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VALIDITY OF AGE DETERMINATION FROM SCALES OF MARKED AMERICAN SHAD

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ABSTRACT

In the fall of 1952, one hundred thousand juvenile American shad, marked by removal of the right pelvic fin, were released in the Connecticut River. Seventeen marked fish were recovered in the river in 1956, 70 in 1957, and 39 in 1958. Ages of the fish, determined from their scales, were 4, 5, and 6 years, respectively. These findings were in agreement with known age established from marking and therefore validate annuli and spawning marks as criteria for age determination of shad.

VALIDITY OF AGE DETERMINATION FROM SCALES OF MARKED AMERICAN SHAD

By MAYO H. JUDY, *Fishery Research Biologist,*
Bureau of Commercial Fisheries

In 1950, the U.S. Fish and Wildlife Service, as the primary research agency of the Atlantic States Marine Fisheries Commission, began a study of the American shad (*Alosa sapidissima*) on the Atlantic coast of the United States. Objectives of this investigation were to determine the causes for decline in the commercial yield from approximately 50 million pounds in 1896 to 8 million pounds in 1950, to determine conditions favoring recovery, and to provide information for scientific management of the fishery. A necessity for accomplishing these objectives was an accurate method of aging shad.

Prior to this investigation, techniques for aging shad had been presented by various workers. Leim (1924) determined age by means of winter rings or annuli on scales and established the relation between scale and body length. Borodin (1925) presented a method of reading scales by counting the number of transverse grooves and dividing by 2 to determine the age in years. Barney (1925) found evidence in otolith markings to indicate that age estimates as reported by Borodin were correct, but Greeley (1937) stated that Borodin's method gave misleading results. Greeley found that Leim's method of age determination agreed with the results of his studies on Hudson River shad.

Cating (1953) proposed a method for reading shad scales for total age, age at first spawning, and number of times the fish had previously spawned. Transverse groove counts were used to separate true from fasle annuli to the fourth annulus, and age of fish spawing for the first time was determined by counting the number of annuli and adding 1 year for the scale edge. Age of fish spawning for the second or more times was obtained by counting the number of annuli plus the number of spawning marks and adding 1 year for the scale edge.

Although Cating aged shad with apparent confidence he did not establish the validity of his readings. LaPointe (1958), using Cating's method, validated the annulus to be a true year mark on scales of fish spawning for the first time. He found that Leim mistook the fresh-water mark for the first annulus, thus causing a difference of 1 year between Leim's age determination and those in his study. Hammer (1942) confirmed that the fresh-water zone was a distinct and measurable scale growth formed while juveniles are in fresh water.

In 1952, prior to the completion of Cating's scale study, a marking program was conducted on juvenile shad in the Connecticut River. The objective of this program was to recover in future years marked fish of known age, thereby to check the method employed by Cating and to establish a correct method for aging shad from their scales. This was deemed necessary because techniques used prior to this time were subject to question.

Data presented in this paper were derived from the scales of marked adult shad recovered 4, 5, and 6 years following the marking program. Scales from these fish of known age were studied to determine the validity of annuli and spawning marks for age determination.

Appreciation is expressed to the Connecticut Power and Light Company for use of the Windsor Locks Canal System, and to the shad fishermen and fish dealers of the Connecticut River for their cooperation in this study.

LIFE HISTORY

Shad range on the Atlantic coast from the St. Johns River in Florida to the St. Lawrence River in Canada. It is an anadromous fish and spawning migrations begin as early as November in

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Florida and as late as June in Canada. The young remain in the rivers until fall, attaining lengths from 3 to 5 inches, then migrate to sea. Winters are probably spent off the Middle Atlantic, and summer and fall in the Gulf of Maine. After reaching maturity, in 3 to 6 years, they return to the rivers to spawn. Adult shad native to streams north of Cape Hatteras (N.C.) that survive spawning and other hazards return to the sea and re-enter the rivers to spawn again in successive years. Shad native to streams south of Cape Hatteras die after spawning (Talbot and Sykes, 1958).

MATERIALS AND METHODS

In the fall of 1952, 100,000 downstream migrant juvenile shad were marked on the Connecticut River in the Windsor Locks Canal, Windsor Locks, Conn. Marking of these fish, which averaged about 4 inches in fork length, was accomplished by clipping the right pelvic fin close to the body of the fish. Juveniles were trapped, seined, and marked in one level of the canal and then placed in a lower level of the canal and flushed into the main river. Samples of fish were held overnight to obtain an estimate of mortality. Mortality from marking was estimated at 30 percent; therefore, it was assumed that 70,000 marked juveniles were returned to the river.

The first marked fish were recaptured in the Connecticut River in 1956 from commercial catches and shad passed by the fishway at Hadley Falls Dam, Holyoke, Mass. Subsequent recoveries were made in 1957 and 1958 from commercial and sport catches. Approximately 35,000 shad were examined annually. From the 1956 collection it was determined that some shad had malformed, or naturally missing, pelvic fins. Therefore, in 1957, fish with various pelvic fin abnormalities were collected so that a wide assortment of abnormal fins would be available for comparison with marked fins. The pelvic girdle section of each fish collected was removed, labeled, and preserved. In addition, scale samples were taken and the length, weight, and sex recorded.

