DETERMINING AGE OF ATLANTIC SHAD FROM THEIR SCALES

By JAMES P. CATING

FISHERY BULLETIN 85

UNITED STATES DEPARTMENT OF THE INTERIOR, Douglas McKay, *Secretary*
FISH AND WILDLIFE SERVICE, John L. Farley, *Director*

ABSTRACT

Determining the age of shad (*Alosa sapidissima*) from scales has been considered difficult by many workers, and recent investigators have attempted to ascertain only the number of times of spawning. Much of the difficulty in reading scales arises in locating the first three annuli because accessory rings, or false annuli, sometimes are found in this area of the scale, and the annuli are not always clearly defined.

A method of locating these annuli, using transverse-groove counts, is presented. After the positions of the first three annuli are known, the age of the fish can be determined by counting any additional annuli which usually are easy to see, and adding the number of spawning marks. Criteria for determining whether annuli have been obliterated by spawning marks and the number of times the fish has spawned when one spawning mark has eroded into another are also presented.

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By JAMES P. CATING, *Fishery Research Biologist*

Determining the age of fish is important in any study requiring knowledge of the age-class composition of the population. An accurate reading of shad scales was needed in the investigation of the shad fishery of the Atlantic coast, being carried on by the United States Fish and Wildlife Service to furnish information for fishery regulations to the Atlantic States Marine Fisheries Commission.

This paper presents criteria established for reading the age of shad (*Alosa sapidissima*) from their scales, in the hope that it may be of aid to other investigators. It is possible that the criteria given here, with minor changes, may be applied to other clupeids having scale markings similar to the shad's.

Fishery biologists have generally considered shad scales difficult to read, although most of them agree that some scales, especially from fish 4 years or younger, are easily read because the annuli are clear cut and proportionately spaced.

Leim's (1925) paper on the life history of the shad (*Alosa sapidissima*) in Canadian streams discusses the work by European investigators on age and growth of *Alosa alosa* and *Clupea finta*—very similar to *Alosa sapidissima*—in which they assumed the validity of the annuli as year marks. By plotting the length of scale against the length of the fish for a group of shad, Leim showed that the growth in length of the scale is almost proportional to the growth in length of the shad. He back-calculated the lengths of a series of shad at each winter of their life, and the calculated lengths agreed closely with length of fish as he had measured them at a given age. His total lengths plotted against age gave a curve that rose rapidly till the fourth year, and then gradually leveled off. In establishing the relation of length of scale to length of fish, he fulfilled one of the important requirements for establishing the validity of annuli as year marks on shad scales.

In his work on the fresh-water growth of shad, Hammer (1942) found that shad scales are constant in number and retain their identity throughout the life span of the fish. He did not attempt to age shad, but did show that back-calculated lengths determined for the fish at the time they left fresh water agreed with actual measured lengths of shad at that time.

Borodin (1925) presented a method of reading shad scales by counting the number of transverse grooves and dividing by 2 to get the age. Greeley (1937), however, has pointed out that this method gives erroneous results on Hudson River shad scales and his age determinations from easily read scales agreed closely with Leim's. Later workers, for instance Moss (1946), read only spawning marks on the shad scales and presented no data on the age of the fish studied.

These investigators did not establish criteria for separating the false from the true annuli on scales or for ascertaining the amount of absorption that takes place at the scale edge during the spawning migration of older fish.

I wish to acknowledge the assistance of members of the staff at the Beaufort Laboratory of the Fish and Wildlife Service who helped with this study through their constructive criticism and advice during the period of its development. These are C. E. Atkinson, G. B. Talbot, R. A. Fredin, and John H. Finucane who worked with me during the earlier part of the studv and assisted in reading scales.

DESCRIPTION OF A SCALE

Figure 1 illustrates a scale from a Hudson River female shad that was 11 years old, 22½ inches long, and weighed 6½ pounds when taken. The anterior, sculptured portion of the scale comprises about three-fourths of the scale surface, while the posterior area (exposed portion of scale) consists of the remaining one-fourth of

FIGURE 1.—A scale from a female shad measuring 22½ inches and weighing 6½ pounds. There are five annuli and five spawning marks, and the fish was spawning for the sixth time, which makes it 11 years old. The Roman numerals I through V represent the annuli, and VI through X the spawning marks. The Arabic numerals indicate the following: 1, annuli, or winter rings; 2, false annuli, or accessory rings; 3, fresh-water zone; 4, spawning marks; 5, striae; 6, transverse grooves; and 7, the baseline.

the surface area. The anterior portion has seven types of visible markings that are indicated by Arabic numerals on figure 1, as follows:

1. *Annuli, or winter rings.*—These are the lines seen on the surface of the scale following the contour of the periphery through both the anterior and posterior portions.[1] The annuli are usually most clearly seen in the lateral fields of the anterior portion near the baseline. On some scales they show very clearly on a diagonal line running from the center of the baseline to the shoulders of the scale.

2. *False annuli.*—These are also called accessory rings and are similar in appearance to true annuli. On easily read scales they do not show up as clearly as do the annuli, and are not usually found circling into the posterior portion of the scales studied. These marks make age determination from shad scales difficult. Notice the less-emphasized false annuli between the true ones on the scale shown in figure 2.

3. *Fresh-water zone.*—This is an important false annulus found on all shad scales and is laid down

[1] For optical reasons, the posterior areas of the annuli cannot be seen in this photograph. They may, however, be seen during microscopic reading of the scale by changing direction of the lighting.

