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RAPPORT DES RECHERCHES COLLECTIVES

NO. 188

Atlantic Salmon Scale Reading Guidelines

International Council for the Exploration of the Sea

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ATLANTIC SALMON SCALE READING GUIDELINES

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CONTENTS

1 INTRODUCTION

Under the auspices of the International Council for the Exploration of the Sea (ICES), two Atlantic Salmon Scale Reading Workshops were held in the Marine Laboratory, Aberdeen. The first Workshop, in 1984, produced a comprehensive guide to the collection and interpretation of Atlantic salmon scales and the second Workshop, in 1988, amended a number of these guidelines in light of the experience which had been gained in their use. The second Workshop also established guidelines for computerized scale reading and developed new parameters for stock identification. Because some of the problems which had arisen in the interval between the two Workshops could not be immediately resolved, a number of research recommendations were added to the list which appeared in the first Workshop report.

This report presents these guidelines, the new parameters for stock identification, and the research recommendations.

2 AIMS

The purpose of scale reading is to interpret the age of an Atlantic salmon consistently from features on its scales. Different objectives may require determination of river age, sea age, and various scale characters for stock discrimination. Although it is not possible in most instances to be certain that a fish has been aged correctly, it is most important that consistency in interpretation be achieved. Therefore, the aim of the Scale Reading Workshops was to define a set of rules to consistently interpret the age of a fish.

3 DEFINITIONS

The following definitions based on Berg and Grimaldi (1967) were adopted together with the life history terminology described by Allen and Ritter (1977).

Focus

The point on the scale that is in the centre of the concentric lines; synonymous with nucleus.

Circuli (singular circulus)

Circuli appear on the surface of the scale as dark concentric lines; synonymous with rings and sclerites.

Band

A concentric region of the scale which is formed during a particular time of year. Thus, there are dark bands composed of narrow-spaced circuli appearing when growth is decreasing and light bands composed of wide-spaced circuli associated with increasing growth:

a) Winter band: a dark band thought to be associated with slow growth during the cold period of the year.

b) Summer band: a light band thought to be associated with rapid growth during the warmer period of the year.

c) Winter check: up to three wide-spaced circuli occurring within a winter band.

d) Summer check: narrow-spaced circuli, generally fewer in number than a winter band, occurring within a summer band.

Annual zone

A concentric region of the scale referring to a complete year of life.

Annulus

A theoretical boundary between two successive annual zones.

Plus growth

A region of wide-spaced circuli which may follow the last annulus of the sea zone. This signifies that a full year of growth has not yet been completed.

Erosion

Reabsorption of the edge (and sometimes the surface) of the scale, as shown in Plate 22.

Spawning mark

Erosion associated with the spawning migration, as shown in Plate 25.

4 THE SCALE

The examination of an adult salmon scale reveals two distinct parts which can be defined, on the basis of the definitions accepted, as follows:

a) River zone: the period spent in freshwater up to last river annulus.

b) Sea zone: the period from the onset of sea growth; it may include time spent in freshwater as an adult.

There is a third distinct part on some scales which occurs between the river and sea zones described above. On the basis of the definitions, this part can be defined as follows:

> Run-out: a period of intermediate growth between the last river annulus and the start of the sea growth. In some instances, it may be difficult to distinguish between run-out and early sea growth.

5 NOTATION

In Plate 1, the age of the fish is given as 5.1+ and in Plate 25, the age of the fish is given as 3+.1+SM1+. The first figure is the number of annuli in the river zone. When followed by a plus sign, this signifies run-out on the scale. The stop indicates the transition to sea growth. The next figure is the maiden sea age of the fish and a following plus sign indicates that plus growth was present. A spawning mark is indicated by SM and further annuli and plus growth described as for maiden sea years. When river age is unknown, the code letter A should be used to denote the river age, e.g., A.1+.

6 POSITION ON A FISH FROM WHICH SCALES SHOULD BE SELECTED

Examination of the available literature indicates the wide range of locations from which scales have been selected for ageing and stock discrimination purposes. As a result of the ICES recommendations (Anon., 1982), most countries are now selecting scales from the recommended area. This area is on the left hand side of the fish 3-6 rows above the lateral line and on a line extending from the anterior edge of the anal fin to the posterior edge of the dorsal fin (Figure 1). However, Martynov (1983) showed that the further a scale is located from the lateral line, the later it is formed on the body, the lesser the number of circuli laid down, and the smaller the size of the scale. In years of delayed development, salmon fingerlings can lack scale coverage in the areas adjacent to the dorsal fin and have scales only on those rows which are nearest to the lateral line. In those cases when complete scale coverage takes two years to complete, the first annulus is missing on the scales distant from the lateral line rows. Thus, the importance of choosing the best area for sampling scales becomes self-evident. The basic requirement when using discriminant analysis to distinguish stocks or stock groups is to minimize variability of counts of scale characters within each group to be discriminated. Although this requirement is better met when scales are sampled from rows 1-3 above the lateral line, it has been found that scale samples from this area give an unacceptably high proportion of unreadable scales. If scales are absent from this location, the equivalent position on the right side of the fish or just ahead of the preferred area on the left side should be used as alternatives.

7 COLLECTION OF SCALES

Collection

Prior to sampling, excess mucus should be removed from the recommended area using the back of a knife. The knife should be cleaned before the scale sample is removed and between each sample.

The scale sample (about 20 scales) should be placed inside a scale envelope and allowed to dry slowly before being stored. Under no circumstances should scale samples be placed in plastic bags.

All available information should be recorded on each scale packet including when possible:

a) code number

b) whole weight

c) gutted weight

d) fork length

e) total length

f) sex

g) date

h) site or position of capture

i) fishing gear

j) remarks, e.g., tag number (if a recapture), coloration if taken in freshwater, fin conditions, and any other useful information. Note whether scales were removed from the recommended area.

Cleaning

If scales need to be cleaned, they should be placed in a petri dish with soapy water and rubbed between the fingers. They should then be placed between tissue paper and allowed to dry.

Mounting

Scales to be read may be mounted, including impressions, or unmounted. The use of unmounted scales is fast, but when scales are also being used for discriminant analysis, mounted scales have a number of advantages.

The process provides a permanent record and an individual scale can easily be recognized at a later date. Furthermore, mounting by making impressions reduces the need for cleaning. The scale sample to be mounted should include the five "best" scales selected from the total sample removed from the fish. In order to make impressions, the scales should be placed between two cellulose acetate strips and passed through a jeweller's press with just enough pressure to impress the scale pattern on the cellulose acetate strip. The use of a roller press often causes distortion of the cellulose acetate strips used to make scale impressions. This causes errors when measurements are made from scale impressions and prevents the whole scale image from remaining in focus at the same time, causing difficulties for computerized scale reading using image analysis equipment. A hydraulic press can be used to produce distortion-free impressions. In Finland, only one cellulose acetate strip is used when making impressions, the other strip being made of smooth tin-plate. A microfiche reader incorporating a high quality copier may also be used to make a permanent record which can be used for ageing purposes.

8 INTERPRETATION OF SCALES

The following general process should be used to interpret a scale:

a) Identify the best scale.

b) Locate the beginning of the rapid sea growth phase.

c) Identify and count the annuli in the river zone.

d) Identify and count the annuli and spawning marks in the sea zone.

9 GOOD SCALES

Atlantic salmon scales from a variety of countries were examined to define the requirements of a scale suitable for ageing. In order to avoid missing the first annulus, any scale selected for ageing should have a distance from the focus to the first circulus of less than 0.5 mm. It is interesting to note that circulus formation appears to begin when juveniles reach the same length irrespective of country. The error which can arise from reading a bad scale instead of a good scale is shown in Plates 1 and 2. In each case, the focus of the scale is designated F and the end of each winter band is identified and numbered. The river zone is designated R and the sea zone is designated S. Plate 1 shows a scale suitable for reading that was aged 5 years of river life, while the scale shown in Plate 2 is unsuitable for reading and was aged at only 3 years of river life. This is in spite of the fact that both scales came from the same fish. On most scales, there is a clear transition from slower river or run-out growth to wide-spaced circuli associated with rapid sea growth.

10 CRITERIA FOR AN ANNULUS

Annual zones on a scale are characterized by a succession of bands of wide-spaced and narrow-spaced circuli. An annulus is always present where cutting over exists, but the lack of cutting over in narrow-spaced circuli does not necessarily mean that the annulus is absent. The transition from one annual zone to the next may be identified by the first continuous circulus of the new growth season cutting over the last incomplete circulus of the preceding season. However, when this cutting over is not observed, the annulus is identified by the transition from narrow- to wide-spaced circuli. The annulus is an ideal or theoretical line running midway between the last of the narrow-spaced circuli (may be discontinuous) of a winter band and the first of the wide spaced circuli of the following summer band. Information can sometimes be gained by examining the posterior (exposed) part of a scale on which annuli and spawning marks can be seen as continuous bands. This can only be done using mounted scales since these features are not so clear on plastic impressions. A scale is read or interpreted by counting the number of annuli. The time of annulus formation (or birthday of the fish) is arbitrarily set as 1 April as implied by Allen and Ritter (1977). For convenience, particularly when examining the scales of fish caught in the high seas fisheries, it is necessary to set other arbitrary birthdays so that fish can be allocated to the appropriate smolt year class, thus anticipating the formation of the next annulus.

The identification of spawning marks is discussed in Section 15.

11 BACK-CALCULATION OF LENGTHS

In order to interpret various parts of the scale growth pattern, it is sometimes useful to be able to estimate the length of the fish at the time that a particular feature (e.g., a check) was laid down. It is generally accepted (Carlander, 1981) that scale growth is not in direct proportion to fish growth; not only is the regression probably non-linear, but it also does not pass through the origin. However, a simple proportional relationship will provide a satisfactory estimate of length for the purpose of reading scales.

A variety of manual and semi-automatic methods of making back-calculations exist, but in all cases the principle is the same. Measurements are made from the focus along the longest axis to the edge of the scale (St) and to the feature being examined (Sf). The length of the fish at the time a feature was laid down (Lf) is estimated by:

$$Lf = Lt \cdot Sf/St$$

where Lt is the length of the fish when the scale was removed.

It is inadvisable to use back-calculated lengths on scales which show signs of erosion or spawning marks.

12 RIVER ZONE

When reading a scale, an initial decision has to be made whether it was from a wild or hatchery-reared fish. This is difficult when dealing with fish caught in mixed stock fisheries. In addition to any genetic differences, salmon parr populations in different areas experience a very wide range of environmental conditions and thus exhibit large differences in patterns and rates of growth. The mean age at which salmon smoltify, therefore, varies from between one and two years in some southern populations in Europe and North America to seven years in Labrador and northern Norway. It is important, therefore, in ageing salmon scales that the scale readers have knowledge of the life history of the stocks. Few rules for interpreting river growth that would apply to all stocks can be specified and it is frequently necessary to have some local knowledge of the stock being examined.

However, the following general guidelines apply for the majority of stocks:

a) River annuli are usually fairly evenly spaced, particularly in older smolts.

b) The distance from the focus to the first annulus is sometimes less than and often only half the distance between adjacent river annuli.

c) There are difficulties in ageing salmon from cold rivers, e.g., in Norway and Labrador, due to a lack of scales on yearling fish (Jensen and Johnsen, 1982). Some fish do not grow enough in the first year (33-34 mm for scales to form). Thus, ageing these fish accurately at a later stage of growth purely from scale material results in their age being underestimated by one year. Also on scales from Newfoundland, Scottish, and Icelandic stocks, an annulus is frequently found close to the focus with no or only a few wide-spaced circuli before the narrow-spaced circuli of the winter band.

Although only a few examples were available from fish with a known river life history, all of the examples chosen to represent certain specific ages conformed to the patterns on fish of known age. There were no disagreements on the ageing of any of the samples examined.

Plates 3-15 show the identification of annuli on a variety of salmon scales ranging in age from 1-8 river years. In each case, the focus of the scale is designated F and the end of each winter band is identified and numbered. When appropriate, river growth is designated R, run-out is designated RO, lake-type growth is designated L, and sea growth is designated S.

The Finnish scale (Plate 4) has a much bigger river zone than the Scottish scale (Plate 5) with many more circuli, especially in the winter band. The scale from the Atlantic salmon from France (Plate 6) has many wide circuli compared to the narrower-spaced circuli in the Finnish (Plate 7) and Icelandic (Plate 8) scales.

The lake-type growth is much faster than typical river-type growth in the same system. Examples of the two types are shown in Plates 16 and 17. Some data are available from the Burrishoole system in Ireland and from Iceland and should be examined.

13 SEA ZONE

There is less variation in sea growth patterns than in river growth patterns. Accordingly, it is easier to formulate a set of general rules for interpreting the sea zone than for the river zone. However, in particular sea areas, such as the Baltic Sea, the growth patterns on scales from different individuals may be similar to each other, but markedly different from those illustrated by fish in the Atlantic.

During the sea phase of scale growth, three types of dark "bands" may be observed:

a) winter band

b) summer check

c) closing at the edge of the scale: this is not necessarily associated with winter growth, but may occur in response to, e.g., maturation, homeward migration, and cessation of feeding.

Four types of light band may also be observed:

a) summer band

b) winter check

c) spawning mark

d) plus growth

As defined above, a winter check comprises no more than three wide-spaced circuli in a winter band. Where this is seen, the annulus is assumed to be located at the end of the whole winter band.

Typical scales

In many cases, it will be possible to identify clear winter bands for which there is no ambiguity. In such cases, the annulus position is defined as above. Examples of typical scale patterns for 1-, 2-, 3-, and 4-sea-winter fish are shown in Plates 18-21. In each case, the focus is designated F and the end of each winter band is identified and numbered. River growth is designated R and sea growth is designated S.

Problem scales

When several dark bands can be seen, there may be difficulty in distinguishing between sea-winter bands and summer checks. The following guidelines should be used when such problems arise. It must be noted, however, that not all scale samples will fit these rules precisely.

First sea-winter band

The first sea annulus will normally occur between 40 and 60 cm estimated by a linear back-calculation. Therefore, when there is doubt about the identification of the first sea-winter band, any band occurring at a back-calculated length of less than 35 cm is assumed to be a check. However, this rule may not apply in the Baltic Sea where there is a tendency for fish to grow relatively slowly in their first sea year. When more than one band occurs within the permissible area, i.e., 36-60 cm, the band with the greatest number of circuli is assumed to be the first sea-winter band.

Second sea-winter band

As with the first sea-winter band, there may be problems about identifying which of several dark bands should be selected as the second sea-winter band. In such cases, the following rules should be adopted in identifying the second sea-winter band:

a) Any band occurring at a back-calculated length of less than 1.55 times the distance of the first sea-winter band from the focus (i.e., a back-calculated length less than 1.55 times the back-calculated length at the first sea annulus) should be regarded as a check. However, it has been found that a value of 1.4 is more applicable to some UK stocks.

b) The second sea annulus is then defined as that occurring at the end of the next dark band.

Third sea-winter band

The problems likely to be experienced are similar to those identified for the second sea-winter band, i.e., multiple bands. In such cases, the following rules should be adopted in identifying the third sea-winter band:

a) The second sea annulus should be identified (if necessary, using the rules given above for second sea-winter bands).

b) The third sea-winter band will usually occur at a distance from the focus of more than 1.2 times the back-calculated distance of the second sea annulus (i.e., at a back calculated length 1.2 times the back calculated length at the second sea annulus). The first dark band beyond this point should therefore be taken as the winter band. Three-sea-winter fish, irrespective of the time of year of capture, rarely show plus growth at the edge of the scale. If there is apparent plus growth at the edge of the scale and the date of capture is early in the year, the possibility of the scale being from 4-sea-winter fish should be considered.

Fourth sea-winter Band

There is rarely a problem in identifying 4-sea-winter fish. In cases when multiple bands are observed, the positions of the first three sea annuli should be identified as shown above. There is, as a rule, no plus growth visible at the edge of the scales and, indeed, there may be little evidence of the fourth sea-winter band.

