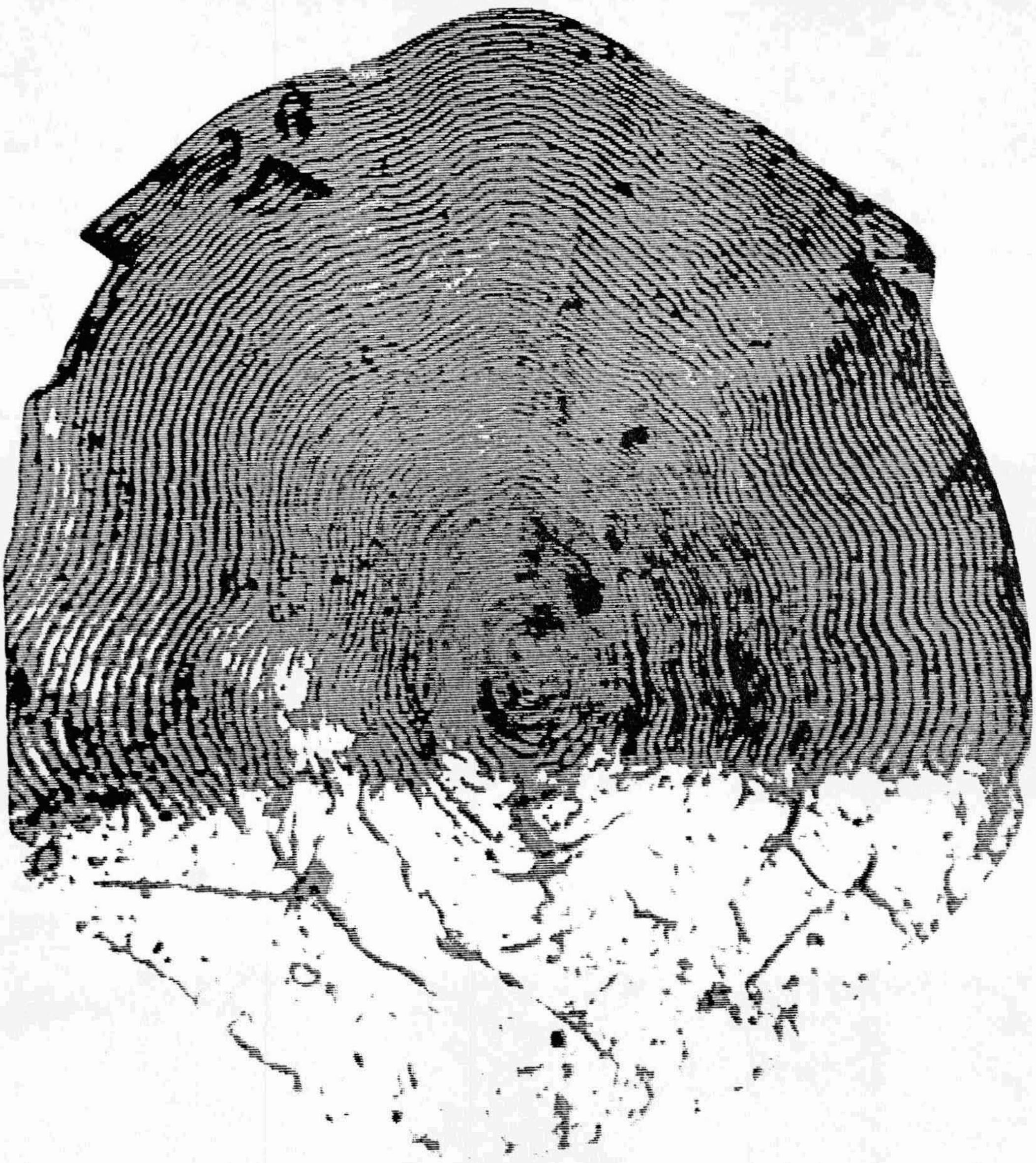
International Council for the Exploration of the Sea

C.M. 1991/M:7 Ref. J
Anadromous and Catadromous Fish Committee

BALTIC SALMON SCALE READING



REPORT OF THE BALTIC SALMON SCALE READING WORKSHOP

Utsjoki, Finland, 15-17 January, 1991

REPORT OF THE BALTIC SALMON SCALE READING WORKSHOP

1. PARTICIPANTS

Bartel, Ryszard	Poland
Borzecka, Irena	Poland
Christensen, Ole	Denmark
Erkinaro, Jaakko	Finland
Fransson, Gun	Sweden
Hiilivirta, Pekka	Finland
Ikonen, Erkki (chairman)	Finland
Kangur, Mart	USSR
Karlsson, Lars	Sweden
Kazakov, Rostislav	USSR
Kilpelä, Seija-Sisko	Finland
Kuusela, Jorma	Finland
Lappalainen, Jyrki	Finland
Margonski, Piotr	Poland
Mehli, Swein Aage	Norway
Mitans, Andis	USSR
Moen, Kjell	Norway
Niemelä, Eero	Finland
Pruuki, Veijo	Finland
Tolonen, Arto	Finland

2. TERMS OF REFERENCE

A Workshop on Scale Reading for Baltic Salmon (Chairman: Mr E.Ikonen, Finland), with members drawn from all countries participating in the Baltic Salmon and Trout Assessment Working Group (BSTAWG), was held in Utsjoki, Finland on 15-17 January 1991 to:

a) review, update, and report on the technique used to distinquish wild and hatchery-reared salmon by scale examination;

b) evaluate and report on the scale sampling programme and make recommendations as to how it can be improved;

c) report to the 1991 meetings of the Baltic Salmon and Trout Assessment Working Group and the Anadromous and Catadromous and Baltic Fish Committees.

3. BACKGROUND AND AIMS

The remaining, naturally reproducing salmon stocks suffer from lack of spawners entering the river. This is due to overfishing of these stocks in the sea. The International Baltic Sea Fisheries Commission has been worried about the status of these stocks and asked ICES to assess the status of Baltic salmon stocks and provide catch options within safe biological limits defined to safeguard wild Baltic salmon stocks.

The status of wild stocks can be assessed by electro-fishing surveys in parr nursery areas. It is also possible by trapping descending smolts during smolt run. These methods are, however, more or less reliable only in small rivers. Therefore the proportions of wild and hatchery-reared salmon in catches are needed to estimate the status of wild stocks in the Baltic Sea.

The Baltic Salmon and Trout Assessment Working group has gathered data of wild and hatchery-reared salmon in catches in various parts of the Baltic Sea. These data have been used to estimate the development of the ratio between wild and hatchery-reared salmon in the Baltic Sea. These data can also be used to estimate wild smolt production in rivers around the Baltic Sea.

For fishery management purposes it is important to know the share of wild salmon in the catches in different areas and in different fisheries. The aim of this workshop is to develop methods for distinguishing wild and hatchery-reared salmon on the basis of scale structure. Intercalibration of scale interpretation and evaluation of scale sampling programmes will also be carried out between participants representing various laboratories.

4. SALMON SMOLT PRODUCTION IN THE BALTIC SEA IN 1989

In the rivers of the northern part of the Gulf of Bothnia - Sub-division 31 - natural smolt production has been estimated to be annually 177 000 smolts, most of which originate in the Tornionjoki River and the Kalix River. Releases of salmon in this area consisted of Swedish one- and two-year-old hatchery-reared smolts (881 000) and Finnish two- and three-year-old hatchery-reared smolts (1 584 000). Finnish releases have been carried out mainly in the mouths of the Kemijoki, Iijoki and Oulujoki Rivers (Fig. 1) (Table 1).

Natural smolt production of rivers in the southern part of the Gulf of Bothnia - Sub-division 30 - was only about 10 000. Artificial smolt production amounted to 1 506 000 one- and two-year-old smolts (Table 1). Eggs for smolt production in Sweden were obtained from spawners caught in rivers, in Finland mostly from hatchery-reared brood stocks.

In the Gulf of Finland (Sub-division 32) natural smolt production occurs only in the USSR. It was estimated to be very low amounting only to 15 000 smolts, most of which originated in the Neva River. Hatchery-reared smolts in the USSR were released into the Narva River (77 000) and into the Neva River (2 000). In Finland a total of 472 000 one-and two-year-old smolts of the Neva stock were released into the Kymijoki River, the Vantaanjoki River and some smaller rivers (Table 2).

Table 1. Smolt production in the Gulf of Bothnia in 1989 (in 1000s)

SUB-DIV.	RIVER	WILD	HATCHERY-REARED 2-YEAR
31	TORNIONJOKI	75	50
	KEMIJOKI	-	1584
	SIMOJOKI	12	
	IIJOKI	-	
	OULUJOKI	-	
30	KARVIANJOKI 1)	-	242
	KOKEMÄENJOKI 1)	-	
31	KALIX	50	881 2)
	RÅNE	2	
	PITE	1	
	ÅBY	-	
	BYSKE	10	
	KÅGE	-	
	RICKLEÅN	-	
	VINDEL	25	
	ÖRE	1	
	LÖGDE	1	
	SÄVARAN	-	1264 2)
	BURE	-	
	TÖRE	-	
30	LJUNGAN	10	
	TOTAL	187	4021 2)

1) Fish of the River Neva stock are released into the River Kokemäenjoki and the River Karvianjoki and some small other rivers in Sub-divisions 29 and 30.

2) Includes also one-year-old smolts.

Traditional rearing techniques were used in the Neva hatchery. In the Narva hatchery one-year-old smolts were produced by utilising heated effluents (12-17 °C) from a power-plant. The Luga rearing station was completed in 1989, and the first smolts can be expected in the years 1992-93. In the hatcheries of the USSR the eggs for rearing were obtained from salmon spawners caught in rivers.

Table 2. Smolt production in the Gulf of Finland in 1989 (in 1000s)

RIVER	WILD	HATCHERY-REARED 1-YEAR	2-YEAR
KYMIJOKI 1) VANTAANJOKI 1)	-	123	349
NEVA	15	-	2
KUNDA		-	-
LOOBU		-	-
KEILA		-	-
VASALEMMA		-	-
PIRITA		-	-
NARVA	-	77	-
TOTAL	15	200	351

1) Fish of the River Neva stock are released also into some other Finnish rivers

Finnish hatchery-reared smolt production in the Gulf of Finland originates from brood stocks kept in hatcheries. More or less conventional rearing techniques have been used.

Natural smolt production of rivers in the Main Basin was estimated to be 225 000 (Table 3). The biggest production originates from the River Mörrum (120 000 smolts). Most of the remaining natural production comes from Soviet rivers in Sub-division 28. Stocking with one- and two-year-old hatchery-reared smolts amounted to 1 433 000 fishes. Most of these fish were released into rivers emptying into the Gulf of Riga and into the eastern coast of the Baltic Main Basin (Sub-division 28).

Table 3. Smolt production in the Baltic Main Basin in 1989 (in 1000s)

RIVER	WILD	HATCHERY-REARED 1-YEAR	2-YEAR
MÖRRUMSÅN	120	-	149 1)
EMÅN	5	-	82 1)
IRBE	10	-	-
VENTA	15	140	-
SAKA	10	-	-
SALACA	23	380	9
VITRUPE	5	-	-
PETERUPE	5	-	-
GAUJA	20	150	10
DAUGAVA	10	480	20
OTHERS	2	12	1 1)
TOTAL	225	1162	271 1)

1) Includes also one-year-old smolts.

In the Soviet side of the Baltic Main Basin there are six salmon hatcheries. Most of them use ordinary rearing techniques. In all hatcheries eggs for smolt rearing were obtained from spawners caught in rivers and coastal waters.

5. SCALE SAMPLING FOR STOCK DISCRIMINATION

The present situation

The percentage of wild salmon in catch samples from the Baltic Sea has been presented by the BSTAWG from the year 1980 and onwards (Anon. 1990). During this time the share of wild salmon has often shown sudden changes. It seems likely that the data do not reflect the real situation well enough. The main reasons for this are the following:

a. The recommendations have not been sufficiently well defined leading to the fact that the samples have been poorly representative.

b. The data have not been available yearly from all countries, Sub-divisions and gears asked for by the BSTAWG.

c. The BSTAWG has handled only a part of the samples collected because all of the samples have not been analysed before the meeting of the BSTAWG.

Statistical background for scale sampling

The suitable sample size has to be defined in relation to available resources and the aim of the sampling programme. The precision that can be achieved in the programme depends on the error rates in different phases of the programme. There are at least four types of errors involved:

1. The inherent statistical uncertainty in relation to sample size can be evaluated using binomial theory. Table 4. shows sample sizes which are necessary to detect a difference in the incidence of wild fish between two samples. The theory can of course not deal with such things as schooling behaviour and other factors leading to uneven distribution of wild salmon. All such factors therefore increase the required sample sizes above those shown in the table.

2. Uncertainties due to misclassification and errors in scale reading. Errors in scale reading have been repeatedly checked in different countries using scales from fish of known origin. The error rate has generally been below 10%, but in order to make a reliable estimate of the error rate it is recommended that a blind sample with scales of known origin should be read by all persons involved in the scale reading programme. This is especially important in the present situation where natural smolt production is very low and misclassification of scales may have strong effects on the apparent proportion of fish classified as wild. Until this is done no universal estimate of the error rate in this phase is possible.

3. Pooling of samples which, for different reasons, have

different incidences of wild fish. This will decrease the precision of the estimate and make evaluation more difficult. At present all results are summed per Sub-division in the report. Regarding the Main Basin, it was earlier concluded by the Working Group (Anon. 1988) that the distribution of wild and hatchery-reared fish caught in the offshore fishery in the Main Basin was even. To improve the precision of the results, samples from all Sub-divisions belonging to the Main Basin (Sub-divisions 24-29) should be pooled to give the proportion of wild salmon for the total offshore fishery.

In Sub-divisions 30 and 32 the samples are also rather homogeneous and they can therefore be pooled by Sub-division. The situation is, however, quite different in Sub-division 31. Here large releases of hatchery-reared fish are mixed with output from rivers having a considerable wild production. As an example, three Swedish samples in 1989 had an incidence of 3.2, 24.0 and 32.7 % wild fish. It is therefore desirable to divide this Sub-division in smaller areas, with each area or cluster having with in itself as even an incidence of wild fish as possible.

4. A further factor which may possibly cause confusion is the fact that the proportion of wild fish may change both because of changes in number of wild fish and changes in number of hatchery-reared fish. Both Sweden and Finland, however, seem unlikely to considerably change the number of released hatchery-reared fish in the foreseeable future. It therefore seems likely that changes in the proportion of wild fish in catch samples will be mainly due to changes in natural smolt production.

Table 4. Sample sizes required to detect a difference between two proportions of wild fish. The estimate is carried out with 80% certainty of detecting a true difference between two proportions P1 and P2=(I*P1) and at the P=0,05 level of significance (Sokal and Rolf 1981).

	Proportion of wild fish in sample = P1						
I	0,05	0,1	0,15	0,2	0,3	0,4	0,5
	Number of fish						
0,5	984	474	304	219	134	91	65
0,6	1604	770	492	353	214	145	102
0,7	2970	1422	905	647	389	260	183
0,8	6945	3313	2102	1497	892	589	407
0,9	28814	13698	8659	6139	3620	2361	1605
1,1	31644	14954	9392	6611	3830	2439	1605
1,2	8358	3941	2469	1732	996	628	407
1,3	3913	1840	1149	804	459	286	182
1,4	2311	1084	670	471	266	164	103
1,5	1550	725	450	312	175	107	65

Scale sampling

Suitable sample sizes are to be found in Table 4. Regarding the Main Basin offshore fishery, the aim is to be able to detect a 30% change in the proportion of wild fish. The present proportion of wild fish is probably between 10 and 15%. If we examine the table for the change needing the largest sample size for its detection, it will be P1=0.10 and I=1.3, where a sample size of N=1840 fish is needed. To fulfill this requirement, each country should collect scale samples from a total of 300 fish/ Sub-division on at least three (3) different occasions during September-December. This will mean taking scale samples from a total of 2700 fish. All samples should be as representative of the fishery as possible. If samples can not be collected in one Sub-division, more scale samples may be collected in another Sub-division.

In all other Sub-divisions, regarding both coastal and offshore fishery, each country should collect scale samples from at least 300 fish as shown in the table in section 11. In several cases this means that the probability of detecting even as large a change as 50% in the proportion of wild fish will be low. In these cases one can speak only of general monitoring of the situation. Two Sub-divisions are exceptions. The first is Sub-division 30 where Finland has an intensive coastal fishery. Here Finland should collect scales from 600 fish and Sweden from 300 fish to give a total of 900. With a 20% incidence of wild fish this gives a possibility to detect a 30% change in the percentage of wild fish. In Sub-division 31 the situation is more complicated, and any decision regarding suitable sample sizes and the division of the area in smaller, more homogeneous parts must wait until a more detailed examination of samples from individual sites is completed. Until this is achieved, it is recommended that Finland and Sweden both collect a total of 1000 scale samples from Sub-division 31. It is important that all coastal samples are collected during the whole fishing season.

To obtain reliable samples representing the spawners entering the Gulf of Bothnia, sampling should be carried out in the areas where these spawners still exist as a mixed stock. The best samples for this purpose might be obtained from the coastal fishery west of Åland and from both sides of the Bothnian Bay immediately north of the Quark. In the Åland Sea and in the Quark area the number of scale samples should be at least 900. With a 20% incidence of wild fish this gives a possibility to detect a 30% change in the proportion of wild fish.

Regarding wild stocks, scale sampling should be carried out outside the river mouths. The most important rivers having wild stocks are the Ume, the Kalix and the Torne. Sampling outside the rivers having wild salmon stocks is somewhat problematic: if very extensive sampling is necessary, the sampling itself may have a deleterious effect on the stocks already suffering from a lack of spawners. Therefore, this sampling should be carried out in connection with the breeding fishery.

Samples should also be collected from rivers having both wild and artificial production of smolts, but sample sizes must depend on local conditions.

Each country has to examine samples collected since the beginning of the 1980's and complete analyses concerning the proportion of wild salmon in the catches. After this the BSTAWG has to renovate the tables and figures concerning this and assess the development of wild salmon stocks on the basis of corrected data.

6. PRESENT STATUS OF SCALE READING FOR STOCK IDENTIFICATION

In the course of the Workshop it became evident that the "visual scale reading method" (Antere and Ikonen 1983) has been widely adopted in the countries around the Baltic Sea.

The main advantages of this method are its quickness, cheapness and simplicity (no sophisticated equipment is needed); the principal disadvantages are the facts that it requires at least some special training and that a subjective element is included.

Among the participating countries, the visual method is being used as the only scale reading method in Denmark, Norway, Soviet Union and Sweden. In ageing caught salmon attention has previously been paid mostly to the sea-phase of the scales; only during the last three years has the freshwater zone been taken into consideration in connection with stock discrimination studies.

Lately, attempts have been made in Poland and in Finland to develop discriminant functions to provide more accurate and less subjective discrimination between wild and hatchery-reared salmon. Though some promising results have been obtained the work must still be regarded as incomplete, especially when the whole Baltic Sea is considered.

7. COMPUTER AIDED SCALE READING SYSTEM

Hardware

The Computer Aided Scale Reading (CSR) system includes a Personal Computer (PC) and software, a zooming macroscope, a video camera and monitor. The PC is equipped with a video digitizer pad (PIP-1024B by Matrox Electronic Systems Ltd., Canada) which features eg. 4 image areas (512x512 pixels in 256 grey levels) and digital 2x zoom. The Wild M420 stereoscopic macroscope's magnification range is 5.8x - 35x. The video camera (CCD) and monitor are black and white (Fig. 2).

Software

The scale in the macroscope is viewed on the video monitor. The focus point and the direction of the line along which the scale is read are marked by means of a mouse. From adult salmon scales two images are stored, the freshwater growth phase and the whole scale. The program searches for circuli along the measuring line using pixel brightness values. The circuli are checked visually and the false ones (e.g. dirt particles) are corrected. Each annulus is marked with cursor and mouse. The results, a symbol representing the growth phase, the number of circuli in the annual zone and the distance from the focus point to annulus are output to the PC's monitor. Incorrect growth marks can be corrected. The CSR system makes scale interpretation faster, easier and more accurate than manual measurement. After scale measurement the length and weight of the fish can be back calculated.

8. POSSIBILITIES TO USE DISCRIMINANT ANALYSIS IN BALTIC SALMON SCALE READING

Discriminant analysis has been used to discriminate between salmon originating from North America and Europe (Lear and Sandeman 1980; Reddin and Burfitt 1983). A study concerning the use of discriminant functions in distinguishing stocks of Baltic salmon and sea trout on the basis of scale structure was initiated by Sych and Tuszynska (1983). In the following results of a discriminant analysis (SAS 1988) performed with the aid of the computer aided scale reading system are presented.

The sample size of hatchery-reared fish was 240 and that of wild fish 311. The hatchery-reared fish originated from the stocks of the River Oulujoki (n=100) and the River Iijoki (n=70) (Sub-division 31). The wild fish originated from the River Simojoki (n=181)(Sub-division 31). A randomly chosen sample of hatchery-reared (n=70) and wild fish (n=130) from the Finnish sea area was also included in the material (Sub-divisions 29-32).

Since no differences in the first sea years of these two groups were found, only the following characters were chosen for the discriminant analysis:
-the width of the first (freshwater) annual zone (in mm)
-the number of circuli in the first annual zone and
-the mean number of circuli per annual zone in the freshwater phase (= the total number of circuli in the freshwater zone divided by freshwater age).

The hatchery-reared fish had higher means and variances in all three characters:

Hatchery-reared fish (n=240)

Variable	Mean	Variance	S.D.
Width of the first freshwater annual zone	0.42883	0.02514	0.15854
Circuli in the first freshwater annual zone	13.75833	24.89533	4.98952
Mean number of circuli in the freshwater phase	18.37500	15.00081	3.87309

Wild fish (n=311)

Variable	Mean	Variance	S.D.
Width of the first freshwater annual zone	0.25302	0.00497	0.07051
Circuli in the first freshwater annual zone	8.76206	10.31739	3.21207
Mean number of circuli in the freshwater phase	11.85798	8.20356	2.86419

The means differ clearly between these two groups, so that a fairly good discrimination between the groups can be expected. The following table summarizes the results of the discriminant analysis. It shows that 81% of the hatchery-reared fishes are classified correctly. In wild fishes this proportion is higher: over 92%.

Actual group		Groups in which fish were classified: Hatchery-reared	Wild	Total
Hatchery-reared	n	195	45	240
	%	81.25	18.75	100.00
Wild	n	22	289	311
	%	7.07	92.93	100.00
Total	n	217	334	551
	%	39.38	60.62	100.00

The error count estimate, which is the same as the probability of misclassification, is under 13%.

	Hatchery-reared	Wild	Total error
Rate	0.1875	0.0707	0.1291
Priors	0.5000	0.5000	

Thus the *linear discriminant functions* are:

	Hatchery-reared	Wild
Constant	-17.53100	-6.81779
First freshwater annual zone	43.80385	19.86527
Circuli in the first freshwater annual zone	-1.33652	-0.64191
Mean number of circuli in the freshwater phase	1.88657	1.20034

A preliminary test conducted on a randomly chosen sample of wild (n=23) and hatchery-reared (n=19) fish gave some promising results (only one fish misclassified), but the material is too small for definite conclusions.

9. EXAMPLES OF SCALE FEATURES IN DIFFERENT AREAS

Since the 1980's wild and hatchery-reared Baltic salmon have been distinguished by the visual method described e.g. by Antere and Ikonen (1983). Lately, attempts have been made to distinguish Baltic salmon stocks with the help of discriminant analysis and CSR (see sections 7 and 8).

In this section pictures of scales collected from various parts of the Baltic Sea are presented. The quality of the pictures is not, perhaps, first-class, a fact mainly due to the low resolution (512x512 pixels in 256 grey levels) of the video digitizer pad (for details see section 7). However, pads with a higher resolution are not readily available and they are as expensive as the complete CSR system.

An attempt has been purposely made to select scales that are easy to read, although they may not in every instance be "typical" for the salmon stock or region concerned.

Below each picture data are given concerning the origin of the fish, date of capture, length and weight (as far as available). In addition, there is a table showing the results of scale analysis with the help of the CSR. In this table, the figures above the horisontal line show the age of the fish. Of the figures below the line, the upper ones show the distance of each annulus from the focus (in mm), the lower ones the number of circuli in each annual zone.

In the pictures, the annuli are marked by black dots and symbols that show the phase of life cycle and age of the fish; e.g.: F = focus, 2.0 = second freshwater year, 2.1 = first sea year after two years in freshwater.

Comments on the scales in the figures

Note: the counts of circuli and measurements may vary depending on the direction of the line along which they are made.

Fig. 3. A hatchery-reared, tagged salmon of the River Iijoki stock. Age A(2).2+. The freshwater zone has no distinct winter bands, but fairly widely spaced circuli whose structure resembles that of the circuli of the sea phase. This indicates hatchery origin. The first sea winter band is considered to be the inner of the two checks in the first sea year. Otherwise the second sea year would become too narrow and have too few circuli in relation to the rapid rate of growth. The zone of plus growth is rather narrow (only five circuli).

Fig. 4. A wild salmon tagged as a smolt from the River Simojoki stock. Age 2.1+. A fairly clear-cut scale with, however, a rather diffuse first sea winter band. In the freshwater zone it is seen that the circuli become more closely spaced towards each annulus indicating wild origin.

Fig. 5. A wild salmon tagged as a smolt from the River Simojoki stock. Age 3.2+. A scale that is very easy to read showing some run-out growth after the freshwater period (best seen in the picture of the centre of the scale).

Fig. 6. A wild salmon tagged as a smolt from the River Simojoki stock. Age 4.1+. The plus growth is at first fairly rapid, but after a few circuli the growth rate decreases. The annulus of 1974 has not yet been formed.

Fig. 7. A wild salmon of the River Ume stock (origin determined by the visual method). Age 3.2+. The freshwater zone is fairly easy to read with three distinct annual zones. The fish has grown rather little during the first sea year, but the growth rate of the second sea year has already improved. A feature which may be considered - at least to some extent - typical for scales collected from the most northern parts of the Baltic Sea is a first sea year that shows a more or less slow growth rate.

Fig. 8. A wild salmon tagged as a smolt from the River Ume stock. Age 4.2+. The freshwater zone is well defined showing four winter bands. The winter band of the first sea year seems rather wide, suggesting perhaps a decrease of growth rate for some other reason than temperature.

Fig. 9. A hatchery-reared, tagged salmon of the River Ume stock. Age A(2).2+ (stocking age three summers). The freshwater zone is clearly defined, but the stocking age is difficult, if not impossible, to determine. The sea zone is very clear-cut.

Fig. 10. A wild salmon from Sub-division 30 (origin determined by the visual method). Age 3.2+. A very clear-cut scale showing in the freshwater zone three distinct winter bands with closely spaced circuli. There is a check approximately in the middle of the first sea year, but otherwise the growth rate has remained fairly constant during the sea phase.

Fig. 11. A wild salmon from Sub-division 30 (origin determined by the visual method). Age 4.2+. Perhaps the most prominent feature of this scale is the rapid growth during the fourth freshwater summer resembling that of the sea phase. The growth of 1985 is concidered to be only seven circuli wide, i.e. there is a check just inside the second winter band.

Fig. 12. A hatchery-reared salmon from Sub-division 30. Age A(2).3. The origin of this fish has been determined by the visual method. Therefore, the stocking age cannot be determined with absolute certainty. The time of stocking is clearly marked with closely spaced circuli and is also seen at the posterior part of the scale. Note that the first circuli of the sea zone curve slightly outwards, a feature not uncommon in Finnish material (both wild and hatchery-reared). There is a period of rather slow (estuarine?) growth in the beginning of the sea phase, and the first sea winter band is rather incospicuous. The scale shows no plus growth, which is due to the rather early date of capture.

Fig. 13. A wild salmon from Sub-division 29 (origin determined by the visual method). Age 3.2+. An easily read scale. Although both sea winter bands are rather indistinct, the beginning of new growth is clearly marked by more widely spaced circuli.

