A, E, G, and I

Known age group	Number collected	Collection period (1972)	Number with new annuli	Percent with new annuli
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

TABLE 10.--Channel catfish with newly formed annuli in age determination collections from Ponds B, F, G, and H

Known age group	Number collected	Collection period (1972)	Number with new annuli	Percent with new annuli
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

TABLE 11.--Mean calculated total lengths at the end of each year of life and mean empirical total length of all age groups for largemouth bass

Known age group	Number of indi- vidual	Mean empirical total length (mm)	Calculated total lengths at each annulus (mm)			
			1	2	3	4
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

TABLE 12.--Mean calculated total lengths at the end of each year of life and mean empirical total lengths of all age groups for channel catfish

Known age group	Number of indi- vidual	Mean empirical total length (mm)	Calculated total lengths at each annulus (mm)			
			1	2	3	4
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

channel catfish increased, the mean empirical total lengths of the fishes also increased (Tables 11 and 12). This indicated that scale and spine markings which were identified as annuli were added systematically (Hile, 1941; and Hooper, 1949).

To indicate 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 based upon 108 fish (Figure 7) was defined by the formula,

$$\underline{L} = -0.181 + 12.642\ \underline{S}.$$

The body-spine relationship for channel catfish based upon 107 fish (Figure 8) was defined by the formula,

$$\underline{L} = -70.853 + 29.574\ \underline{S}.$$

Mean empirical total lengths and mean empirical scale or spine measurements, calculated for every 25 millimeter interval of scale or spine measurement, were plotted to indicate the fit of the data to each respective regression line (Figures 7 and 8). 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

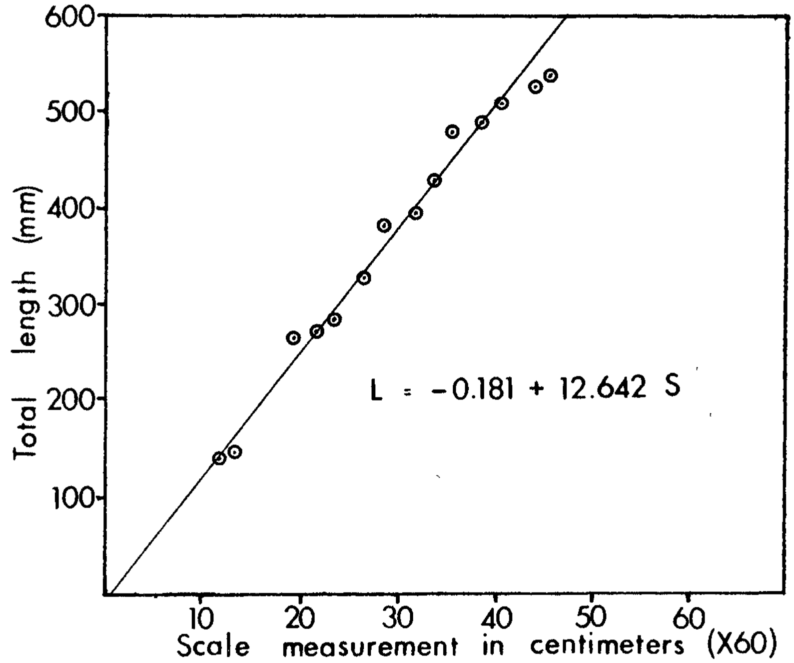

FIGURE 7.--Body-scale relationship for largemouth bass from Ponds A, E, G, and I.

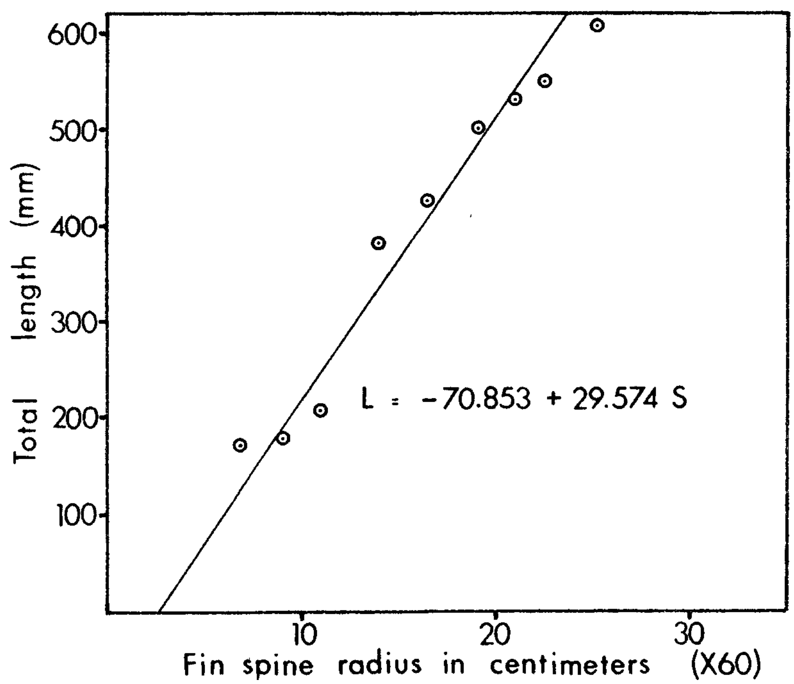

FIGURE 8.--Body-spine relationship for channel catfish from Ponds B, F, G, and H.

were considered adequate to describe the body-scale and body-spine relationships for this study. Mean calculated total length of fishes at each annulus (Tables 11 and 12) was found to agree closely to the total lengths of fishes of various ages at the time of capture.

From this study it was apparent that criteria for validation of the age determination methods for these largemouth bass and channel catfish were 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 B, D, F, G, and H. Mean empirical total lengths increased with an increase in the number of annuli on the scales or spines, which indicated 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 indicated regularity of annulus formation.

CHAPTER IV

SUMMARY

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 fin 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 shown 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.

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