Closing at the edge of the scale

A slowing down in growth will produce the formation of narrow-spaced circuli. These may occur at the edge of the scale. In some cases, these will signify that the fish was captured before the start of the next growing season, and the closing, therefore, signifies the beginning of a winter band. However, fish, especially 1-sea-winter (1SW) fish, may be caught in late summer and show narrow-spaced circuli at the edge of the scale. In such cases, the date of capture is essential information if a correct interpretation of the sea age is to be made as these one sea-winter fish will appear to have the same sea age as 2-sea-winter fish caught earlier in the year. As a result of geographic differences between stocks, no firm rule can be applied to the date at which a split is made. However, rules can be established for each individual stock by applying local knowledge.

14 EROSION

Due to sexual maturation, material is reabsorbed from the margins of the scale and sometimes from the surface.

When scales from salmon which have spent some time in freshwater, especially kelts, are viewed under magnification, this reabsorption of material can be seen as erosion of the scale margin and, sometimes, of the surface detail of the scale. Plate 22 illustrates a scale from an Atlantic salmon from Norway showing both marginal and surface erosion. In severe cases, especially when the fish has spent many months in freshwater, complete bands may be lost as a result of erosion.

15 PREVIOUS SPAWNERS

There are likely to be a number of problems in the determination of total sea age of fish in this group. Plate 23 shows a scale from a maiden fish with three complete sea-winter bands, and Plate 24 shows a scale from the same fish on its next return one year later with the third sea-winter band completely eroded (the spawning mark is designated SM). Accordingly, previous spawners should be regarded as a group of fish separate from the various sea age groups of maiden fish.

The time of entry of previous spawners into freshwater tends to be similar to the time of entry on their original upstream migration (MacPhail, 1974). Similarly, the growth pattern demonstrated on the scales is frequently repeated, e.g., scales showing plus growth immediately prior to capture also showed plus growth immediately prior to the spawning mark (On Plate 25, the spawning mark is designated SM). On the basis of this evidence, the following general rules would apply when ageing the sea zone of previous spawners:

a) The time of entry into freshwater of a previous spawner on its first spawning migration is assumed to have been the same as is known or estimated for its second spawning migration.

b) The growth pattern on the scales is repeated so that scales showing plus growth prior to capture are assumed to have shown plus growth prior to the spawning mark, and fish showing no plus growth prior to capture are assumed to have shown no plus growth prior to the spawning mark.

These rules have allowed correct interpretation of sea ages of previous spawners when applied to material of known age obtained from tag recapture experiments. In certain instances, these rules may not hold and local experience and knowledge may be required to interpret material from particular stocks. However, the consensus of opinion from the Workshop was that the scales from previous spawners were interpreted consistently by different researchers.

16 NON-WILD SALMON

The production of hatchery-reared salmon is increasing and in some countries now exceeds that of wild stocks. For example, in the Baltic Sea in 1988, 80% of the adult salmon caught were of hatchery origin. Hatchery-reared smolts are produced for: a) stock enhancement, b) ocean ranching, and c) farming. Plates 26-28 show examples of scales from hatchery-reared salmon from Finland, Iceland, and Scotland, respectively.

Scale samples from hatchery fish of known ages from a number of hatcheries in various countries were examined. It was apparent that there could be considerable difficulty in ageing the river zone of reared salmon using standard procedures. Furthermore, a considerable variation was observed in the growth patterns shown by fish from different hatcheries as a result of different rearing regimes.

Ageing

It is generally recognized that the age determination of hatchery-reared fish presents a number of problems not encountered when dealing with wild salmon. When it is suspected that hatchery-reared fish are present in an area from which scale samples are being collected, this should be borne in mind when examining scale material.

The amount of growth made in the river zone tends to be greater than that of equivalent age wild fish from the same stock. Furthermore, the growth pattern on the scales is more irregular than that shown by the majority of wild fish. If ageing using accepted criteria produces over-aged or under-aged fish for the particular area from which the samples came, then the possibility of these fish having been reared for at least part of their lives should be considered. Ageing of the river zone can produce mis-aged fish because of the effect of artificial rearing regimes on the growth of the fish.

Identification

Plate 29 illustrates a typical 1SW Scottish farmed salmon from a sea cage (upper) and a typical 1SW Scottish wild salmon (lower). Note the deformed fins and a typical pigmentation in the farmed salmon. Plate 30 shows a scale from the farmed fish illustrated in Plate 29.

At present, scale analysis only forms one part of the discriminating technique between wild and reared fish. Other techniques include the identification of certain physical abnormalities, such as deformed fins, particularly the dorsal, caudal, and pectoral fins, and eroded gill covers. Morphometric and biochemical analyses may also be used.

If stocking is carried out with salmon at an early development stage (eggs, fry, or parr), the surviving fish will probably have scale characteristics that are indistinguishable from wild stocks in the same area. The following scale characteristics may be helpful in distinguishing wild from non-wild fish.

a) Smolt size

If back-calculations show that the smolt length exceeds that normally encountered in wild stocks from the same area, the possibility that the scale is from a salmon originating from a ranching or stock enhancement programme should be considered. However, in the south of England and France, this rule may not be applicable.

b) Smolt age

If a salmon is found to have a smolt age that is different from wild fish in the same area, the fish may have spent some time in a hatchery.

These two criteria are only likely to be reliable for reared fish (farmed, ranched, and stock enhancement) that are recaptured on return to freshwater. However, they are likely to be less reliable the further from the river of origin the fish are caught.

c) Sea life

The scale pattern associated with sea life of salmon originating from ranching and stock enhancement programmes may be indistinguishable from wild fish, making it difficult to identify reared fish in a mixed stock fishery. However, if farmed salmon escape after some time spent in sea cages, examination of the transition zone between the freshwater and salt water zones on the scale, the incidence of checks, and the proportion of regenerated scales during sea life may yield significant differences to those of wild and ranched salmon. Discriminant analysis based on these characteristics tested on material of known origin has given good results in Norway (Table 1).

Plate 31 shows a scale from a salmon of hatchery origin from Norway. This fish was reared to the smolt stage at the Research Station at Ims and transferred to a sea cage in May. In August of the same year, it was released into the fjord and was recaptured in the fish trap at Ims the following year. The fish is known to have been a one-year-old smolt which then spent one winter in the sea, but could be aged from its scales as 3.1+. The scale shows a large amount of run-out, indistinct transition from freshwater to sea growth, and a summer check during the first sea summer, features commonly seen on the scales of farmed fish.

17 NON-AGREED-UPON SCALES

As discussed earlier, the scale samples of adult salmon caught in the Baltic Sea have a last river annulus and first sea annulus that are sometimes difficult to locate. Reasons for this might include the very slow growth rate during the first sea year caused by very cold environmental conditions when the smolts enter the sea. Plates 32 and 33 illustrate scales from Baltic salmon. Both salmon were released at the age of two years and caught during the summer two years later (Plate 32 was recaptured 14 June and Plate 33 was recaptured 20 August). In both cases, the last river annulus and the first sea annulus are difficult to locate.

18 STOCK IDENTIFICATION

Circuli counts of salmonids have been widely used for stock discrimination in Atlantic salmon (Lear and Sandeman, 1980; Lear and Misra, 1978; Reddin and Burfitt, 1983) as well as in Pacific species (Cook and Lord, 1978; Major *et al.*, 1975).

There have been two basic techniques used for deciding which circuli to include or exclude from the analysis, the problem being that the salmon scales tend to have broken or branched circuli. The two techniques used are:

1) Only those circuli are counted that continue intact through a line drawn along some defined axis of the scales (Figure 2).

2) Only those circuli are counted that continue intact within an angle of 5° on each side a line drawn through some defined axis of the scale (Figure 3).

Technique 1 has the advantage of being much faster than Technique 2, which is better for reducing variance. The method chosen, therefore, depends on the number of samples to be analyzed and the difference anticipated to occur between the groups to be discriminated. Recent analyses have shown that circuli counts at different axes can be quite useful (Reddin and Burfitt, 1983). The axis or axes will depend on the object of the study.

19 COMPUTERIZATION OF SCALE ANALYSIS

Several systems for computerized scale image analysis are currently available or being developed in Canada, Finland, France, Scotland, and the United States. While these systems have been developed independently, common elements exist among them. The two objectives of these systems are: a) automating scale reading and growth pattern determination, and b) acquiring parameters for stock discrimination that cannot practically be manually collected.

Ageing

Problems associated with the automation of scale reading and growth pattern determination include: a) a hardware problem of acquiring the entire image with sufficient resolution; b) a software problem of integrating information from different axes; c) a lack of quantitative definitions for structures (i.e., checks and annuli); and d) a translation of observer experience into algorithms. Despite these problems, progress has been made in ageing and growth determination in the sea zone.

Stock discrimination

The main problem in analyzing data for stock discrimination is statistical. Despite this difficulty, it is possible to discriminate between pairs of salmon stocks.

Hardware requirements

It is impossible at present to define the best software for scale image analysis, but minimum hardware requirements can be defined as follows:

a) Microscope or stereoscope with binocular lens, both using transmitted illumination.

b) CCD or video tube black and white camera. If a CCD camera is chosen, one with square photo-elements and numerical output would be preferred. The best solution for the future will be to examine the entire scale image and use a CCD camera with higher resolution (2000 by 2000) and numerical output.

c) A digitizing pad is necessary if numerical output is not available with the camera chosen. The digitizer should also be capable of analog to numerical conversion and a minimum 512 by 512 definition. The digitizer must have a minimum capability of distinguishing 256 shades of grey (for discrimination purposes by scale shape analysis, only 64 grey levels are necessary). It is important to note that most of the digitizers available convert the 4:3 video image to a 1:1 image causing distortions not always visible on the video screen, but existing in the frame memory. These will induce measurement errors depending on the direction of the measurement. In such cases, an x-axis component correction will be necessary.

d) A black and white television monitor is acceptable, but colour is preferred for clearer viewing.

e) A 32-bit microcomputer with either a 80386 Intel (IBM compatible) or 68020 Motorola (Sun station, MacIntosh) processor is preferred. If the camera produces numerical output, it is necessary to add a converter to the microcomputer to produce a video image. The best medium for storing the image is a video disk. Figure 4 shows a schematic diagram of an image analysis microsystem.

Conclusion

It is important to standardize methodologies among laboratories by agreeing on standard algorithms and maintaining a standard scale reference collection.

Definitions

To be successful, definitions are required for computation of scale analysis and to ensure that the results of scale reading on scale analysis equipment developed at different laboratories are comparable.

a) The annulus has already been defined in Section 11.

b) The summer band ends and the winter band begins at the point where narrow but regularly spaced circuli begin. Winter and summer bands are defined in Section 3.

c) The precise point at which the transition from summer band to winter band occurs should be determined mathematically.

d) Cutting over is defined as the first continuous circulus of the new growth season cutting over the last incomplete circulus of the preceding season.

e) The feature on a scale which defines the time the fish left freshwater is the annulus immediately following the last river zone winter band.

Standardization

A reference set of scales should be established to permit the calibration of any computerized scale reading apparatus which may be developed.

20 RECOMMENDATIONS FOR RESEARCH

The following research topics were identified:

a) Further research into the identification and ageing of hatchery and farmed fish.

b) Since much of the production of many river systems may come from lakes, lake- as distinct from river-type growth should be investigated.

c) Further study of the identification of spawning marks occurring in the river zone is required.

d) The investigation of the relationship between various environmental factors and the development of scale features (e.g., check, annuli) should continue as it would be conducive to improved age determination by scale reading.

e) The use of a heated, photographic mounting press to produce distortion-free impressions should be investigated.

f) The information carried on the exposed part of the scale should be investigated.

g) The factors (with confidence limits) used to determine the positions of sea zone annuli should be re-examined in the various countries.

h) The possibility of defining factors (with confidence limits) which can be used to determine the positions of river zone annuli should be investigated in the various countries.

i) Further investigations into the use of scale shape or other parameters for stock discrimination should be carried out.

j) Research is required to quantify the characters used in the "Definitions" given in Section 19 (b, c, and e).

21 CONCLUSIONS

This report contains a set of guidelines for the interpretation of scales. These guidelines are not designed to be used by people with very limited scale reading experience. Rather, their purpose is to try to standardize the interpretations of more experienced readers. It is very important that new readers be instructed by more experienced workers before they attempt to apply these guidelines.

22 ACKNOWLEDGEMENTS

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23 REFERENCES

Allen, I.R.H. and J.A. Ritter. 1977. Salmonid Terminology. J. Cons. int. Explor. Mer, 37(3): 293-299.

Anon. 1982. Report of the Working Group on North Atlantic Salmon. ICES CM 1982/Assess:19.

Berg, A. and E. Grimaldi. 1967. A critical interpretation of the scale structures used for the determination of annuli in fish growth studies. Mem. Int. Ital. Idrobilo., 21: 225-239.

Carlander, K.D. 1981. Caution on the use of the regression method of back-calculating lengths from scale measurements. Fisheries, 6(1): 2-4.

Cook, R.C. and G.E. Lord. 1978. Identification of stocks of Bristol Bay sockeye salmon *(Oncorhynchus nerka)* by evaluating scale patterns with a polynomial discriminant method. Fish. Bull., 76: 415-423.

Jensen, A.J. and B.O. Johnsen. 1982. Difficulties in aging Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*) from cold rivers due to lack of scales as yearlings. Can. J. Fish. aquat. Sci., 39: 321-325.

Lear, W.H. and R.K. Misra. 1978. Clinal variation in scale characters of Atlantic salmon *(Salmo salar)* based on discriminant function analysis. J. Fish. Res. Board Can., 35: 43-47.

Lear, W.H. and E.J. Sandeman. 1980. Use of scale characteristics and discriminant functions for identifying continental origin of Atlantic salmon. *In* ICES/ICNAF Joint Investigations on North Atlantic Salmon. Rapp. P.-v Réun. Cons. int. Explor. Mer, 176: 68-75.

Major, R.L., A. Murai, and J. Lyons. 1975. Scale studies to identify Asian and Western Alaskan chinook salmon. Int. North Pac. Fish. Comm. Ann. Rep., 1973: 80-91.

MacPhail, D.K. 1974. Photographic reproductions of Atlantic salmon scales from fish of known sea ages. Tech. Rep. Ser. No. MAR/T-74-1, Resource Development Branch, Fisheries and Marine Service, Department of the Environment, Halifax, NS, Canada.

Martynov, V.G. 1983. On variability of scale characteristics in Atlantic salmon (*Salmo salar* L.). ICES CM 1983/M:5.

Reddin, D.G. and R.F. Burfitt. 1983. An update: the use of scale characters and multivariate analysis to discriminate between Atlantic salmon (*Salmo salar* L.) of North American and European origin caught at West Greenland. ICES CM 1983/M:11.

Table 1. The results from two discriminant analysis models based on the scale characters: transition freshwater/salt water (clear or unclear on their scales), number of summer checks in a) first sea summer band, b) second sea summer band, and proportions of replacement scales at a) freshwater stage and b) sea stage, tested on independent materials of known origin.