Fig. 14. A hatchery-reared salmon from Sub-division 29 (origin determined by the visual method). Age A.1+ (probable stocking

age two years). The time of stocking is marked with closely spaced circuli; the first circuli of the sea phase curve outwards. Near the end of the first sea year there are some closely spaced circuli forming an incomplete ring; because of its incompleteness the ring is considered a check (note that the circuli of the first sea winter band are closely spaced also at their posterior ends).

Fig. 15. A wild salmon from Sub-division 32 (origin determined by the visual method). Age 3.2+. In the freshwater zone the more widely spaced circuli of summer growth are to be seen (best seen from the right-hand side of the scale). In the middle of the first sea year there is a check which does not extend to the end of the circuli. In contrast to this, the first sea winter band is clearly defined extending all around the scale.

Fig. 16. A hatchery-reared salmon from Sub-division 32 (origin determined by the visual method). Age A.1+ (the rearing age is very likely two years). A clear-cut scale with the freshwater growth rate and circuli resembling those of the first sea year; a typical feature of hatchery-reared fish. The boundary between the freshwater and sea phase is clearly seen also in the posterior part of the scale.

Fig. 17. A wild salmon from the River Neva stock. Age 2.1+ (origin determined by the visual method). A very clear-cut scale where the circuli in the freshwater zone show distinct winter bands indicating wild origin. During the first sea year growth has been slower at first, a feature more pronounced in the northern parts of the Baltic Sea (e.g.in the Bothnian Bay).

Fig. 18. A hatchery-reared, tagged salmon of the River Neva stock. Age A(2).1+. Compared with fig. 17, the freshwater zone is wider and the circuli do not form distinct winter bands, features that indicate hatchery origin. During the first sea year growth has been slow at first giving the impression of two checks, but the growth rate increases towards the end of the year.

Fig. 19. A hatchery-reared, tagged salmon of the River Neva stock. Age A(2).2+SM+ (the additional growth before spawning is not easily seen in the picture). After stocking there is a period of slower (run-out) growth. Note the irregular structure and broken circuli of the freshwater zone.

Fig. 20. A wild salmon of the River Neva stock (origin determined by the visual method). Age 2.3+. The freshwater zone is clearly defined also at the posterior part of the scale. The sea growth has been rapid at first, but in the middle of the first sea year there is a period of slow growth comprising about ten circuli. The first sea winter band is rather weakly developed.

Fig. 21. A wild salmon of the River Neva stock (origin determined by the visual method). Age 3.2+. The scale shows severe surface erosion which, in addition to the irregular structure of the freshwater zone, makes the reading of the scale difficult.

Fig. 22. A hatchery-reared salmon from the River Narva (actually the fish belongs to the River Neva stock since the salmon stock of River Narva is extinct). Age A(1).2+SM+. There is some run-out growth in the beginning of the sea phase and an inconspicuous check before the first winter band. The plus growth before spawning is fairly wide.

Fig. 23. A hatchery-reared salmon from the River Narva. Age A(2).3+. The growth rate has been rather slow during the first sea year.

Fig. 24. A wild salmon of the River Salaca stock (hatchery-reared fish are marked by adipose fin clippings in the River Salaca). Age 1.1+. The freshwater zone is compact and clearly defined, but the first sea winter band is not easy to locate.

Fig 25. A wild salmon of the River Salaca stock. Age 2.1+. There is no clear winter band in the first freshwater year, but the circuli of the second freshwater year become more closely spaced towards the end of the growth season (best seen from the sides).

Fig. 26. A hatchery-reared salmon of the River Salaca stock. Age A(2).2+. The freshwater zone is fairly well defined. There is some run-out growth in the beginning of the first sea year.

Fig. 27. A wild salmon of the River Daugava stock (as in the River Salaca, the hatchery-reared fish of River Daugava are adipose fin clipped). Age 1.1+. A scale that is fairly easy to interpret. The first sea winter band is formed by approximately six or seven closely spaced circuli; the approximately three closely spaced circuli outside it are considered to form a check in the second sea year since they do not completely encircle the anterior part of the scale.

Fig. 28. A wild salmon of the River Daugava stock. Age 2.1+. Compared with scales of wild Finnish fish with two river years, the freshwater zone gives a somewhat irregular impression. There are several checks in the rather wide first sea year.

Fig. 29. A wild salmon of the River Daugava stock. Age 2.1+. As in fig. 28, the freshwater zone has some "reared" features, e.g. the second winter band is very weakly developed. The first sea year is wide and its count of circuli fairly high.

Fig. 30. A hatchery-reared salmon of the River Daugava stock. Age A.1+ (the probable stocking age is two years). The point of stocking is very clearly seen even in the posterior part of the scale. The first sea year is rather wide.

Fig. 31. A wild salmon tagged as a smolt from the River Mörrum stock. Age 1.1+. The freshwater zone is fairly well defined, but the pattern and structure of circuli somewhat resemble those of hatchery-reared fish. On the other hand, the relative "compactiveness" of the freshwater zone is a feature typical for wild fish.

Fig. 32. A wild salmon tagged as a smolt from the River Mörrum

stock. Age 2.2+. The freshwater zone is clearly defined and the two winter bands are easily seen. The sea zone is more difficult to interpret. Growth in the sea is rapid at first but then slows down. It seems, however, that this check is too near the center to represent the first winter band. Also the location of the second annulus presents difficulties. It seems that the plus growth of 1967 has for some reason been very weak.

Fig. 33. A hatchery-reared, tagged salmon from the River Mörrum stock. Age A.2+ (probable stocking age two years). The freshwater zone is clearly defined. In the beginning of the first sea year there is a check that can be seen even in the posterior part of the scale. Its position near the stocking point and its low count of circuli, however, indicate that it is not a true winter band. The second sea year has two checks, both of which disappear well before the posterior part of the scale.

10. CONCLUSIONS CONCERNING STOCK DISCRIMINATION

The Bothnian Bay

The wild and hatchery-reared fish of the Bothnian Bay stocks can be fairly accurately separated both by the visual method and by the discriminant function presented in section 8 on the basis of scale structure as follows.

Visual method:
- the circuli in the freshwater zone of wild fish form distinct winter bands whereas those of hatchery-reared fish are more evenly spaced
- during the freshwater phase the growth pattern of hatchery-reared fish tends to resemble the pattern of growth in the sea phase, i.e. the freshwater zone is wide, has numerous circuli which are fairly widely spaced and often broken whereas the freshwater circuli of wild fish are more closely spaced and continuous

Discriminant function method:
The discriminant function method utilizes the following three variables, whose values are usually larger when hatchery-reared fishes are concerned:
- the width of the first freshwater zone (in mm)
- the number of circuli in the first annual zone
- the mean number of circuli per annual zone in the freshwater phase

The Gulf of Finland

The same visual criteria and discriminant function may be applied when distinguishing between wild and hatchery-reared salmon originating from the stocks of the Gulf of Finland. However, there is some evidence suggesting that the differences in the structure of the freshwater zone of fish originating from the stocks of the Gulf of Finland are perhaps not quite as easily discernible as in the Bothnian Bay.

Southern stocks

Visual method:
On the basis of the material examined in this context the more southern stocks, e.g. those of the rivers Mörrum, Daugava and Salaca, present some difficulties in that the differences between wild and hatchery-reared fish seem to decrease southwards, probably due to the more favourable climatic and food conditions. For example, it seems that even in wild fish the winter band of the last freshwater year may be very weak or practically nonexistent. Some wild fish from e.g. the River Mörrum would almost certainly have been classified as hatchery-reared on the basis of scale structure, had they been caught, for instance, in the Gulf of Finland.

Discriminant function method:
Attempts to classify fish from the more southern stocks (e.g. River Mörrum) with the help of discriminant analysis made it evident that either the basis of the discriminant function derived from Finnish material must be greatly broadened to include the southern stocks, or a separate function must be developed for them.

11. RECOMMENDATIONS

1) Member countries are required to collect samples according to the following table (see also section 5):

Country	Sub-divisions	Location	Period	Sample size/ Sub-div.
Denmark	24,25	offshore	Sept.-Dec.	300
Finland	29,30,32	offshore	Sept.-Dec.	300
	29,30,31,32	coastal, river	the whole fishing season	300[1,2,3]
Poland	26	offshore	Sept.-Dec.	300
	25	coastal	the whole fishing season	300
Sweden	26,27,28	offshore	Sept.-Dec.	300
	30,31	coastal, river	the whole fishing season	300[4]
USSR	26,28,32	offshore,	Sept.-Dec.	300
	28,29,32	coastal, river	the whole fishing season	300

1) Sub-division 29: 900 scale samples
2) Sub-division 30: 600 scale samples
3) Sub-division 31: 1000 scale samples
4) Sub-division 31: 1000 scale samples

2) The Workshop recommends that stock discrimination is continued by the visual method (Antere and Ikonen 1983). However, the Workshop also strongly encourages the participants to continue the development of the discriminant function method taking also the southern stocks into consideration (see also Appendix I, Borzecka 1991).

3) It is also recommended that the amount of misclassification should be tested by a blind test carried out in all laboratories and institutes participating to the Baltic salmon scale reading programme. Scales from both southern and northern wild stocks as well as from hatchery-reared fish with different rearing backgrounds should be included in the test.

References

Anon. 1988. Report of the Baltic Salmon and Trout Assessment Working Group. ICES Doc. C.M. 1988/Assess:19.

Anon. 1990. Report of the Baltic Salmon and Trout Assessment Working Group. ICES Doc. C.M. 1990/Assess:21.

Antere, I. and Ikonen, E. 1983. A method of distinguishing wild salmon from those originating from fish farms on the basis of scale structure. ICES, C.M. 1983/M:26.

Lear, W. H. and Sandeman, E. J. 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 reun. Cons. Int. Explor. Mer, 176:68-75.

Reddin, D. G. and Burfitt, R. F. 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. Int. Counc. Explot. Mer, Anacat Committee, C.M. 1983/M:11.

SAS 1988. SAS/STAT User's Guide, Release 6.03 Edition. Cary, NC: SAS Institute Inc. 1028 pp.

Socal, R. R. and Rolf, F. J. 1981. Biometry. Second edition, New York 859 pp.

Sych, R. and Tuszynska, L. 1983. Attempts of using the scale characteristics for separation of some Baltic Salmon and Sea Trout stocks. ICES, C.M.1983/M:29, Appendix 6.

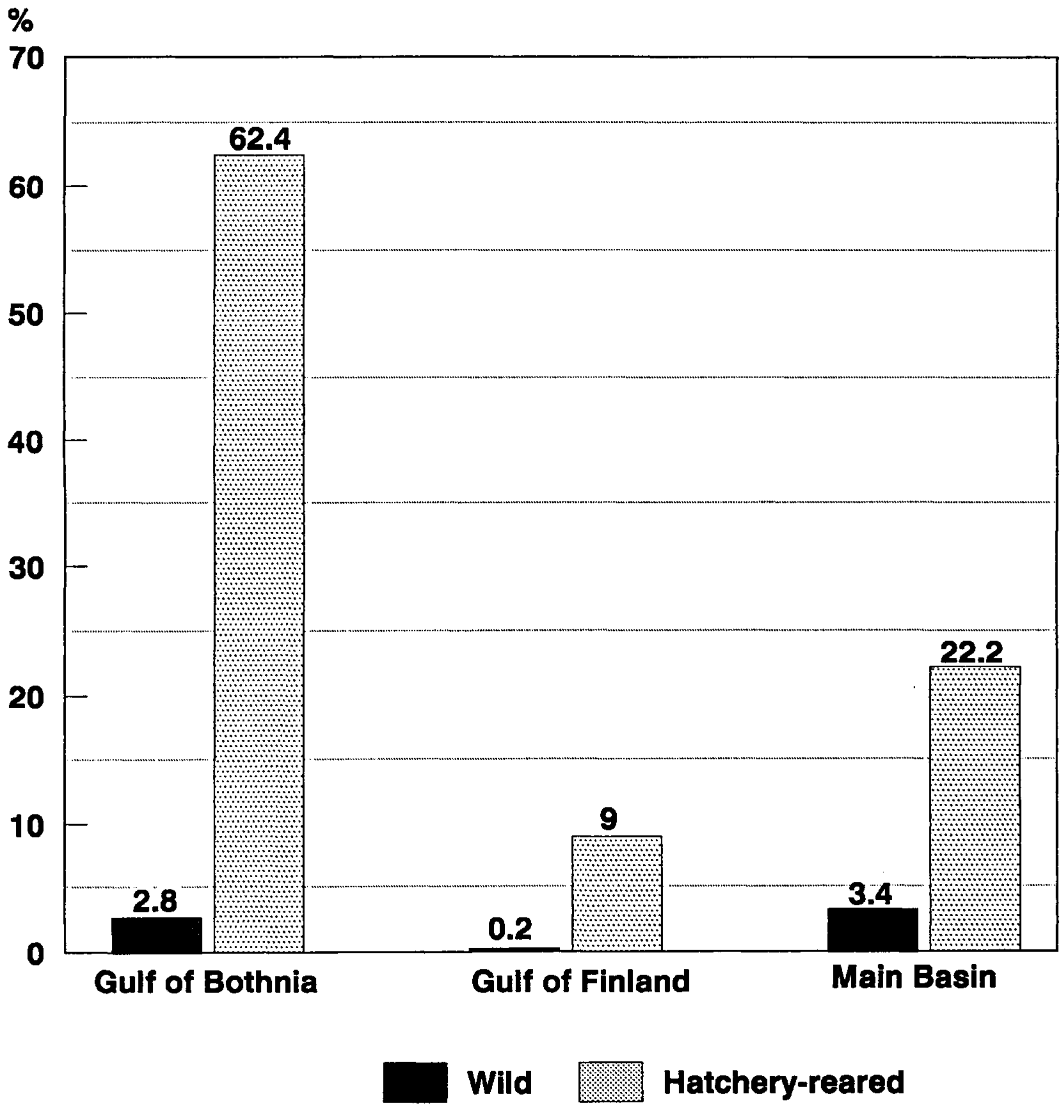


Figure 1. Smolt production in the Baltic Sea in 1989

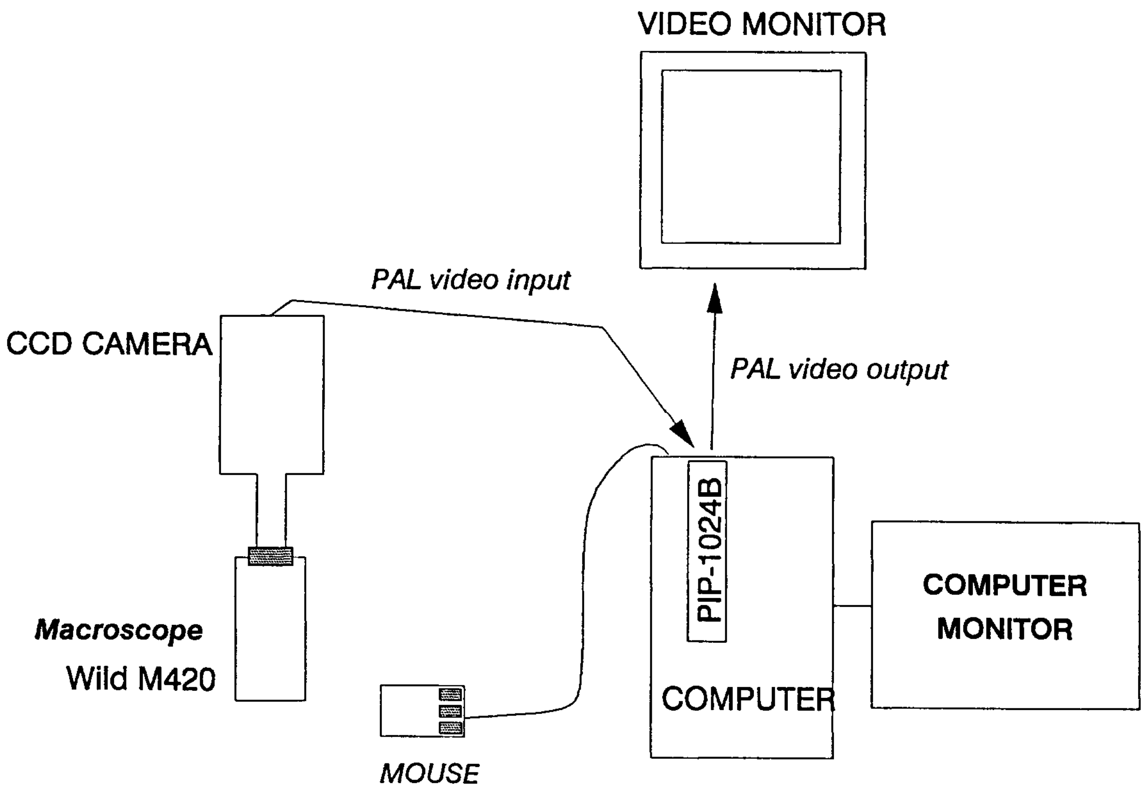


Figure 2. Computer aided scale reading system

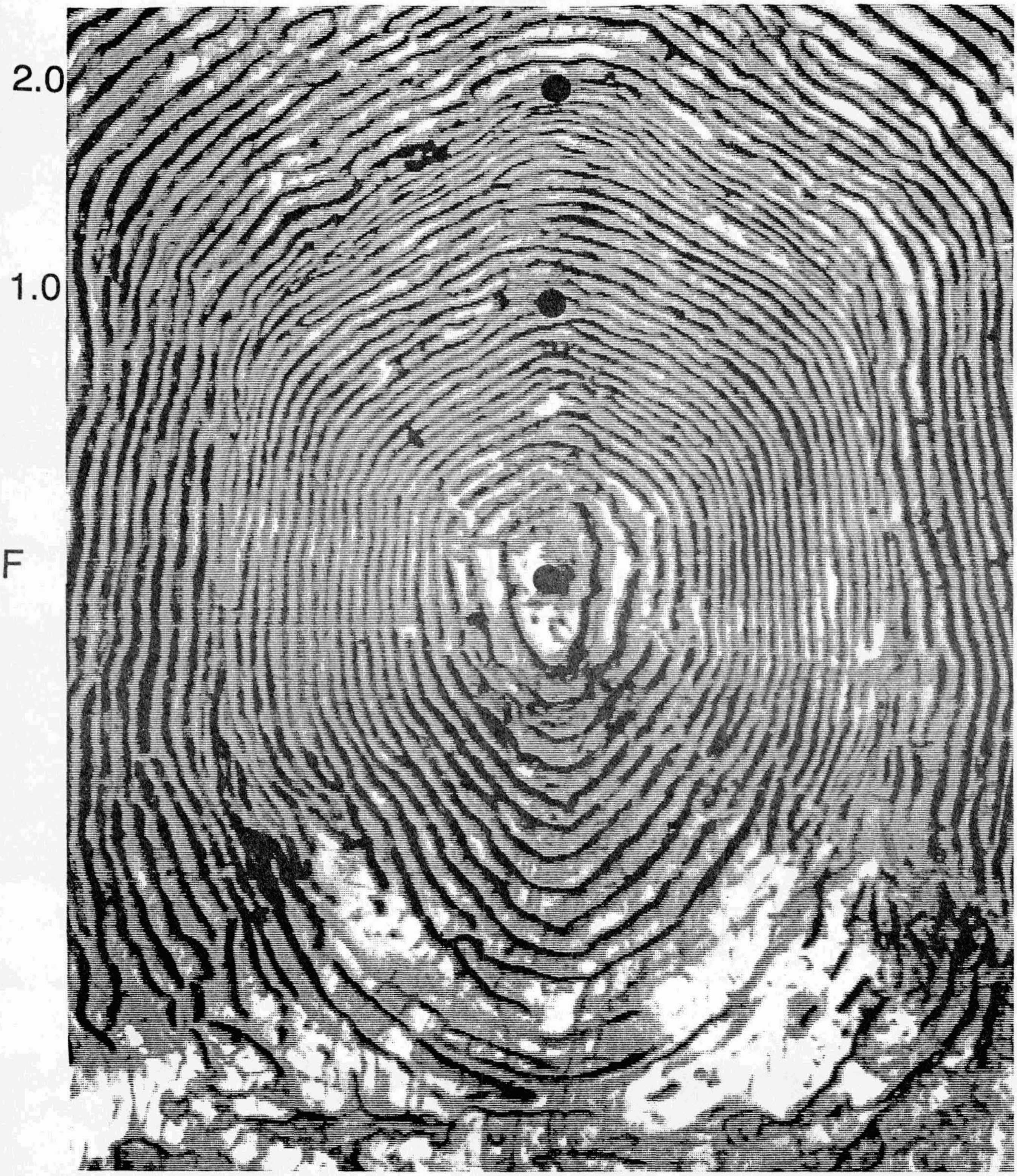


Figure 3a. Sub-division 31, River Iijoki stock

Date of capture 10.07. 1984
Age 2.2+ hatchery-reared
length 61.5 cm weight 1.8 kg

Analysis:

	River zone		Sea zone		
Age	1.0	2.0	2.1	2.2	2.2+
Length (in mm)	0.503	0.92	1.65	2.82	3.11
Circuli	16	16	16	21	5

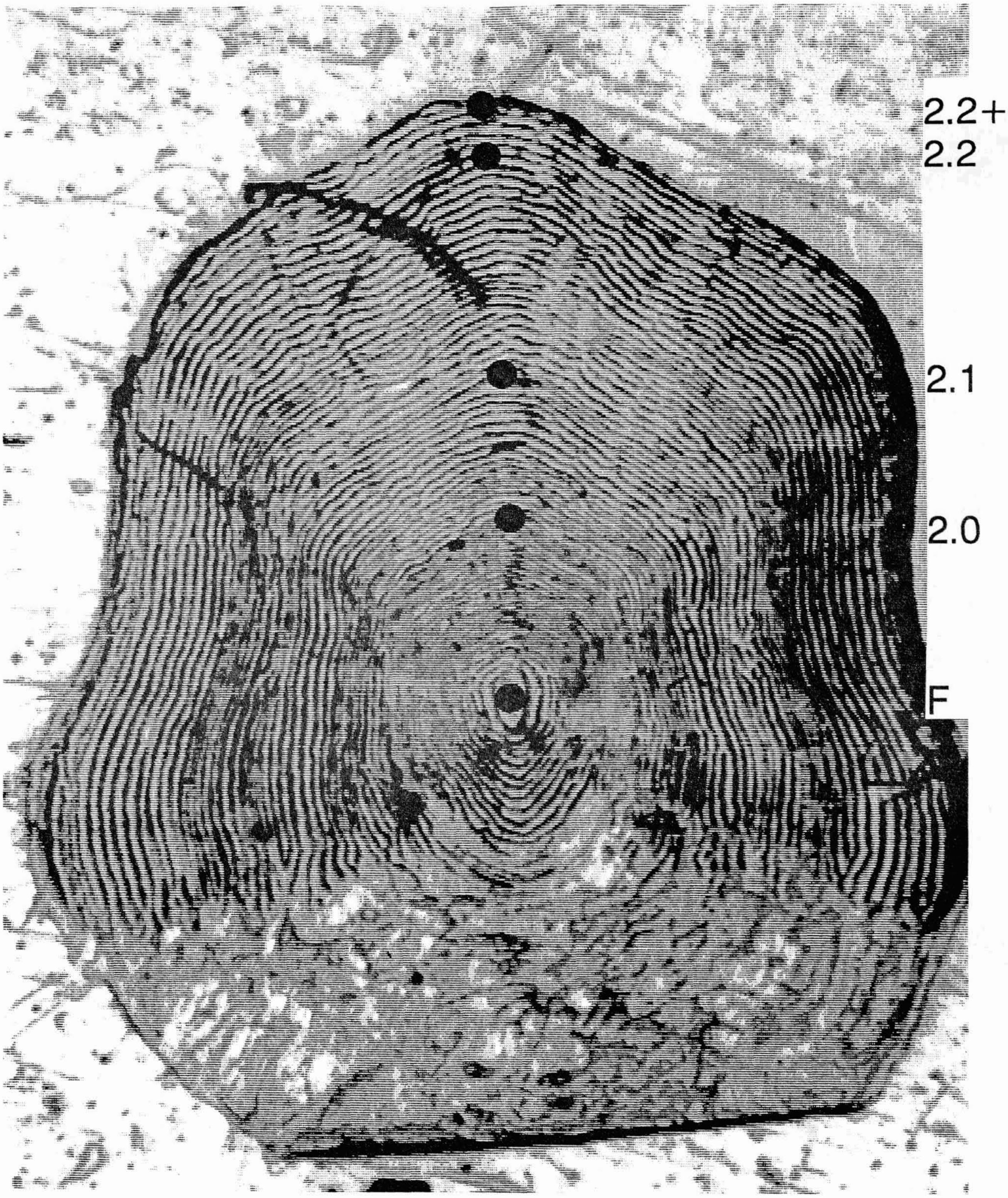


Figure 3b. Sub-division 31, River Iijoki stock

Date of capture 10.07. 1984
Age 2.2+ hatchery-reared
length 61.5 cm weight 1.8 kg

Analysis:

	River zone		Sea zone		
Age	1.0	2.0	2.1	2.2	2.2+
Length (in mm)	0.503	0.92	1.65	2.82	3.11
Circuli	16	16	16	21	5

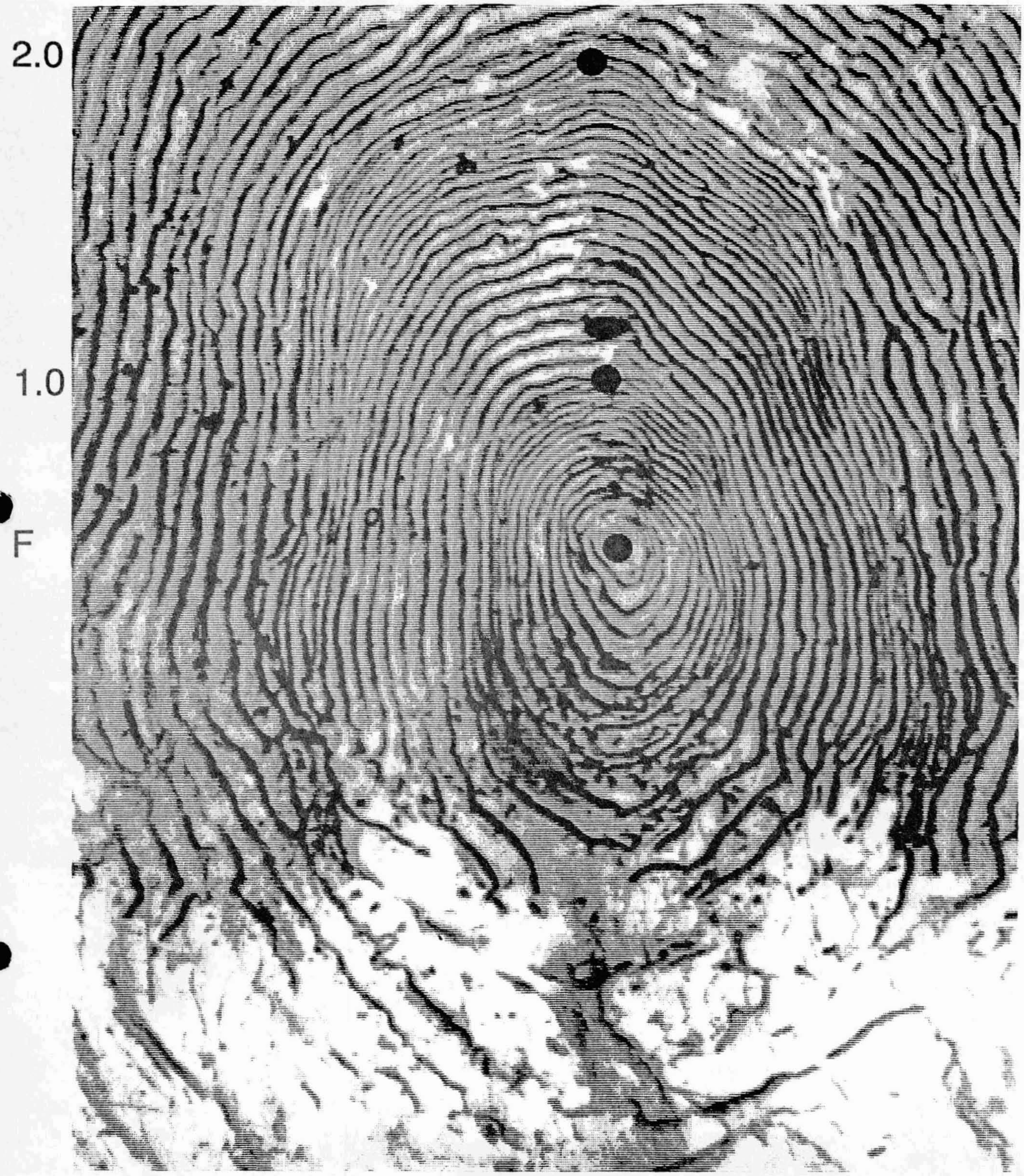


Figure 4a. Sub-division 31, river Simojoki stock

Date of capture 05.10. 1985
Age 2.1+ wild
length 75.0 cm weight 2.8 kg

Analysis:

	River zone		Sea zone	
Age	1.0	2.0	2.1	2.1+
Length (in mm)	0.343	1.02	2.17	3.88
Circuli	13	25	21	28

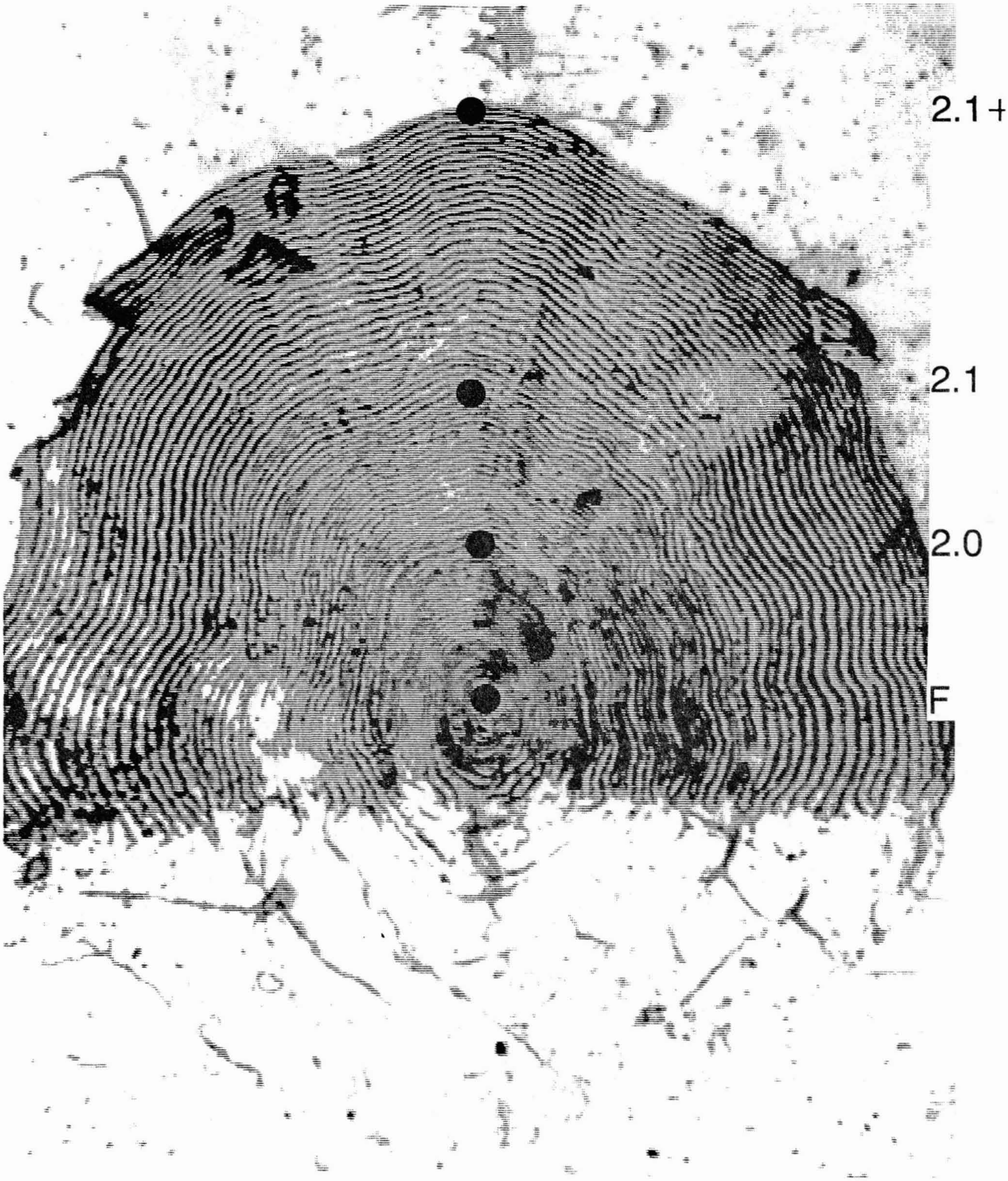


Figure 4b. Sub-division 31, river Simojoki stock

Date of capture 05.10. 1985
Age 2.1+ wild
length 75.0 cm weight 2.8 kg

Analysis:

	River zone		Sea zone	
Age	1.0	2.0	2.1	2.1+
Length (in mm)	0.343	1.02	2.17	3.88
Circuli	13	25	21	28

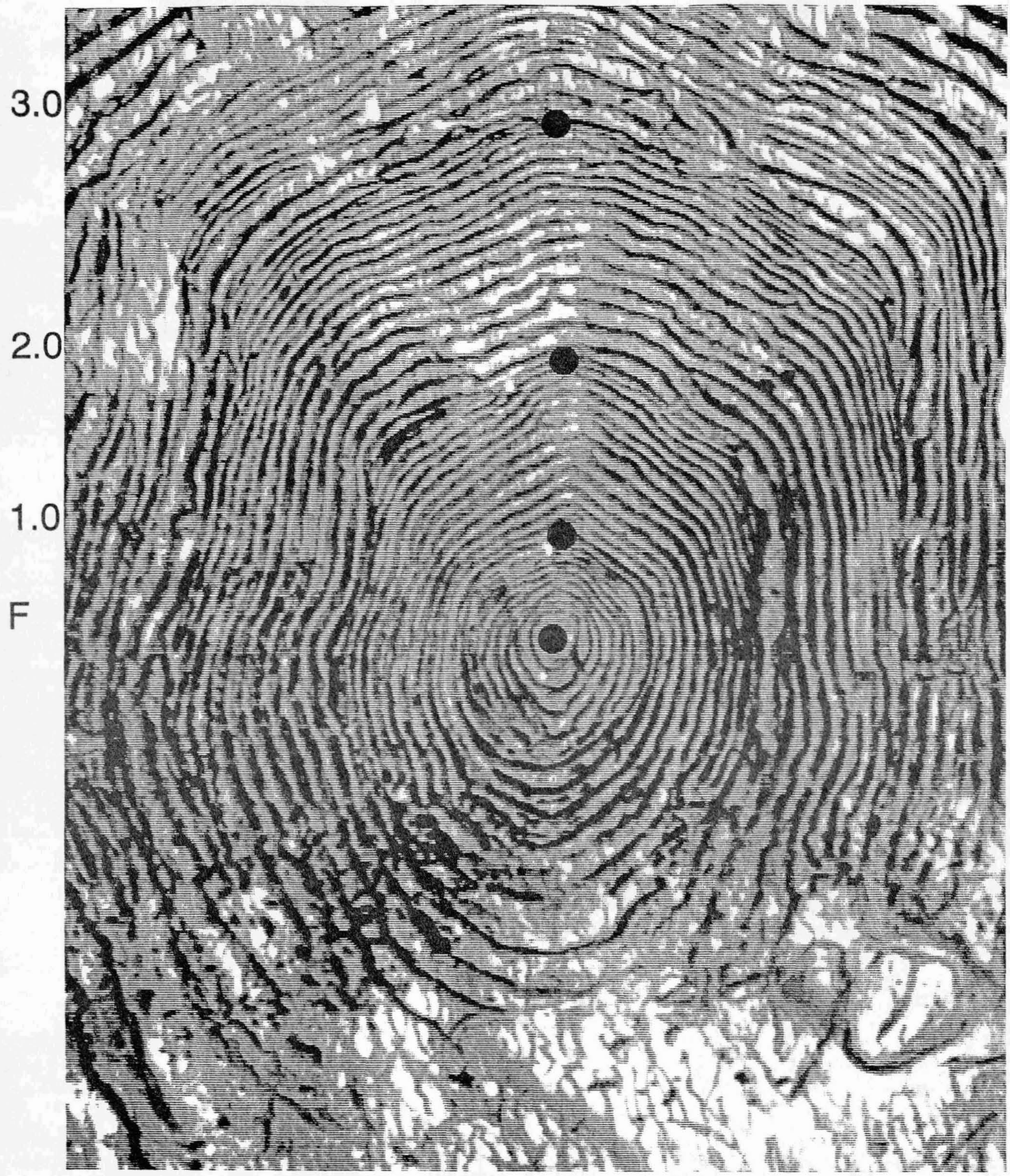


Figure 5a. Sub-division 31, river Simojoki stock

Date of capture 27.08. 1985
Age 3.2+ wild
length 64.0 cm weight 1.9 kg

Analysis:

	River zone			Sea zone		
Age	1.0	2.0	3.0	3.1	3.2	3.2+
Length (in mm)	0.201	0.602	1.1	2.46	3.93	4.86
Circuli	6	17	16	19	28	12

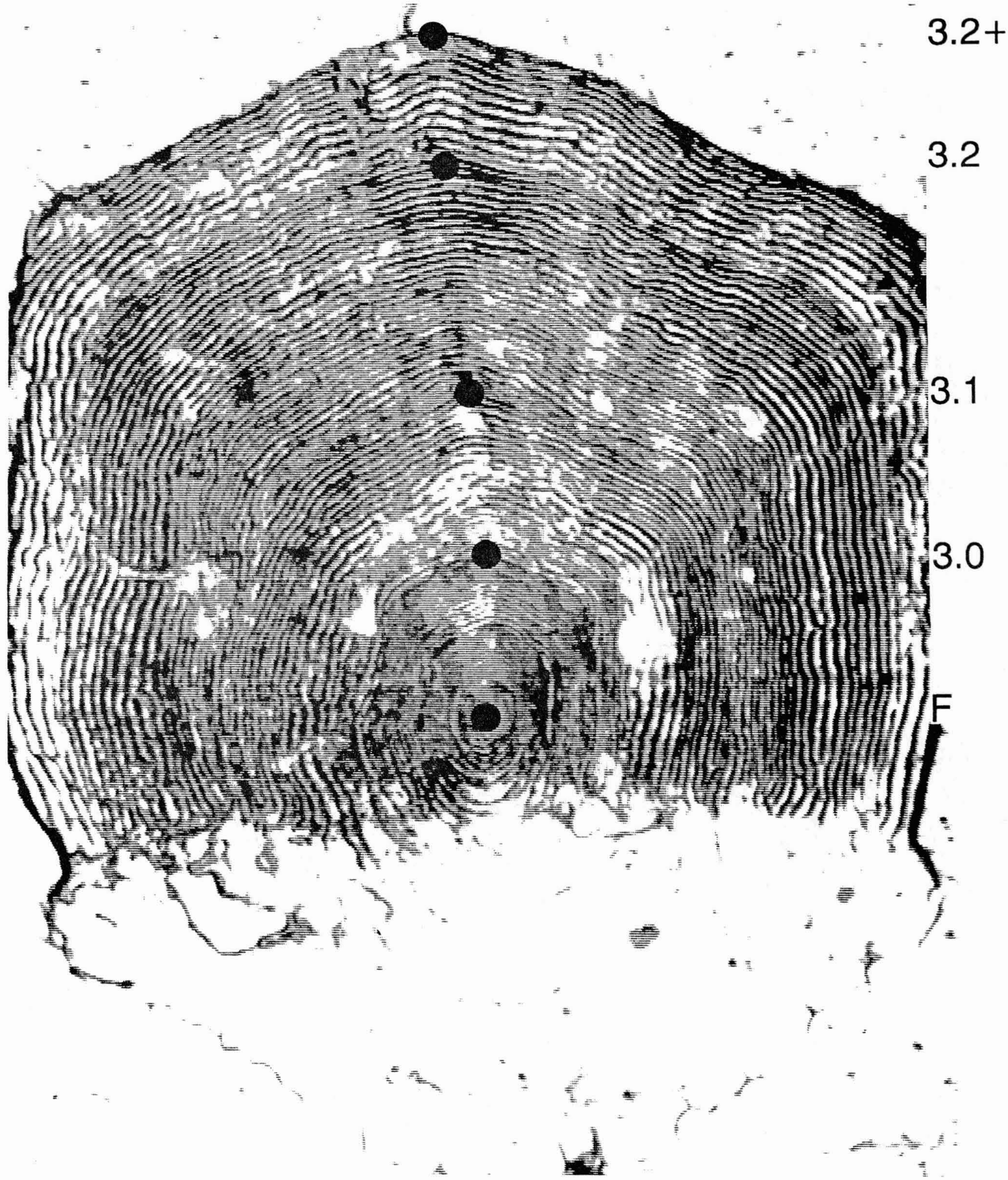


Figure 5b. Sub-division 31, river Simojoki stock

Date of capture 27.08. 1985
Age 3.2+ wild
length 64.0 cm weight 1.9 kg

Analysis:

	River zone			Sea zone		
Age	1.0	2.0	3.0	3.1	3.2	3.2+
Length (in mm)	0.201	0.602	1.1	2.46	3.93	4.86
Circuli	6	17	16	19	28	12

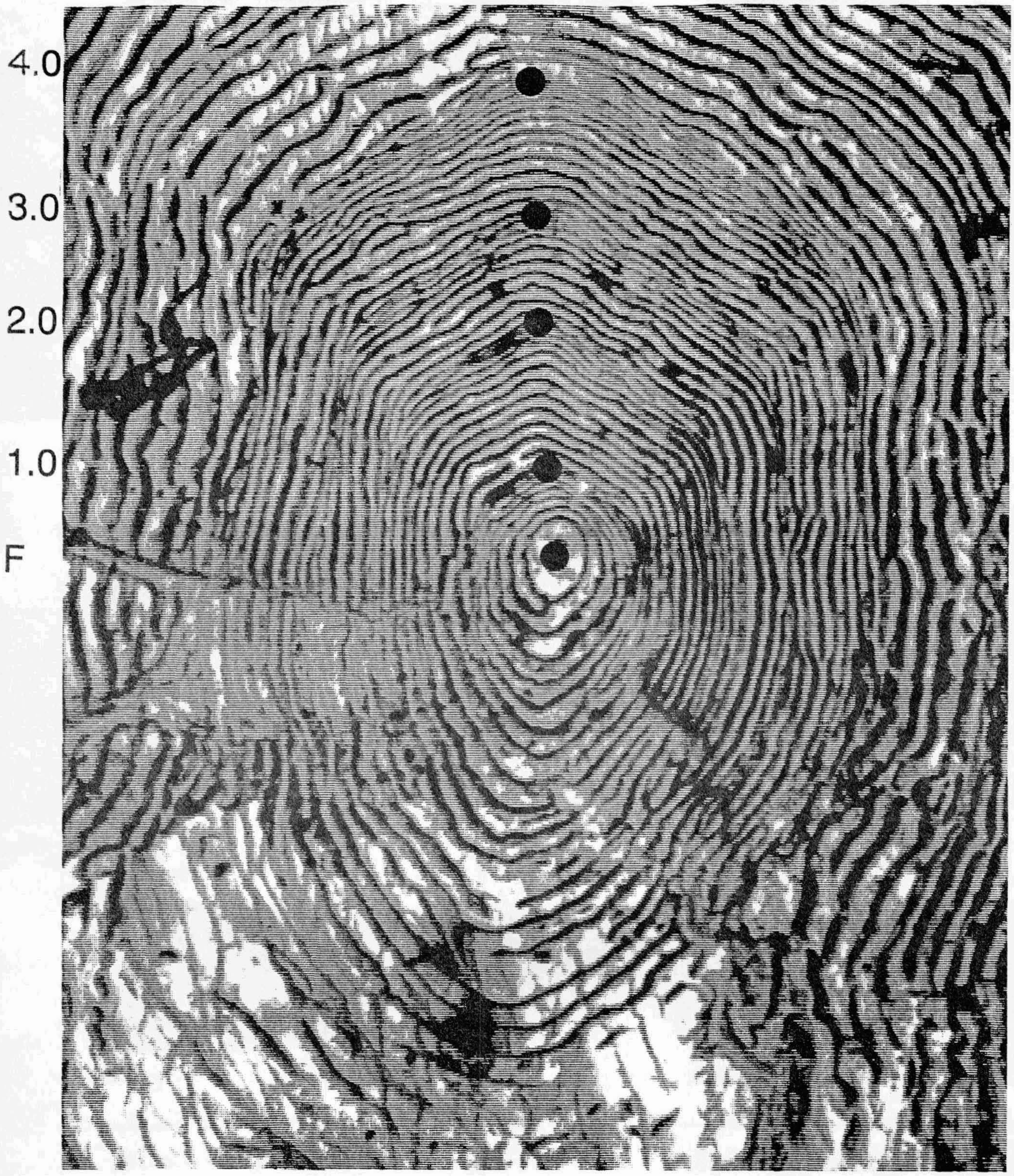


Figure 6a. Sub-division 31, river Simojoki stock

Date of capture 27.03. 1974
Age 4.1+ wild
length 64.0 cm weight 1.9 kg

Analysis:

	River zone				Sea zone	
Age	1.0	2.0	3.0	4.0	4.1	4.1+
Length (in mm)	0.209	0.492	0.693	1.05	2.51	3.62
Circuli	7	11	8	16	29	23

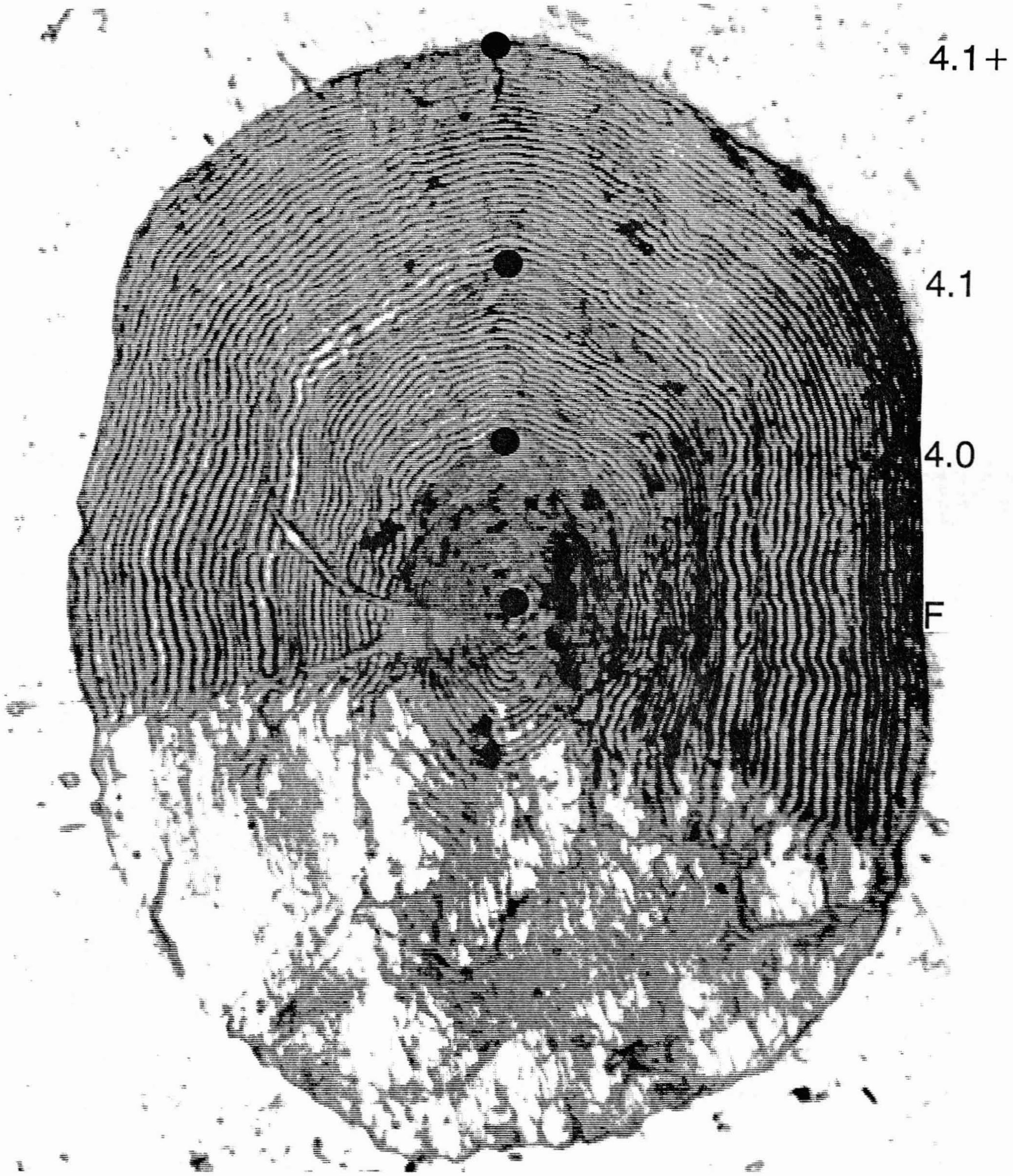


Figure 6b. Sub-division 31, river Simojoki stock

Date of capture 27.03. 1974
Age 4.1+ wild
length 64.0 cm weight 1.9 kg

Analysis:

	River zone				Sea zone	
Age	1.0	2.0	3.0	4.0	4.1	4.1+
Length (in mm)	0.209	0.492	0.693	1.05	2.51	3.62
Circuli	7	11	8	16	29	23

Figure 7a. Sub-division 31, river Ume stock

Date of capture 28.06.
Age 3.2+ wild
length cm weight 2.8 kg

Analysis:

	River zone			Sea zone		
Age	1.0	2.0	3.0	3.1	3.2	3.2+
Length (in mm)	0.44	0.63	0.87	1.5	3.69	4.01
Circuli	14	7	9	12	36	6

Figure 7b. Sub-division 31, river Ume stock

Date of capture 28.06.
Age 3.2+ wild
length cm weight 2.8 kg

Analysis:

	River zone			Sea zone		
Age	1.0	2.0	3.0	3.1	3.2	3.2+
Length (in mm)	0.44	0.63	0.87	1.5	3.69	4.01
Circuli	14	7	9	12	36	6

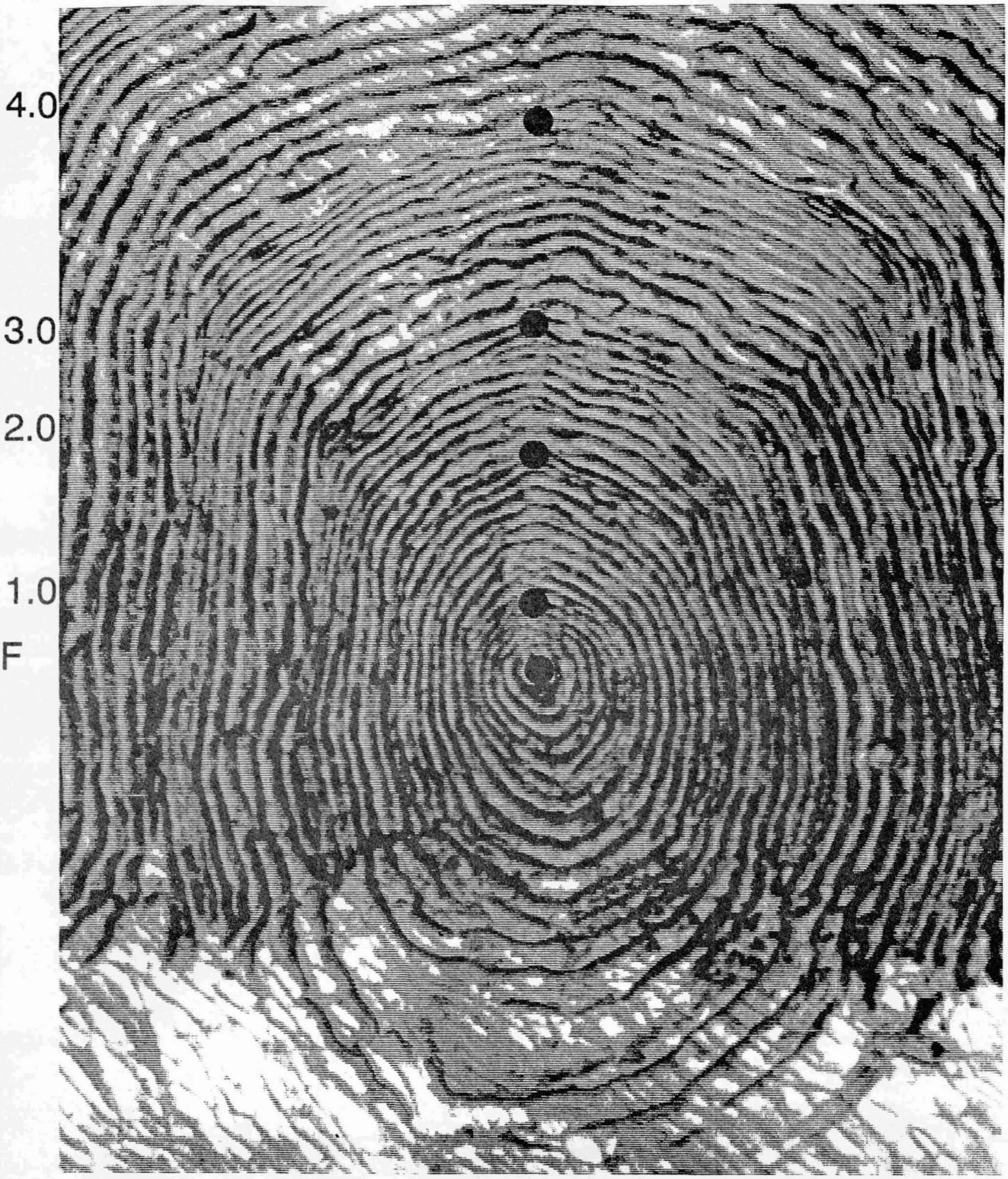


Figure 8a. Sub-division 31, river Ume stock

Date of capture 02.07.
Age 4.2+ wild
length cm weight 3.5 kg

Analysis:

	River zone				Sea zone		
Age	1.0	2.0	3.0	4.0	4.1	4.2	4.2+
Length (in mm)	0.134	0.444	0.702	1.15	2.04	4.34	4.65
Circuli	5	11	9	15	18	38	5