EXAMINATION OF SCALES

Two scales from each fish collected were impressed in plastic, using a modification of the method described by Greenbank and O'Donnell (1950). The scale impressions were read on an Eberbach projector, by two biologists using Cating's (1953) method for determining age of shad. Age readings were compared and the results confirmed.

In this method the scale edge is counted as a year mark because the last annulus (near scale periphery) is frequently eroded during the spawning migration. For example, a shad spawning for the first time (virgin fish) at 4 years of age has 3 annuli on the scale plus the scale edge for a total age of 4 years. After shad spawn and return to the sea, renewed feeding and resumption of growth leaves a characteristic scarlike mark on the scale edge where erosion occurred during the spawning migration (Moss, 1946). This is designated as a spawning mark and is used in place of the eroded annulus, formed prior to spawning, for determining age of "repeater" fish (those spawning for the second or more times). For example, a 6-year-old repeater spawning for the second time has 4 annuli and 1 spawning mark which, when read to include the scale edge, gives a total age of 6 years. The 4 annuli and 1 spawning mark indicate that this fish first spawned at 5 years of age and was on its second spawning run when captured.

EXAMINATION OF PELVIC FINS

Examination of the pelvic fin sections indicated that they contained malformed, missing, and marked fins. Malformed and missing fins are often found in fish as evidenced from studies by Cable (1956), Code (1950), and Rich and Holmes (1928). Marked fins were characterized by a varied pattern of fin regeneration ranging from no regeneration beyond formation of scar tissue to almost complete, but distorted regeneration. These findings are not unusual since, as reported by Stuart (1958), fin clipping seldom results in a uniform series of marks. From microscopic examination of regenerated marked fins, Stuart found that new growth of fin rays does not extend in a regular manner but commences as a thickened and undifferentiated cap, the connective and other tissues keeping pace with the growth of the adjacent rays. The degree and nature of fin regeneration was usually dependent on the angle of the cut and the amount of dermal-fin-ray tissue removed during clipping.

The pelvic fin section of each shad collected in

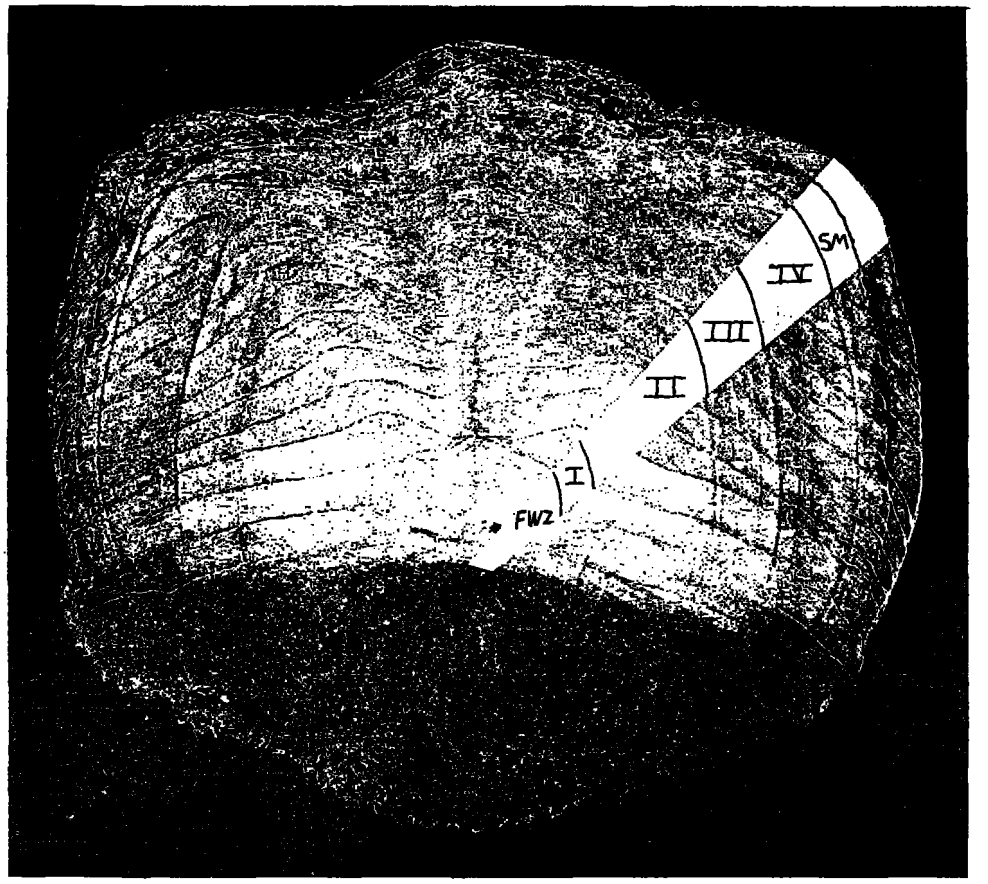

FIGURE 1.—Scale from 6-year-old shad spawning for the second time. (Roman numerals represent annuli, FWZ fresh-water zone, and SM spawning mark.)

this study was X-rayed using a method described by Sutherland (1958). Marked fins were identified from radiographs by an enlargement at the distal end of the radial bones extending partially or completely across the area of separation from the dermal fin rays (fig. 2). This method of classification of marked fish is in agreement with Stuart (1958) who found from microscopic examination that a palpable ridge was formed on marked fins at the site of cutting. Marked fins were classified according to the number of fin rays regenerated, regardless of the length of the rays, and placed in the following categories: (1) no regeneration—no fin rays; (2) one-third regeneration—one to three fin rays; (3) two-thirds regeneration—four to six fin rays; and (4) complete regeneration—seven to nine fin rays (fig. 2).