Actual group	Group predicted membership (%)			
	N	Wild	Adult released as hatchery-reared smolts/farmed	Percentage correctly classified
Model A				
Wild	107	95.0	4.7	
Adults released as hatchery-reared smolts	100	28.0	72.0	
Test groups:				84.06
Farmed	171	7.6	92.4	
River Imsa - wild	100	81.0	19.0	
Model B				
Wild	107	95.3	4.7	
Farmed	171	14.6	85.4	89.21
Test groups:				
Adults released as hatchery-reared smolts	100	34.0	66.0	
River Imsa - wild	100	92.0	8.0	

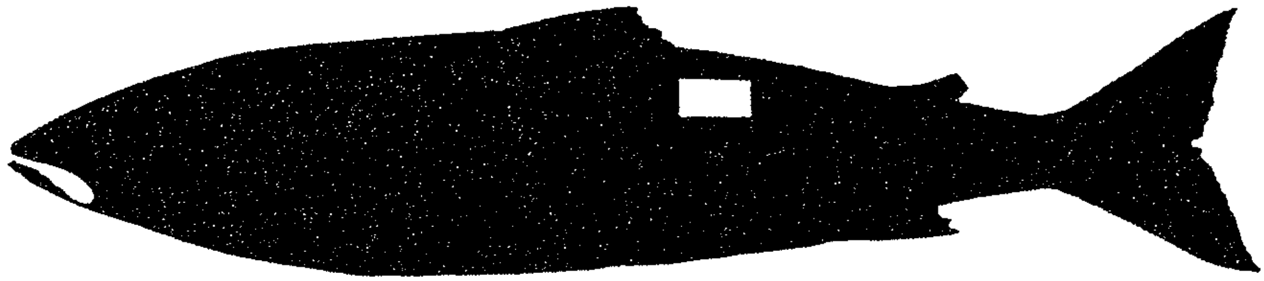

Figure 1

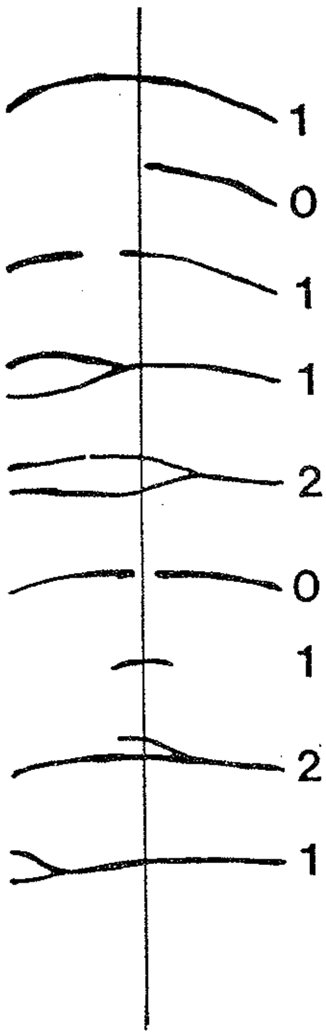

Figure 2

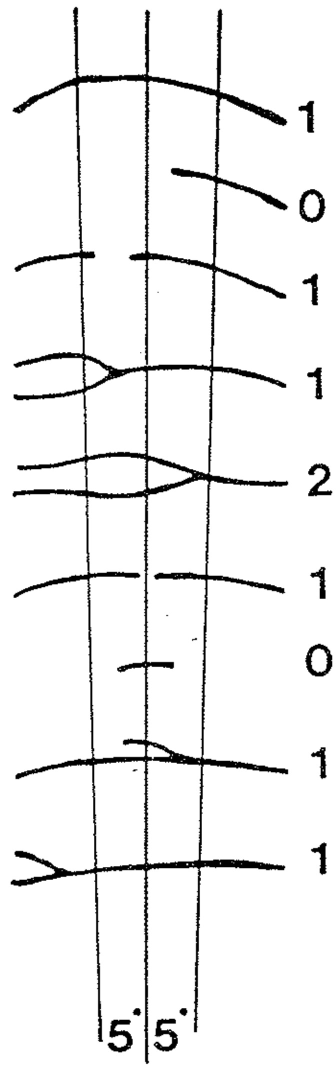

Figure 3

Figure 1. Diagram showing the position on a salmon from which scales should be collected - rows 3-6 above the lateral line and on a line extending from the anterior edge of the anal fin to the posterior edge of the dorsal fin.

Figure 2. Diagram showing Technique 1 for counting circuli. Only those which continue intact through a line drawn along some defined axis of the scale are counted. The numbers beside the circuli show the numbers of circuli which would be counted in each case.

Figure 3. Diagram showing Technique 2 for counting circuli. Those circuli within an angle of 5° on each side of line along some defined axis are counted according to the numbers beside the circuli in the diagram.

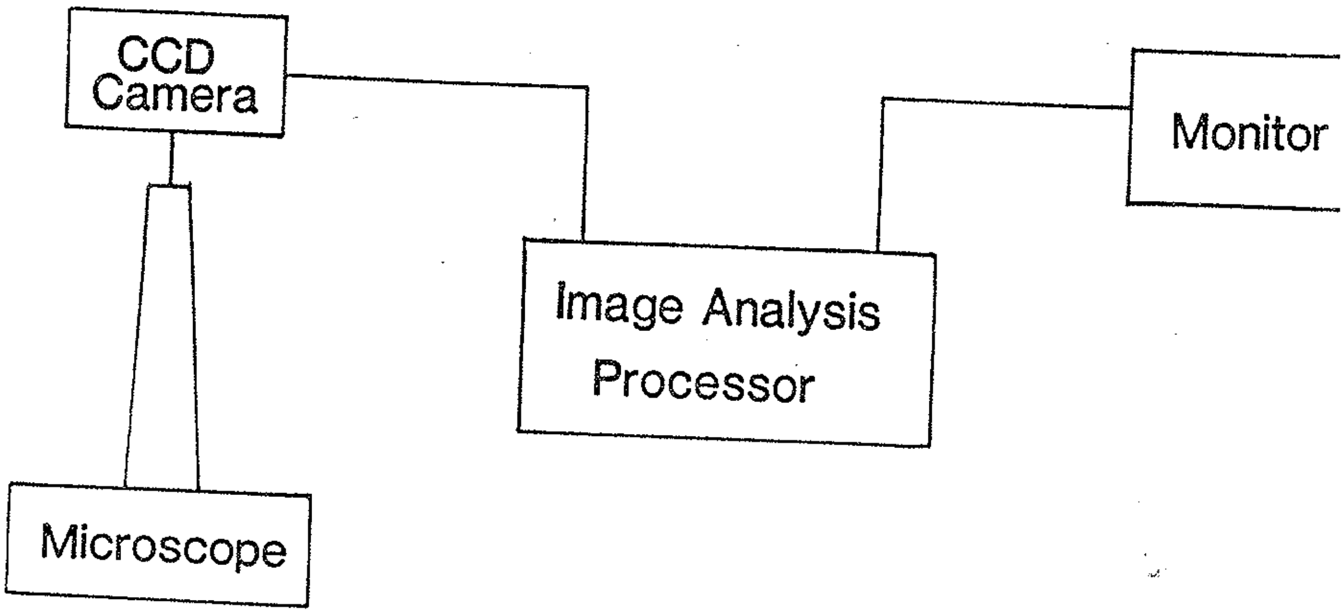

Figure 4. Schematic diagram of image analysis system for scale reading.

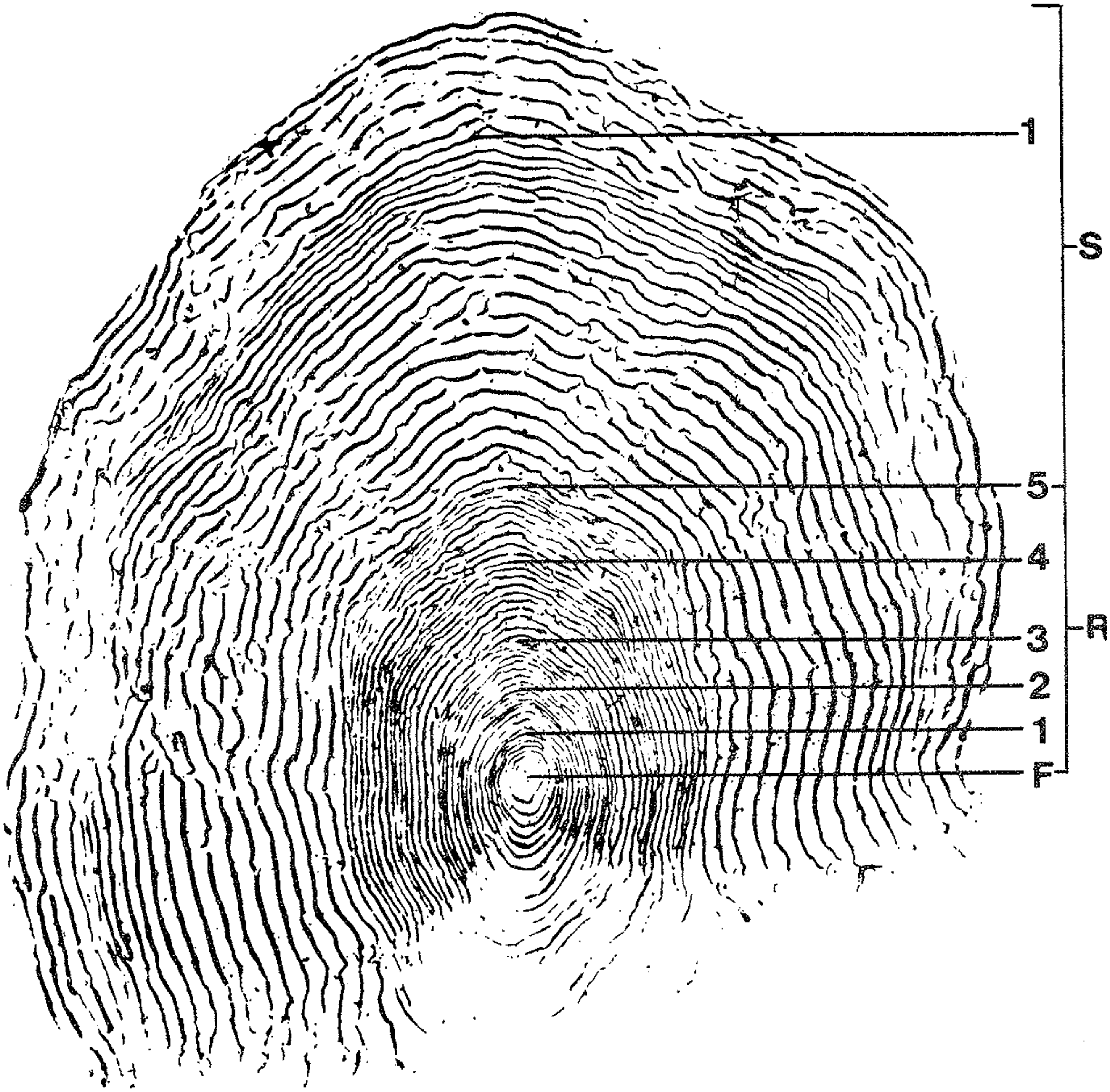

Plate 1. A scale from an Atlantic salmon from Finland. Age 5.1+. An example of a scale suitable for reading.

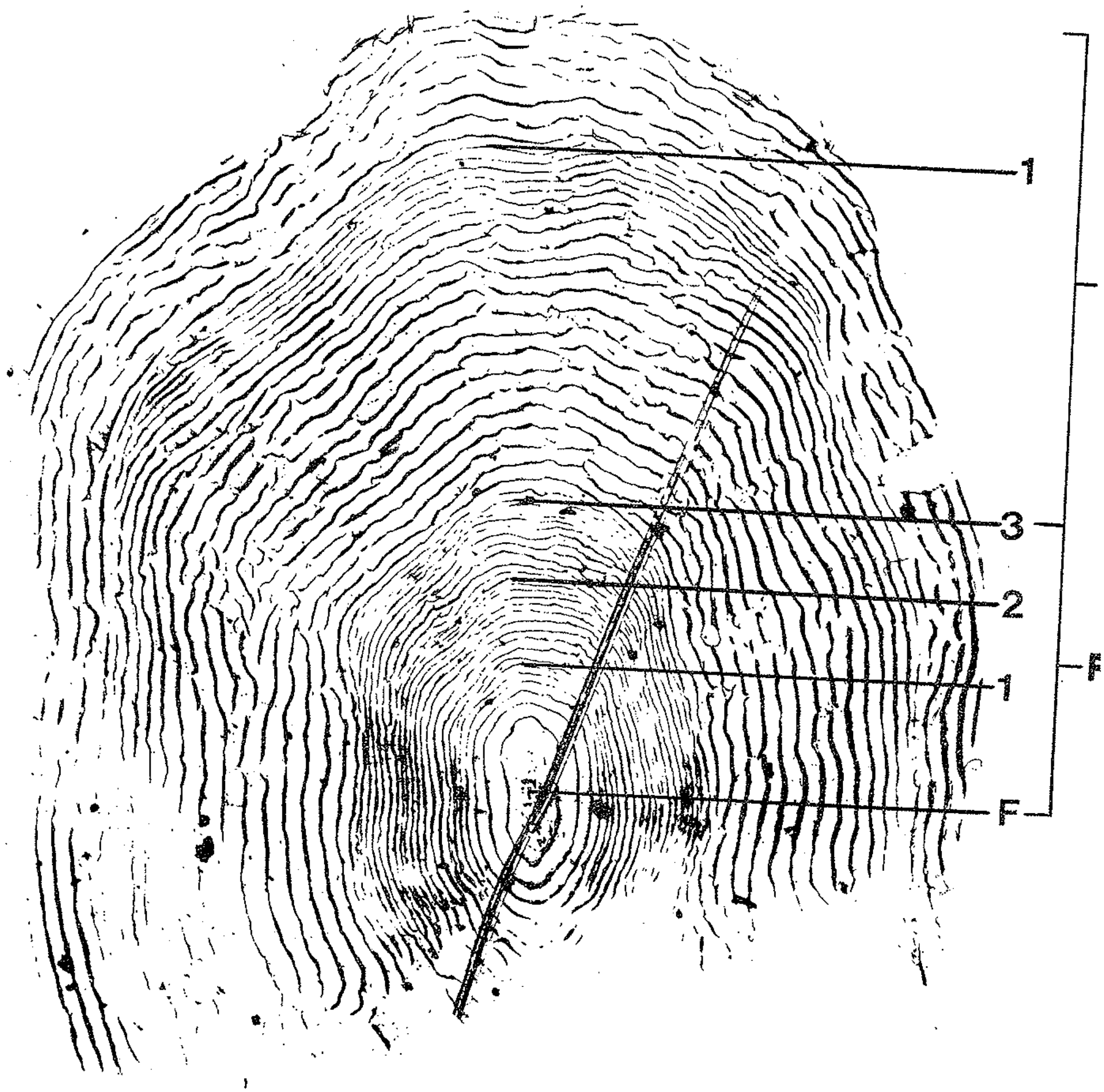

Plate 2. A scale from the same fish as that shown in Plate 1. Age shown is 3.1+. The original scale from this position has been lost and replaced with this one. Details of the first two years of life have been lost.

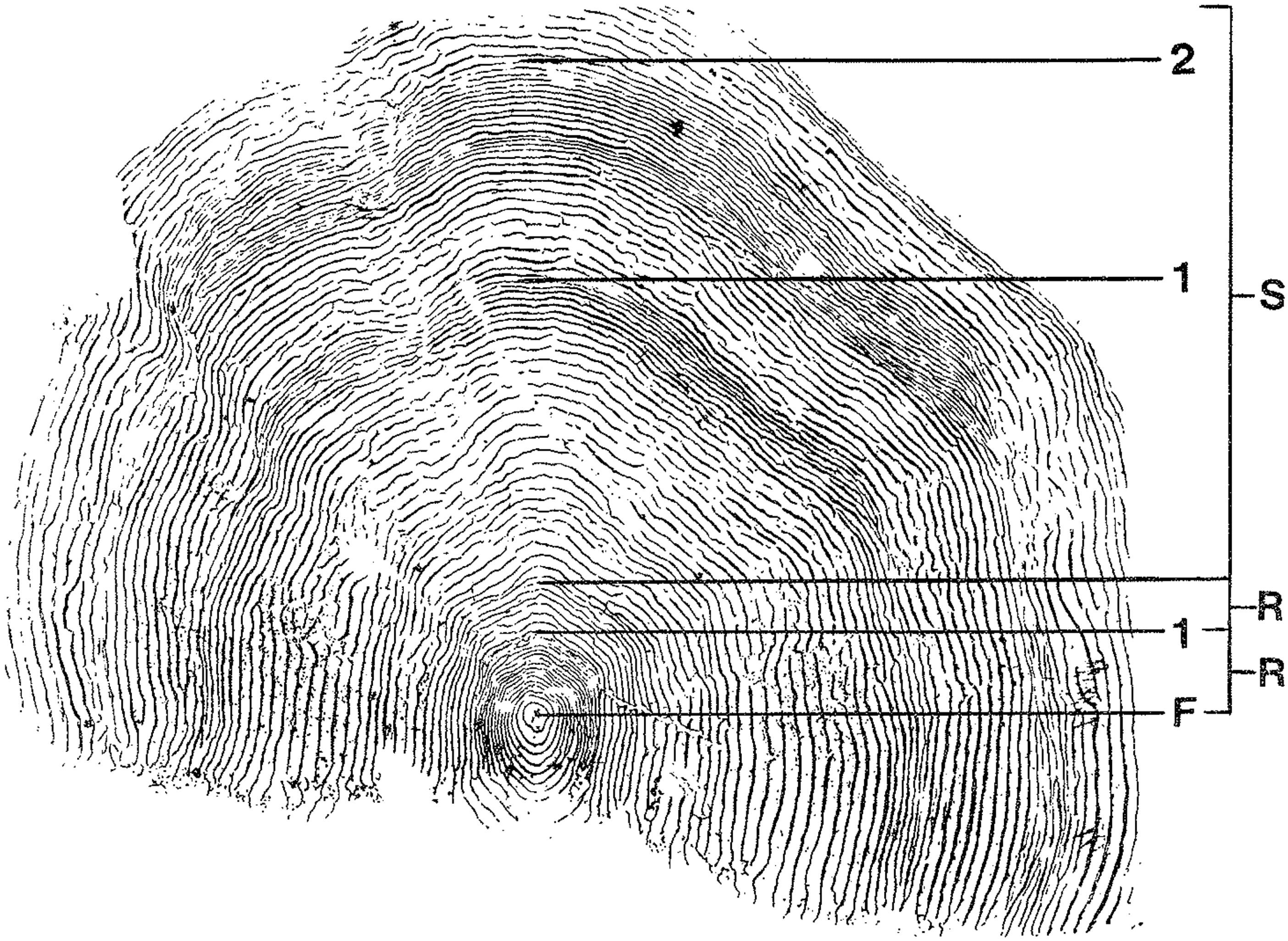

Plate 3. A scale from an Atlantic salmon from Scotland. Age 1+.2+.