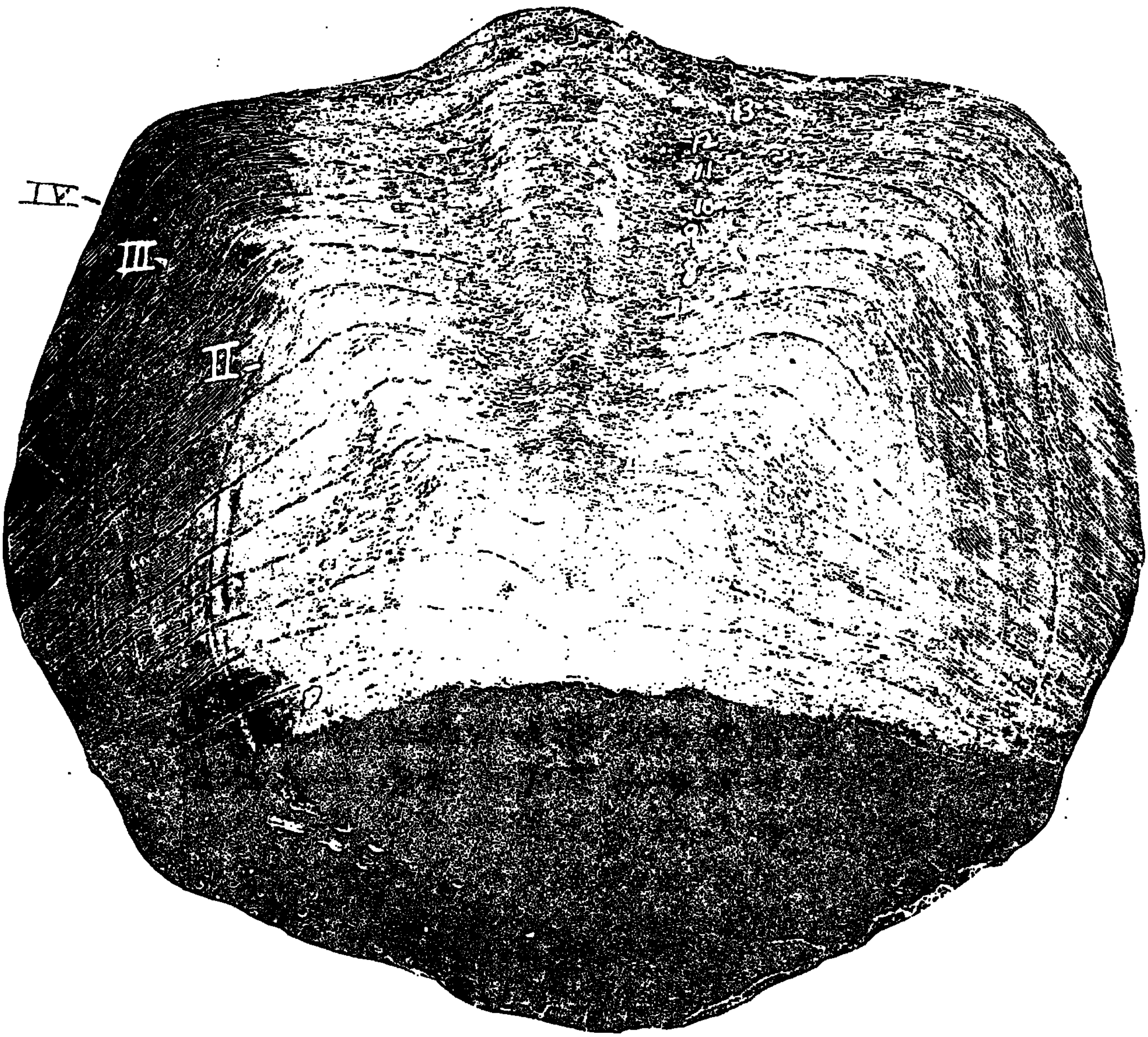

FIGURE 2.—Scale from a 4-year-old male shad measuring 16.2 inches and weighing 2 pounds 8 ounces.

when young shad pass from fresh to salt water at the end of the first summer. Some workers apparently have called this the first winter annulus, but Hammer (1942) has shown that this line forms at the time of transition from fresh water in the parent river to salt water in the ocean when the shad are from 3 to 5 months old. Figure 3 illustrates the scale of a young Hudson River shad estimated to be 4 or 5 months of age and nearly ready to leave fresh water for salt water. If this shad had lived longer the scale, as seen now, would have formed the fresh-water zone of the larger scale.

4. *Spawning marks.*—These marks are scarlike rings extending around the anterior portion of the scale much as do the annuli, but unlike the annuli they extend only a short distance into the posterior portion of the scale. These marks are caused by absorption, or erosion, of the scale during the spawning migration into fresh water where little or no food is eaten by the adult shad. Figure 4 shows the condition of the edge of a scale from a shad just entering the Hudson River on the spawning migration. Notice the smooth margin. Figure 5 illustrates the irregular margin of a scale taken from a shad well up the river on the spawn-

ing ground. Figure 6 clearly illustrates a spawning mark (S. M.) formed a year previous to capture.

5. *Striae*.—These markings are fine ridges in the surface layer covering the anterior portion of the scale. They are very close together and run laterally across the scale in contour with the transverse grooves: figure 7 shows them clearly.

6. *Transverse grooves*.—These are distinct grooves in the surface of the anterior, sculptured portion, crossing it laterally on the same general contour as the striae, but spaced farther apart. Some of the grooves are continuous lines running from one edge of the scale to the other; others extend in from both sides without meeting in the

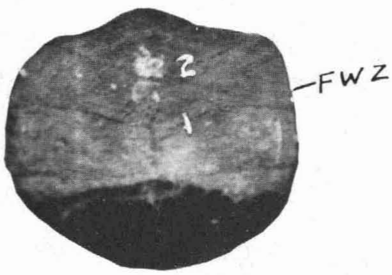

FIGURE 3.—Scale from a juvenile shad, probably 4 or 5 months old, caught while still in the river. There are only two transverse grooves. Had this shad lived longer the scale would have formed the fresh-water zone of the larger scale.

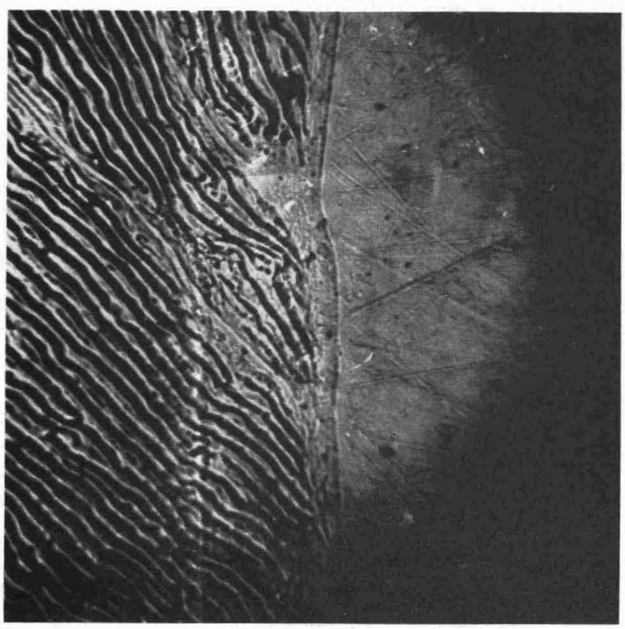

FIGURE 4.—Enlarged view of margin of the scale from a shad just entering the Hudson River on its spawning migration.[2]

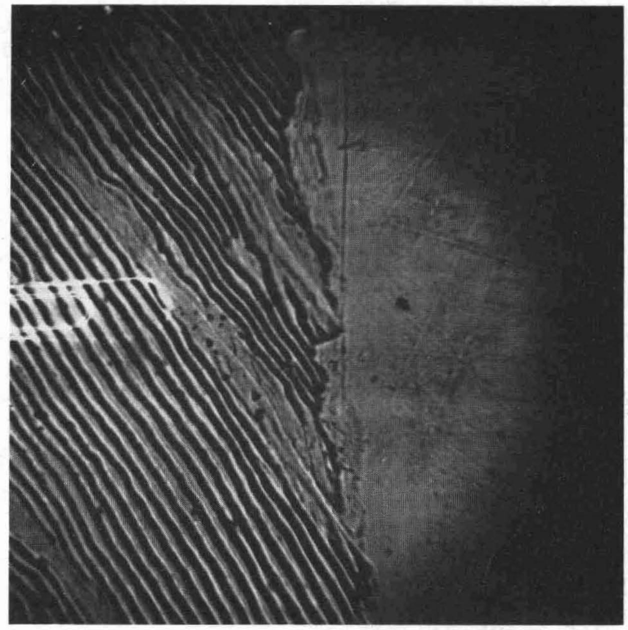

FIGURE 5.—Enlarged view of scale from a shad taken on the spawning ground after a period in fresh water.[2]

center of the anterior field. Some of the grooves start as a single line at the edge of the scale and then branch to form two lines.