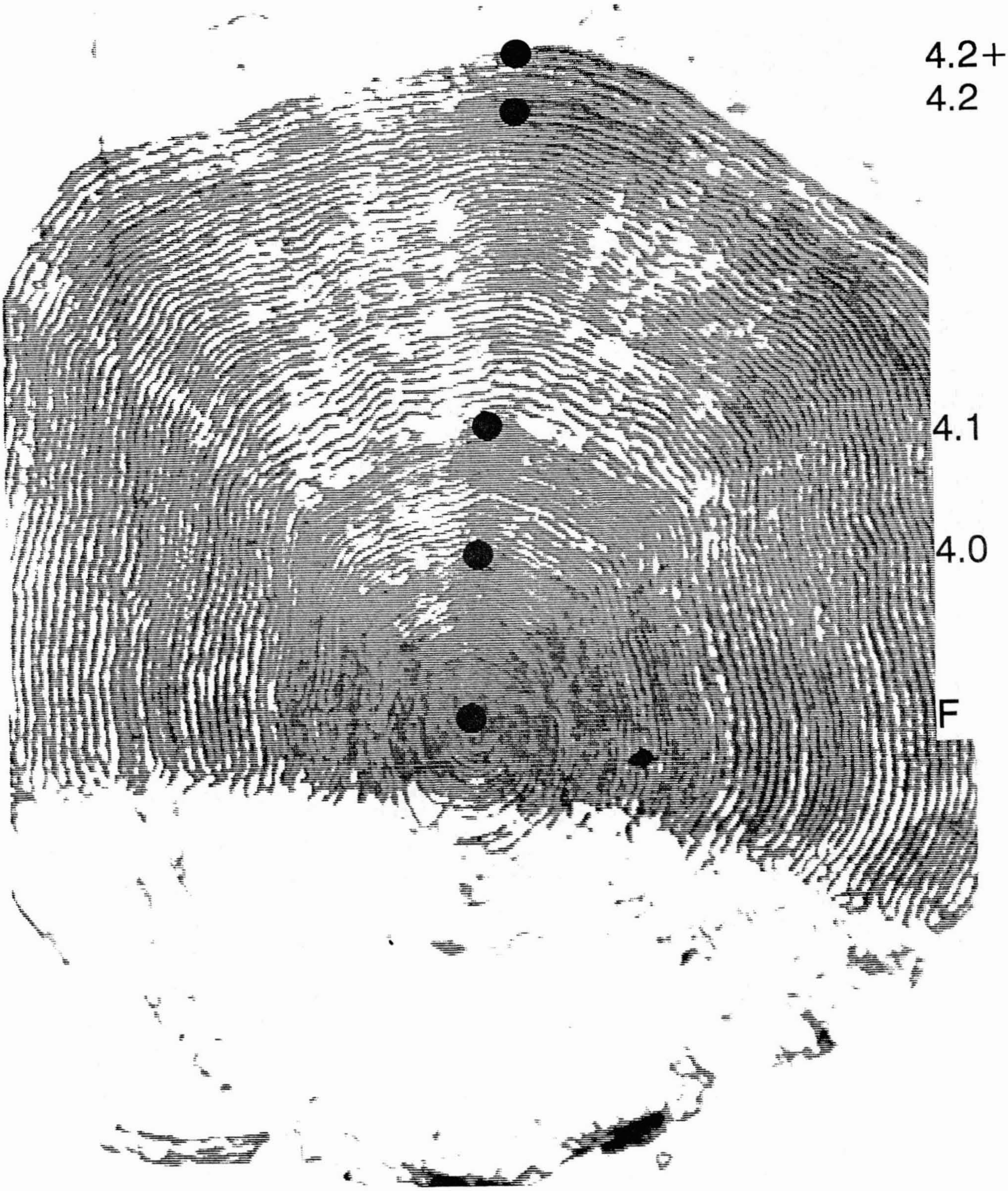


Figure 8b. Sub-division 31, river Ume stock

Date of capture 02.07.
Age 4.2+ wild
length cm weight 3.5 kg

Analysis:

	River zone				Sea zone		
Age	1.0	2.0	3.0	4.0	4.1	4.2	4.2+
Length (in mm)	0.134	0.444	0.702	1.15	2.04	4.34	4.65
Circuli	5	11	9	15	18	38	5

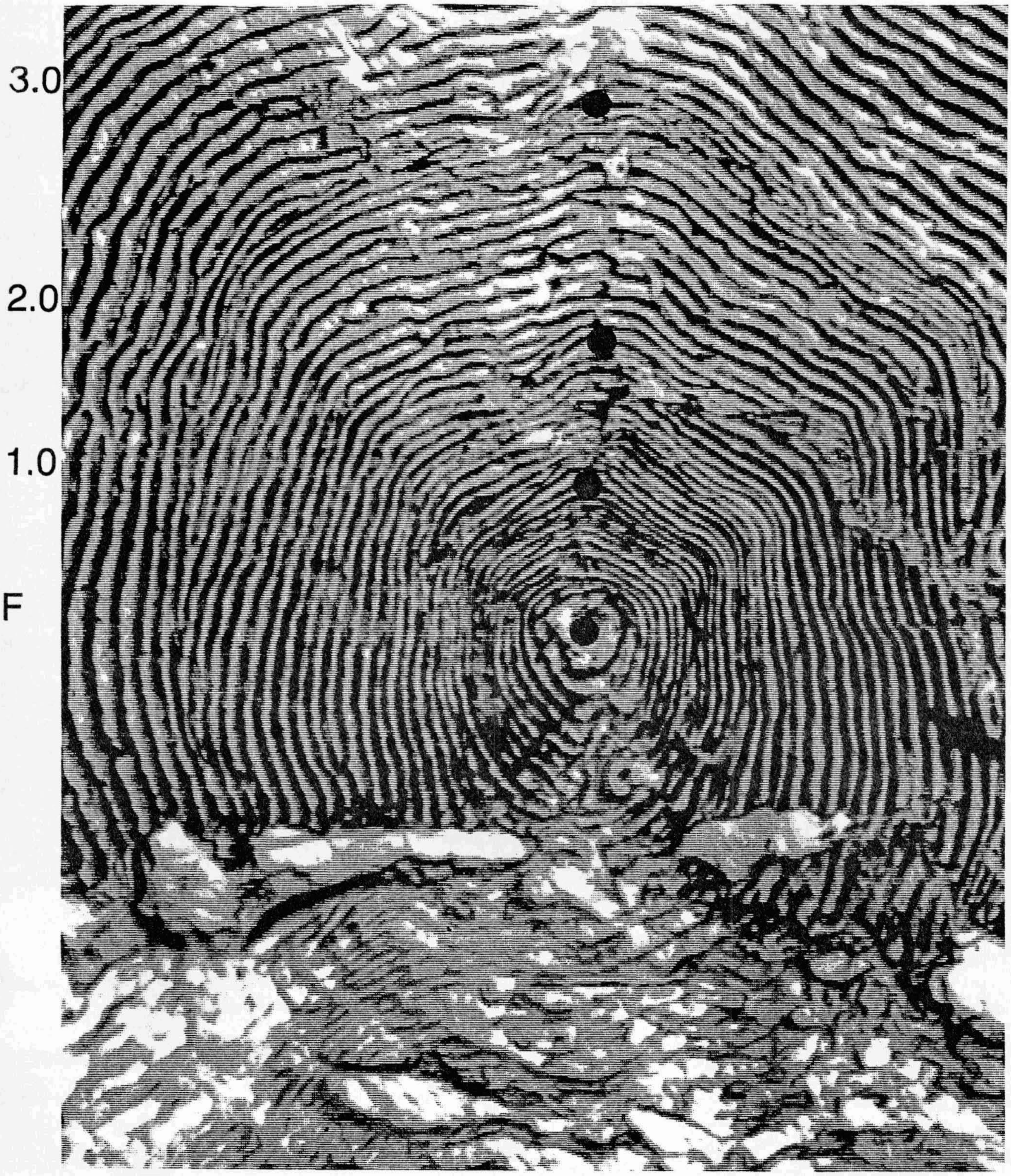


Figure 9a. Sub-division 31, river Ume stock

Date of capture 10.06. 1990
Age 3.2+ hatchery-reared
length cm weight 7.0 kg

Analysis:

	River zone			Sea zone		
Age	1.0	2.0	3.0	3.1	3.2	3.2+
Length (in mm)	0.312	0.608	1.06	2.34	4.11	4.46
Circuli	11	11	14	30	36	6

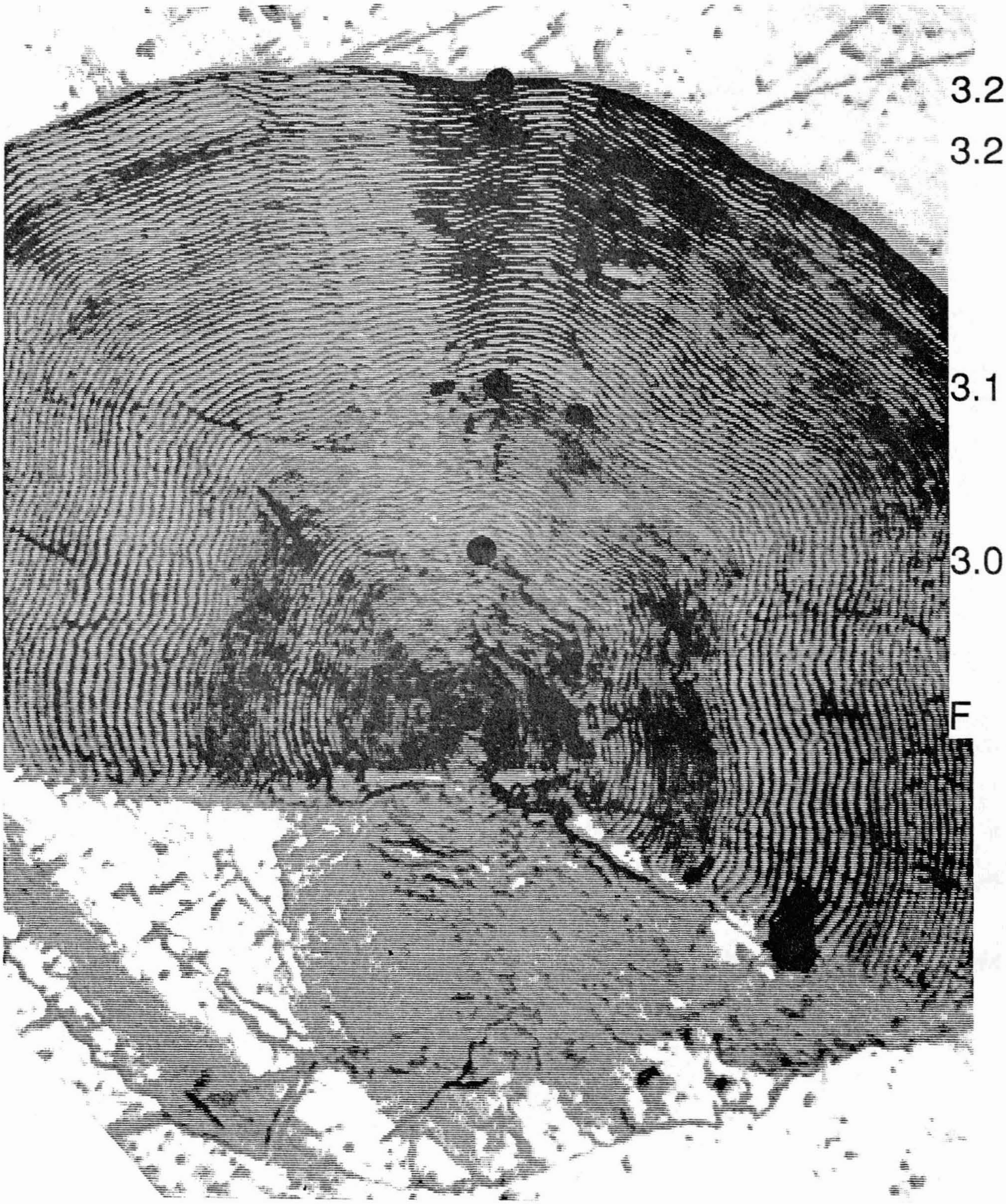


Figure 9b. Sub-division 31, river Ume stock

Date of capture 10.06. 1990
Age 3.2+ hatchery-reared
length cm weight 7.0 kg

Analysis:

	River zone			Sea zone		
Age	1.0	2.0	3.0	3.1	3.2	3.2+
Length (in mm)	0.312	0.608	1.06	2.34	4.11	4.46
Circuli	11	11	14	30	36	6

Figure 10a. Sub-division 30, river stock unknown

Date of capture 04.06.
Age 3.2+ wild
length 84.0 cm weight 5.2 kg

Analysis:

	River zone			Sea zone		
Age	1.0	2.0	3.0	3.1	3.2	3.2+
Length (in mm)	0.264	0.578	0.917	2.39	4.19	4.36
Circuli	10	11	13	27	37	4

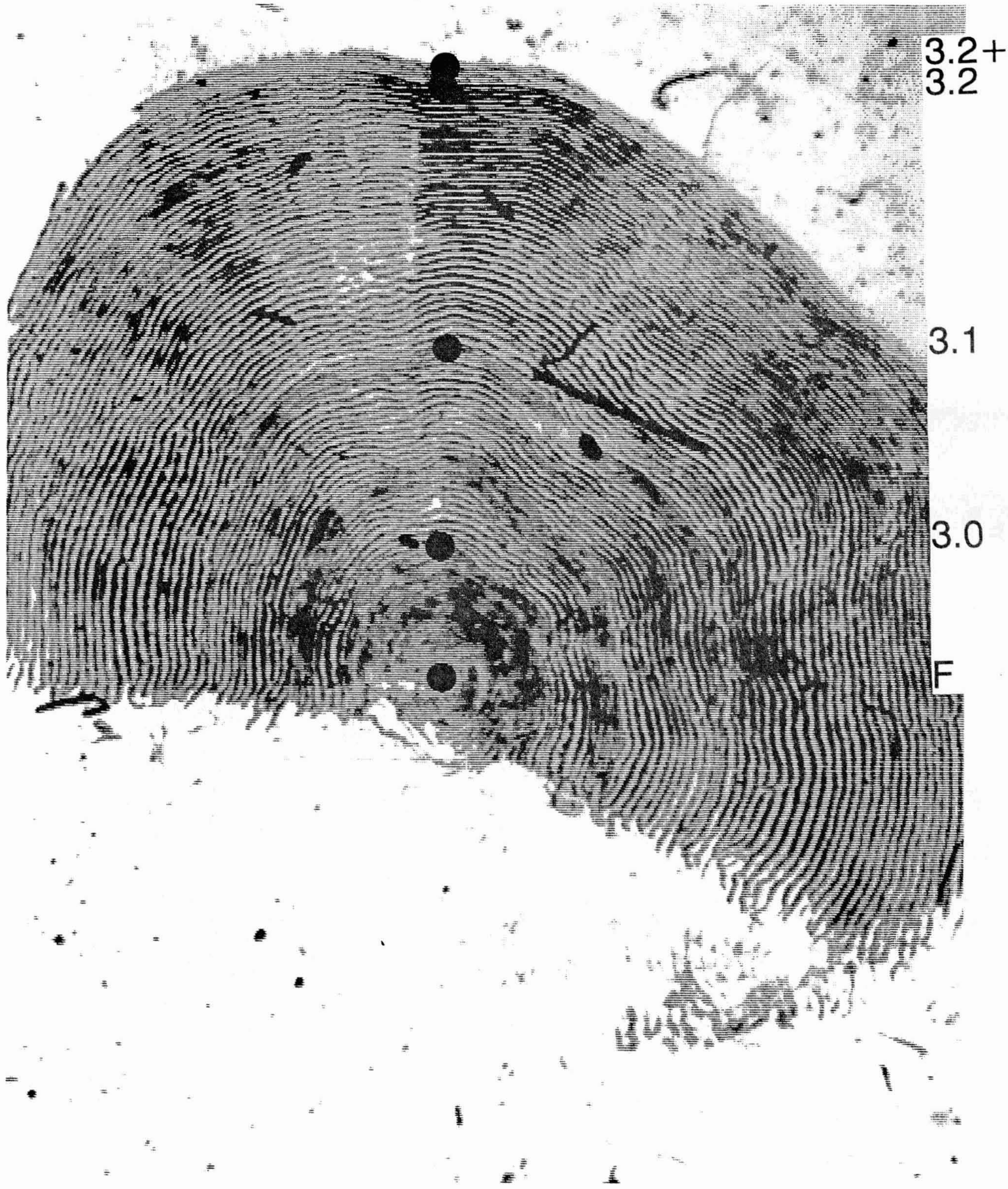


Figure 10b. Sub-division 30, river stock unknown

Date of capture 04.06.
Age 3.2+ wild
length 84.0 cm weight 5.2 kg

Analysis:

	River zone			Sea zone		
Age	1.0	2.0	3.0	3.1	3.2	3.2+
Length (in mm)	0.264	0.578	0.917	2.39	4.19	4.36
Circuli	10	11	13	27	37	4

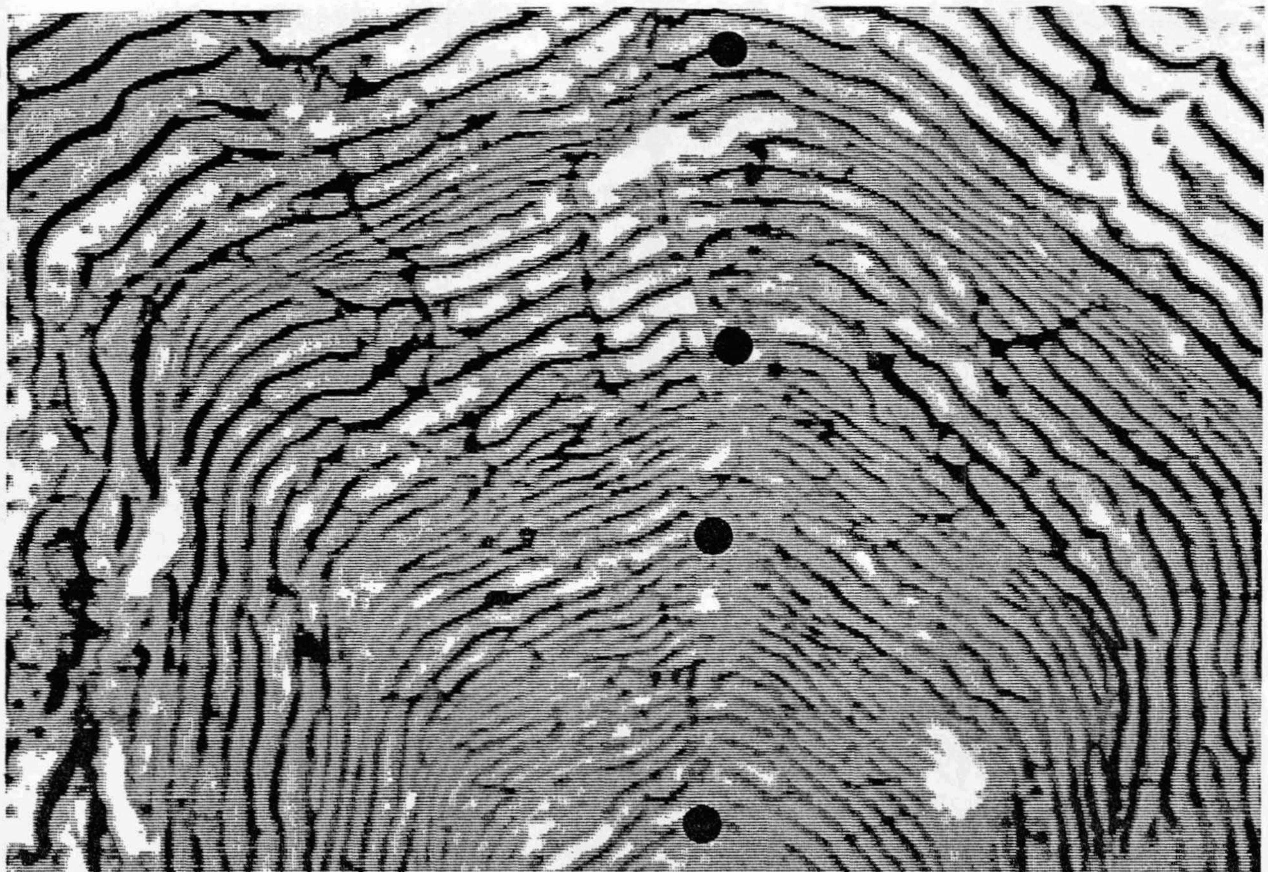


Figure 11a. Sub-division 30, river stock unknown

Date of capture 18.06. 1985
Age 4.2+ wild
length 77.0 cm weight 4.3 kg

Analysis:

	River zone				Sea zone		
Age	1.0	2.0	3.0	4.0	4.1	4.2	4.2+
Length (in mm)	0.292	0.617	0.836	1.23	2.67	4.58	4.96
Circuli	10	10	9	11	23	36	7

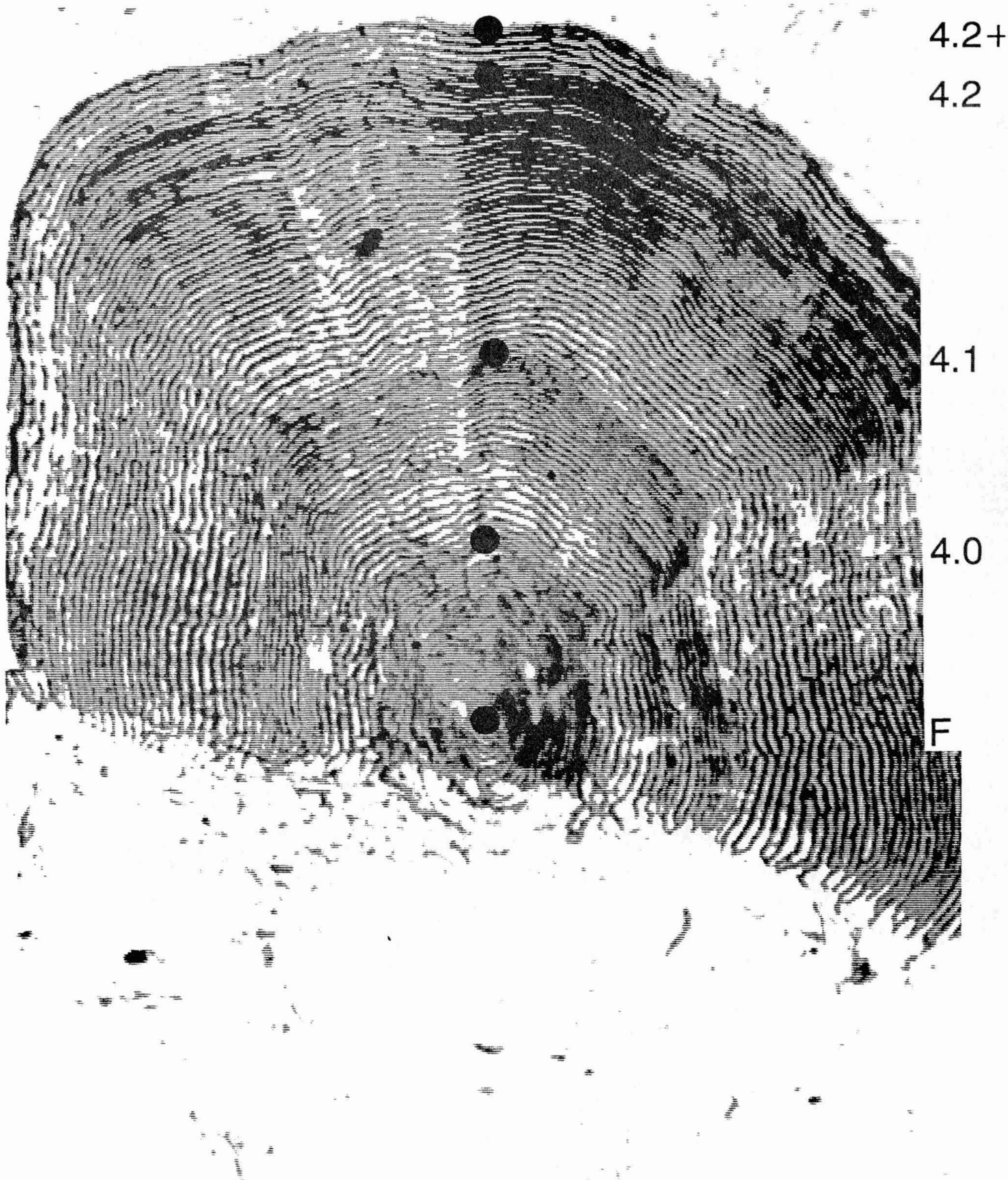


Figure 11b. Sub-division 30, river stock unknown

Date of capture 18.06. 1985
Age 4.2+ wild
length 77.0 cm weight 4.3 kg

Analysis:

	River zone				Sea zone		
Age	1.0	2.0	3.0	4.0	4.1	4.2	4.2+
Length (in mm)	0.292	0.617	0.836	1.23	2.67	4.58	4.96
Circuli	10	10	9	11	23	36	7

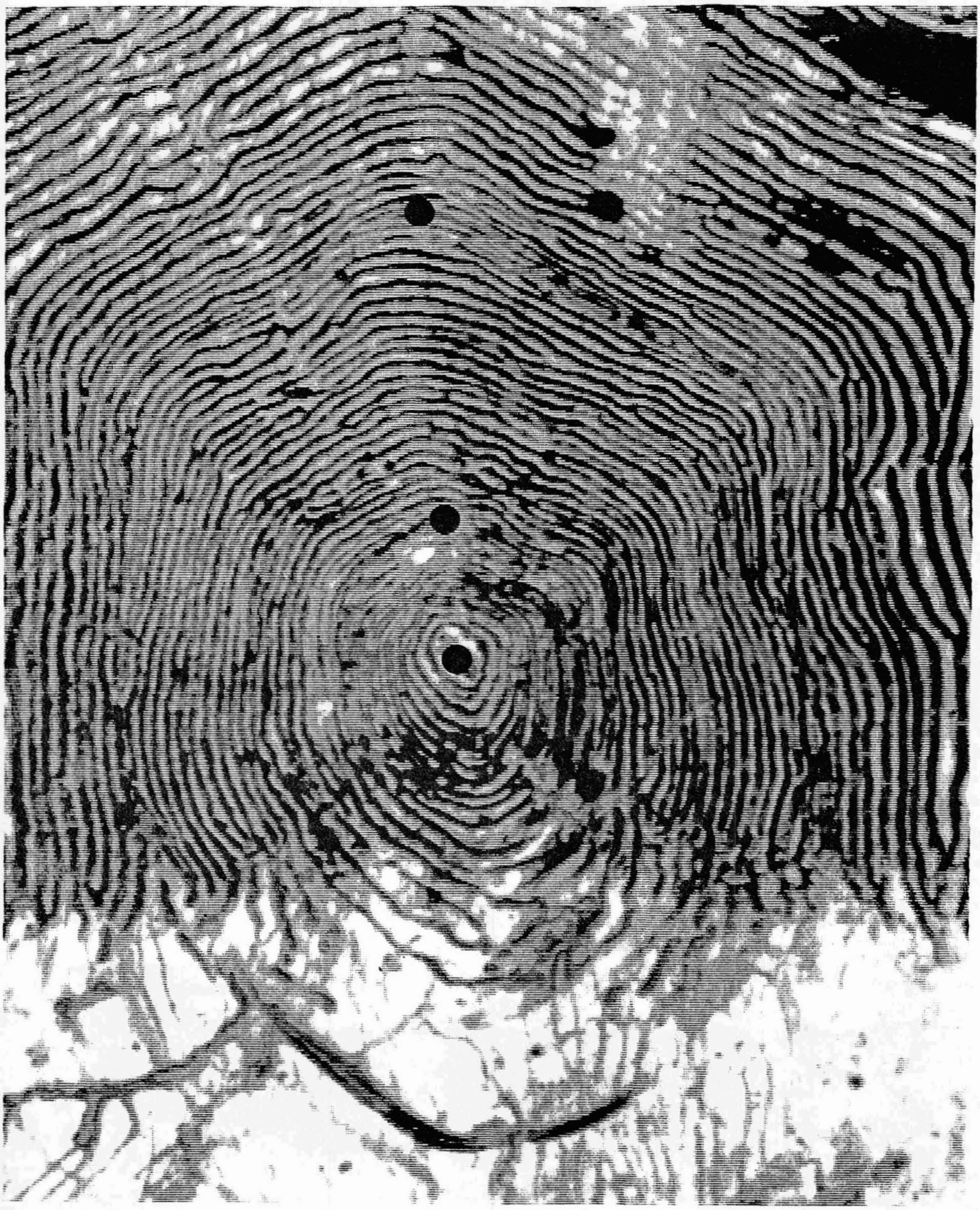


Figure 12a. Sub-division 30, river stock unknown

Date of capture 08.06. 1985
Age 2.3 hatchery-reared
length 89.0 cm weight 5.8 kg

Analysis:

	River zone		Sea zone		
Age	1.0	2.0	2.1	2.2	2.3
Length (in mm)	0.359	1.2	2.34	3.43	4.57
Circuli	12	26	20	23	26

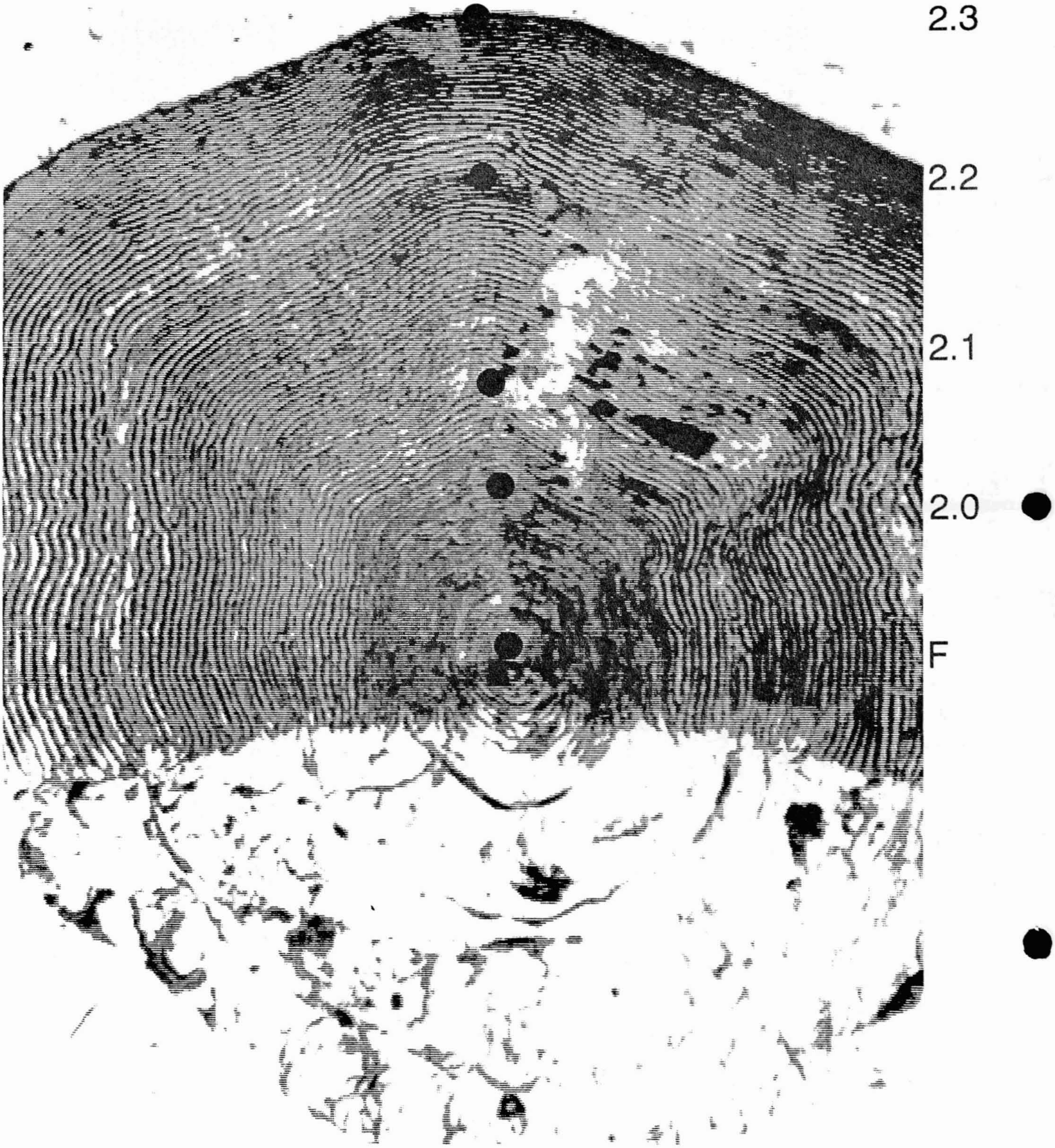


Figure 12b. Sub-division 30, river stock unknown

Date of capture 08.06. 1985
Age 2.3 hatchery-reared
length 89.0 cm weight 5.8 kg

Analysis:

	River zone		Sea zone		
Age	1.0	2.0	2.1	2.2	2.3
Length (in mm)	0.359	1.2	2.34	3.43	4.57
Circuli	12	26	20	23	26

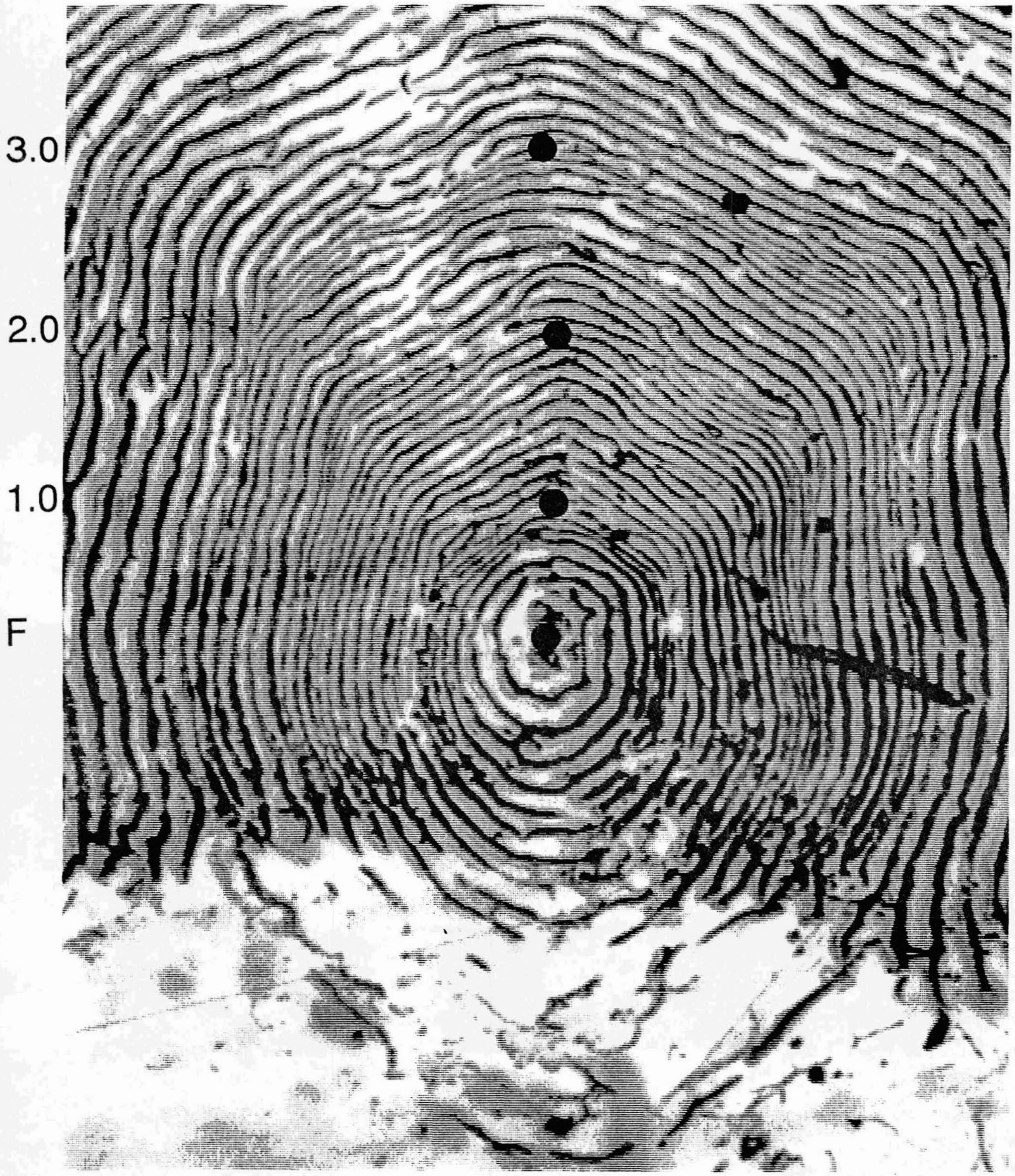


Figure 13a. Sub-division 29, river stock unknown

Date of capture 27.09. 1985
Age 3.2+ wild
length 70.0 cm weight 3.5 kg

Analysis:

	River zone			Sea zone		
Age	1.0	2.0	3.0	3.1	3.2	3.2+
Length (in mm)	0.256	0.622	0.971	2.39	3.8	3.97
Circuli	7	12	12	31	29	3

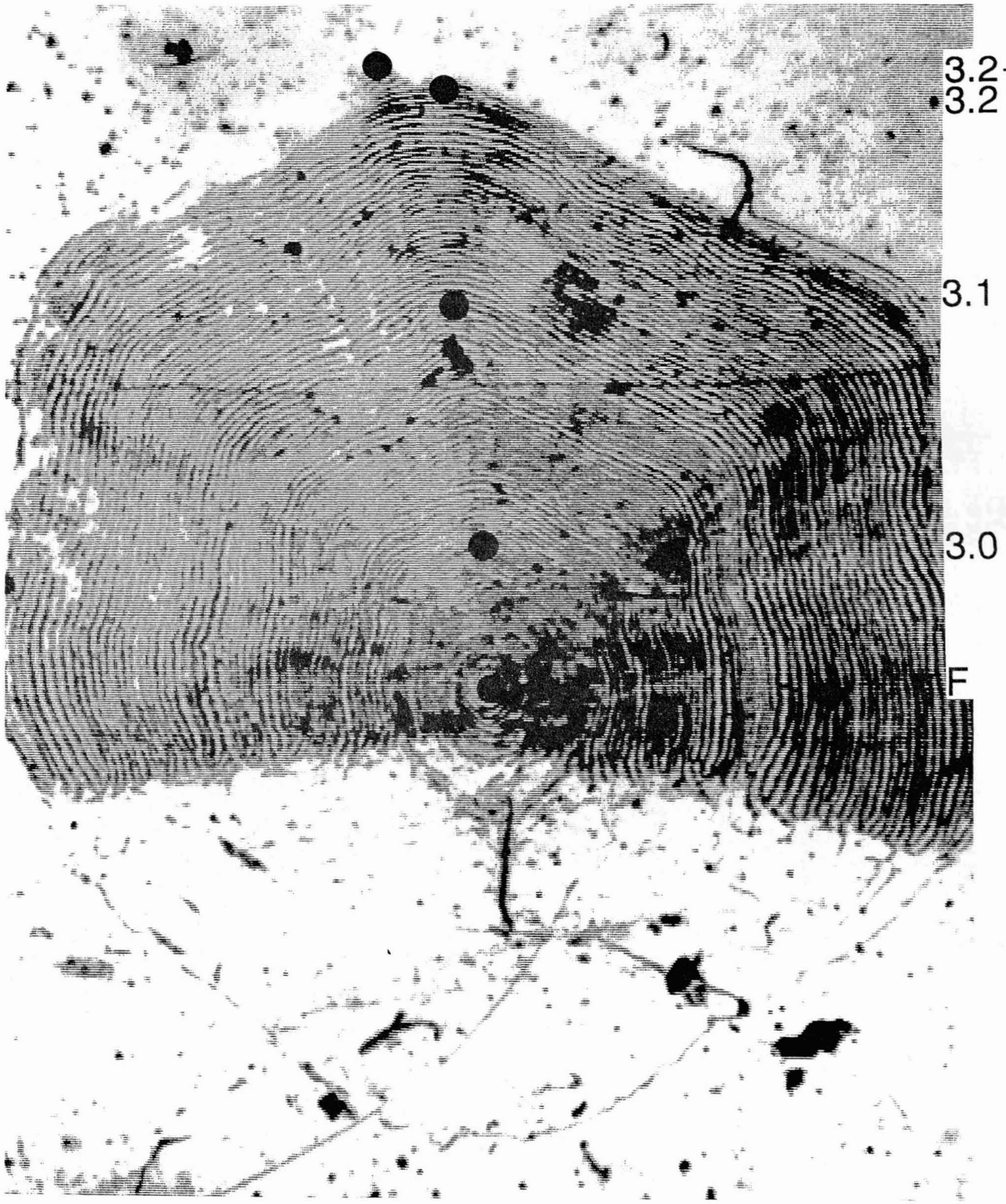


Figure 13b. Sub-division 29, river stock unknown

Date of capture 27.09. 1985
Age 3.2+ wild
length 70.0 cm weight 3.5 kg

Analysis:

	River zone			Sea zone		
Age	1.0	2.0	3.0	3.1	3.2	3.2+
Length (in mm)	0.256	0.622	0.971	2.39	3.8	3.97
Circuli	7	12	12	31	29	3

2.0

1.0

F

Figure 14a. Sub-division 29, river stock unknown

Date of capture 26.06. 1985
Age 2.1+ hatchery-reared
length 62.0 cm weight 2.5 kg

Analysis:

	River zone		Sea zone	
Age	1.0	2.0	2.1	2.1+
Length (in mm)	0.328	1.15	3.43	4.12
Circuli	11	28	38	9

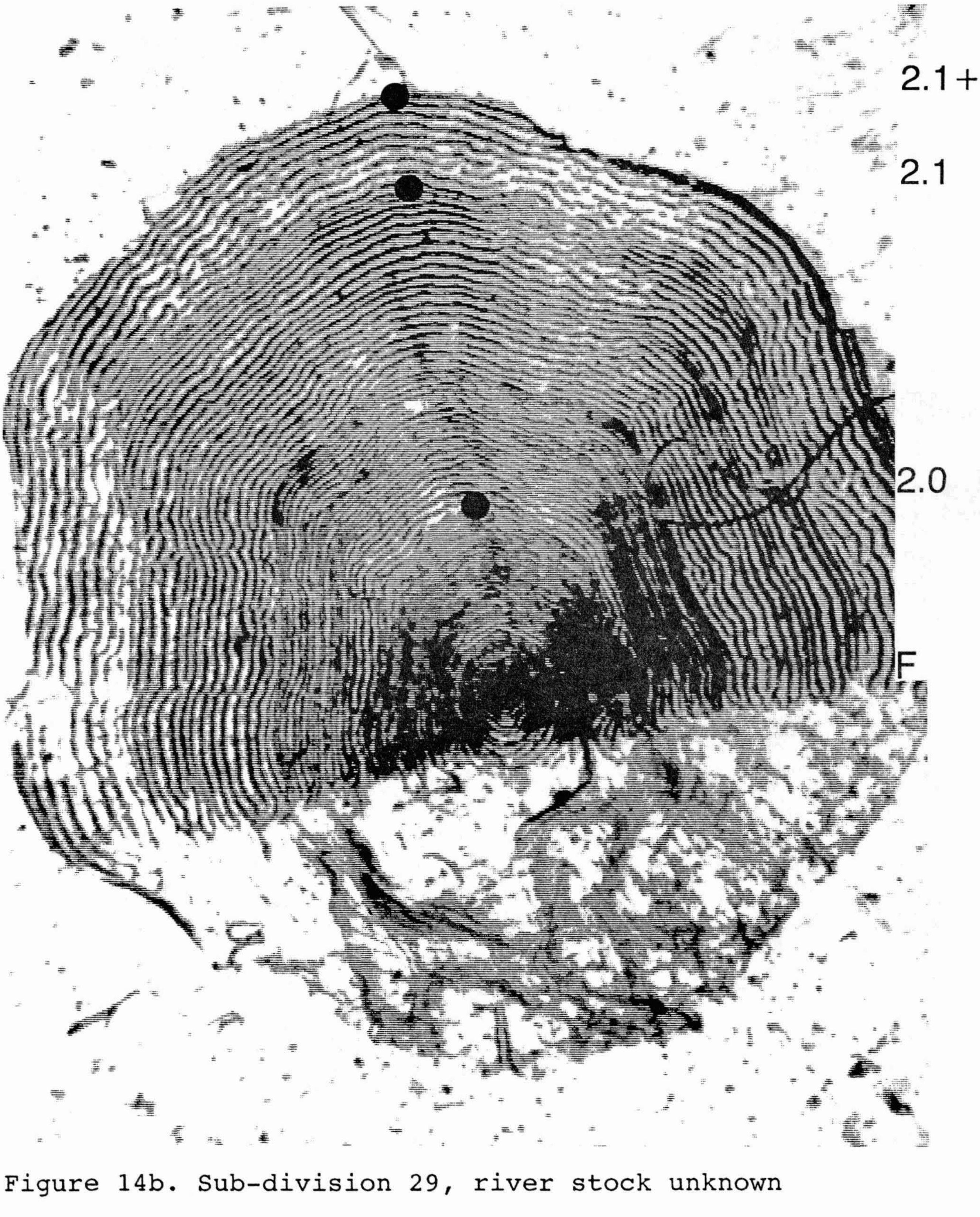


Figure 14b. Sub-division 29, river stock unknown

Date of capture 26.06. 1985
Age 2.1+ hatchery-reared
length 62.0 cm weight 2.5 kg

Analysis:

	River zone		Sea zone	
Age	1.0	2.0	2.1	2.1+
Length (in mm)	0.328	1.15	3.43	4.12
Circuli	11	28	38	9

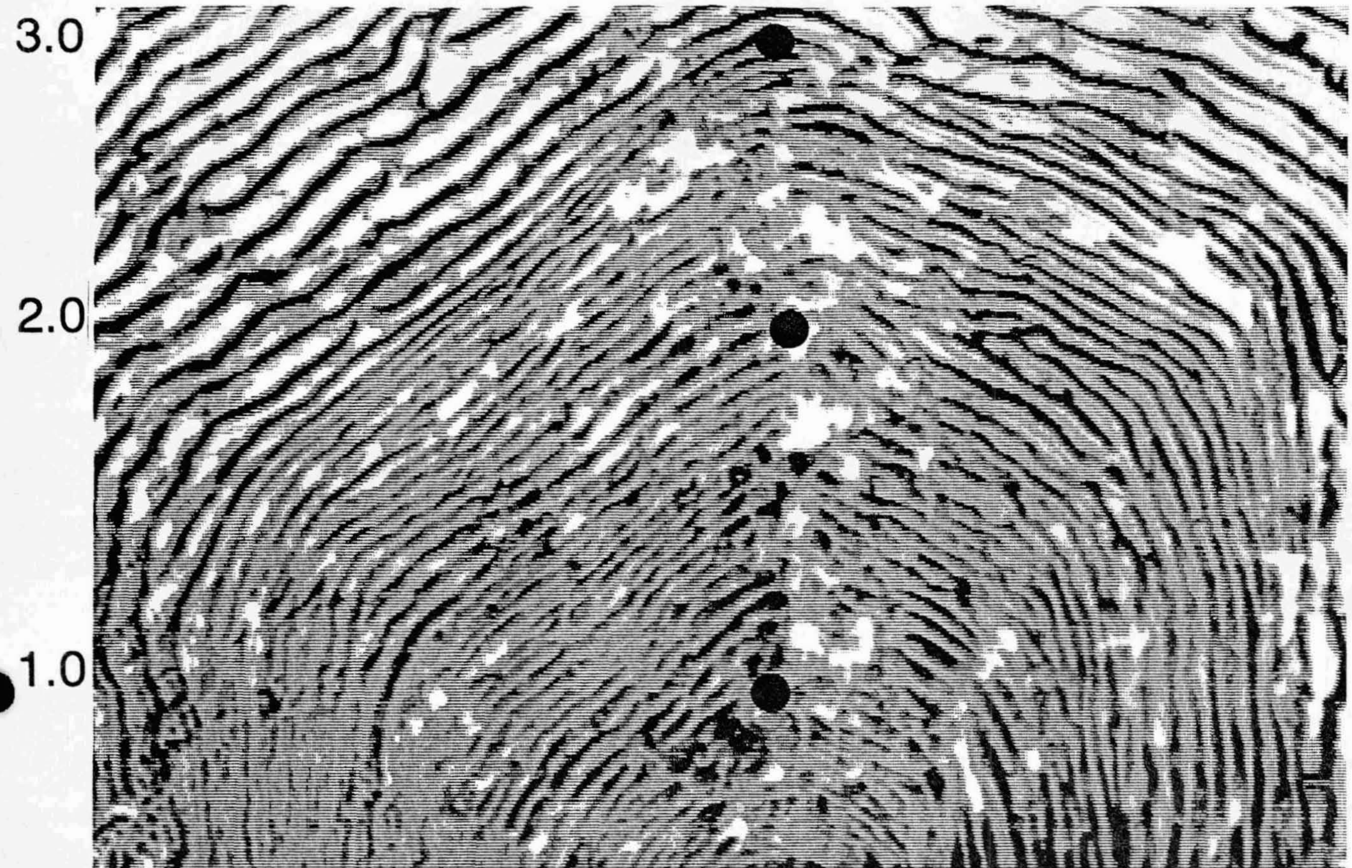


Figure 15a. Sub-division 32, river stock unknown

Date of capture 02.07. 1985
Age 3.2+ wild
length 85.0 cm weight 5.3 kg

Analysis:

	River zone			Sea zone		
Age	1.0	2.0	3.0	3.1	3.2	3.2+
Length (in mm)	0.34	0.699	1.15	2.64	4.38	4.62
Circuli	13	13	15	30	27	3

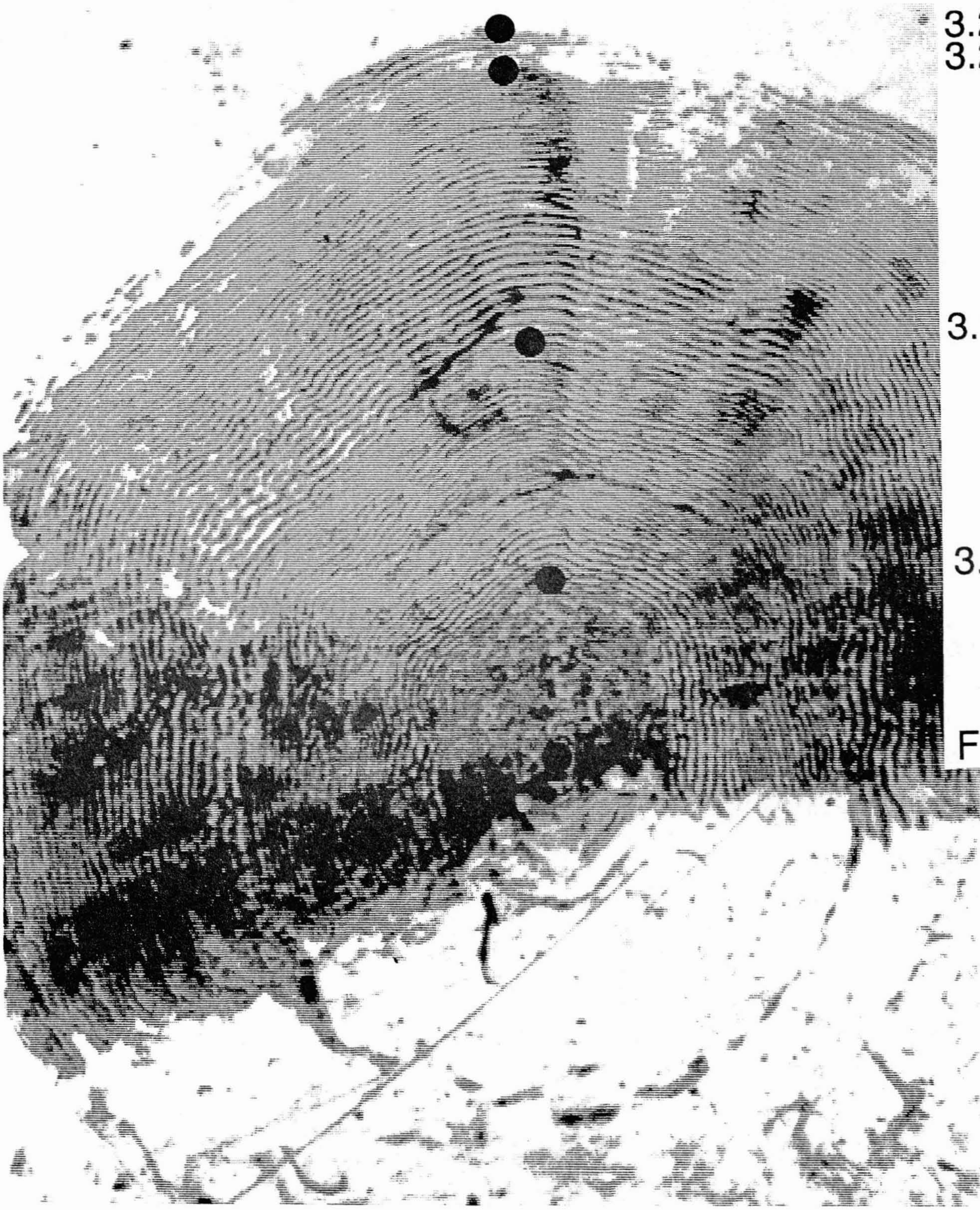


Figure 15b. Sub-division 32, river stock unknown

Date of capture 02.07. 1985
Age 3.2+ wild
length 85.0 cm weight 5.3 kg

Analysis:

	River zone			Sea zone		
Age	1.0	2.0	3.0	3.1	3.2	3.2+
Length (in mm)	0.34	0.699	1.15	2.64	4.38	4.62
Circuli	13	13	15	30	27	3

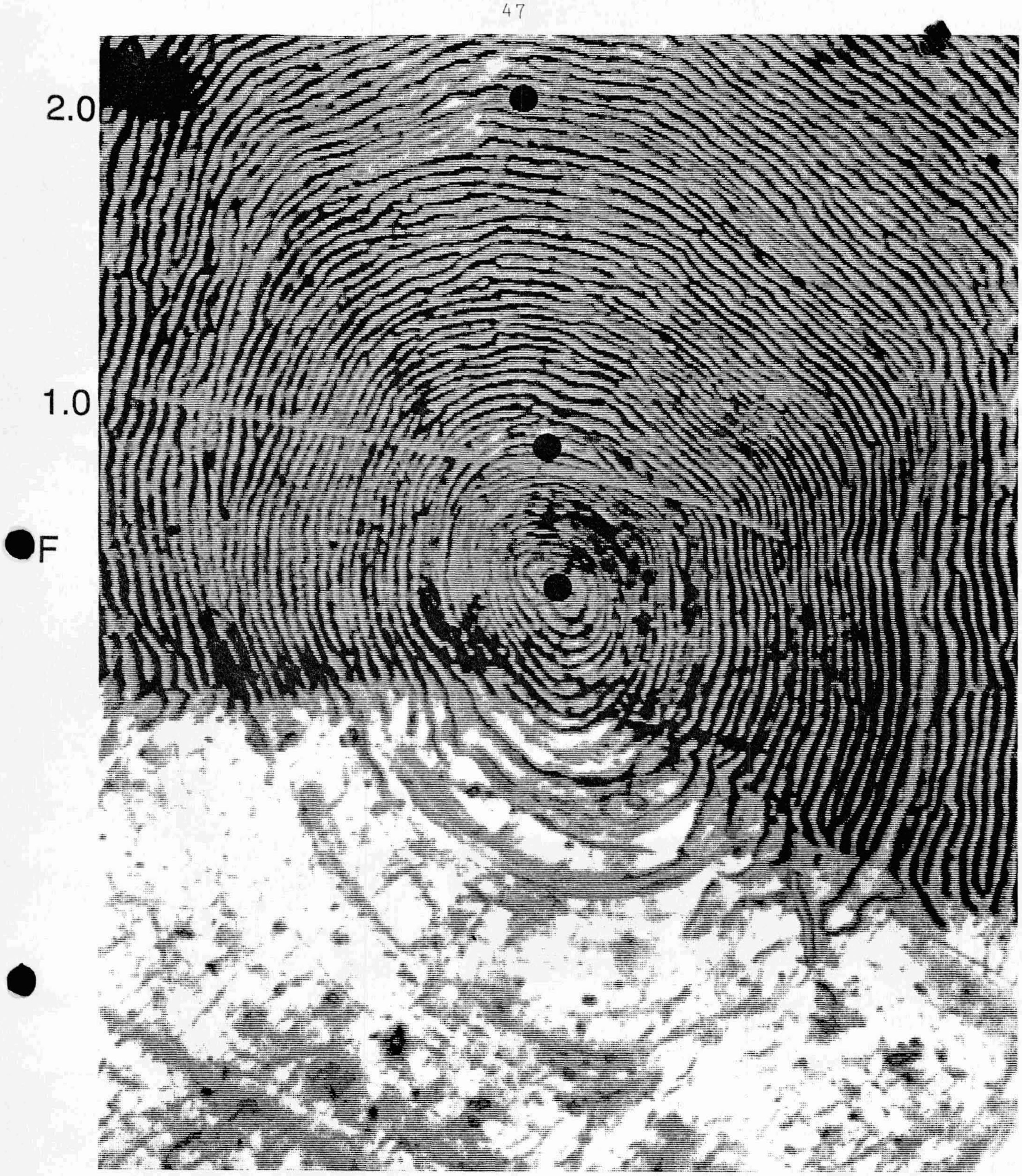


Figure 16a. Sub-division 32, river stock unknown

Date of capture 09.09. 1983
Age 2.1+ hatchery-reared
length 64.0 cm weight 2.4 kg