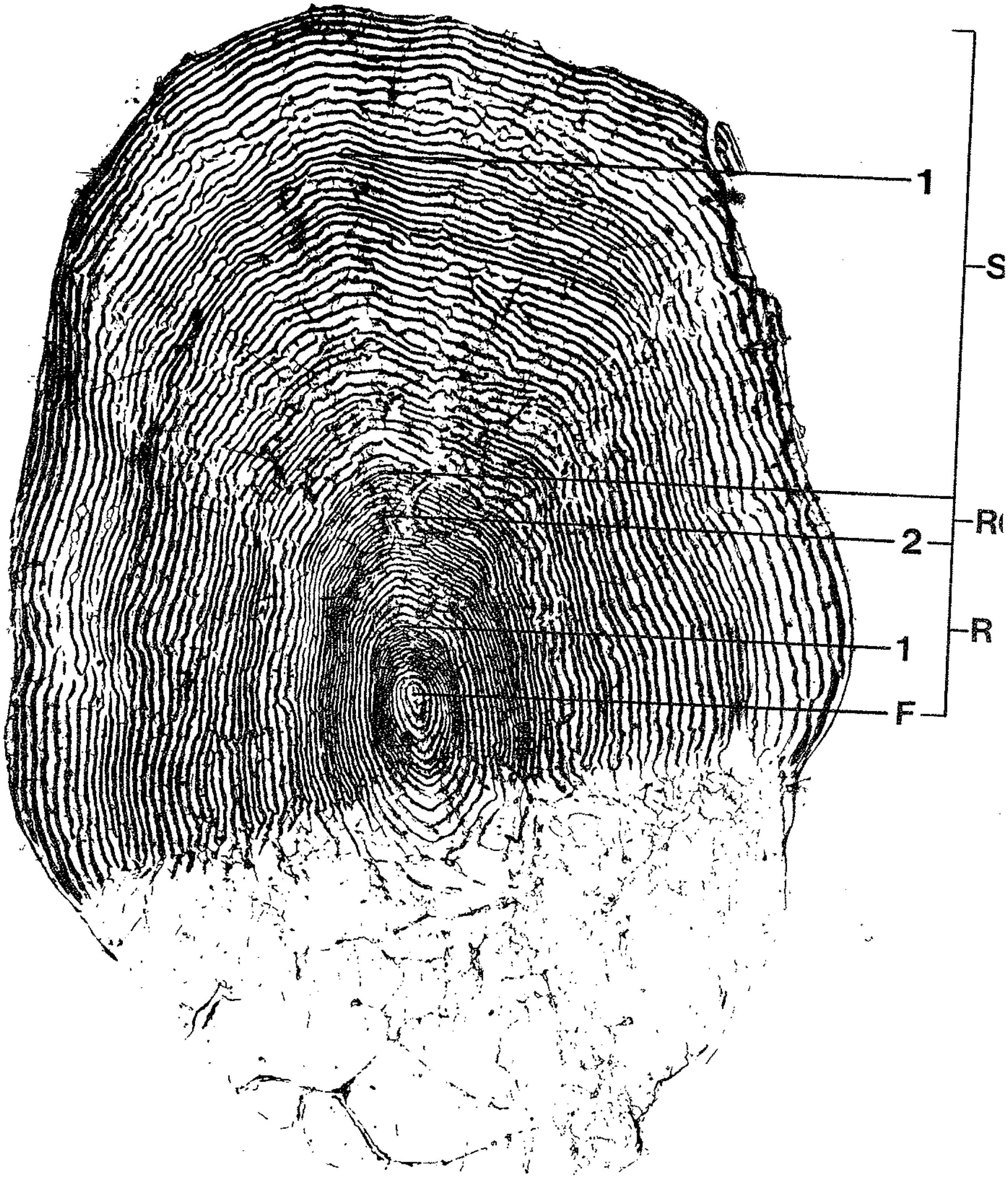

Plate 4. A scale from an Atlantic salmon from Finland. Age 2+.1+.

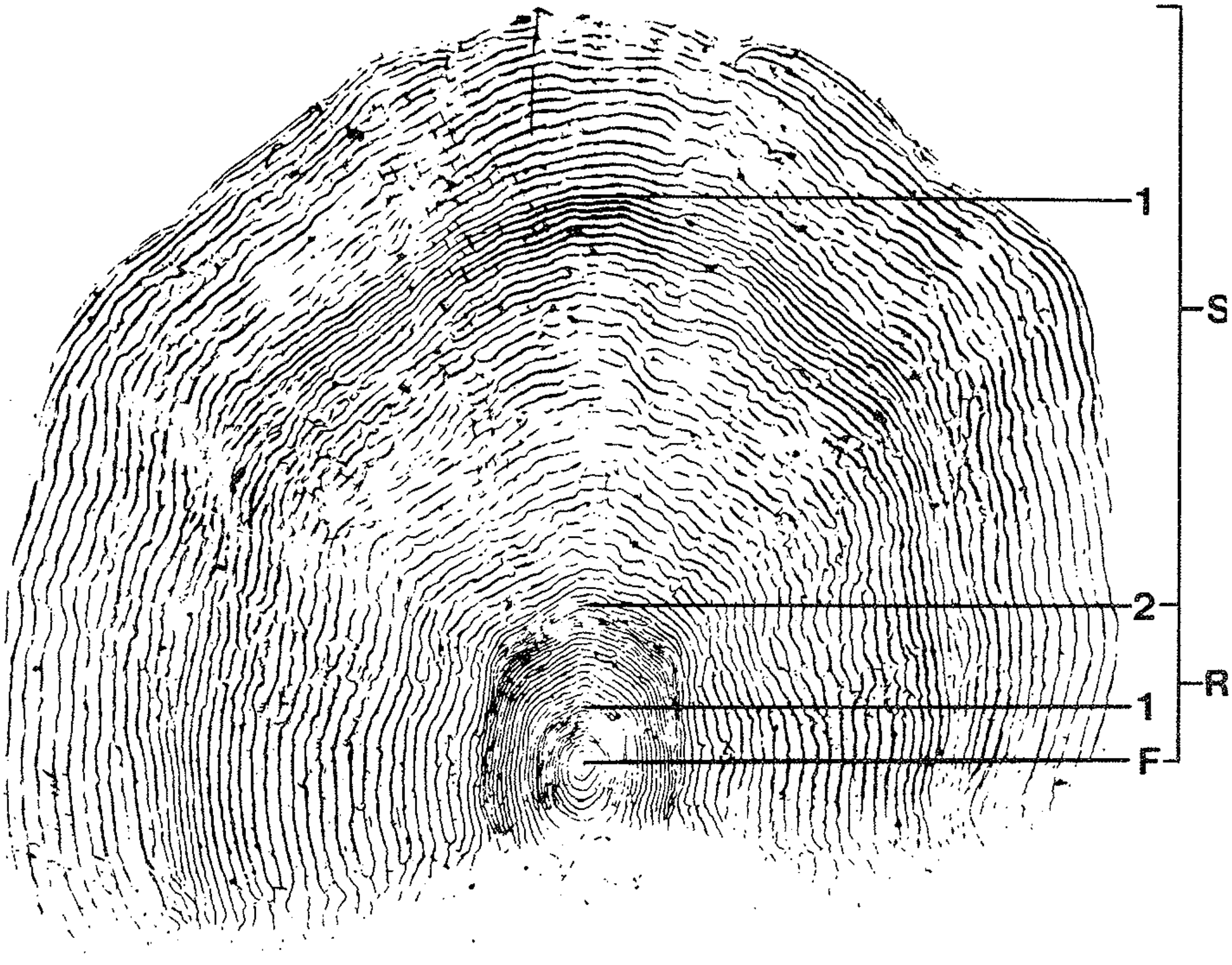

Plate 5. A scale from an Atlantic salmon from Scotland. Age 2.1+.

Plate 6. A scale from an Atlantic salmon smolt from France. Age 3.

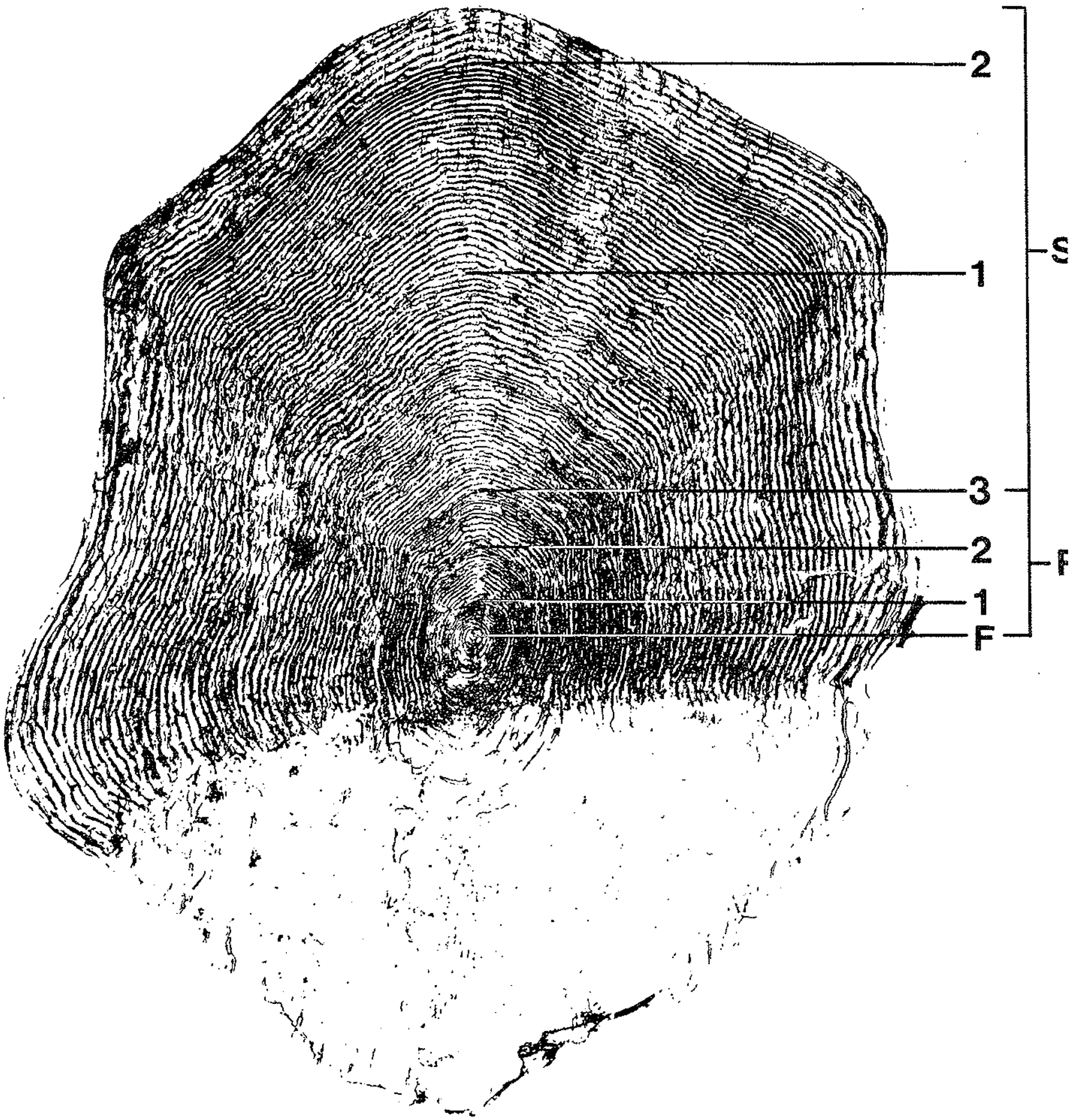

Plate 7. A scale from an Atlantic salmon from Finland. Age 3.2+.

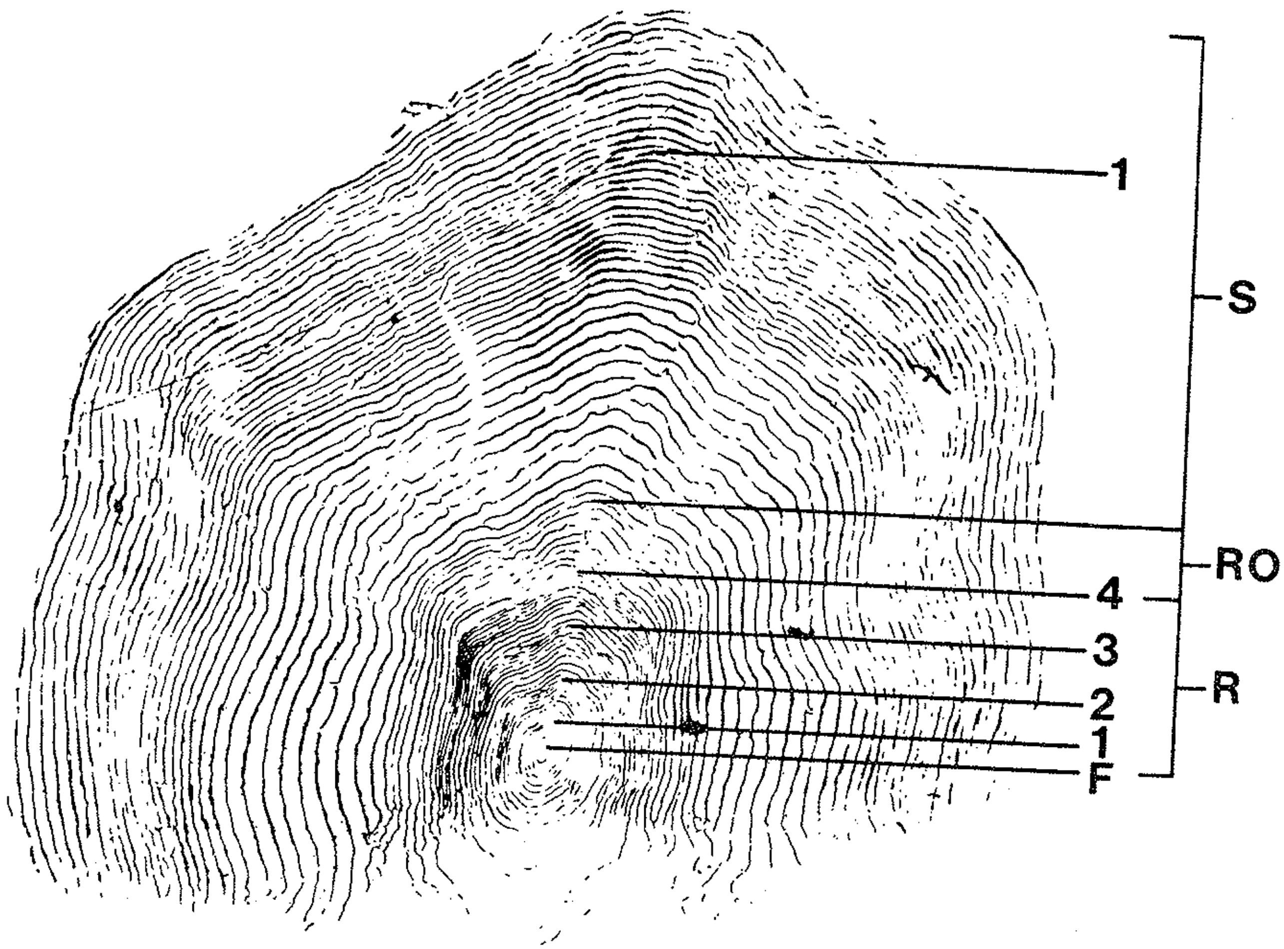

Plate 10. A scale from an Atlantic salmom from Newfoundland, Canada. Age 4+.1+.