Pelvic-fin sections were classified as malformed if there was no enlargement at the distal end of the radials (fig. 3B, C). Missing fins were characterized by absence of radials or, in some specimens, absence of the entire pelvic girdle (fig. 3A, D), and absence of scar tissue at the site of fin origin. Malformed and missing fins were termed abnormal.

From a study of 28 shad collected in 1956, it was determined that 11 had abnormal pelvic fins. These included 4 males and 7 females of which 5 had malformed left or right pelvic fins and 6 had either the left, right, or both pelvic fins missing. These fish ranged in age from 3 to 6 years.

In 1957 fish with a variety of pelvic fin abnormalities were purposely collected. Of the 132 shad sampled, 62 were classified as abnormal.

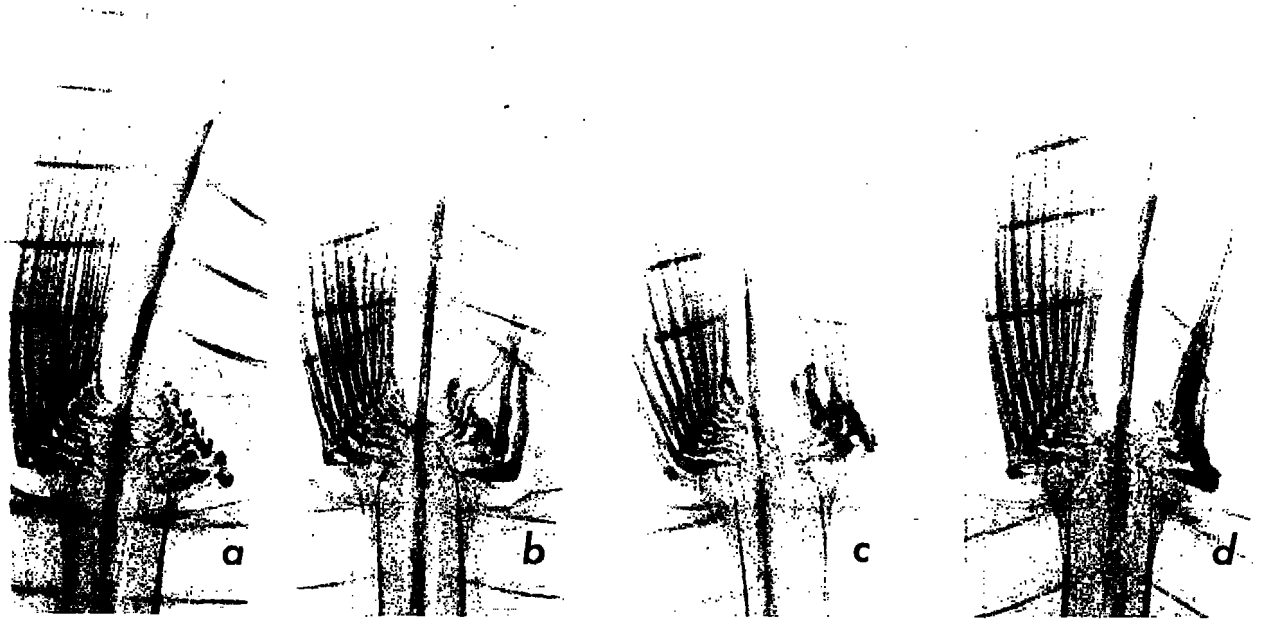

FIGURE 2.—Radiograph of pelvic fin sections from four marked shad. A—no regeneration, B—one-third, C—two-thirds, and D—complete regeneration.