7. *Baseline*.—In this paper the baseline is considered to be the first transverse groove on or just anterior to the demarcation line between the anterior and posterior fields of the scale (also see A in fig. 8).

PREPARING AND READING SCALES

The scales used in this study were collected during the spring of 1950, from Hudson River shad, for use in age, growth, and mortality studies. Many of the scales taken could not be used, either because they were regenerate scales (fig. 9), or because they were asymmetrical and could not be read. Four hundred nonregenerate and symmetrical scales were chosen at random from the collection. Twenty scales, 2 each from 10 fish, were impressed on individual 3″ x 5″ plastic sheets using pressure and heat. Some scales were mounted in glycerine jelly and polyvinyl alcohol on glass slides to compare their readability with scale impressions on plastic. As far as we could determine, the one method is as good as the other, but since plastic impressions are easier to handle and less bulky to file, this method was used.

[2] Photographs from an unpublished manuscript of Louella E. Cable.

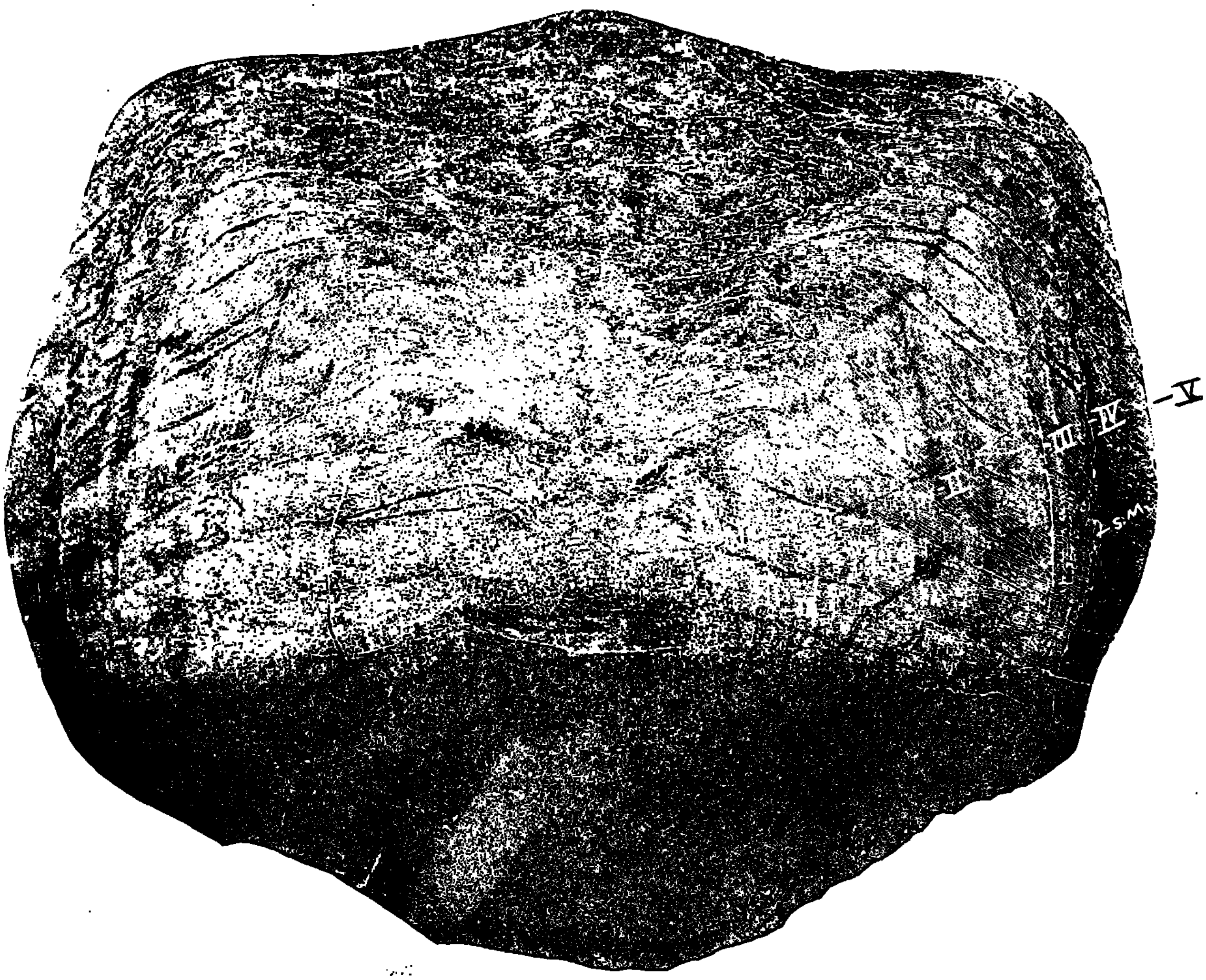

FIGURE 6.—Scale from a 19-inch female shad weighing 4 pounds. The single spawning mark (S. M.) is very clear on this particular scale. Note that the fourth transverse groove is branched. The Roman numerals indicate annuli and spawning mark.

A Recordak projector, designed for microfilm reading, and a binocular microscope of low power were tried as sources of magnification. The Recordak projector was found to be satisfactory for projecting and reading the easily read scales, but where difficulties occurred, it was found that the microscope gave a better image of the scale markings, especially of the spawning marks. Most of the impressions were read by the latter method. The illustrations used in this paper are negatives made from the image on the ground-glass screen of the Recordak projector.

An attempt was made to read 400 selected scales by the conventional method of counting annuli and spawning marks. Agreement in both reading and between 2 independent readings by 2 persons was obtained on 164, or 41 percent of the scales. Agreement between independent readings by two persons on the other 236 scale samples was poor because of poorly defined annuli and numerous false annuli. Because of this high percentage of disagreement it was considered necessary to develop criteria to distinguish the true from the false annuli or otherwise indicate the true age of the fish.

CRITERIA FOR DETERMINING AGE

Counting transverse grooves

Only those 164 scales that were clearly marked and on which consistent agreement had been