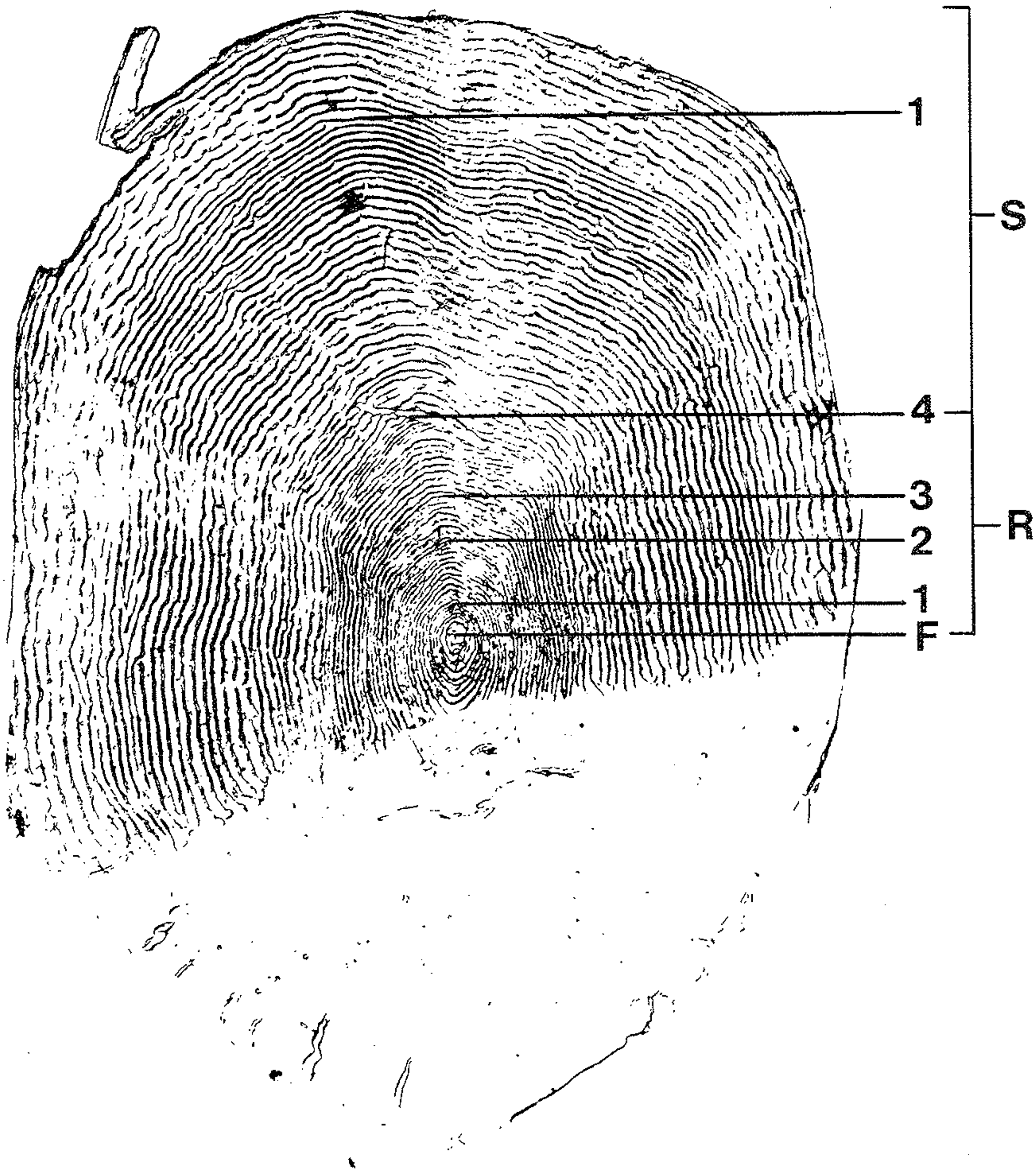

Plate 11. A scale from an Atlantic salmon from Finland. Age 4.1+.

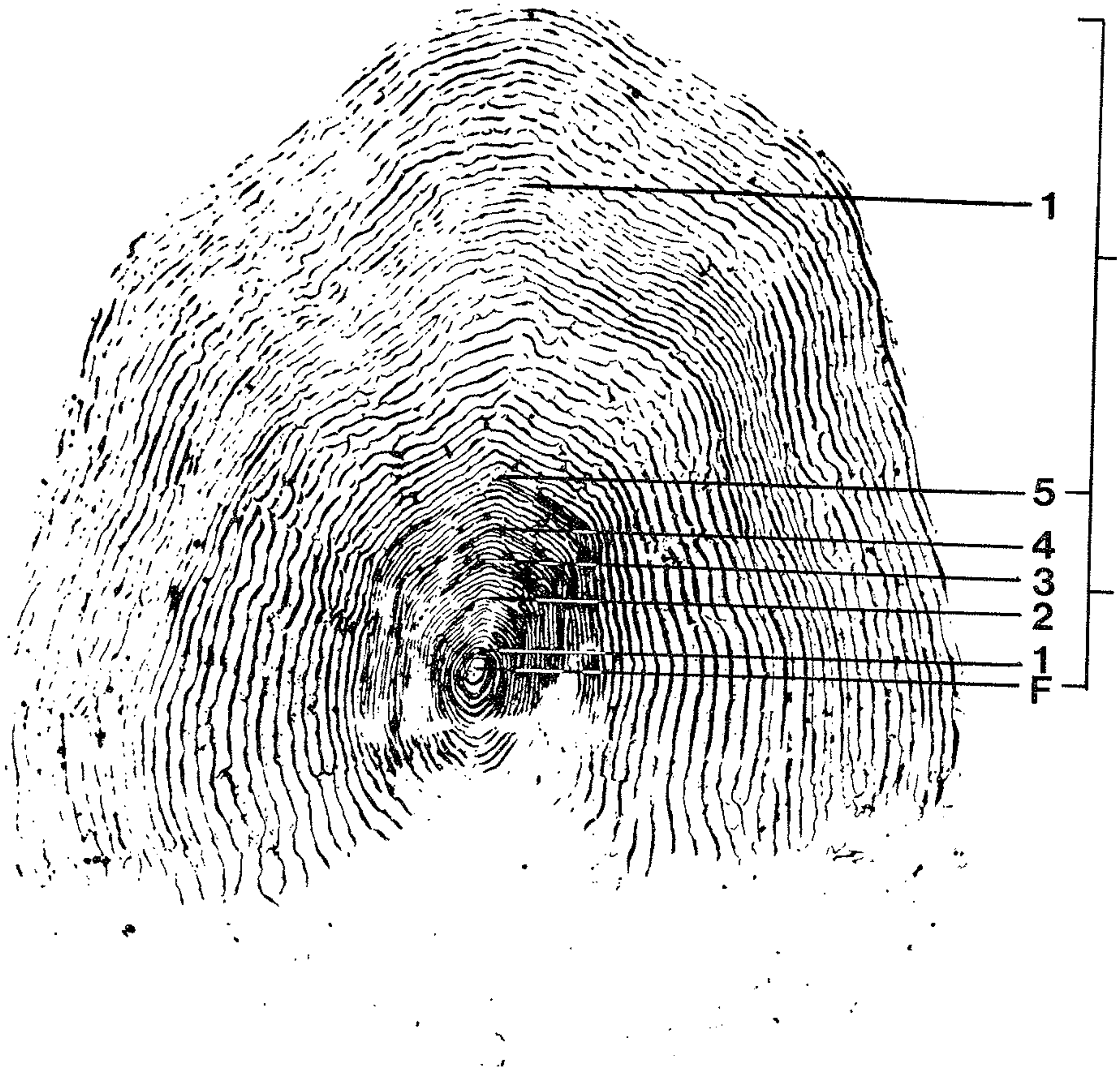

Plate 12. A scale from an Atlantic salmom from Iceland. Age 5.1+.

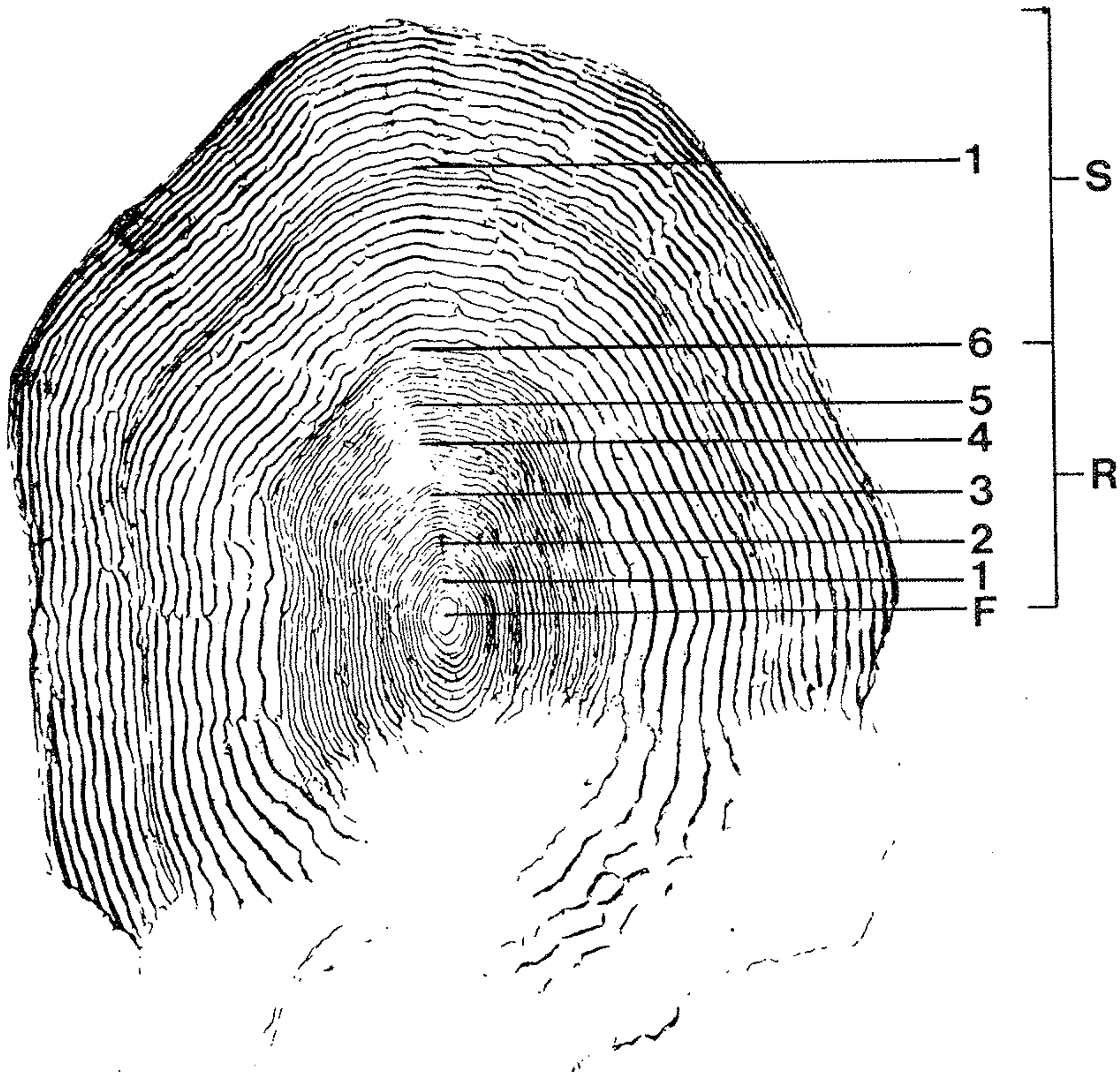

Plate 13. A scale from an Atlantic salmon from Finland. Age 6.1+.

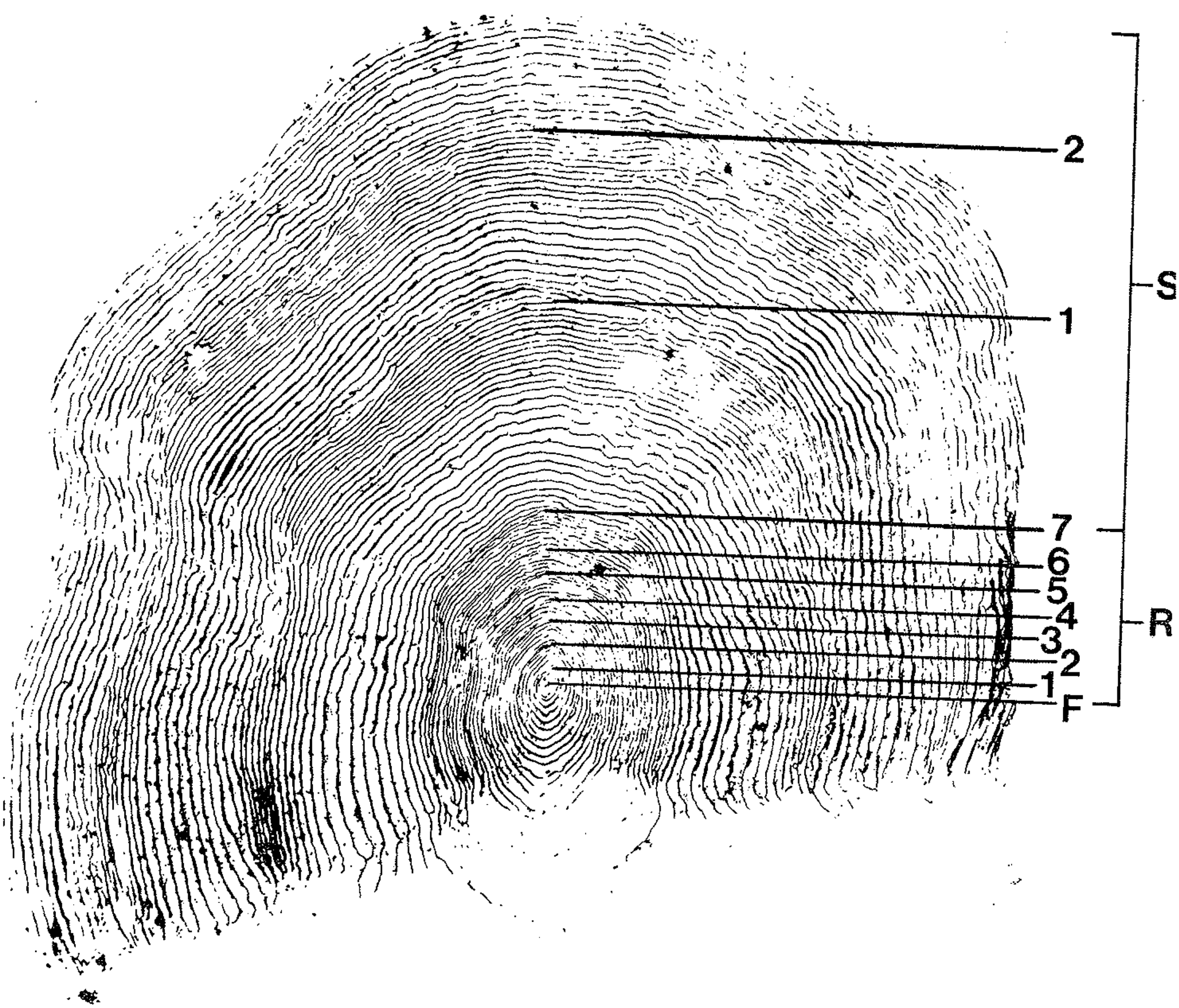

Plate 14. A scale from an Atlantic salmon from Newfoundland, Canada. Age 7.2+.