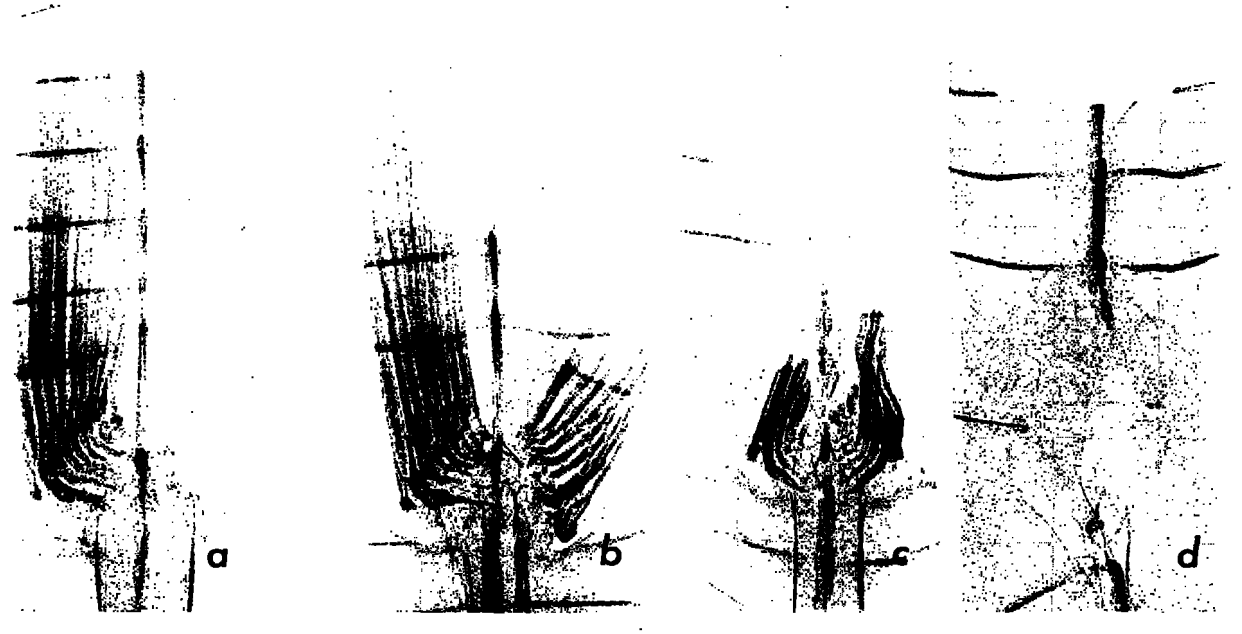

FIGURE 3.—Radiograph of pelvic fin sections from four shad with malformed and missing fins (A—right fin and radial fin supports absent, B—right fin with malformed fin rays, C—double malformation of pelvic fins, and D—pelvic girdle absent.)

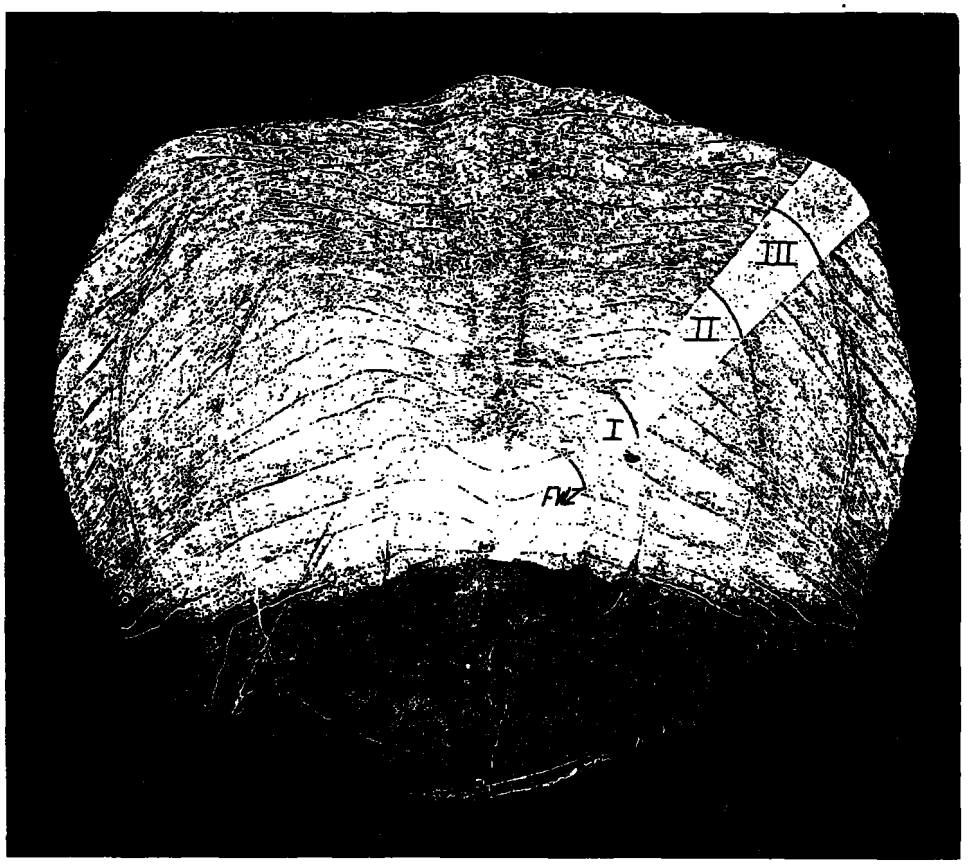

FIGURE 4.—Scale from 4-year-old marked shad spawning for the first time.

These included 21 males and 41 females of which 40 had either the left, right, or both pelvic fins malformed, and 22 had either the left, right, or both pelvic fins missing. These fish ranged in age from 4 to 7 years.

Of the 57 shad collected in 1958, 18 were classified as abnormal. These included 9 males and 9 females of which 6 had either the left, right, or both pelvic fins malformed and 12 had either the left, right, or both fins missing. These fish ranged in age from 4 to 8 years.