Analysis:

Age	River zone 1.0	River zone 2.0	Sea zone 2.1	Sea zone 2.1+
Length (in mm)	0.422	1.32	2.67	3.59
Circuli	12	25	30	19

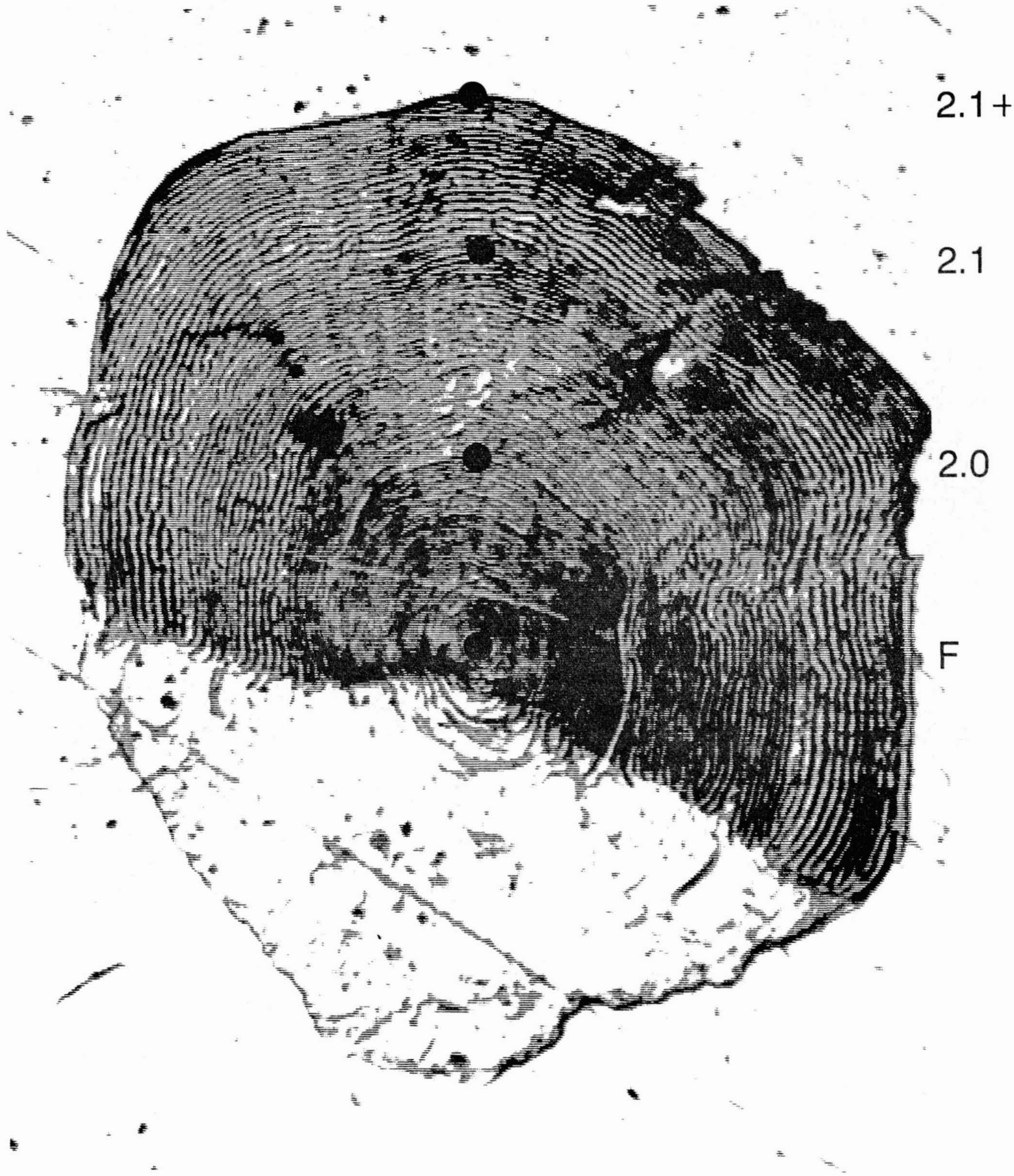


Figure 16b. Sub-division 32, river stock unknown

Date of capture 09.09. 1983
Age 2.1+ hatchery-reared
length 64.0 cm weight 2.4 kg

Analysis:

	River zone		Sea zone	
Age	1.0	2.0	2.1	2.1+
Length (in mm)	0.422	1.32	2.67	3.59
Circuli	12	25	30	19

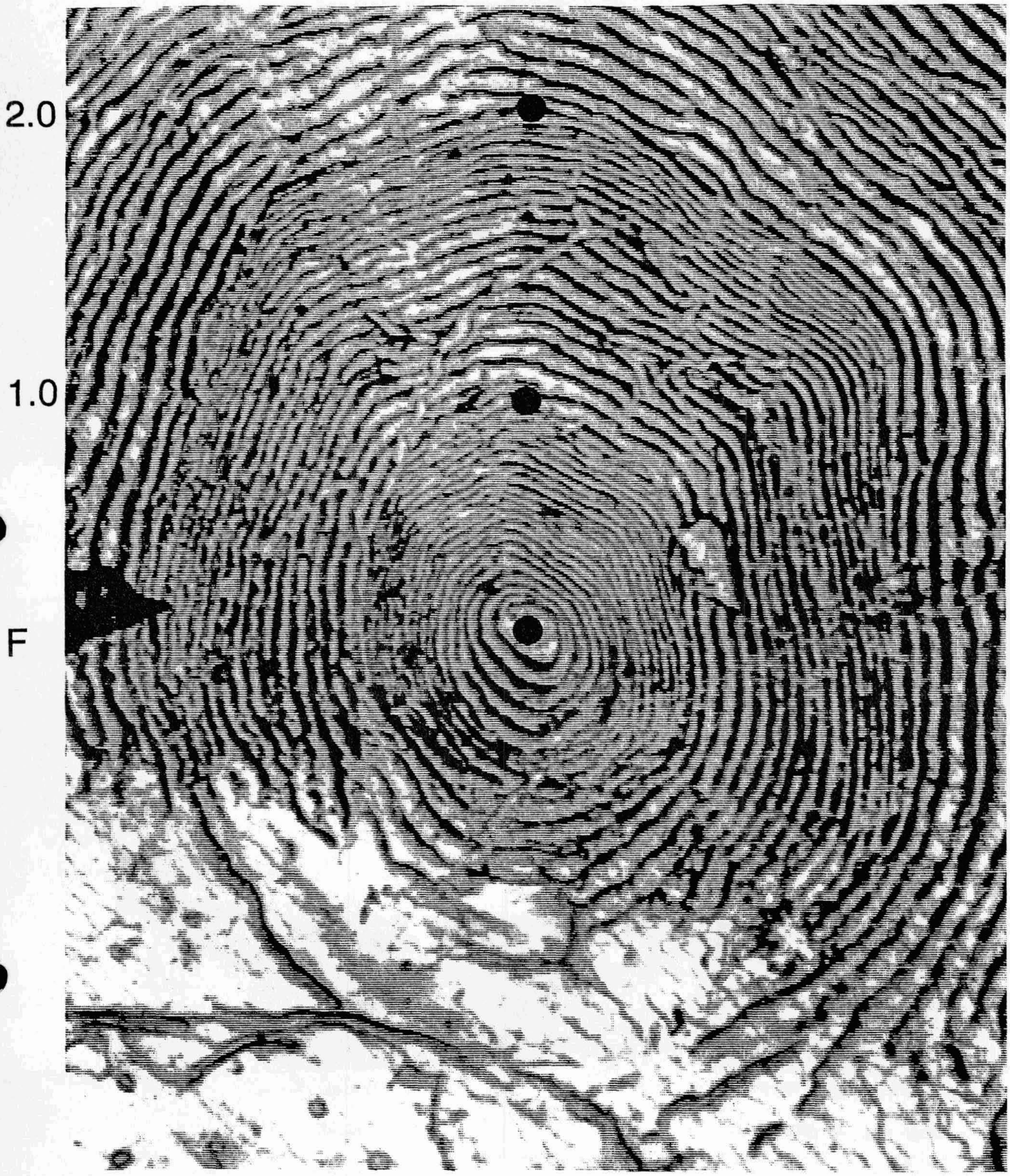


Figure 17a. Sub-division 32, river Neva stock

Date of capture 20.10. 1988
Age 2.1+ wild
length 63 cm weight 2.6 kg

Analysis:

	River zone		Sea zone	
Age	1.0	2.0	2.1	2.1+
Length (in mm)	0.469	1.2	2.94	4.39
Circuli	15	24	38	25

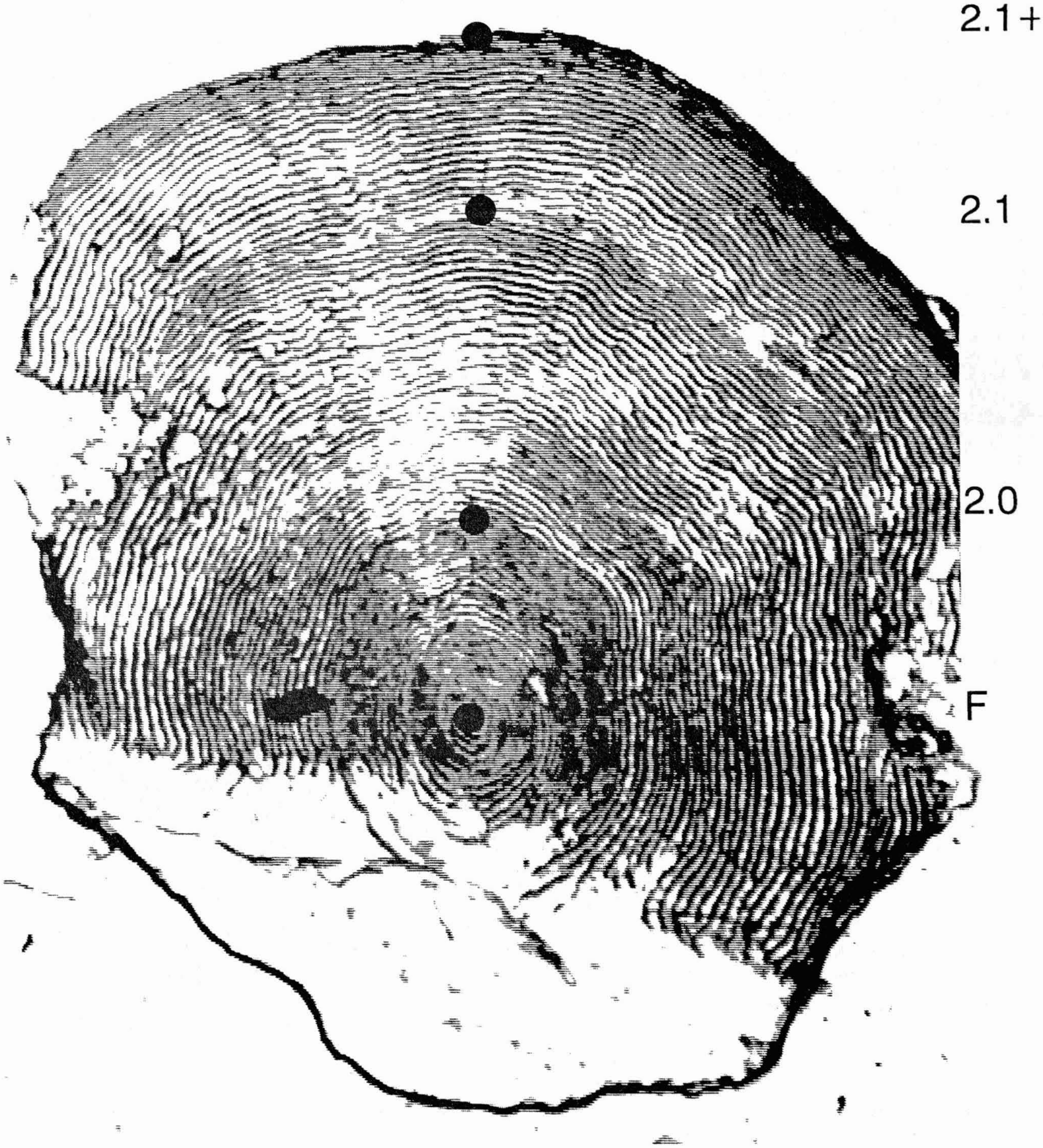


Figure 17b. Sub-division 32, river Neva stock

Date of capture 20.10. 1988
Age 2.1+ wild
length 63 cm weight 2.6 kg

Analysis:

	River zone		Sea zone	
Age	1.0	2.0	2.1	2.1+
Length (in mm)	0.469	1.2	2.94	4.39
Circuli	15	24	38	25

Figure 18a. Sub-division 32, river Neva stock

Date of capture 13.10. 1988
Age 2.1+ hatchery-reared
length 64 cm weight 2.5 kg

Analysis:

	River zone		Sea zone	
Age	1.0	2.0	2.1	2.1+
Length (in mm)	0.544	1.26	3.21	4.32
Circuli	19	22	32	23

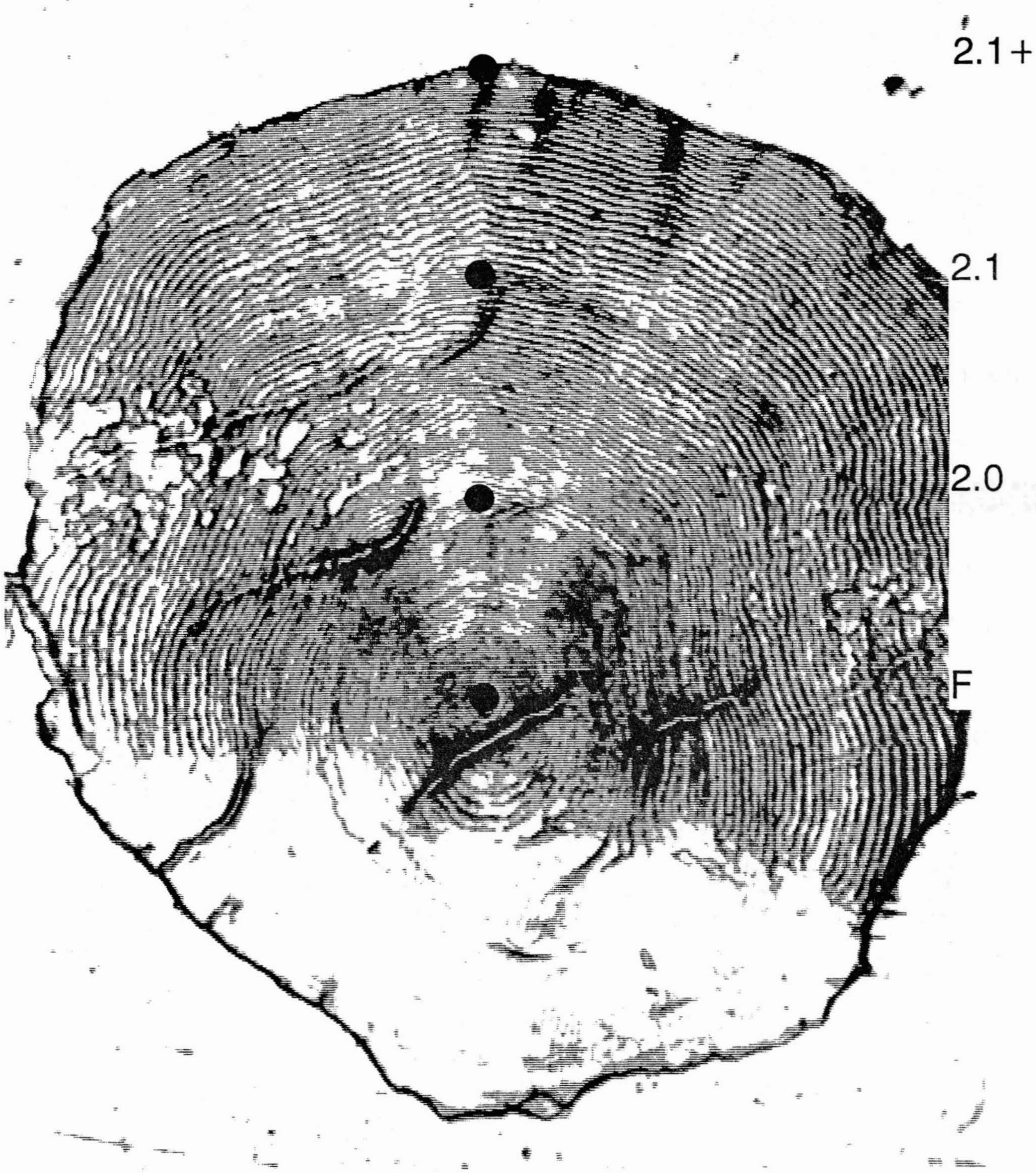


Figure 18b. Sub-division 32, river Neva stock

Date of capture 13.10. 1988
Age 2.1+ hatchery-reared
length 64 cm weight 2.5 kg

Analysis:

	River zone		Sea zone	
Age	1.0	2.0	2.1	2.1+
Length (in mm)	0.544	1.26	3.21	4.32
Circuli	19	22	32	23

Figure 19a. Sub-division 32, river Neva stock

Date of capture 15.10. 1990
Age 2.2+ SM + hatchery-reared
length 82 cm weight 4.7 kg

Analysis:

	River zone		Sea zone				
Age	1.0	2.0	2.1	2.2	2.2+	2.2+SM	2.2+SM+
Length (in mm)	0.448	1.27	3.18	4.8	4.84	4.88	5.34
Circuli	18	29	33	30	1	0	8

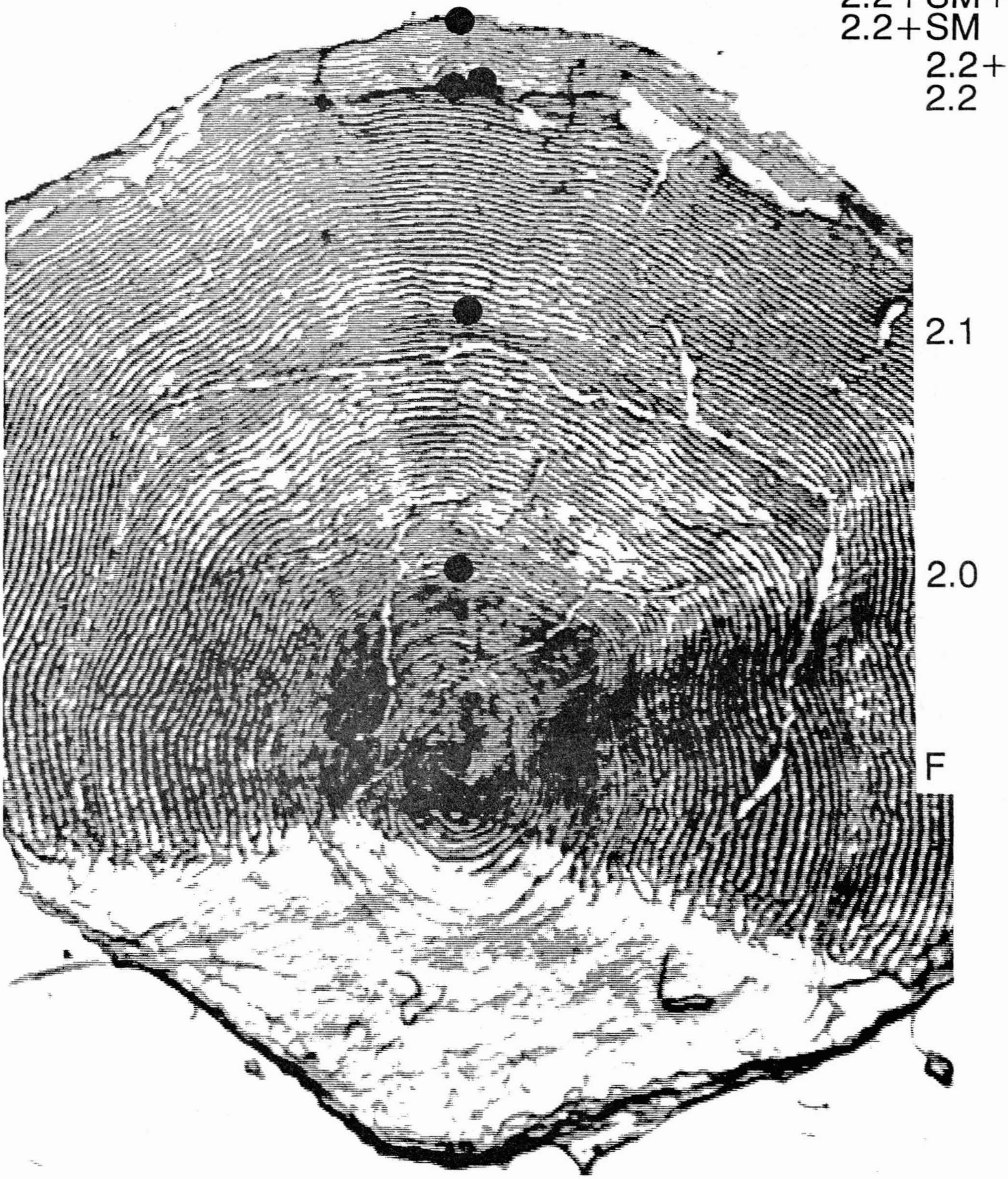


Figure 19b. Sub-division 32, river Neva stock

Date of capture 15.10. 1990
Age 2.2+ SM + hatchery-reared
length 82 cm weight 4.7 kg

Analysis:

	River zone		Sea zone				
Age	1.0	2.0	2.1	2.2	2.2+	2.2+SM	2.2+SM+
Length (in mm)	0.448	1.27	3.18	4.8	4.84	4.88	5.34
Circuli	18	29	33	30	1	0	8

Figure 20a. Sub-division 32, river Neva stock

Date of capture 15.10. 1990
Age 2.3+ wild
length 103.5 cm weight 10 kg

Analysis:

	River zone		Sea zone			
Age	1.0	2.0	2.1	2.2	2.3	2.3+
Length (in mm)	0.315	0.944	2.25	4.56	6.4	6.98
Circuli	8	18	17	35	28	9

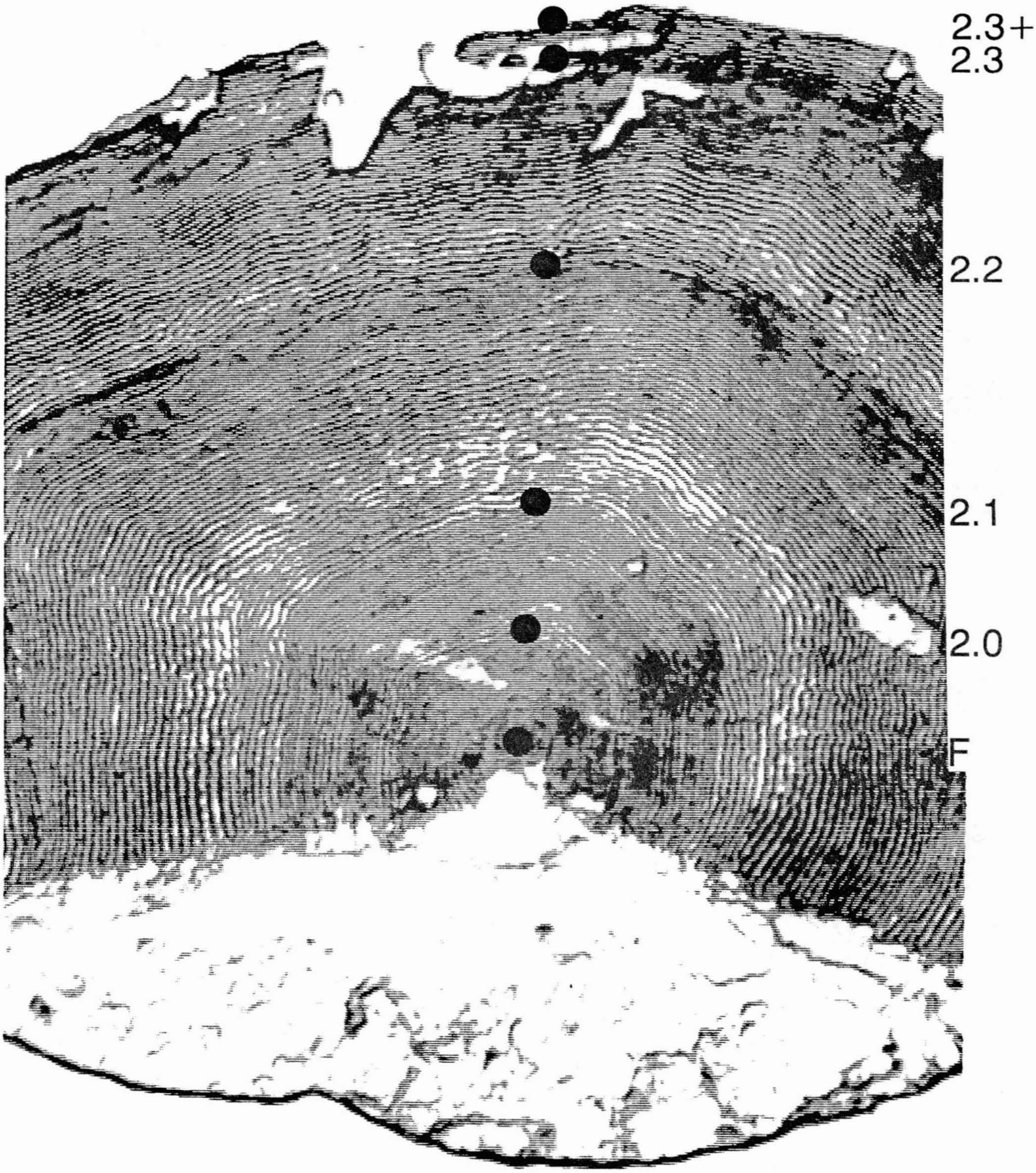


Figure 20b. Sub-division 32, river Neva stock

Date of capture 15.10. 1990
Age 2.3+ wild
length 103.5 cm weight 10 kg

Analysis:

	River zone		Sea zone			
Age	1.0	2.0	2.1	2.2	2.3	2.3+
Length (in mm)	0.315	0.944	2.25	4.56	6.4	6.98
Circuli	8	18	17	35	28	9