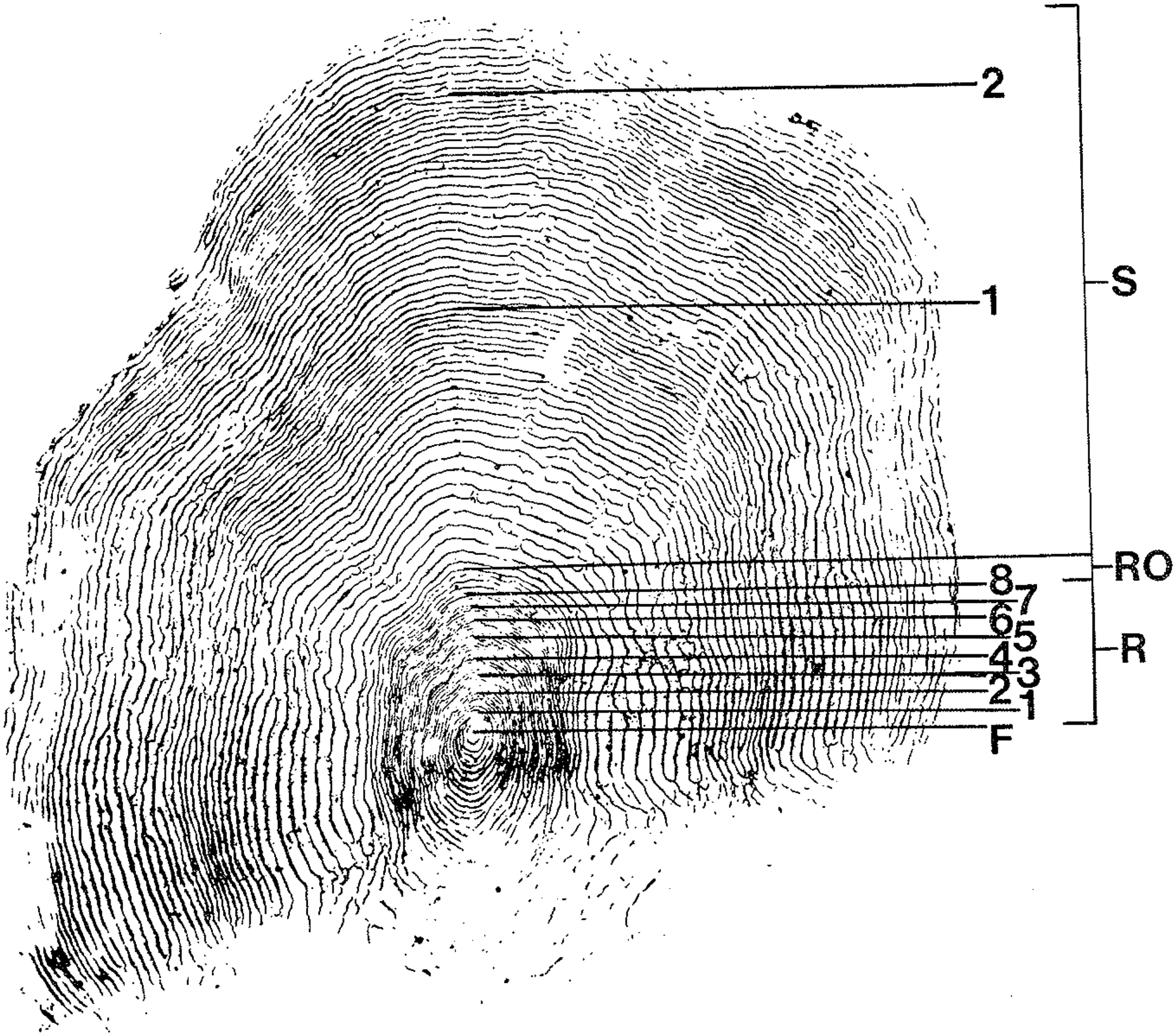

Plate 15. A scale from an Atlantic salmon from Newfoundland, Canada. Age 8+.2+.

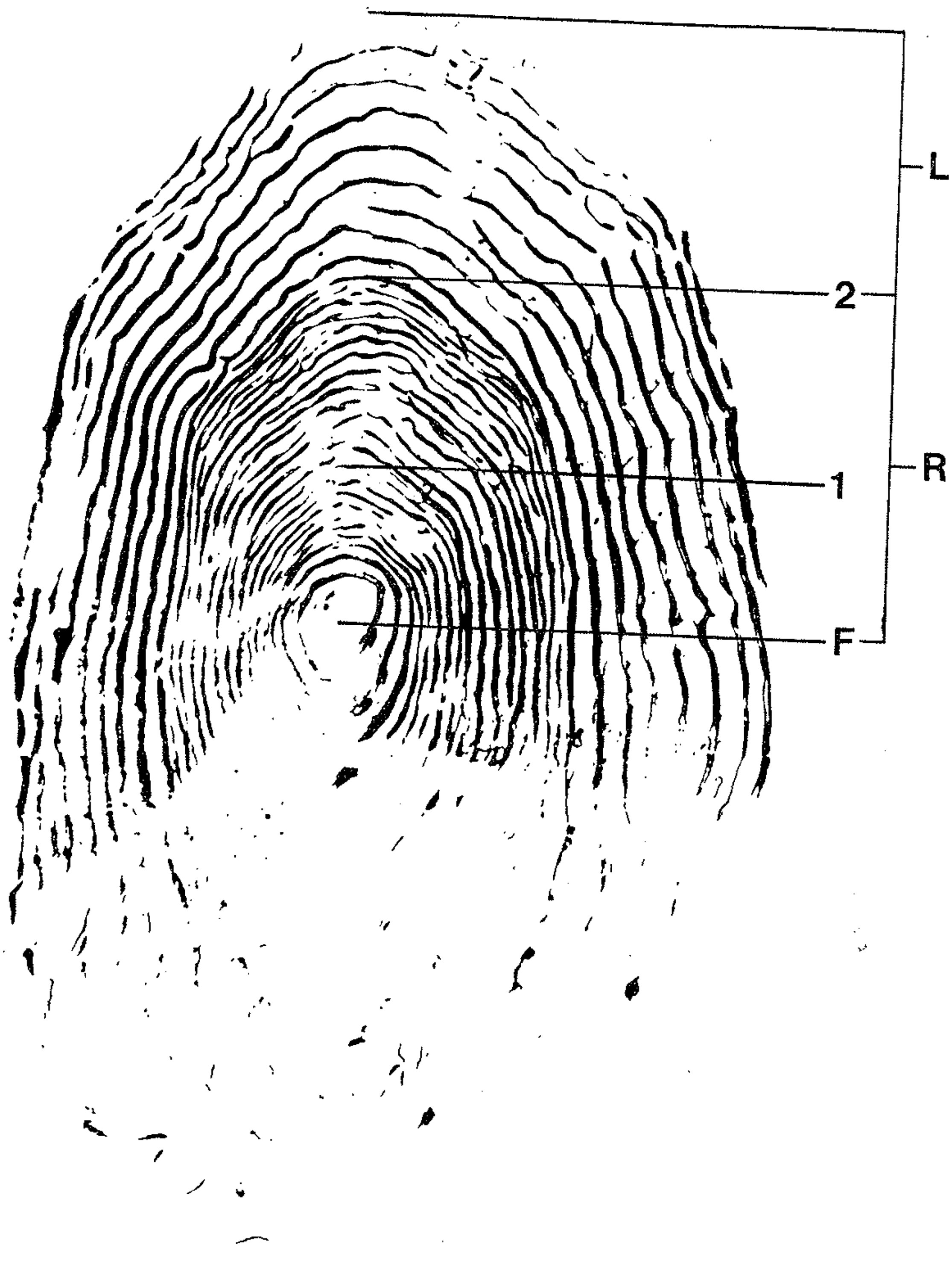

Plate 16. A scale from an Atlantic salmon which has spent the third freshwater summer in a lake environment. Age 2+ caught in its third summer. Lake-type growth is designated L.

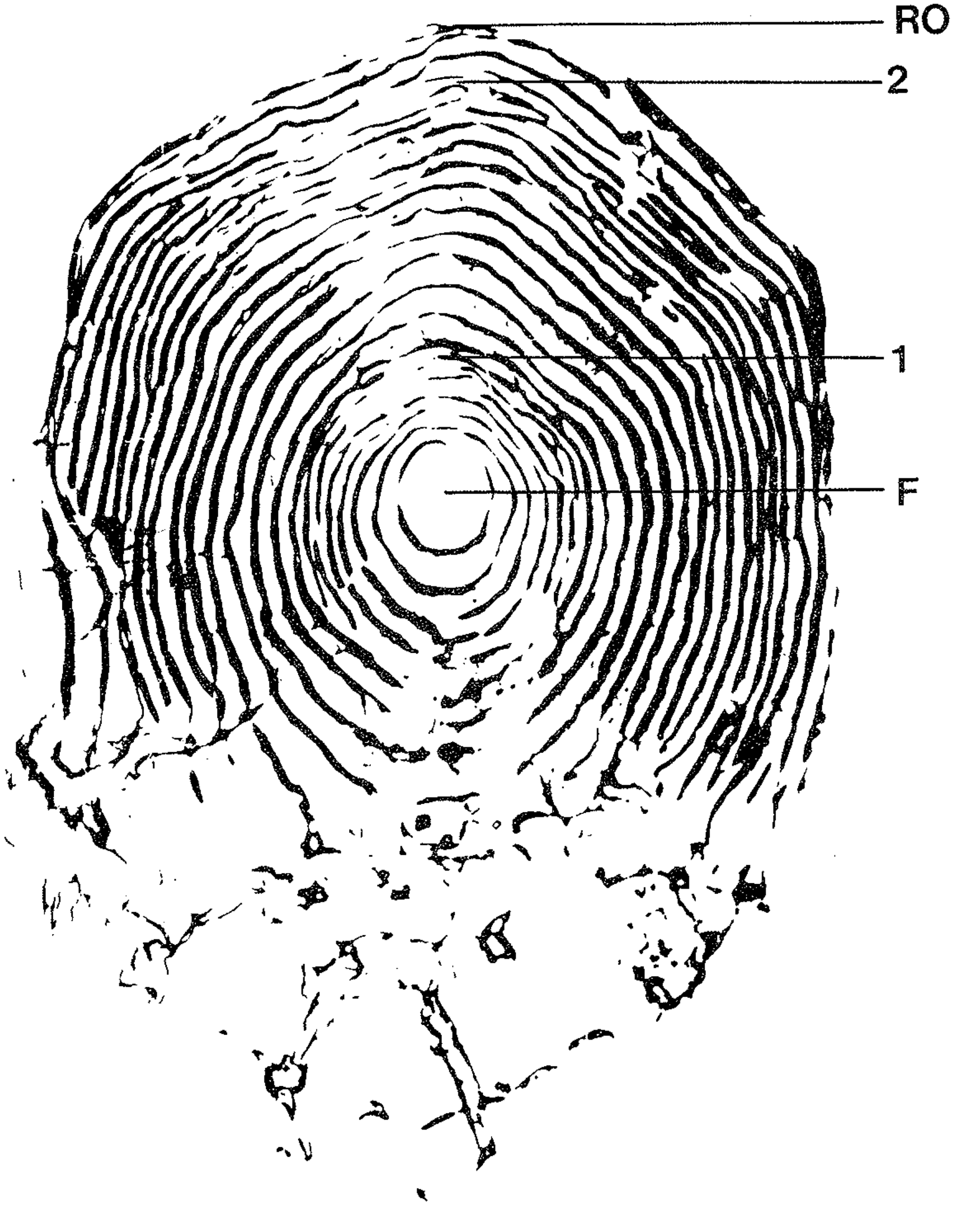

Plate 17. A scale from an Atlantic salmon which has spent two years in a river environment. Age 2+. The plus-growth at the edge of the scale would appear as run-out on the scales of the returning adult.

Plate 18. A scale from an Atlantic salmon from Norway, age 5.1+.

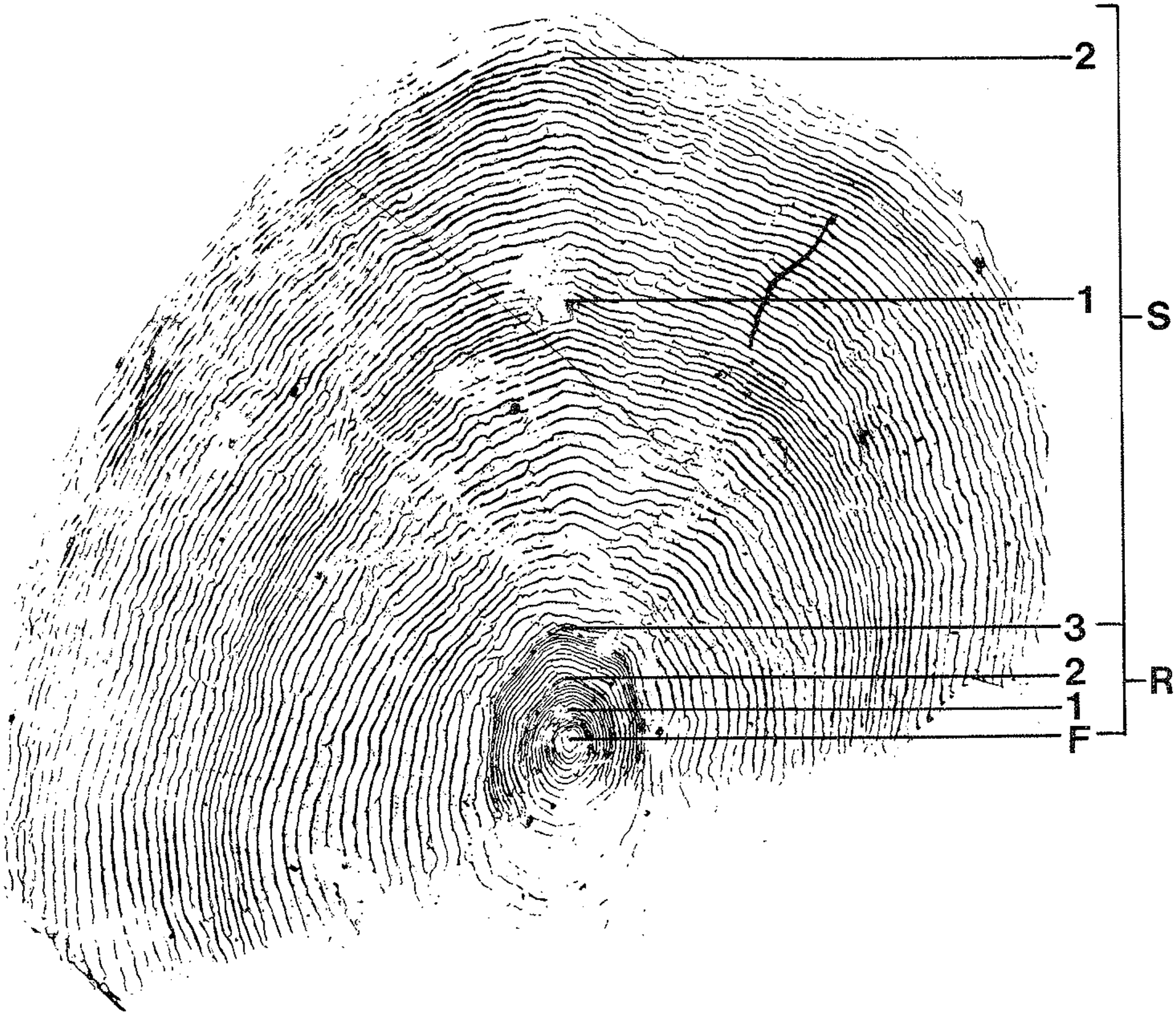

Plate 19. A scale from an Atlantic salmon from New Brunswick, Canada. age 3.2+.