MARKED FISH RECOVERED 1956

From a study of pelvic fin sections and radiographs it was determined that 17 marked shad were recovered in 1956. These included 8 males and 9 females of which 3 had no regeneration of the right fin, 5 had one-third regeneration, 4 had two-thirds regeneration, and 5 had complete regeneration. Age readings indicated that all marked fish recovered were 4 years old, and spawning for the first time (fig. 4). Marked males averaged 16.4 inches, fork length, and 2.4 pounds in weight. Marked females averaged 17.9 inches, fork length, and 3.2 pounds in weight.

MARKED FISH RECOVERED 1957

From a study of pelvic fin sections and radiographs it was determined that 72 marked shad were recovered in 1957. Age determined from scale readings indicated that all but two of these fish were 5 years old. The ages of these two fish were 4 and 6 years. The radiographs and scale samples were re-examined and the above results confirmed. Therefore, on the basis of these findings, an error of approximately 3 percent exists either in interpretation of radiographs or in age determination.

The seventy 5-year-old fish that were marked included 14 males and 56 females of which 11 had no regeneration of the right pelvic fin, 18 had one-third regeneration, 26 had two-thirds re-

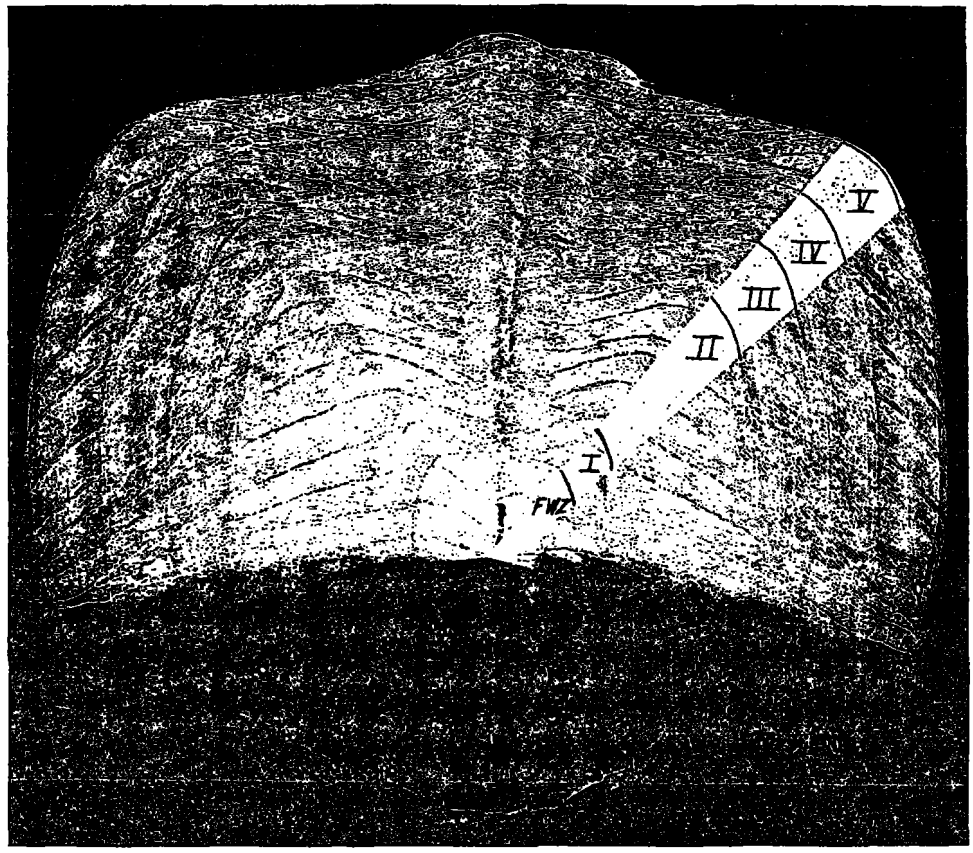

FIGURE 5.—Scale from 5-year-old marked shad spawning for the first time.

generation, and 15 had complete regeneration. This group consisted of 56 first- and 14 second-year spawners. Forty-three percent (6) of the males and 14 percent (8) of the females were spawning for the second time. Figures 5 and 6 illustrate representative scales from 5-year-old marked fish spawning for the first and second time. In figure 5 the fifth or last annulus is plainly visible, but since it was laid down just prior to the spawning migration, it is combined with the scale edge and counted as one year. Fish spawning for the second time (fig. 6) had first spawned in 1956 when 4 years old. Marked males averaged 17.6 inches fork length and 3.2 pounds in weight. Marked females averaged 18.8 inches, fork length, and 4.1 pounds in weight.

MARKED FISH RECOVERED 1958

From a study of pelvic fin sections and radiographs it was determined that 40 marked shad were recovered in 1958. Age determined from scale readings indicated that 39 fish were 6 years old and one was 5 years old. The radiographs and scale samples were re-examined and the above findings confirmed. Therefore, an error of approximately 2 percent exists either in interpretation of radiographs or in age determination.