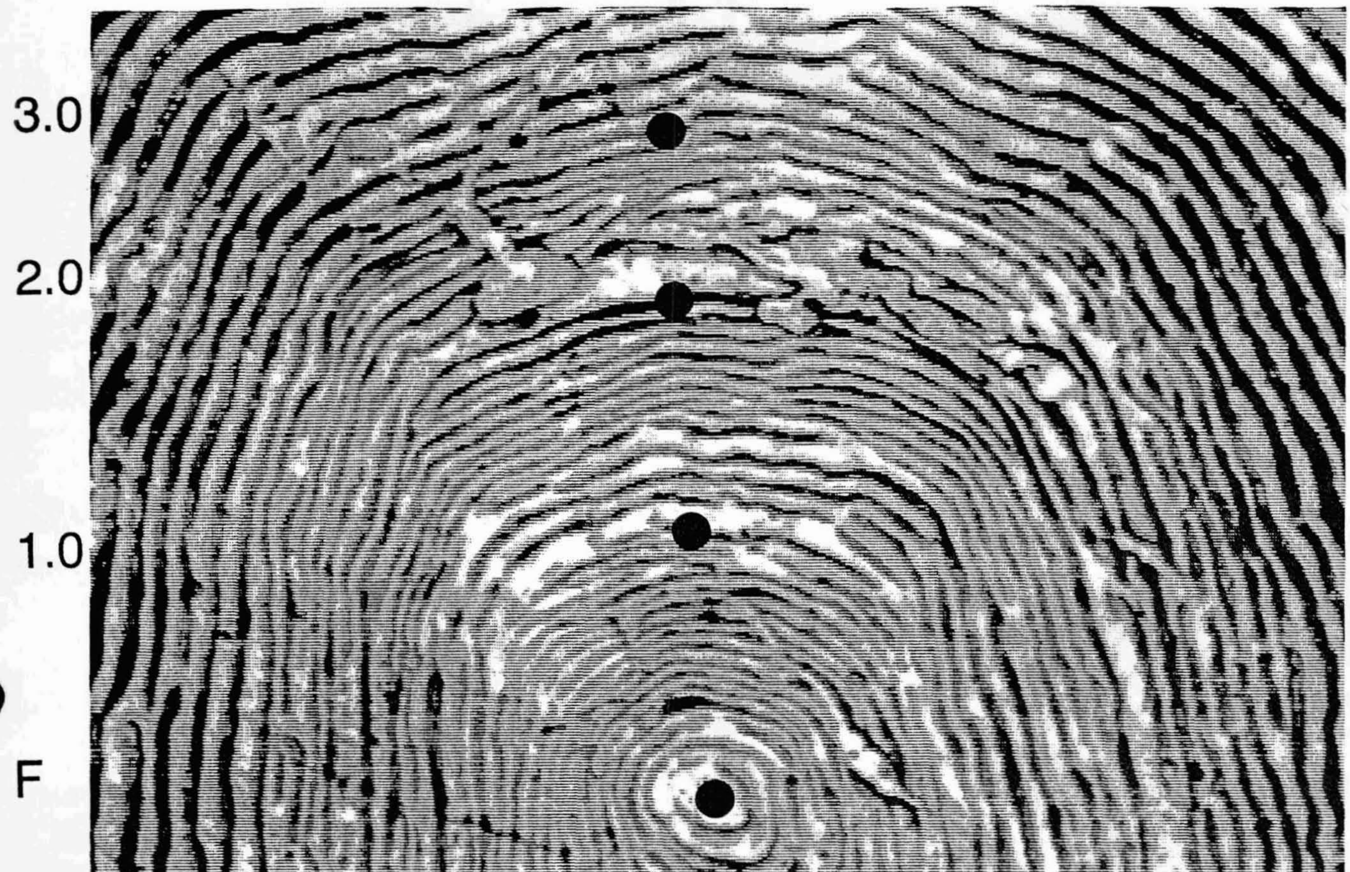


Figure 21a. Sub-division 32, river Neva stock

Date of capture 13.10. 1988
Age 3.2+ wild
length 87 cm weight 7.8 kg

Analysis:

	River zone			Sea zone		
Age	1.0	2.0	3.0	3.1	3.2	3.2+
Length (in mm)	0.338	0.728	0.963	2.59	4.8	5.62
Circuli	13	14	7	24	30	12

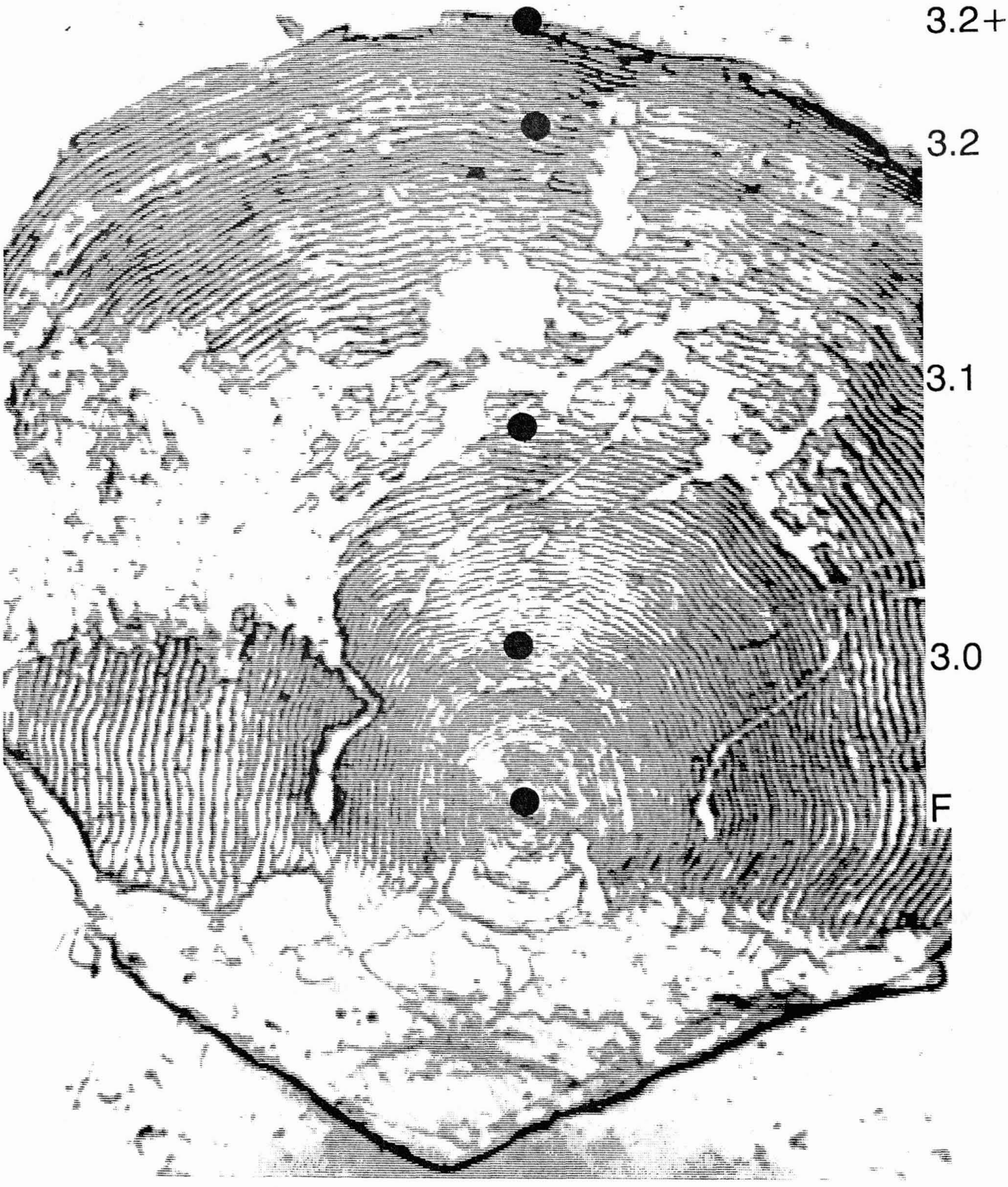


Figure 21b. Sub-division 32, river Neva stock

Date of capture 13.10. 1988
Age 3.2+ wild
length 87 cm weight 7.8 kg

Analysis:

	River zone			Sea zone		
Age	1.0	2.0	3.0	3.1	3.2	3.2+
Length (in mm)	0.338	0.728	0.963	2.59	4.8	5.62
Circuli	13	14	7	24	30	12

Figure 22a. Sub-division 32, river Narva stock

Date of capture 1987
Age 1.2+SM+   hatchery-reared
length 99 cm   weight 13.4 kg

Analysis:

	River zone	Sea zone				
Age	1.0	1.1	1.2	1.2+	1.2+SM	1.2+SM+
Length (in mm)	0.541	2.25	3.97	4.61	4.77	5.06
Circuli	16	30	30	11	4	4

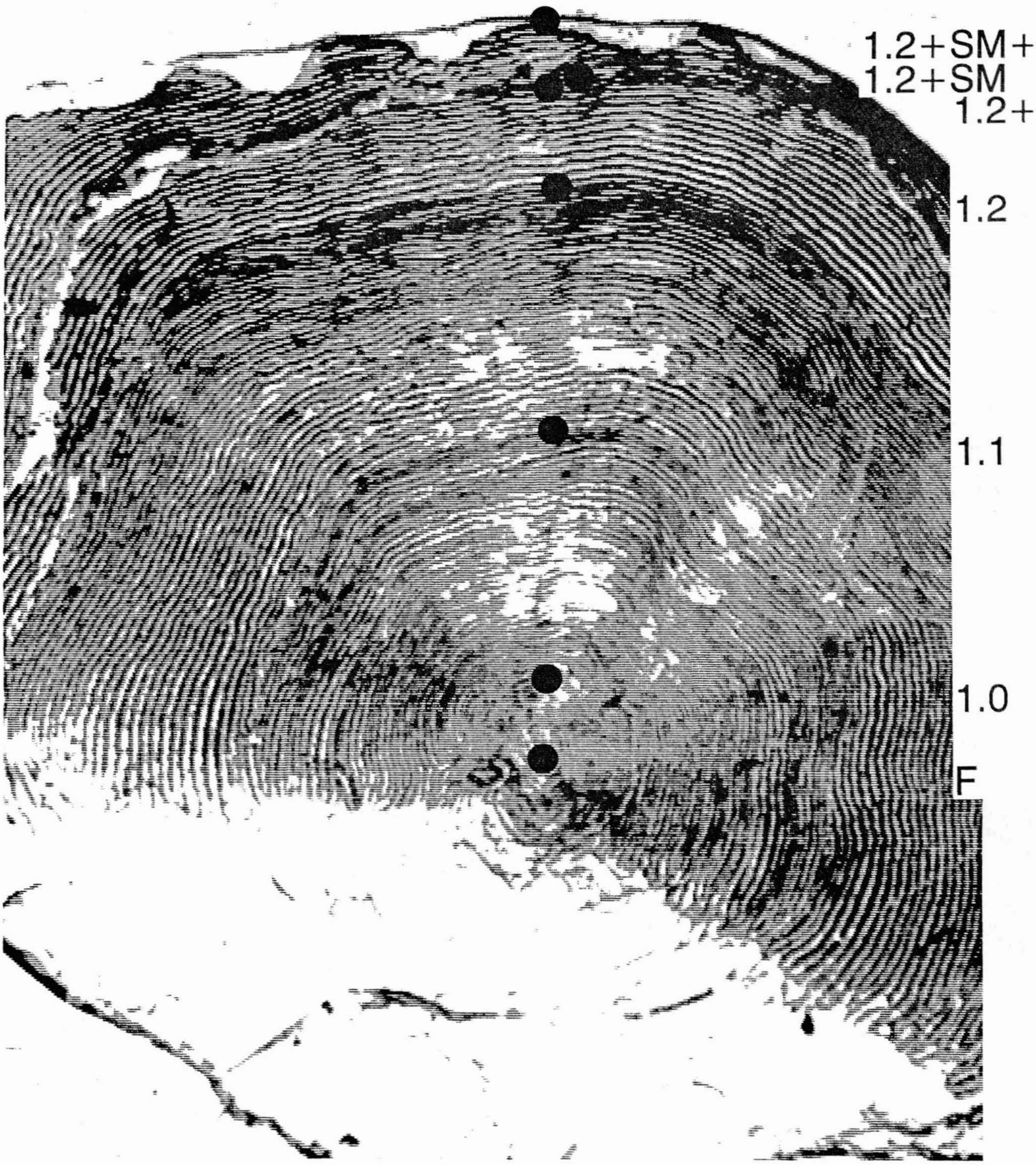


Figure 22b. Sub-division 32, river Narva stock

Date of capture 1987
Age 1.2+SM+ hatchery-reared
length 99 cm weight 13.4 kg

Analysis:

	River zone	Sea zone				
Age	1.0	1.1	1.2	1.2+	1.2+SM	1.2+SM+
Length (in mm)	0.541	2.25	3.97	4.61	4.77	5.06
Circuli	16	30	30	11	4	4

Figure 23a. Sub-division 32, river Narva stock

Date of capture 1987
Age 2.3+ hatchery-reared
length 87 cm weight 8.0 kg

Analysis:

	River zone		Sea zone			
Age	1.0	2.0	2.1	2.2	2.3	2.3+
Length (in mm)	0.466	0.89	1.94	3.28	4.38	4.7
Circuli	15	14	28	30	27	6

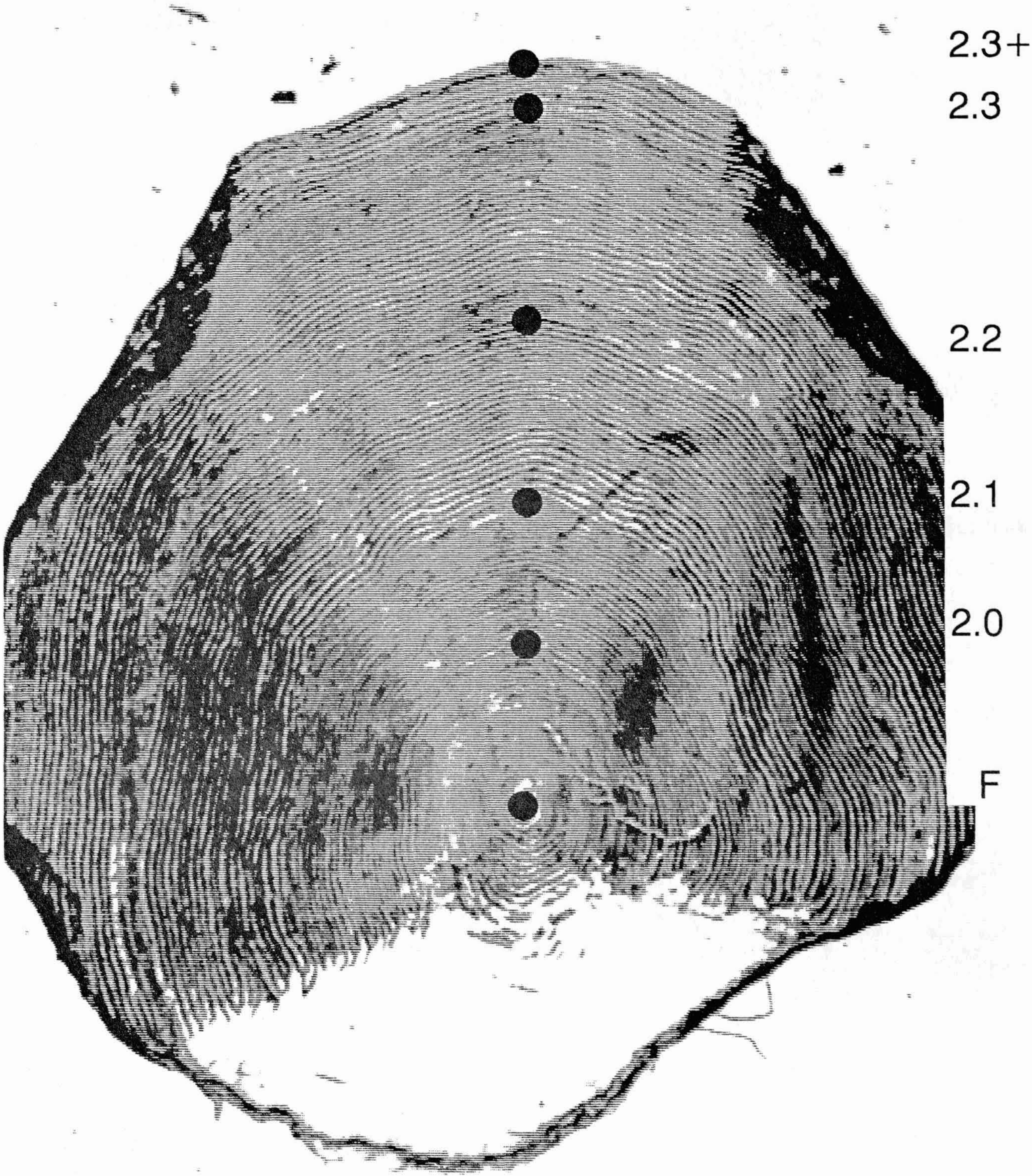


Figure 23b. Sub-division 32, river Narva stock

Date of capture 1987
Age 2.3+ hatchery-reared
length 87 cm weight 8.0 kg

Analysis:

	River zone		Sea zone			
Age	1.0	2.0	2.1	2.2	2.3	2.3+
Length (in mm)	0.466	0.89	1.94	3.28	4.38	4.7
Circuli	15	14	28	30	27	6

Figure 24a. Sub-division 28, river Salaca stock

Date of capture 29.08. 1981
Age 1.1+ wild
length 58.0 cm weight 1.8 kg

Analysis:

	River zone	Sea zone	
Age	1.0	1.1	1.1+
Length (in mm)	0.467	2.34	3.25
Circuli	18	36	17

Figure 24b. Sub-division 28, river Salaca stock

Date of capture 29.08. 1981
Age 1.1+ wild
length 58.0 cm weight 1.8 kg

Analysis:

	River zone	Sea zone	
Age	1.0	1.1	1.1+
Length (in mm)	0.467	2.34	3.25
Circuli	18	36	17

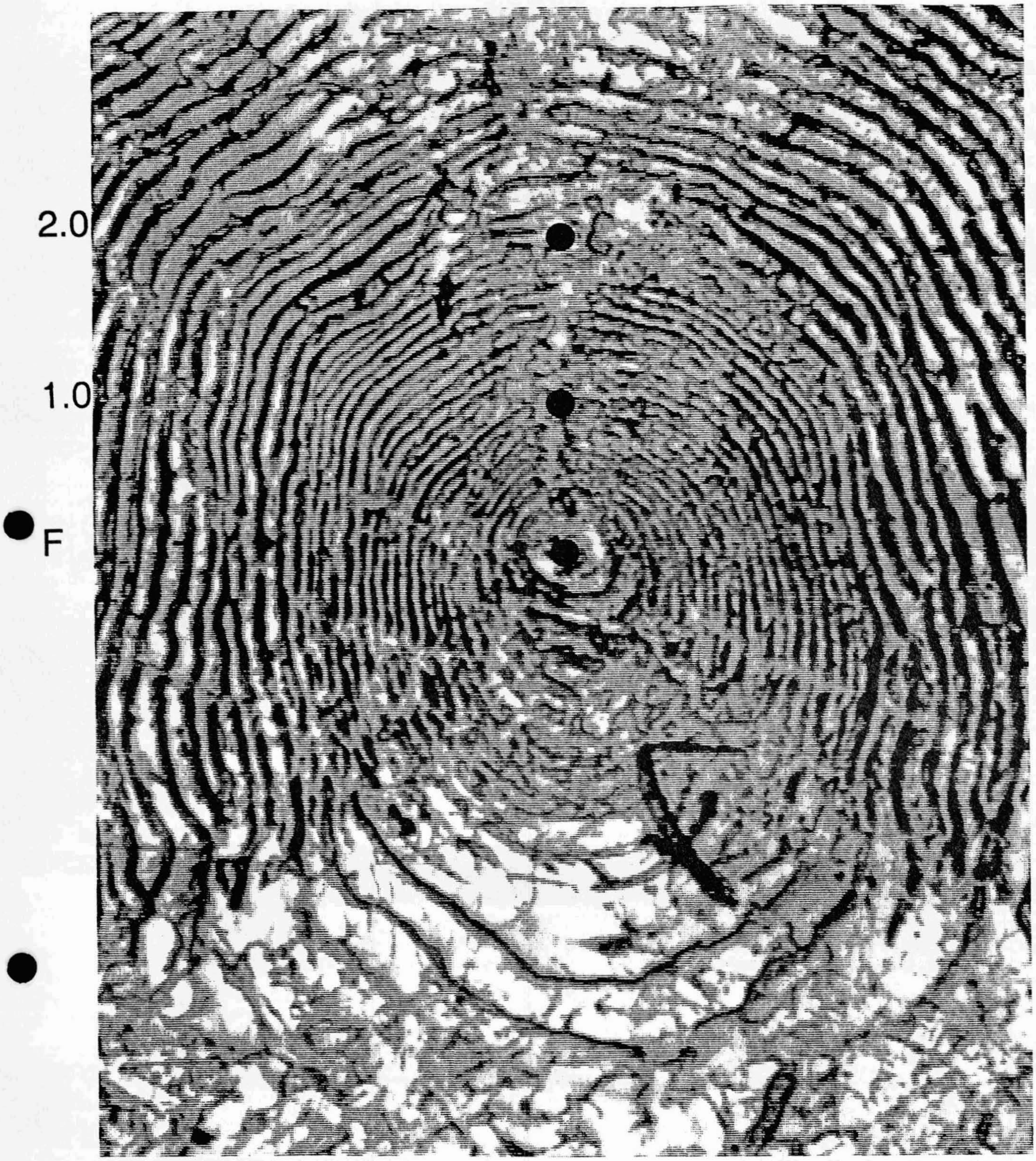


Figure 25a. Sub-division 28, river Salaca stock

Date of capture 19.10. 1981
Age 2.1+ wild
length 60.0 cm weight 1.8 kg

Analysis:

	River zone		Sea zone	
Age	1.0	2.0	2.1	2.1+
Length (in mm)	0.258	0.527	2.08	3.23
Circuli	10	12	31	24

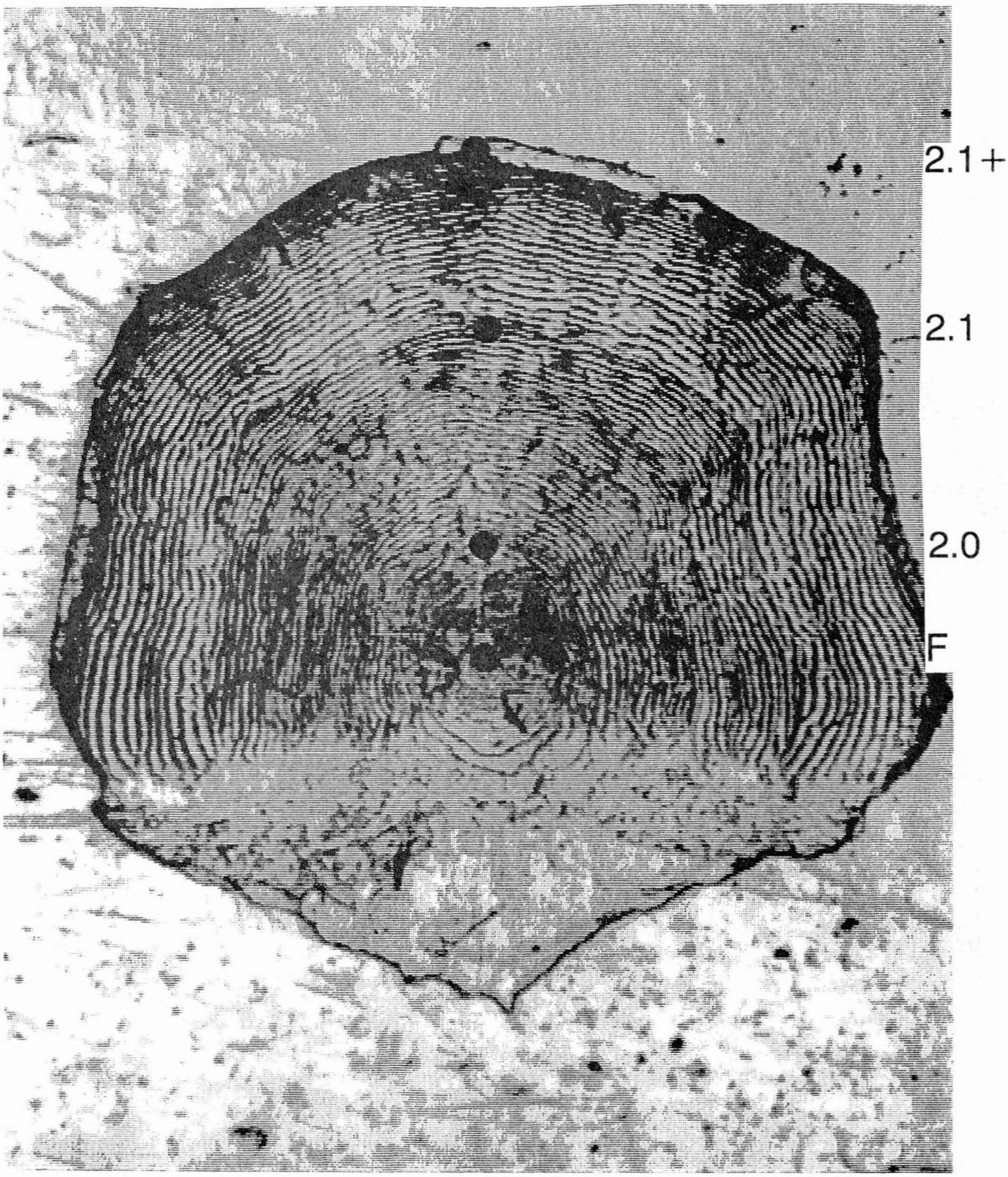


Figure 25b. Sub-division 28, river Salaca stock

Date of capture 19.10. 1981
Age 2.1+ wild
length 60.0 cm weight 1.8 kg

Analysis:

	River zone		Sea zone	
Age	1.0	2.0	2.1	2.1+
Length (in mm)	0.258	0.527	2.08	3.23
Circuli	10	12	31	24

Figure 26a. Sub-division 28, river Salaca stock

Date of capture 19.10. 1981
Age 2.2+ hatchery-reared
length 85.0 cm weight 6.8 kg

Analysis:

	River zone		Sea zone		
Age	1.0	2.0	2.1	2.2	2.2+
Length (in mm)	0.299	0.723	2.79	4.64	5.25
Circuli	9	16	38	37	11