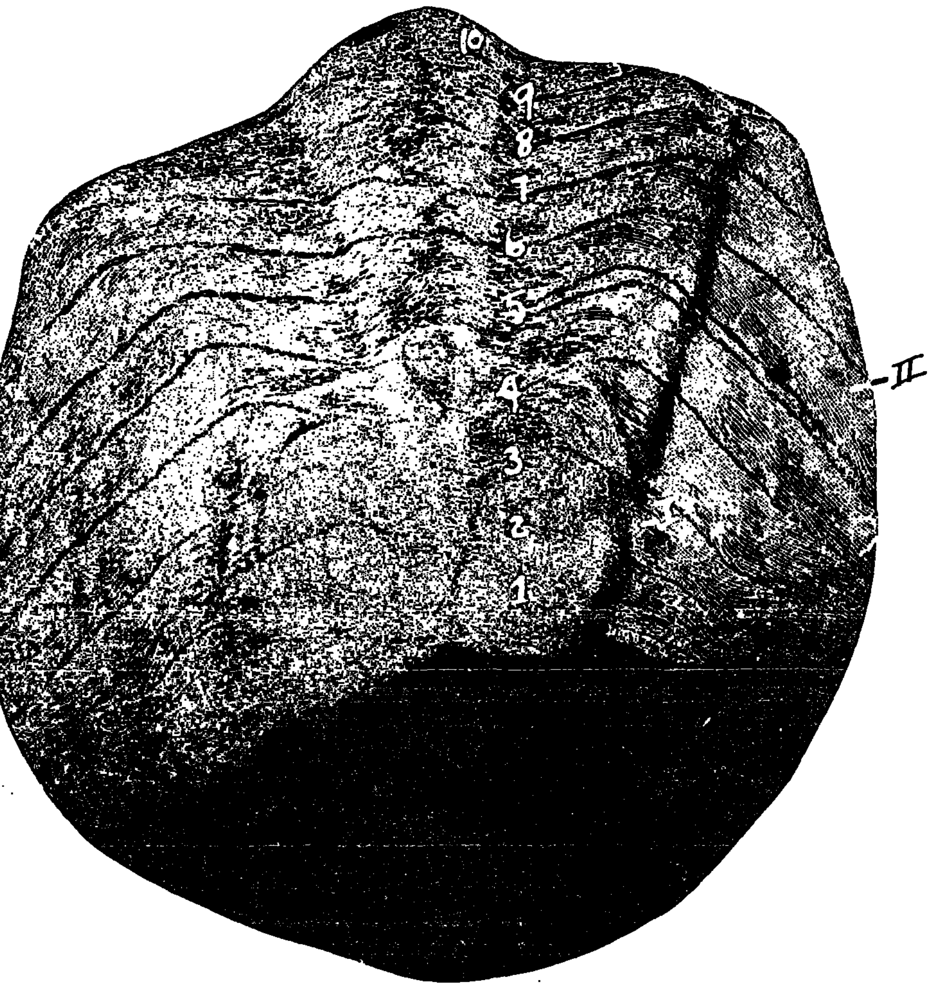

FIGURE 7.—Scale from a small male shad. Note that there are 10 transverse grooves to the edge of the scale as indicated by Arabic numerals. The second annulus is just within the periphery of the scale, and was formed during the winter just previous to this migration into fresh water where the fish was caught.

reached were used in the attempt to develop criteria for age analysis. Borodin's (1925) method of age determination by transverse grooves was tried. However, he gave no clear definition of what constitutes a complete or incomplete transverse groove; since none that we could devise appeared to give the desired results, this method was discarded.

While trying Borodin's method on the clearly marked scales, we noticed that the number of transverse grooves entering the fresh-water zone, and also the first, second, and third annuli, were almost constant from fish to fish. It was also observed that the spacing between transverse grooves, as with annuli, was proportional to growth. In other words, the distance between grooves becomes proportionally less as the fish grows older and its growth slows. Since the formation of grooves seemed to be a function of age and growth, it appeared that their numbers might be used as an index to the amount of growth taking place in any period and to locate the true annuli on scales that were confused by false annuli.

To check these observations, counts were made of the number of transverse grooves entering the fresh-water zone, first, second, and third annuli on the 164 easily read scales. Counting began with the first transverse grooves above the baseline, and grooves which branched were counted as one only. All the transverse grooves entering the fresh-water zone from one side were counted, including those that just touched the line enclosing the fresh-water zone. Those counted included incomplete grooves (not joined in the middle of the scale) as

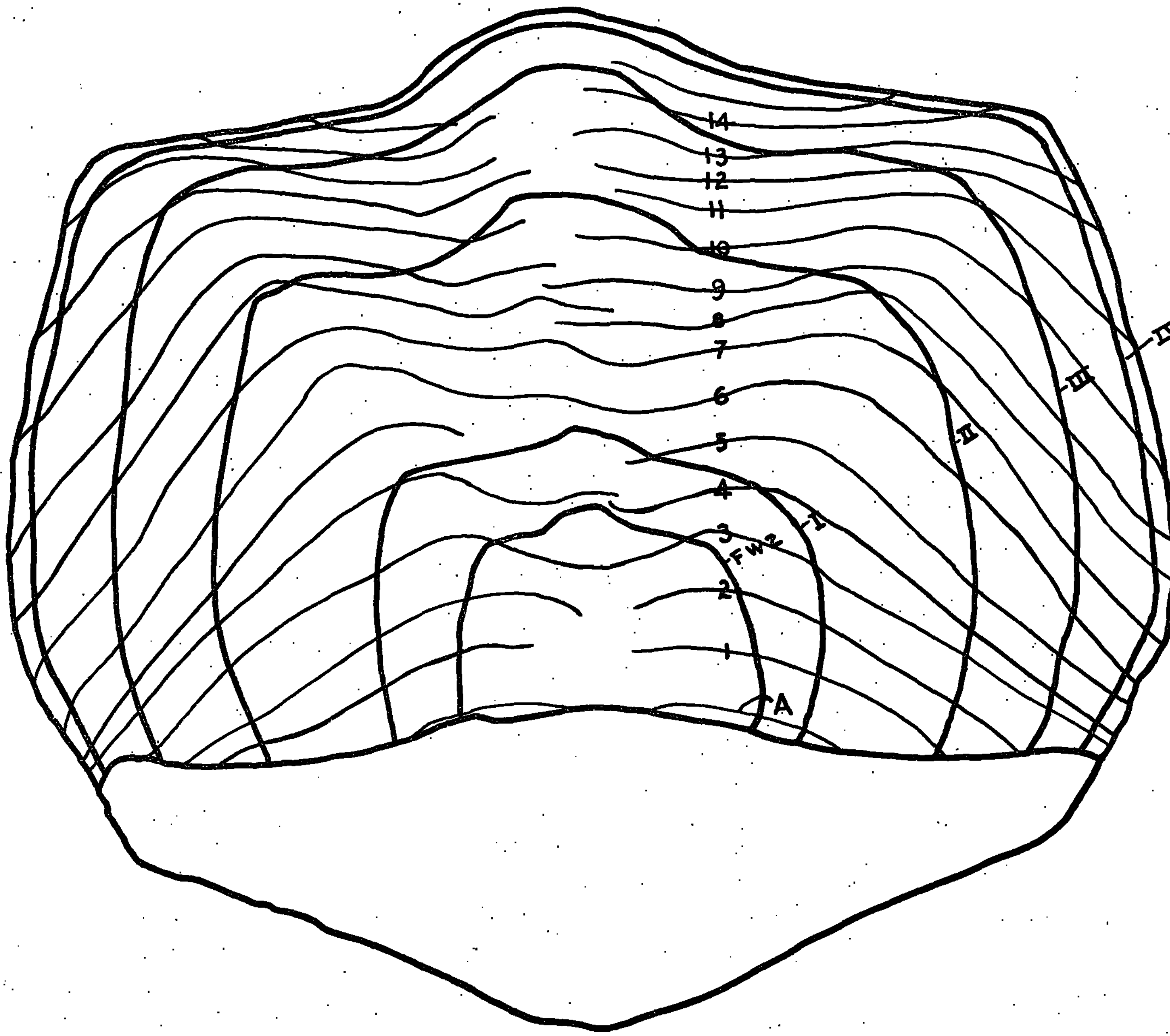

FIGURE 8-A.—Overlay to emphasize the major features of the shad scale in figure 8.