The 39 marked recoveries included 16 males and 23 females, of which 11 had no regeneration of the right fin, 9 had one-third regeneration, 10 had two-thirds regeneration, and 9 had complete regeneration. This group consisted of 13 first-, 18 second-, and 8 third-year spawners. All males (16) and 43 percent (10) of the females had previously spawned. Sixty-two percent (10) of the males and 35 percent (8) of the females were spawning for the second year, and 38 percent (6) of the males and 9 percent (2) of the females were spawning for the third year. Figures 7 and 8 are representative scales from 6-year-old marked

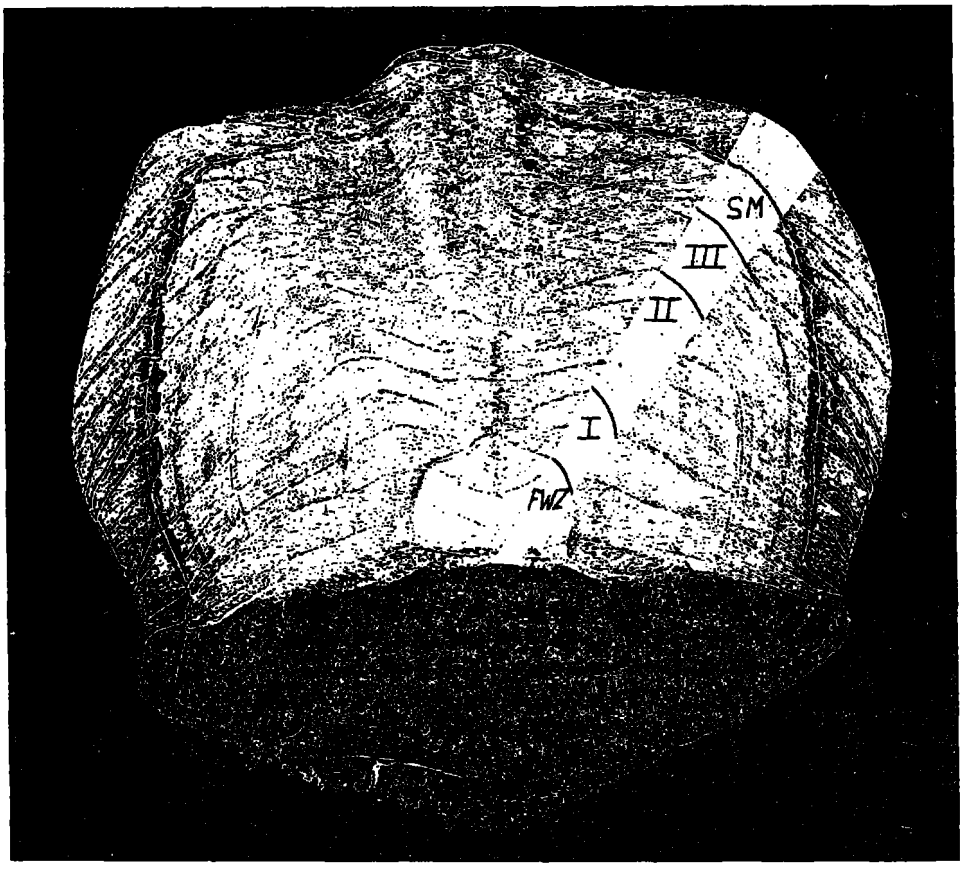

FIGURE 6.—Scale from 5-year-old marked shad spawning for the second time.

fish spawning for the first and third times.[1] Those spawning for the third time had first spawned in 1956 when 4 years old. The second spawning mark was laid down in 1957. Marked males averaged 18.2 inches fork length and 3.6 pounds in weight. Marked females averaged 19.1 inches fork length and 4.5 pounds in weight.

DISCUSSION AND CONCLUSION

Of the 129 fish classified from radiographs as marked, only 3 were in disagreement with age as determined from scale readings. These misclassifications, 2 in 1957 and 1 in 1958, were caused by error either in age determination or in interpretation of radiographs, which in some cases were difficult to interpret. This minor disagreement, approximately 2 percent of the fish classified as marked, was considered insignificant and in no way invalidates the findings of this report.

Methods used by Leim (1924), Borodin (1925), Greeley (1937), and Cating (1953), to age shad were all considered in this study. Of these methods, only Cating's proved to be a complete and valid means for determining total age, age at first spawning, and number of times previously spawned. LaPointe (1958) correctly validated the annulus as a true year mark on scales of shad spawning for the first time and he showed that Leim had mistaken the fresh-water mark for the first annulus. Therefore, the techniques used by Leim and Greeley to age shad gave age assessment 1 year greater than the actual age of the fish. Borodin's method, applied to scales of marked shad, gave erroneous results and could not be justified on the basis of the present study.

Age of marked fish collected in 1956, 1957, and 1958 as determined from scale readings, was in

[1] Figure 1 is a representative scale from a 6-year-old marked shad spawning for the second time. These fish had first spawned in 1957 when 5 years old.