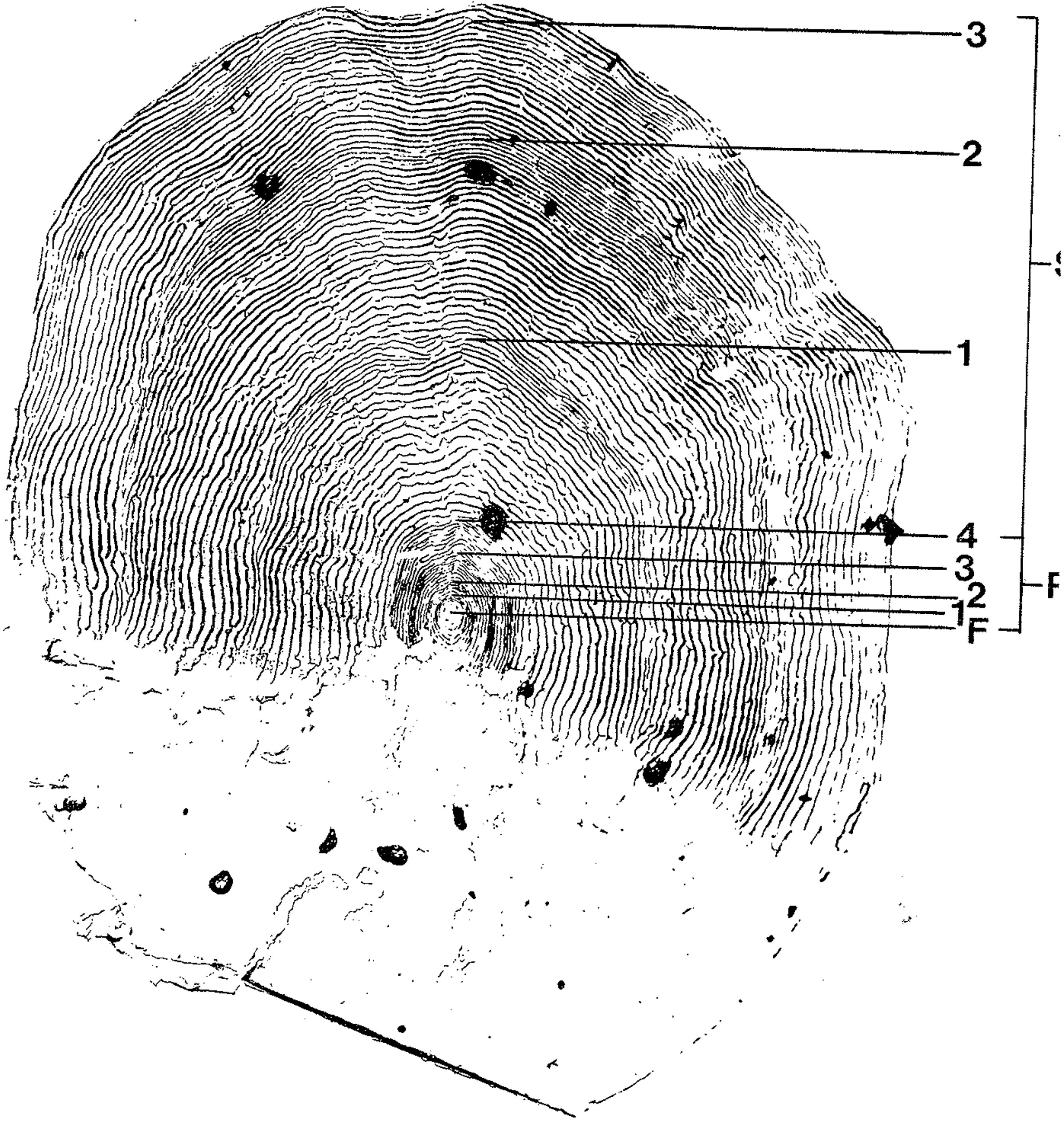

Plate 20. A scale from an Atlantic salmon from Finland. Age 4.3+.

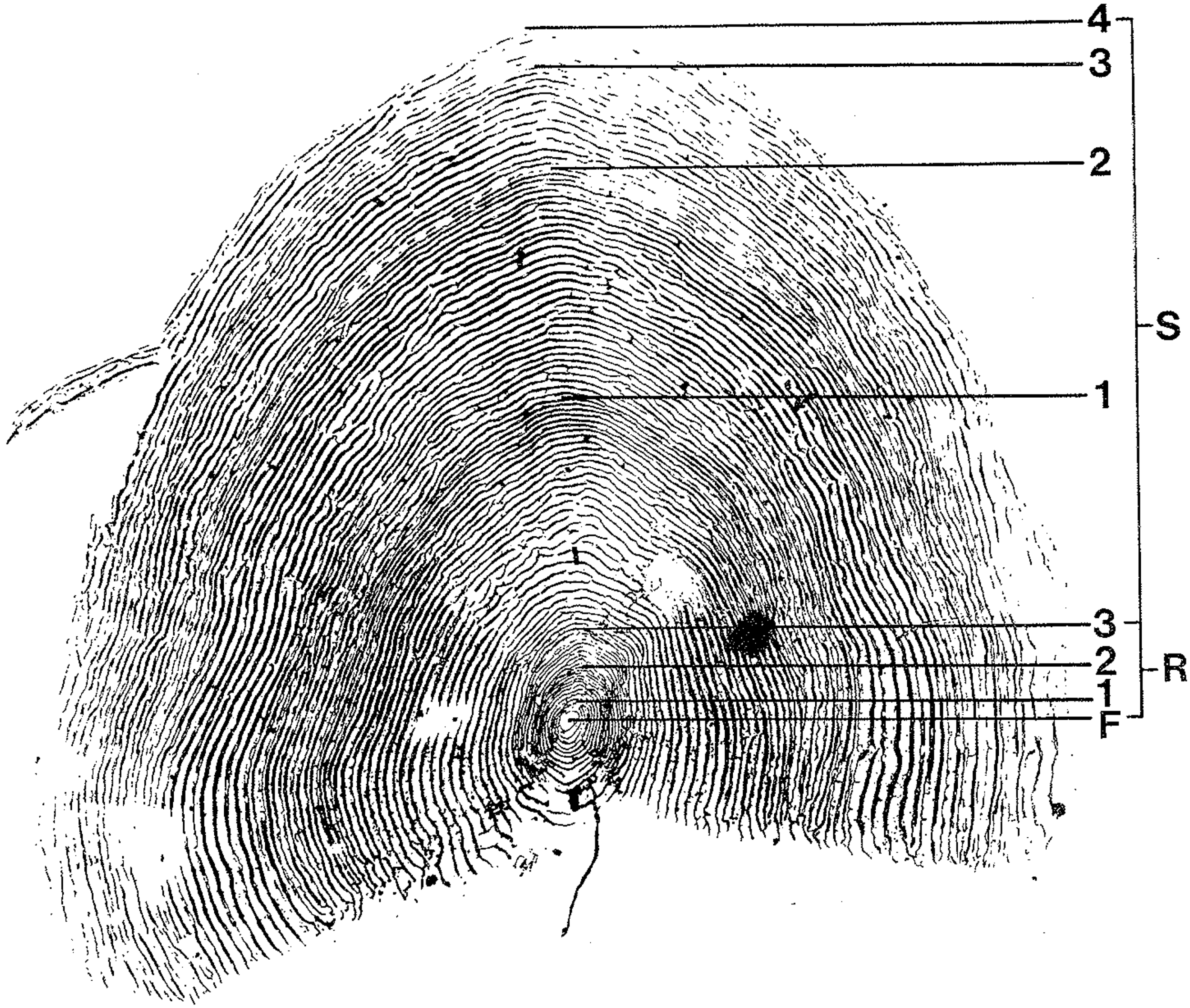

Plate 21. A scale from an Atlantic salmon from Scotland. Age 3.4.

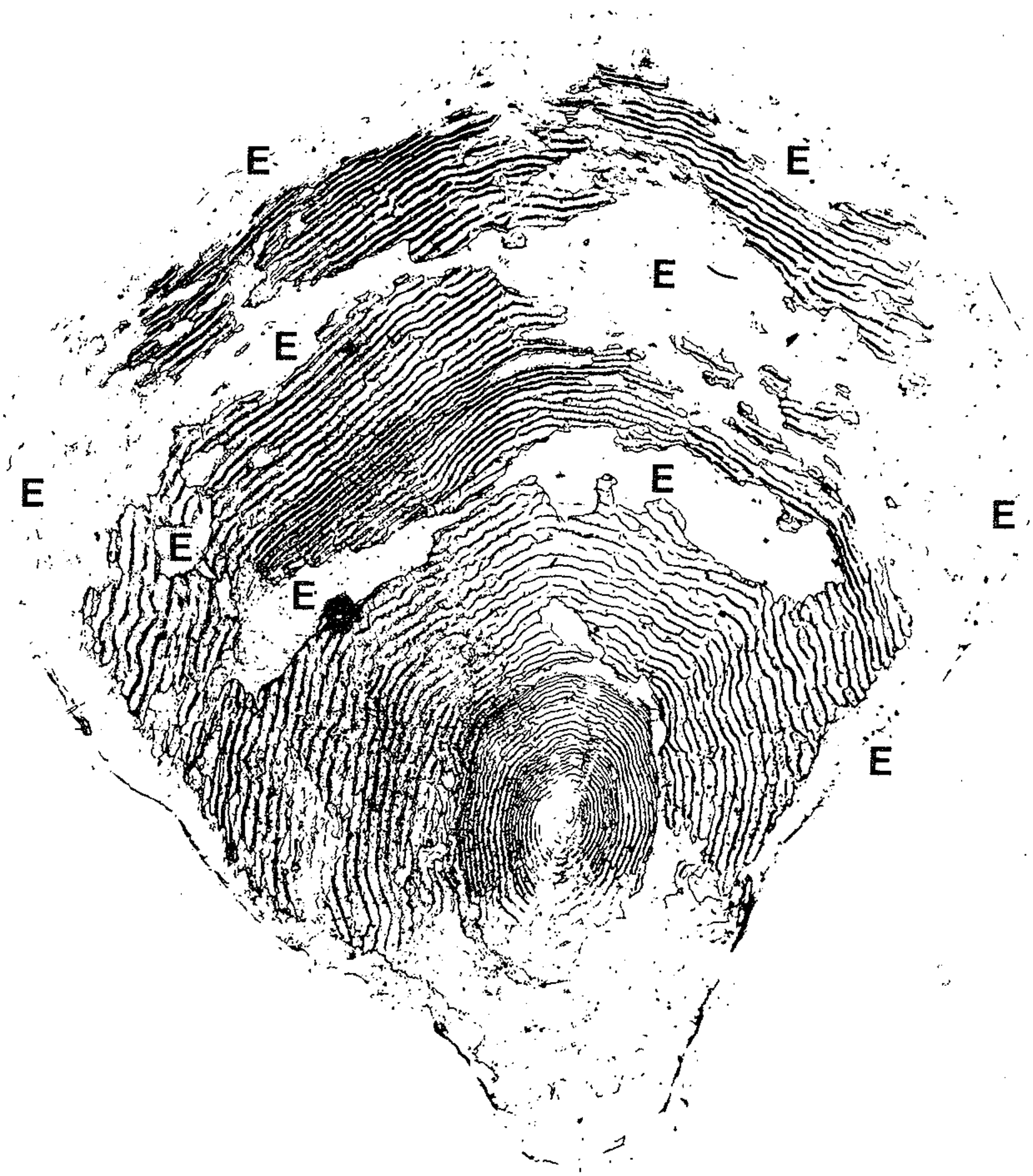

Plate 22. A scale from an Atlantic salmon from Norway showing severe marginal and surface erosion.

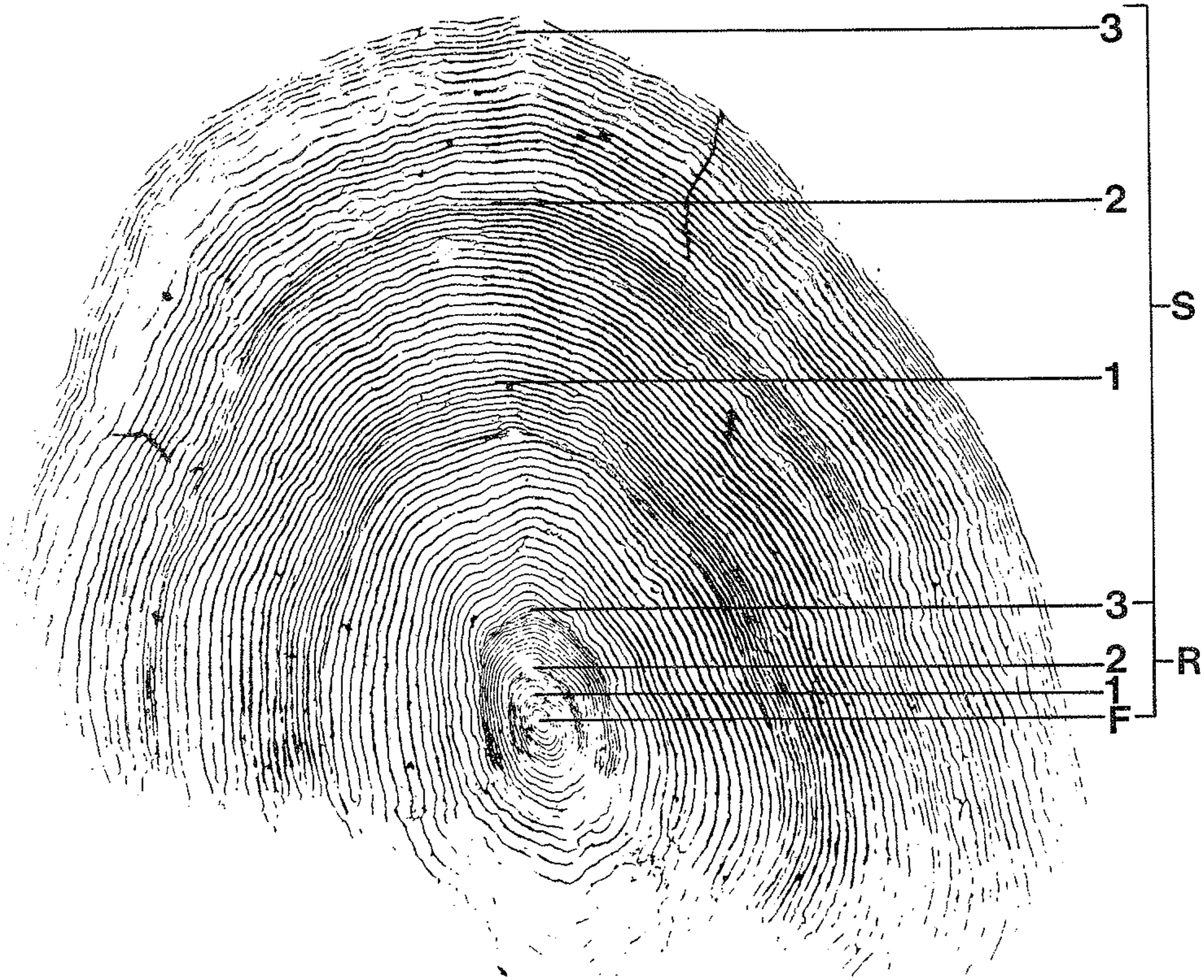

Plate 23. A scale from an Atlantic salmon from New Brunswick, Canada. Age 3.3+.

Plate 24. A scale from the same fish as shown in Plate 23 taken on its next return to freshwater one year later. The third sea-winter band has been completely eroded.