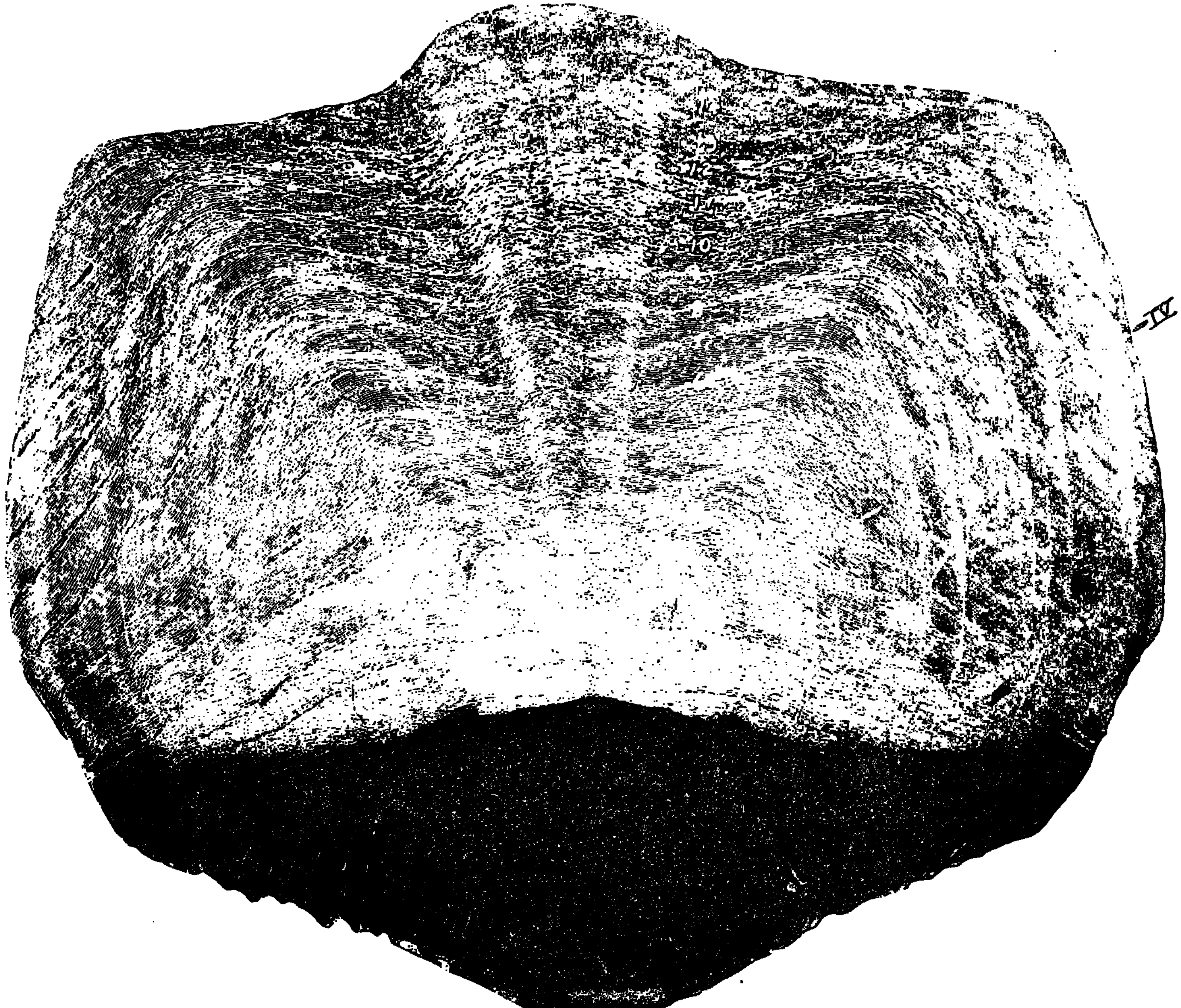

FIGURE 8.—Scale from a female shad measuring 18.7 inches and weighing 4 pounds. Arabic numerals indicate transverse grooves, *A* the base line, Roman numerals the annuli, and *FWZ* the fresh-water zone. Note the annulus just inside the periphery of the scale which was laid down during the winter just previous to spawning.

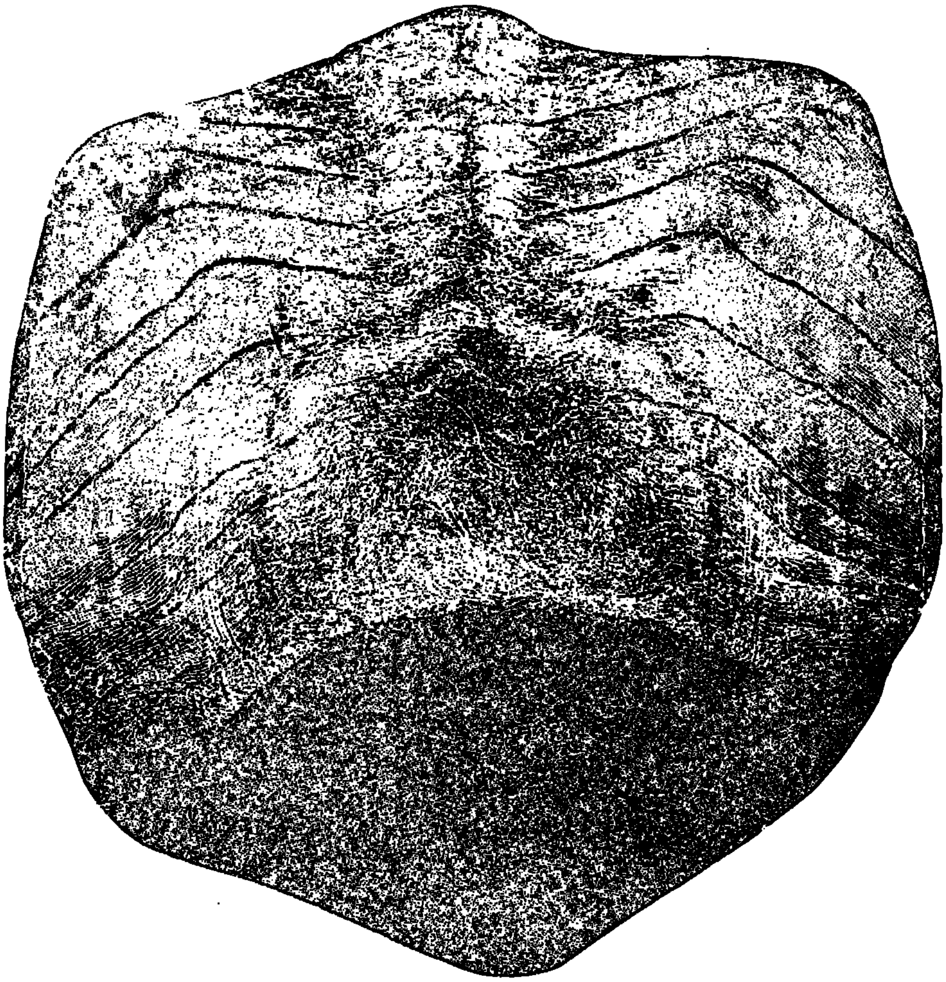

FIGURE 9.—Scale from a male shad that was probably 2 years old. This figure illustrates the appearance of a regenerate scale.

well as complete grooves (extending unbroken from one edge to the other). Figure 8 illustrates this procedure of counting by numbering the transverse grooves 1, 2, 3, and so on, starting with the first transverse groove above the baseline. Since it is impossible to obtain photographs of shad scales with all details clearly shown, the diagrammatic overlay of figure 8 was prepared to help illustrate the items discussed. These are seen while actually reading the scales by changing the focus of the microscope to bring out each detail. The scale in this figure is from a 4-year-old female taken during its first spawning migration. On this scale there are 3 transverse grooves lying within the fresh-water zone, 5 within the first annulus, 10 within the second annulus, and 14 within the third annulus.