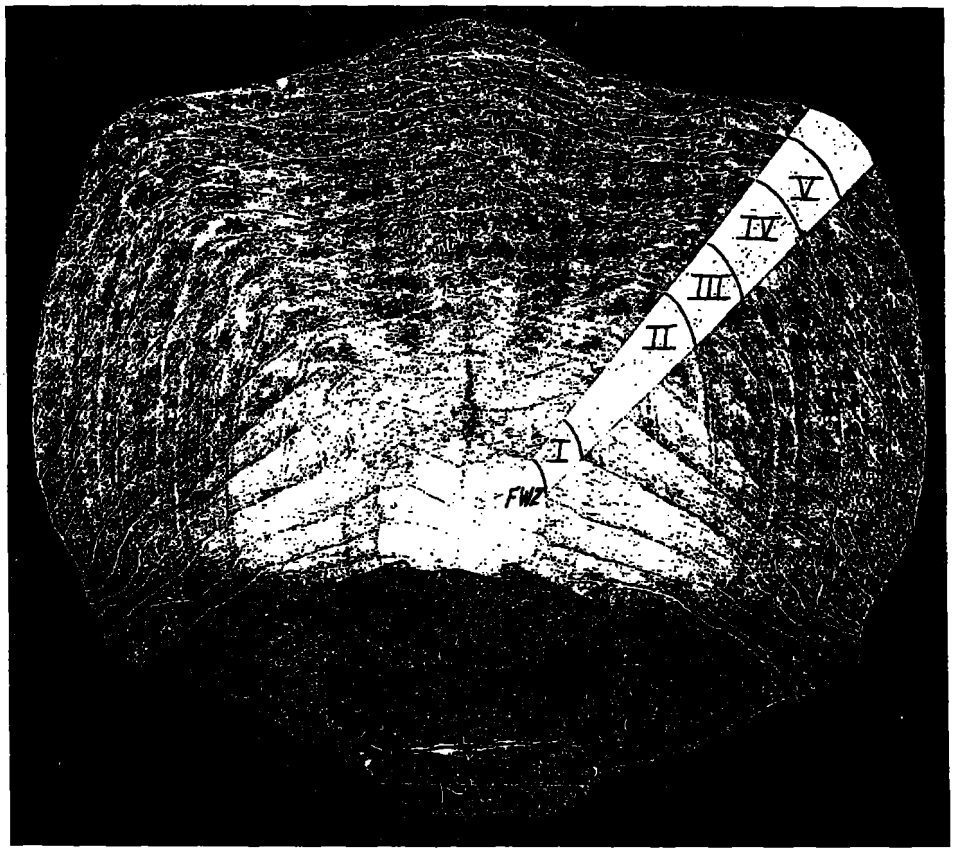

FIGURE 7.—Scale from 6-year-old marked shad spawning for the first time.

agreement with known age established by marking. These findings indicate that the method used to age shad (Cating, 1953) is valid and that annuli and spawning marks are true indicators of age.

SUMMARY

One hundred thousand juvenile shad from the Connecticut River were marked by removal of the right pelvic fin, in 1952. The objective of this program was to recover marked fish of known age in future years, to validate the use of annuli and spawning marks for determining age of shad.

Marked fish were first recovered in the Connecticut River in 1956 with subsequent recoveries in 1957 and 1958. Fish with marked and abnormal fins were collected in each of these years. Twenty-eight were collected in 1956, 132 in 1957, and 57 in 1958.

The pelvic fin section from each fish sampled was X-rayed and classified as follows: (1) marked, (2) malformed, and (3) missing. Marked fins were identified by an enlargement at the distal end of the radial bones at the point of separation from the dermal fin rays. Pelvic fin sections were classified as malformed, when there was no enlargement of the distal end of the radials. Missing fins were classified as to the fin or fins affected. The number of marked fish collected each year was determined from a study of pelvic fin sections and radiographs.

Scales from sampled shad were read for total age and number of times each fish had previously spawned. The 1956 recoveries of marked shad were 4-year-old fish spawning for the first time. Those collected in 1957 were 5-year-old fish, with recoveries divided between first and second year spawners. Fish spawning for the second time had first spawned in 1956. Marked fish collected in 1958 were 6 years old and consisted of first-, second-, and third-year spawners. Those spawning