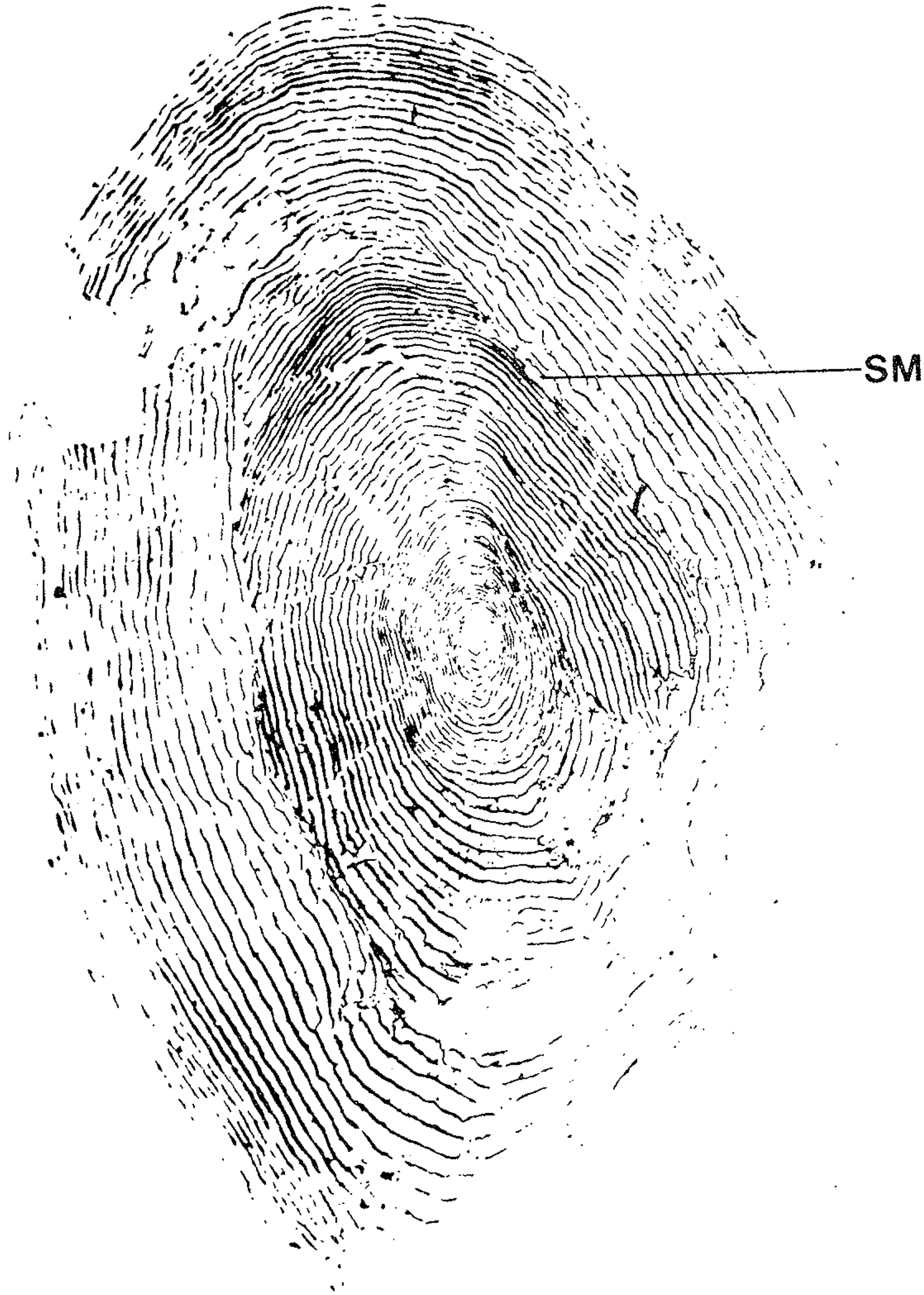

Plate 25. A scale from an Atlantic salmon from New Brunswick, Canada showing a repeating time of return and repeating type of growth pattern. Age 3+.1+SM1+.

Plate 26. A scale from an Atlantic salmon from Finland. This fish was reared in a hatchery and released as a 2-year-old smolt. Age 2.2.

Plate 27. A scale from an Atlantic salmon from Iceland. This fish was reared in a hatchery and released as a 2-year-old smolt. Age 2.1+.

Plate 28. A scale from an Atlantic salmon from Scotland. This fish was reared in a hatchery and released as a 2-year-old smolt. Age 2.1+.

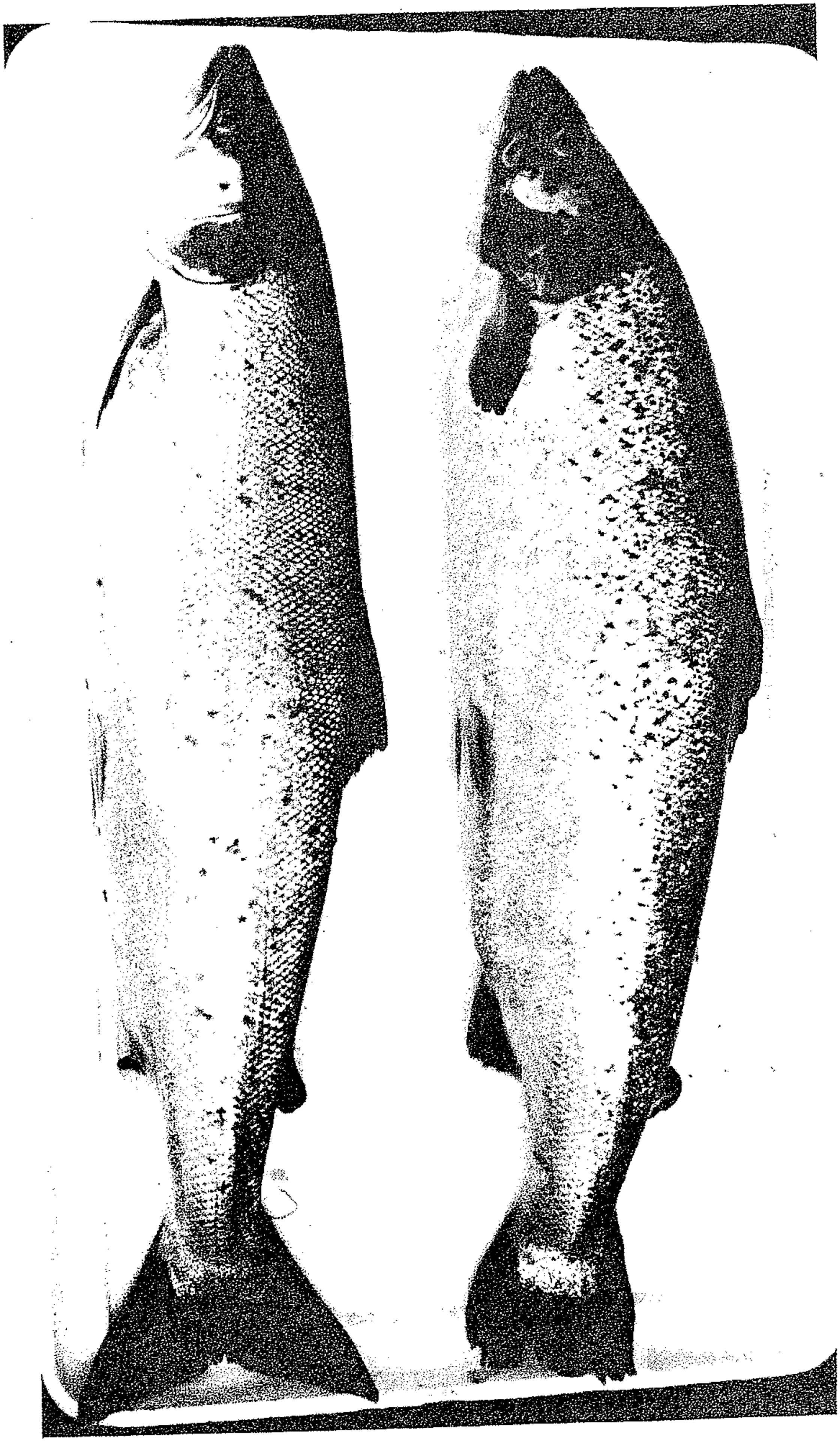

Plate 29. The fish on the right is a typical Scottish 1SW farmed salmon. Note the deformed fins and atypical pigmentation. The fish on the left is a typical Scottish 1SW wild salmon.

Plate 30. A scale from the farmed salmon shown in Plate 29. Known age 2.1+.

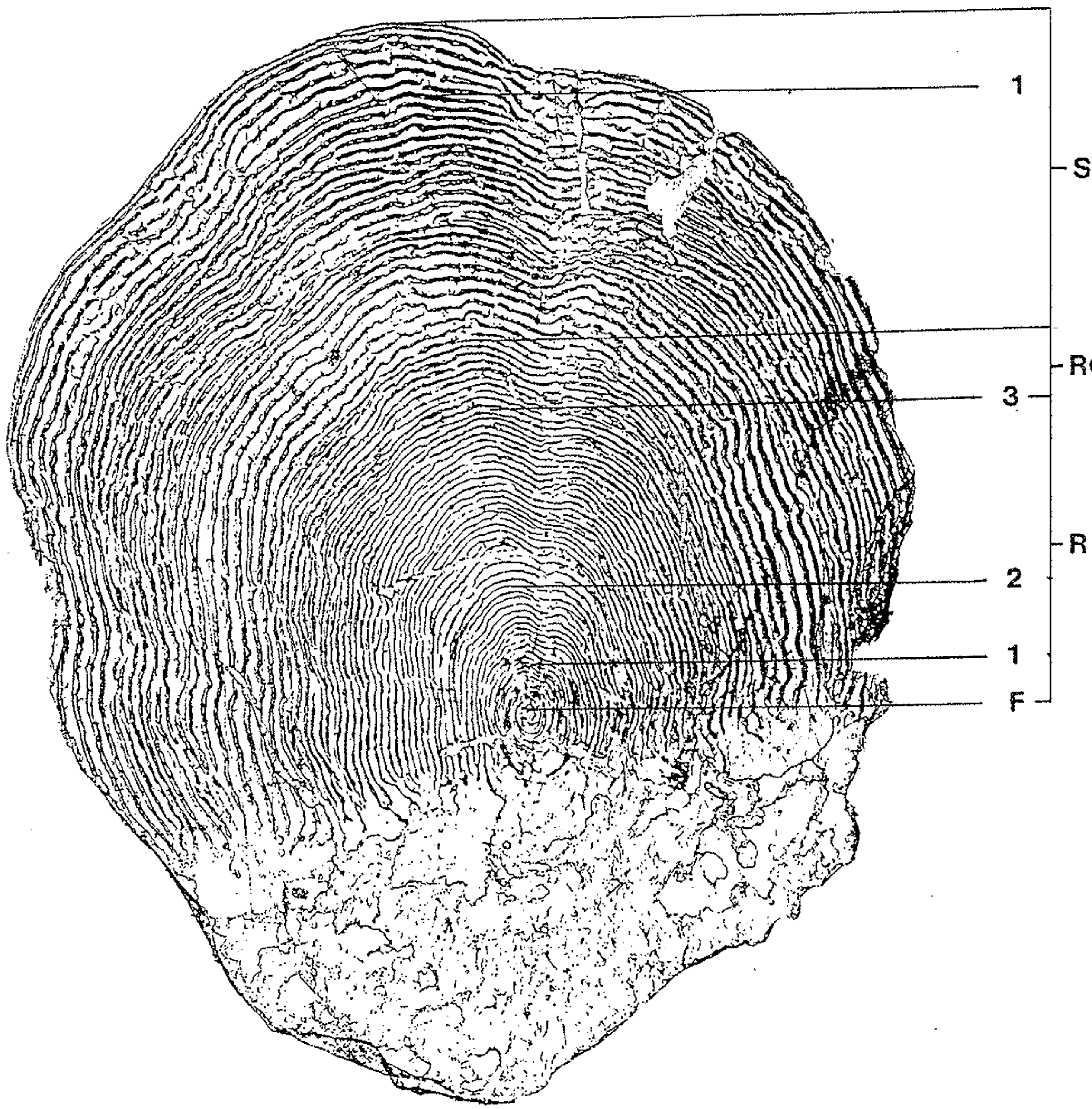

Plate 31. A scale from an Atlantic salmon from Norway. This fish was reared in a hatchery at Ims and released into a sea cage as a 1-year-old smolt in May. The following August it was released into the sea and was recaptured in the fish trap at Ims one year later. Known age 1.1+. Determined age 4.1+.

Plate 32. A scale from an Atlantic salmon from Finland released as a 2-year-old smolt into the Baltic Sea and recaptured two years later.

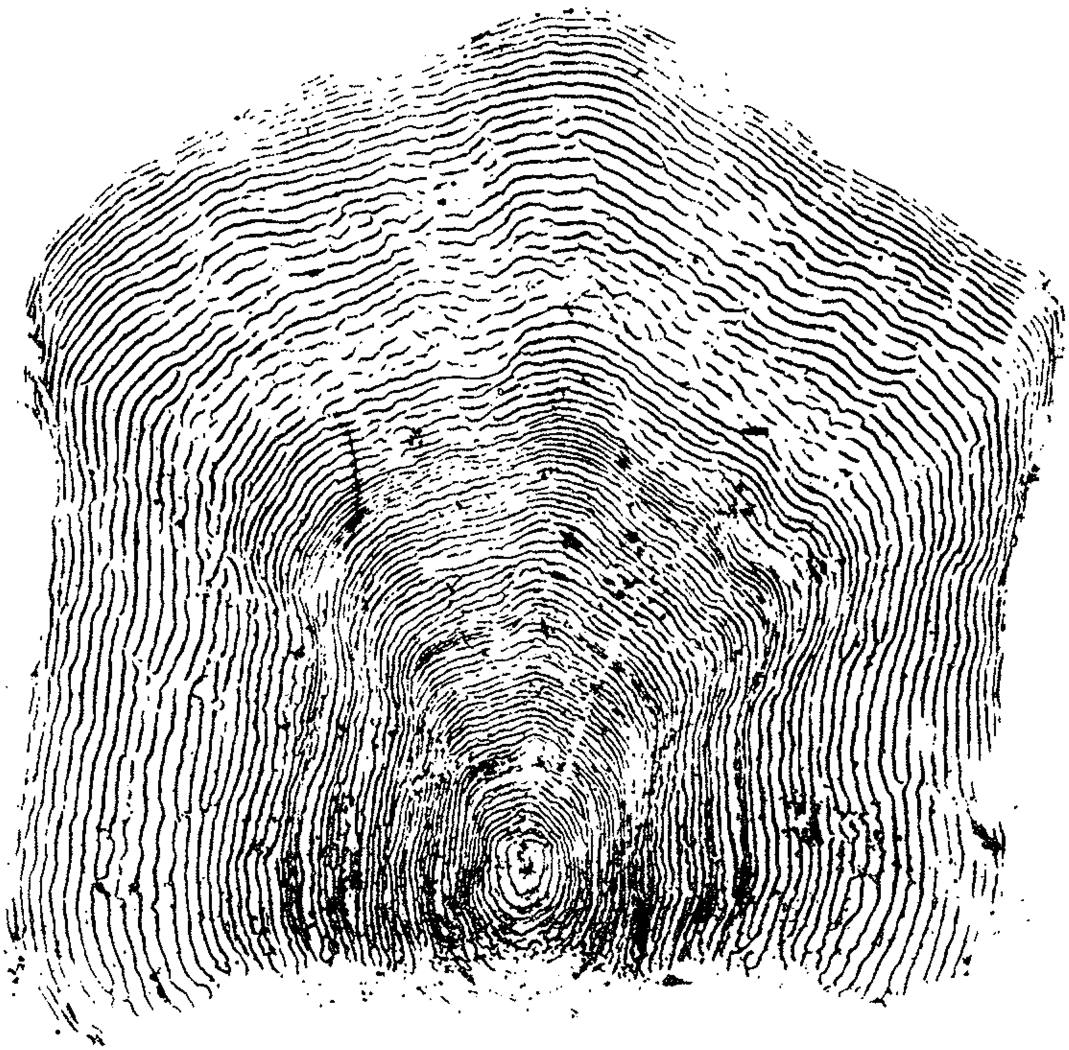

Plate 33. A scale from an Atlantic salmon from Sweden released as a 2-year-old smolt into the Baltic Sea and recaptured two years later.

APPENDIX 1

LIST OF PARTICIPANTS

R.R. Claytor	Canada
D.G. Reddin	Canada
C.P.R. Mills	Ireland
S.M. Einarsson	Iceland
E. Ikonen	Finland
E. Niemela	Finland
P. Prouzet	France
H. Troadec	France
R.A. Lund	Norway
D.A. Dunkley	United Kingdom (Scotland)
J.C. MacLean	United Kingdom (Scotland)
W.D. Riley	United Kingdom (England and Wales)
W.M. Shearer, Chairman	United Kingdom (Scotland)
B.D.M. Whyte	United Kingdom (Scotland)

LIST

R.R. Claytor

D.G. Reddin

C.P.R. Mills

S.M. Einarsson

E. Ikonen

E. Niemela

P. Prouzet

H. Troadec

R.A. Lund

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J.C. MacLean

W.D. Riley

W.M. Shearer, Chairma

B.D.M. Whyte