The transverse-groove counts made on the 164 scales are shown in table 1. The number of transverse grooves lying within the fresh-water zone of the scale ranges from 1 to 5, but is usually 2 or 3. The number entering the area enclosed by the first annulus ranges from 4 to 7, but is usually 5 or 6. Within the second annulus, counts of 9 and 10 transverse grooves predominate, but the range is from 8 to 11. The number entering the area enclosed by the third annulus is generally 13 or 14, with a range from 12 to 16. On a few fish which had not spawned until they were 5 years old or older, it was found that 16 to 18 transverse grooves came into the area enclosed by the fourth annulus; but, because of the confusion of lines caused by the scarred area in the central anterior portion of most scales, it was found to be of value to use groove counts beyond the third annulus. This is not a handicap, however, because the annuli beyond the third are usually legible.

TABLE 1.—*Frequency distributions of number of transverse grooves entering area enclosed by fresh-water zone and first, second, and third annuli on scales of 164 shad taken in the Hudson River, spring 1950*

Number of transverse grooves	Distribution of 164 counts in—							
	Fresh-water zone		First annulus		Second annulus		Third annulus	
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
1	7	4.3						
2	63	38.4						
3	81	49.4						
4	12	7.3	6	3.7				
5	1	.6	85	51.8				
6			69	42.1				
7			4	2.4				
8					16	9.8		
9					58	35.4		
10					78	47.5		
11					12	7.3		
12							8	4.9
13							57	34.8
14							79	48.2
15							18	10.9
16							2	1.2
Total	164	100.0	164	100.0	164	100.0	164	100.0

Constancy of transverse-groove counts

To determine if the numbers of transverse grooves were constant within the various annuli on scales taken from various locations on the fish, selected samples of scales were mounted and read from five predetermined body locations on each of 26 Hudson River shad brought to the laboratory for special studies. The five locations chosen on the left side of each shad were as follows: (1) The midline of side just behind the gill opening; (2) the midline of side under the dorsal fin; (3) the midline of side near the tail; (4) just under the dorsal fin; (5) just above the pelvic fins. A count of the number of transverse grooves entering the fresh-water zone and each of the first 3 annuli was made from a scale from each of the 5 locations. This procedure was repeated for each of the 26 shad. In most cases we found no variation in transverse-groove counts between scales from the five locations on individual fish, and at most they varied not more than ± 1. The slight variation in scales from different locations could be a result of the difference in legibility of markings and of possible error in counting, but in all cases the counts fell within the ranges shown in table 1.

It should be pointed out that the most symmetrical and legible, and therefore most easily read scales, are located on the midline of the side below the dorsal fin. Since even in this location many are regenerated scales (fig. 9), it was found necessary when sampling in the field to take about 20 scales in order to be sure of 2 good ones for mounting.

Spawning-mark criteria

The transverse grooves cannot be seen clearly on the part of the scale beyond the first spawning mark, due to scarring of the scale surface and the closeness of the spawning marks to each other. Since the spawning marks in most cases are clearly visible, there is no need for any index to them, for usually after a shad has spawned once, the spawning marks on the scales can be used with the annuli to determine the age of the fish. Only on shad that have spawned many times do the spawning marks become so crowded near the edge of the scale that they are hard to separate. This situation may be observed in figures 1 and 10 which show five spawning marks each. As many as nine spawning marks have been found on scales of individual fish taken in the 1950 Hudson River sample. On these scales it is usually possible to find traces of each spawning mark clearly visible just below the baseline in the posterior field of the scales where apparently not so much absorption takes place as in the anterior field.

Another problem encountered with spawning marks is that during the first spawning migration the previous year's scale growth around the periphery of the anterior portion is sometimes partially or wholly eliminated.

It is important when reading shad scales to examine the spawning marks to determine if an annulus has been eroded away. On scales where the annulus, laid down a year previous to the first spawning, has disappeared in the anterior portion of the scale due to erosion, a part of the annulus may be found near or just below the baseline of the scale inside the spawning mark, indicating that the absorption process does not affect the posterior portion of the scale to the same extent as the anterior portion. Figure 11 illustrates such a situation, and in reading this scale the part of the annulus remaining in the posterior region and the