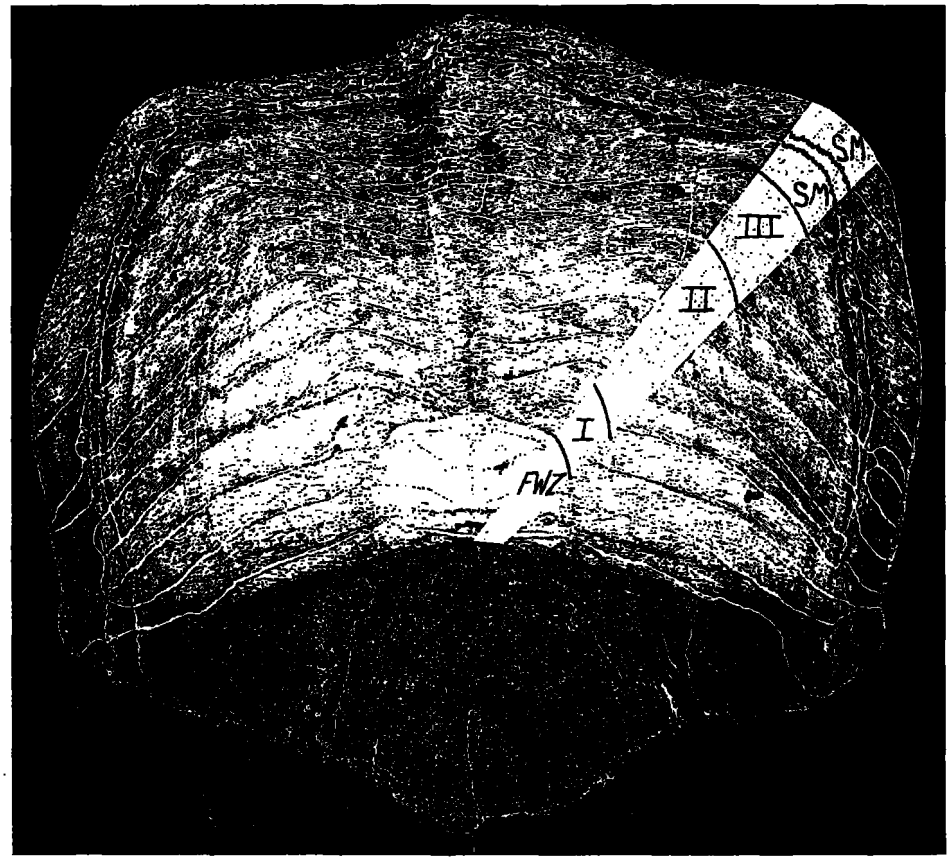

FIGURE 8.—Scale from 6-year-old marked shad spawning for the third time.

for the second time had first spawned in 1957, and those spawning for the third time had first spawned in 1956.

Age of marked shad, as determined from scale readings, was in agreement with known age established by marking. These findings validate the use of annuli and spawning marks for determining total age of shad.

LITERATURE CITED

BARNEY, R. L.
1925. A confirmation of Borodin's scale method of age determination of Conecticut River shad. In Mitchell, P. H., A report of investigations concerning shad in the rivers of Connecticut, Part III, pp. 52–60. Hartford, Conn.

BORODIN, N. A.
1925. Age of shad *Alsoa sapidissima* (Wilson), as determined by the scales. In Mitchell, P. H., A report of investigations concerning shad in the rivers of Connecticut, Part II, pp. 46–51. Hartford, Conn.

CABLE, LOUELLA E.
1956. Validity of age determination from scales, and growth of marked Lake Michigan lake trout. U.S. Fish and Wildlife Service, Fishery Bulletin, No. 107, vol. 57, pp. 1–59.

CATING, JAMES P.
1953. Determining age of Atlantic shad from their scales. U.S. Fish and Wildlife Service, Fishery Bulletin, No. 85, vol. 54, pp. 187–199.

CODE, MARK R.
1950. Cutthroat trout without dorsal fins. Progressive Fish Culturist, vol. 12 (2): pp. 85–86.

GREELEY, JOHN R.
1937. Fishes of the area with annotated list. In New York Conservation Department: A biological survey of the lower Hudson watershed; supplemental to twenty-sixth annual report, 1936. Part II, pp. 45–103. J. B. Lyon Company, Albany, N.Y.

GREENBANK, JOHN, and D. JOHN O'DONNELL.
1950. Hydraulic presses for making impressions on fish scales. American Fisheries Society, Transactions, vol. 78 (1948), pp. 32–37.

HAMMER, RALPH CURTIS.
1942. The homing instinct of the Chesapeake Bay shad *Alosa sapidissima* (Wilson), as revealed by a

study of their scales. Thesis, University of Maryland, 45 pp. (typewritten).

LAPOINTE, DONALD F.

1958. Age and growth of the American shad, from three Atlantic coast rivers. American Fisheries Society, Transactions, vol. 87 (1957), pp. 139–150.

LEIM, A. H.

1924. The life history of the shad *Alosa sapidissima* (Wilson), with special reference to the factors limiting its abundance. Biological Board of Canada, Contributions to Canadian Biology, vol. 2 (new series), No. 11, pp. 161–284.

MOSS, DOUGLAS D.

1946. Preliminary studies of the shad (*Alosa sapidissima*) catch in lower Connecticut River, 1944. Eleventh North American Wildlife Conference, Transactions, pp. 230–239.

RICH, W. H., and H. B. HOLMES.

1928. Experiments in marking young chinook salmon on the Columbia River, 1916 to 1927. U.S. Bureau of Fisheries, Bulletin, vol. 44, pp. 215–264.

STUART, T. A.

1958. Marking and regeneration of fins. Scottish Home Department, Freshwater and Salmon Fisheries Research, No. 22, pp. 1–14.

SUTHERLAND, DOYLE F.

1958. Use of diagnostic X-ray for determining vertebral numbers of fish. U.S. Fish and Wildlife Service, Special Scientific Report—Fisheries No. 244, 9 pp.

TALBOT, GERALD B., and JAMES E. SYKES.

1958. Atlantic coast migrations of American shad. U.S. Fish and Wildlife Service, Fishery Bulletin, No. 142, vol. 58, pp. 473–490.

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