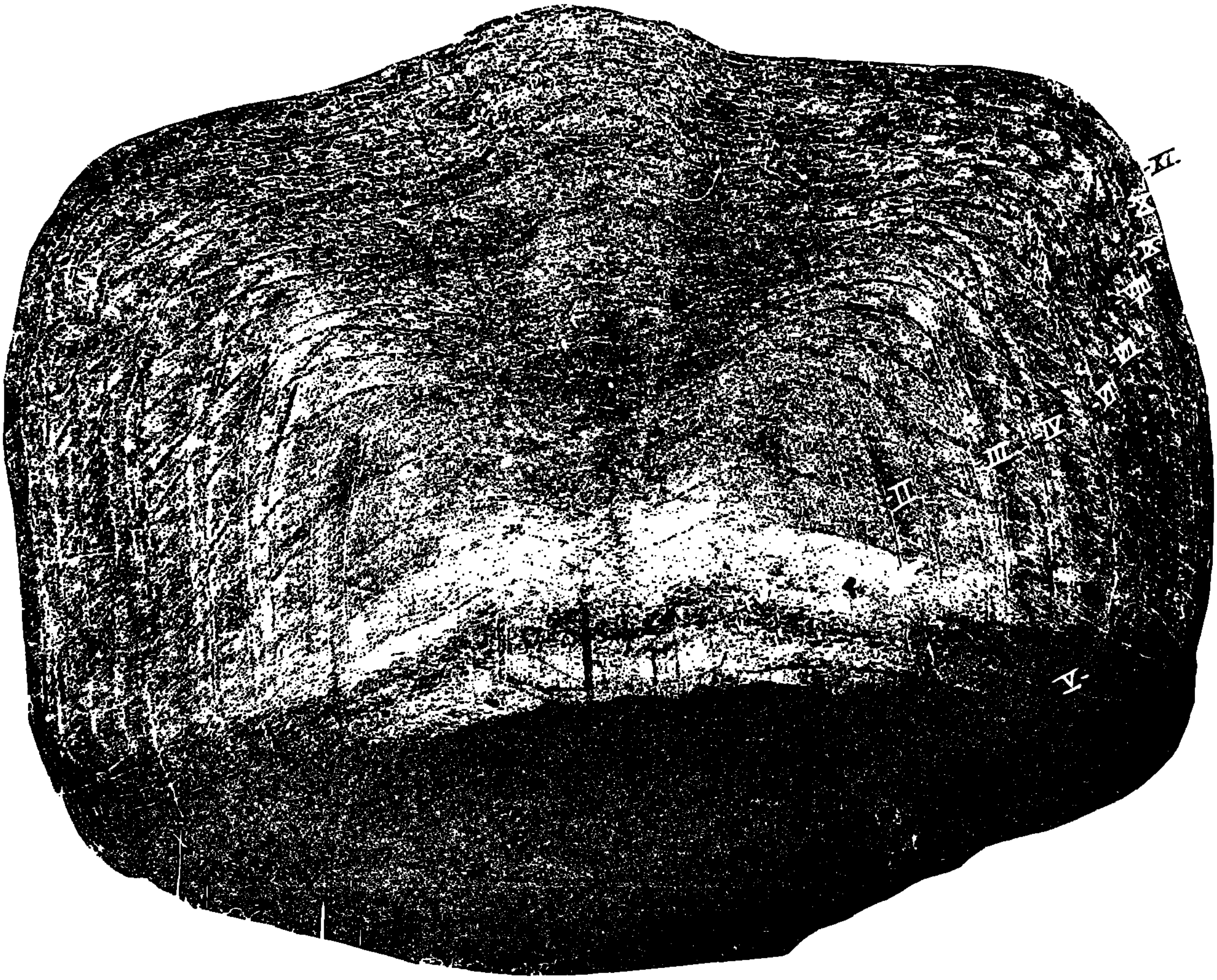

FIGURE 10.—Scale from an unusually large shad, a female, measuring 22.7 inches and weighing 7 pounds 9 ounces. Roman numerals VI through X represent spawning marks. Unfortunately, in this illustration the posterior portion of the scale is obscured so that the fifth annulus cannot be seen as separate from the first spawning mark just below the baseline in the posterior portion.

spawning mark should each be counted as a year. We were fortunate in obtaining, through our tagging program in the Connecticut River during 1951, direct evidence of the amount of absorption occurring while the shad is in fresh water. Shown in figure 12 is a scale taken from a shad at the mouth of the Connecticut River during a tagging operation; it shows five distinct annuli and a space to the edge of the scale representing the growth during the sixth year. This shad was just entering the river on its migration to the spawning grounds as is evidenced by the smooth scale margin. A scale was taken from this same tagged fish when it was caught 51 days later off the coast of Massachusetts by a trawler; this fish apparently had spawned in the Connecticut River and then migrated out of the river and northward into the Atlantic Ocean. The second scale is shown in figure 11. One year's growth has almost been eroded away, leaving only pieces of the fifth annulus to be seen around the anterior periphery of the scale. The fifth annulus can still be clearly seen near the baseline just inside the ragged edge of the scale.

The amount of erosion, or absorption, during the first spawning migration appears to vary with the age at first spawning. For example, the scale of a shad spawning for the first time at 6 years

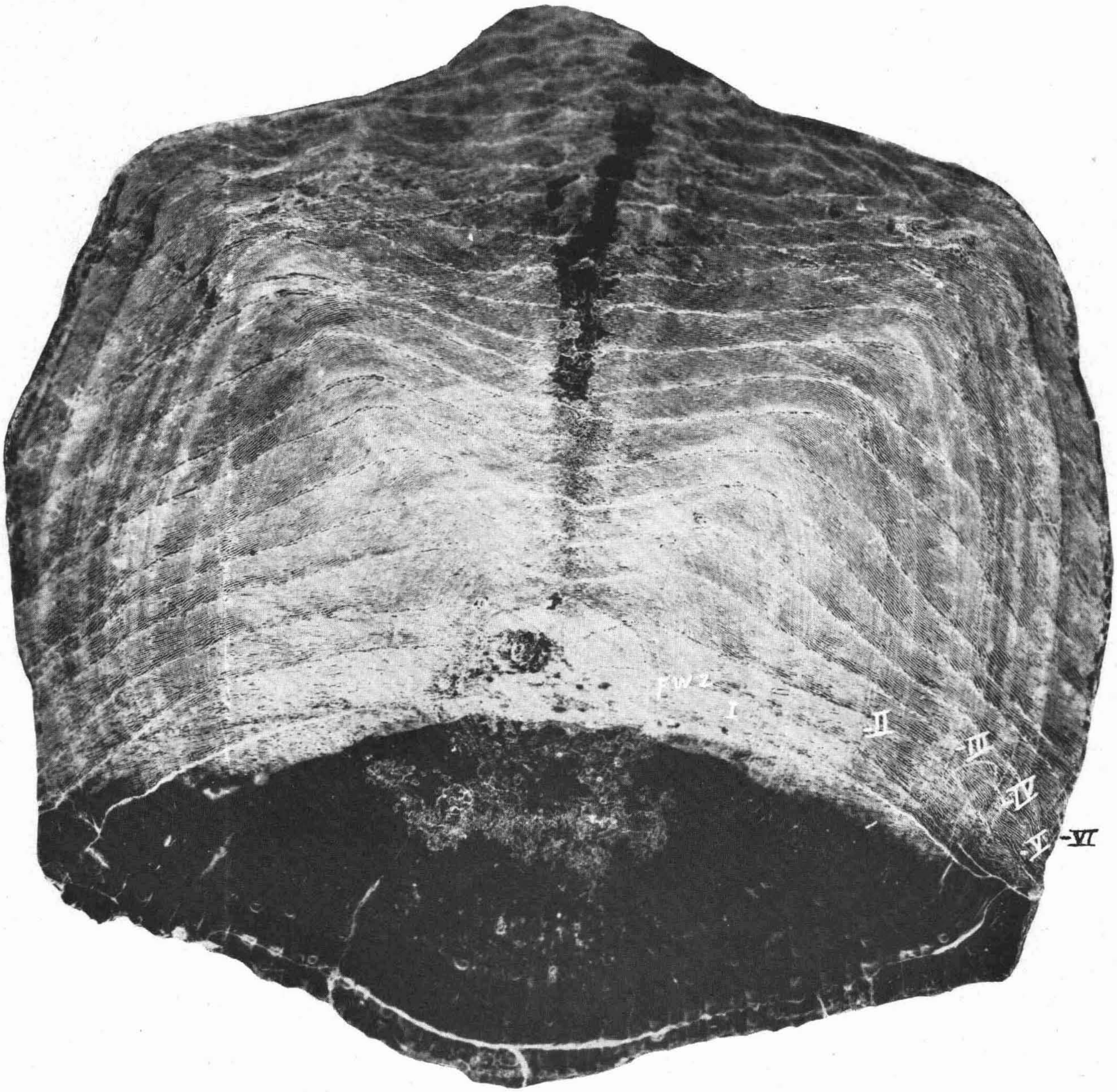

FIGURE 11.—Scale from the same female shad as scale shown in figure 12, but taken 51 days later. The fish was caught in the Atlantic Ocean off the coast of Massachusetts after leaving the river. Note the ragged periphery caused by absorption during the stay in fresh water, and the extent to which the edge was absorbed. The fifth annulus can be seen in only a few places. Compare this scale with the one shown in figure 12.

of age usually shows absorption to or over the fifth annulus, as illustrated in figure 10; scales from shad that are spawning for the first time at 5 years of age are usually absorbed back to the fourth annulus; scales from shad spawning for the first time at 4 years are usually absorbed back about half way toward the third annulus as shown in figure 6; and a shad coming back to spawn at 3 years of age usually has scales absorbed one-fourth to one-half the distance to the second annulus. During any particular spawning run, the amount of absorption depends on the time the fish spends in fresh water. If the scales are from shad taken just before they enter fresh water, little or no absorption of the previous year's growth should be found.

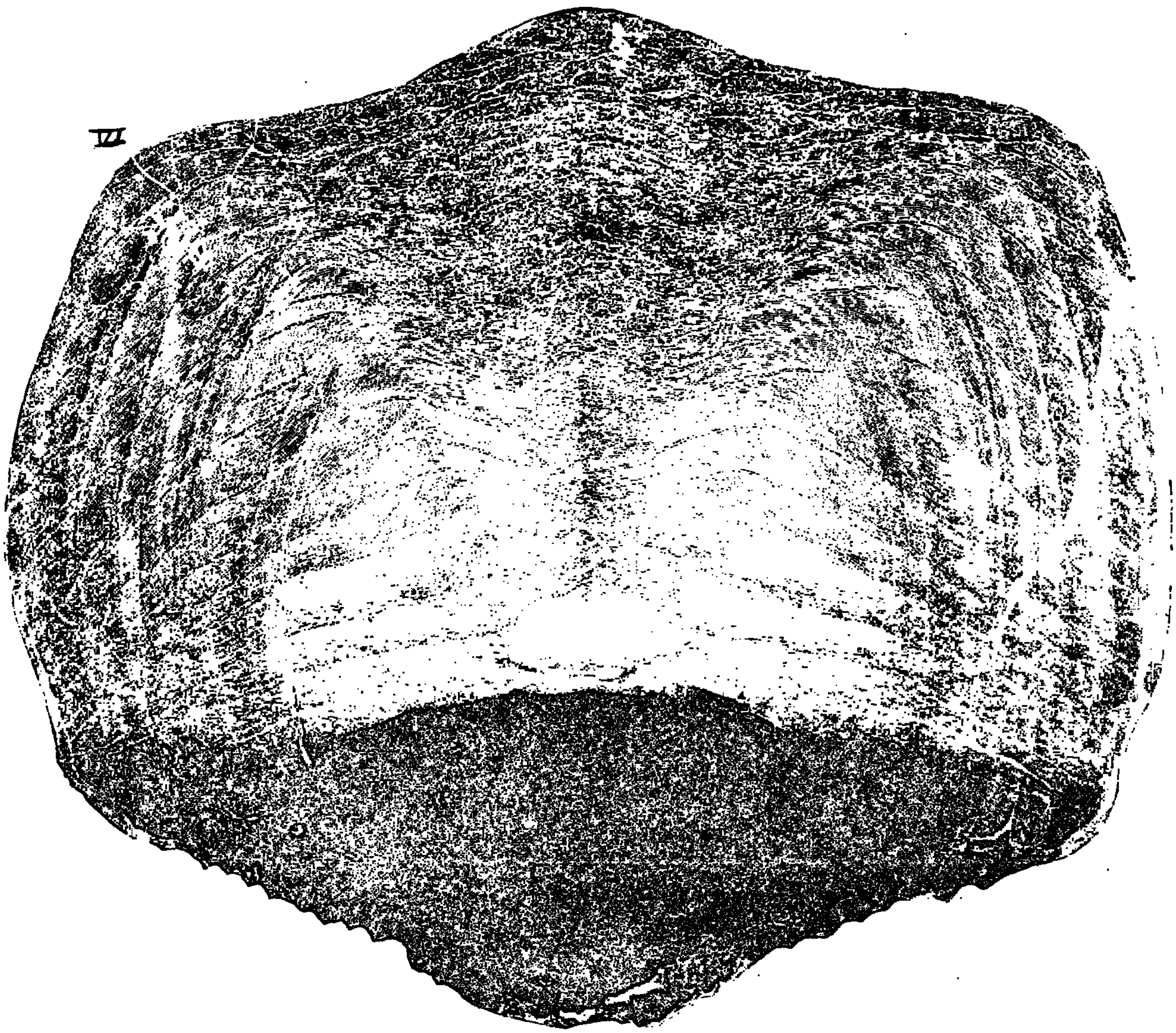

FIGURE 12.—Scale from a 6-year-old female shad measuring 19.1 inches. The fish was taken at the mouth of the Connecticut River on its way to spawn for the first time.

APPLICATION OF CRITERIA

The criteria, as described, were applied to the scales on which poor agreement was reached, and little difficulty was experienced in determining the location of the first, second, and third annuli. Once the location of an annulus was determined by groove count, the annulus usually could be traced from the anterior sculptured area into the posterior area of the scale even though obscured and confused by false annuli. Usually the true annuli were represented by more heavily defined ridges in the posterior section than the false annuli.

The fourth, fifth, and sixth annuli were usually clearly visible and proportionately spaced on scales of fish which had not previously spawned; hence, by using transverse-groove counts to locate the first, second, and third annuli and then counting each annulus past the third one, it was possible to determine the age of shad which had not previously spawned.

Proficiency in interpreting the age of any species of fish from scales requires practice. This is especially true when working with scales as difficult to read as the shad's; however, it is believed that by applying the criteria presented here, anyone wishing to learn to read shad scales accurately can do so in a relatively short time. It is suggested that anyone interested in applying these criteria should select several hundred shad scales, and read them a number of times until the different readings reach a desired level of agreement.

SUMMARY

From scales of the Atlantic shad (*Alosa sapidissima*) collected in the Hudson River in the spring of 1950, 164 of the more easily read scales were selected to serve as the basis for establishing criteria for determining the age of shad from their scales.

By counting the number of transverse grooves entering the fresh-water zone, and the first, second, and third annuli, it was found that the number of such grooves is relatively constant from fish to fish. The predominant number of transverse grooves entering the fresh-water zone was 3; the first annulus, 5; the second annulus, 10; and the third annulus, 14. In a period of slow growth when two annuli lay close together, the distance between the transverse grooves was found to be proportionately less. Once the location of an annulus was determined by groove count, the annulus usually could be traced.

When a shad has previously spawned the spawning marks must be used with the annuli to determine the age of the fish. The spawning marks are scarlike rings extending around the anterior portion of the scale which are caused by erosion or absorption of the scale when the shad enters fresh water to spawn. The amount of absorption that occurs depends on the age of the fish at the time it makes its first spawning migration. Thus, it was found that scale absorption on a fish making its first spawning migration when 3 years old usually extends from one-fourth to one-half the distance to the second annulus. On a scale from a 6-year-old shad spawning for the first time, however, the absorption usually extends to or over the fifth annulus. It is important, therefore, to examine scales closely from fish apparently spawning for the first time at 5 or 6 years of age to determine if an annulus has been absorbed during the first spawning migration. Usually, remnants of the annulus previous to the first spawning can be seen near the edge of the posterior region of the scale. When there are several spawning marks on a scale, and the marks have overlapped each other, traces of each spawning mark are clearly seen just posterior to the baseline.

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