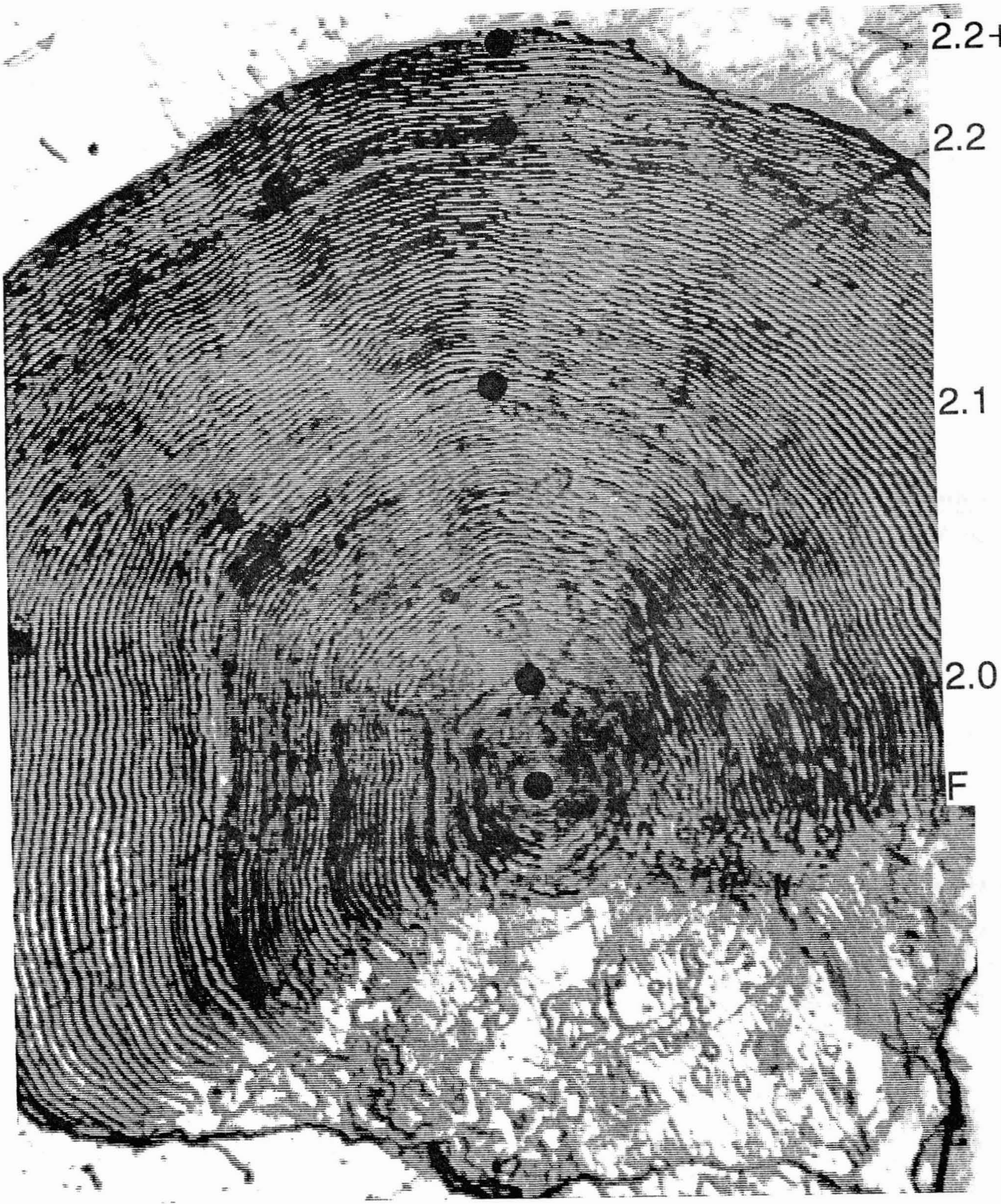


Figure 26b. Sub-division 28, river Salaca stock

Date of capture 19.10. 1981
Age 2.2+ hatchery-reared
length 85.0 cm weight 6.8 kg

Analysis:

	River zone		Sea zone		
Age	1.0	2.0	2.1	2.2	2.2+
Length (in mm)	0.299	0.723	2.79	4.64	5.25
Circuli	9	16	38	37	11

Figure 27a. Sub-division 28, river Daugava stock

Date of capture 25.08. 1981
Age 1.1+ wild
length 58.0 cm weight 1.8 kg

Analysis:

	River zone	Sea zone	
Age	1.0	1.1	1.1+
Length (in mm)	0.371	1.79	3.33
Circuli	14	31	30

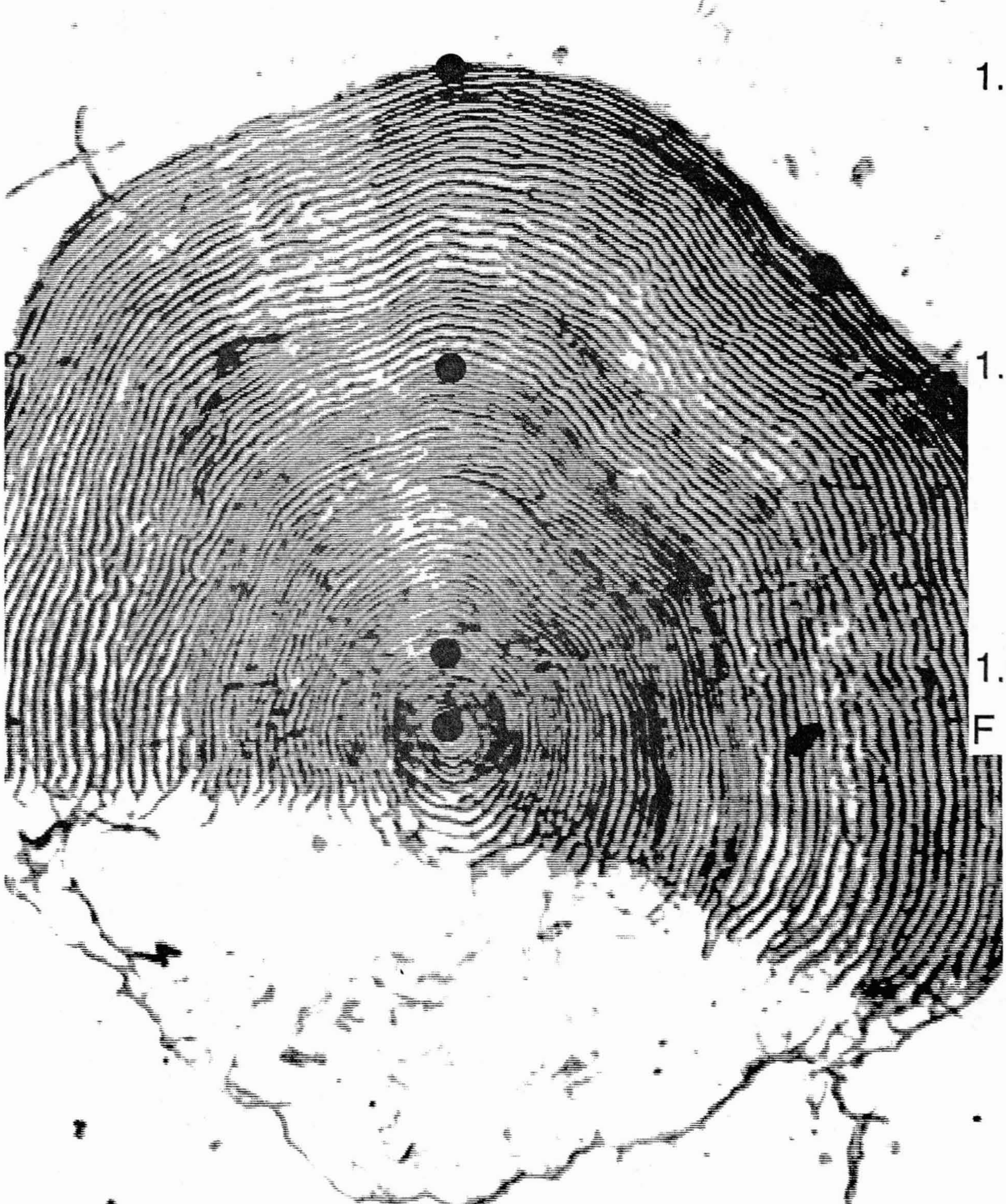


Figure 27b. Sub-division 28, river Daugava stock

Date of capture 25.08. 1981
Age 1.1+ wild
length 58.0 cm weight 1.8 kg

Analysis:

	River zone	Sea zone	
Age	1.0	1.1	1.1+
Length (in mm)	0.371	1.79	3.33
Circuli	14	31	30

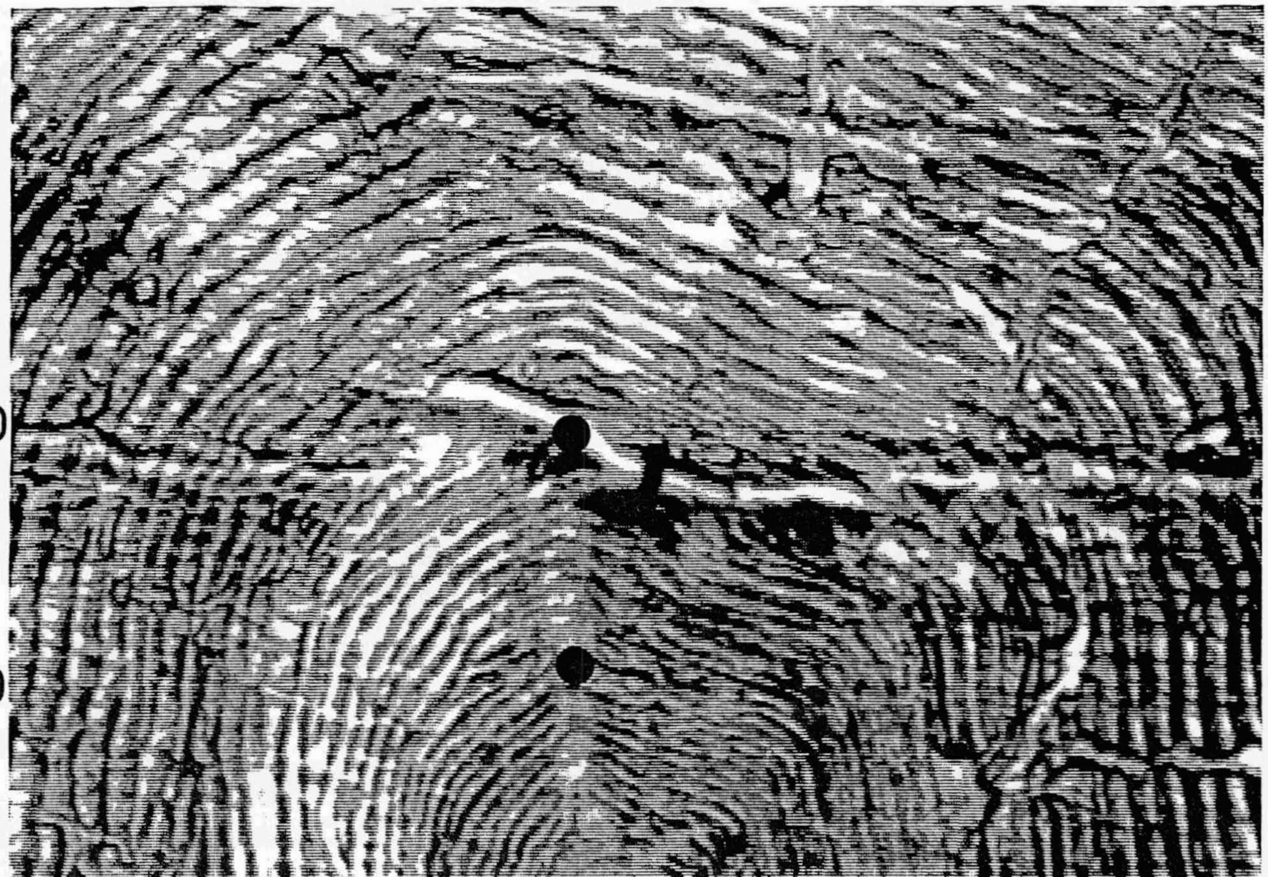


Figure 28a. Sub-division 28, river Daugava stock

Date of capture 19.09. 1981
Age 2.1+ wild
length 63.5 cm weight 3.0 kg

Analysis:

	River zone		Sea zone	
Age	1.0	2.0	2.1	2.1+
Length (in mm)	0.213	0.427	2.63	3.99
Circuli	10	10	38	23

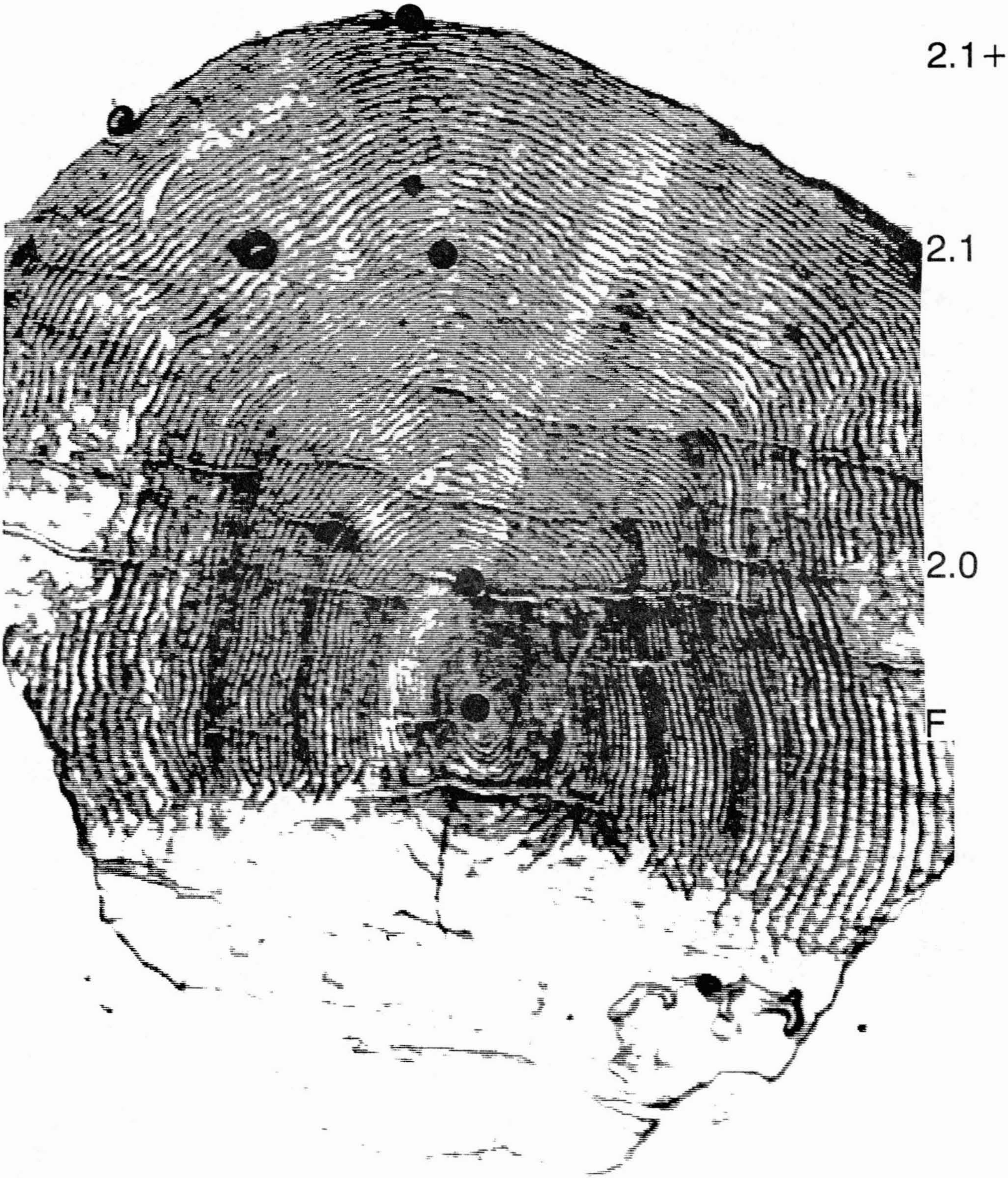


Figure 28b. Sub-division 28, river Daugava stock

Date of capture 19.09. 1981
Age 2.1+ wild
length 63.5 cm weight 3.0 kg

Analysis:

	River zone		Sea zone	
Age	1.0	2.0	2.1	2.1+
Length (in mm)	0.213	0.427	2.63	3.99
Circuli	10	10	38	23

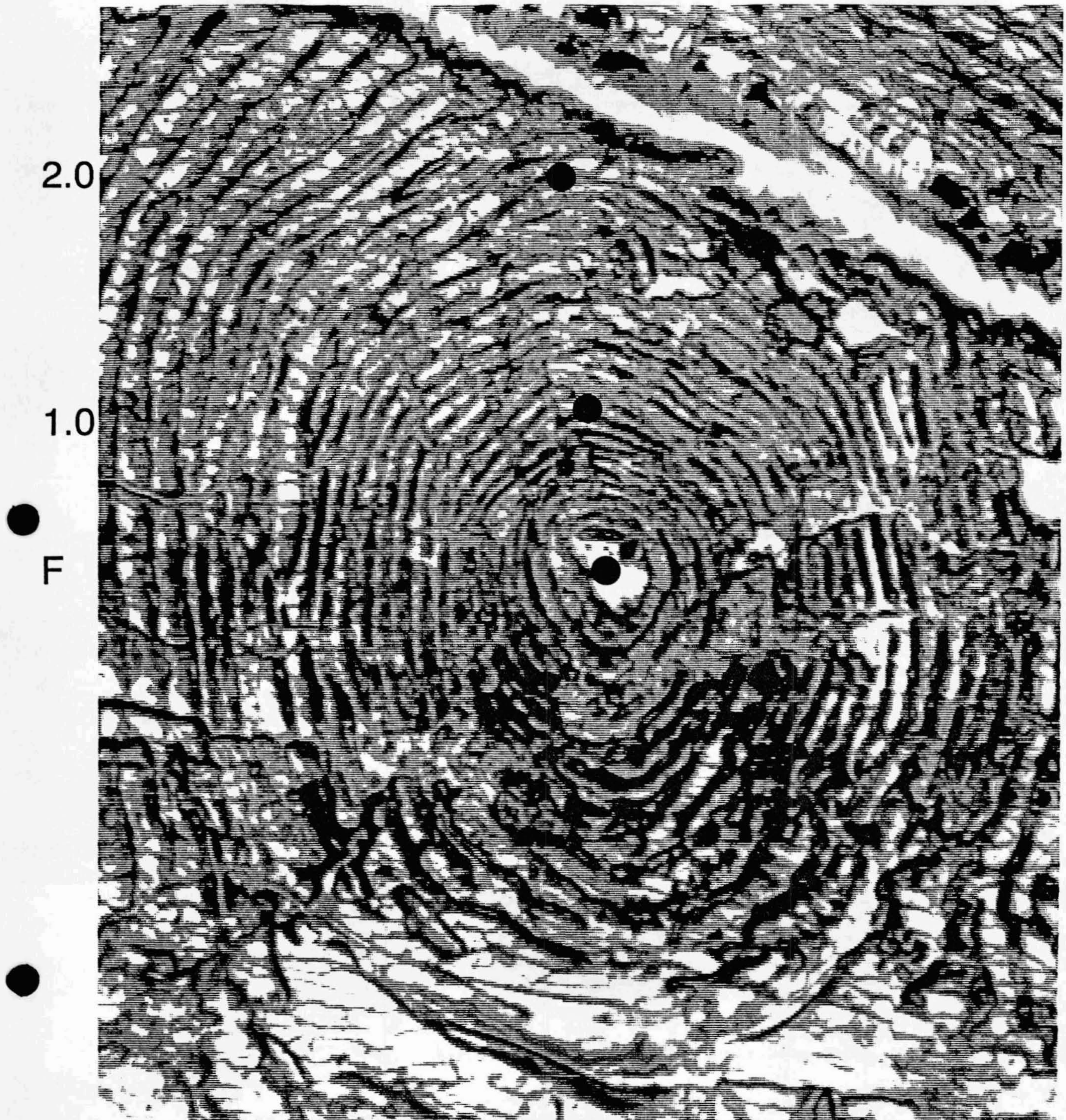


Figure 29a. Sub-division 28, river Daugava stock

Date of capture 10.09. 1981
Age 2.1+ wild
length 62.5 cm weight 2.2 kg

Analysis:

	River zone		Sea zone	
Age	1.0	2.0	2.1	2.1+
Length (in mm)	0.328	0.851	2.9	4.53
Circuli	13	21	35	26

Figure 29b. Sub-division 28, river Daugava stock

Date of capture 10.09. 1981
Age 2.1+ wild
length 62.5 cm weight 2.2 kg

Analysis:

	River zone		Sea zone	
Age	1.0	2.0	2.1	2.1+
Length (in mm)	0.328	0.851	2.9	4.53
Circuli	13	21	35	26

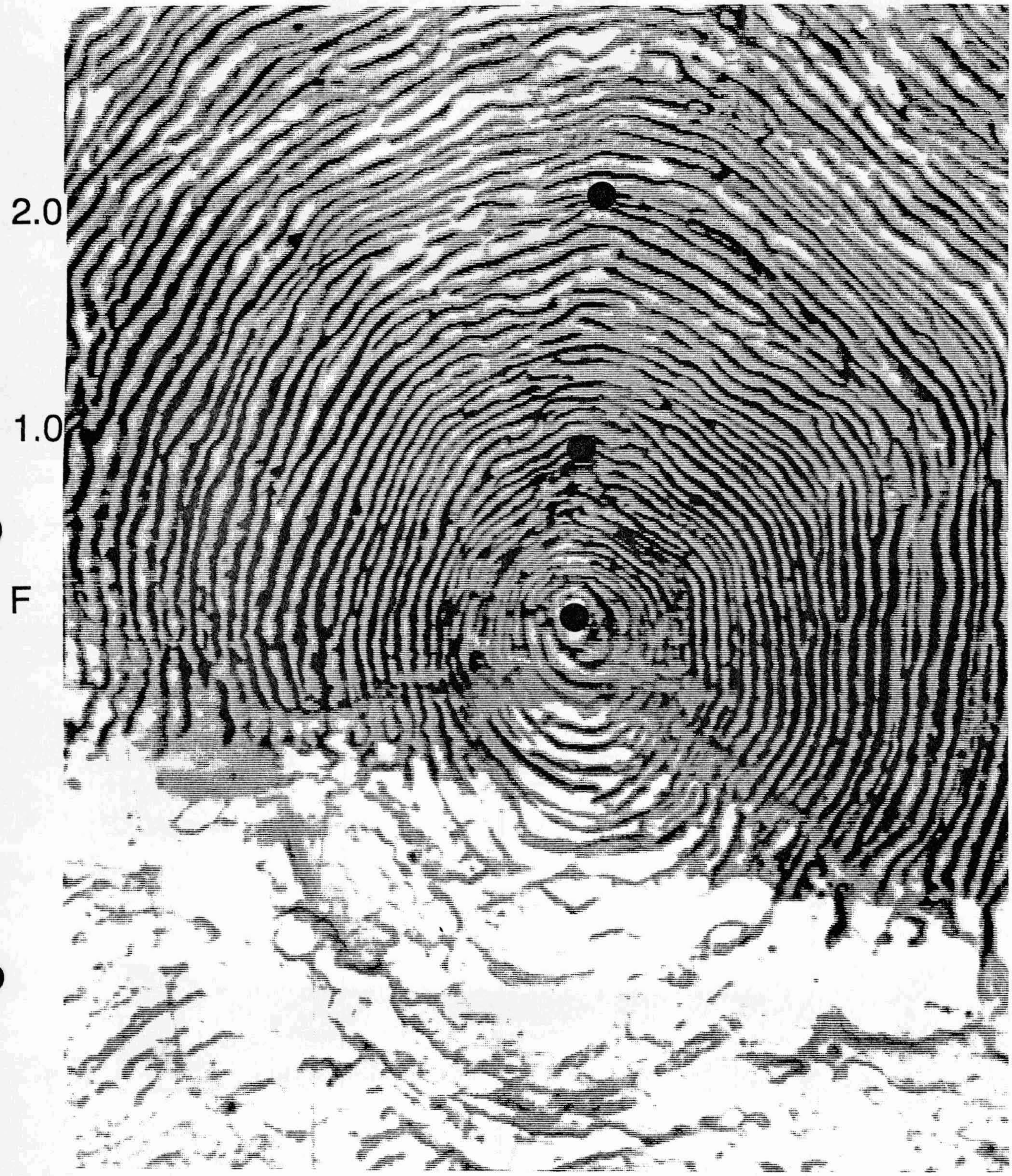


Figure 30a. Sub-division 28, river Daugava stock

Date of capture 05.09. 1990
Age 2.1+ hatchery-reared
length 61.0 cm weight 2.3 kg

Analysis:

	River zone		Sea zone	
Age	1.0	2.0	2.1	2.1+
Length (in mm)	0.373	0.906	2.82	3.96
Circuli	13	12	35	21

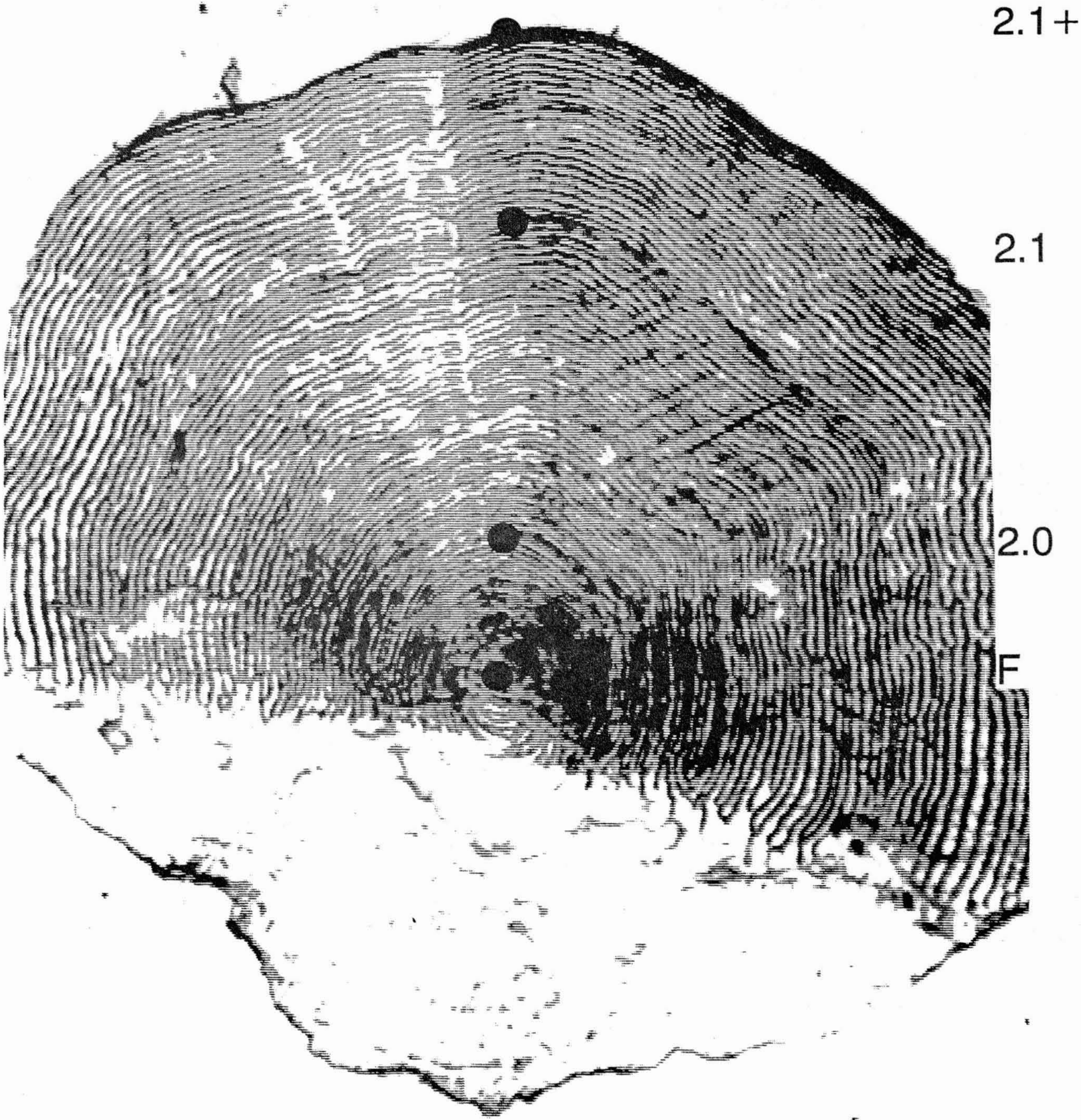


Figure 30b. Sub-division 28, river Daugava stock

Date of capture 05.09. 1990
Age 2.1+ hatchery-reared
length 61.0 cm weight 2.3 kg

Analysis:

	River zone		Sea zone	
Age	1.0	2.0	2.1	2.1+
Length (in mm)	0.373	0.906	2.82	3.96
Circuli	13	12	35	21

Figure 31a. Sub-division 25, river Mörrum stock

Date of capture 16.12. 1966
Age 1.1+ wild
length 68 cm weight 2.4 kg

Analysis:

	River zone	Sea zone	
Age	1.0	1.1	1.1+
Length (in mm)	0.711	2.15	4.06
Circuli	29	28	37

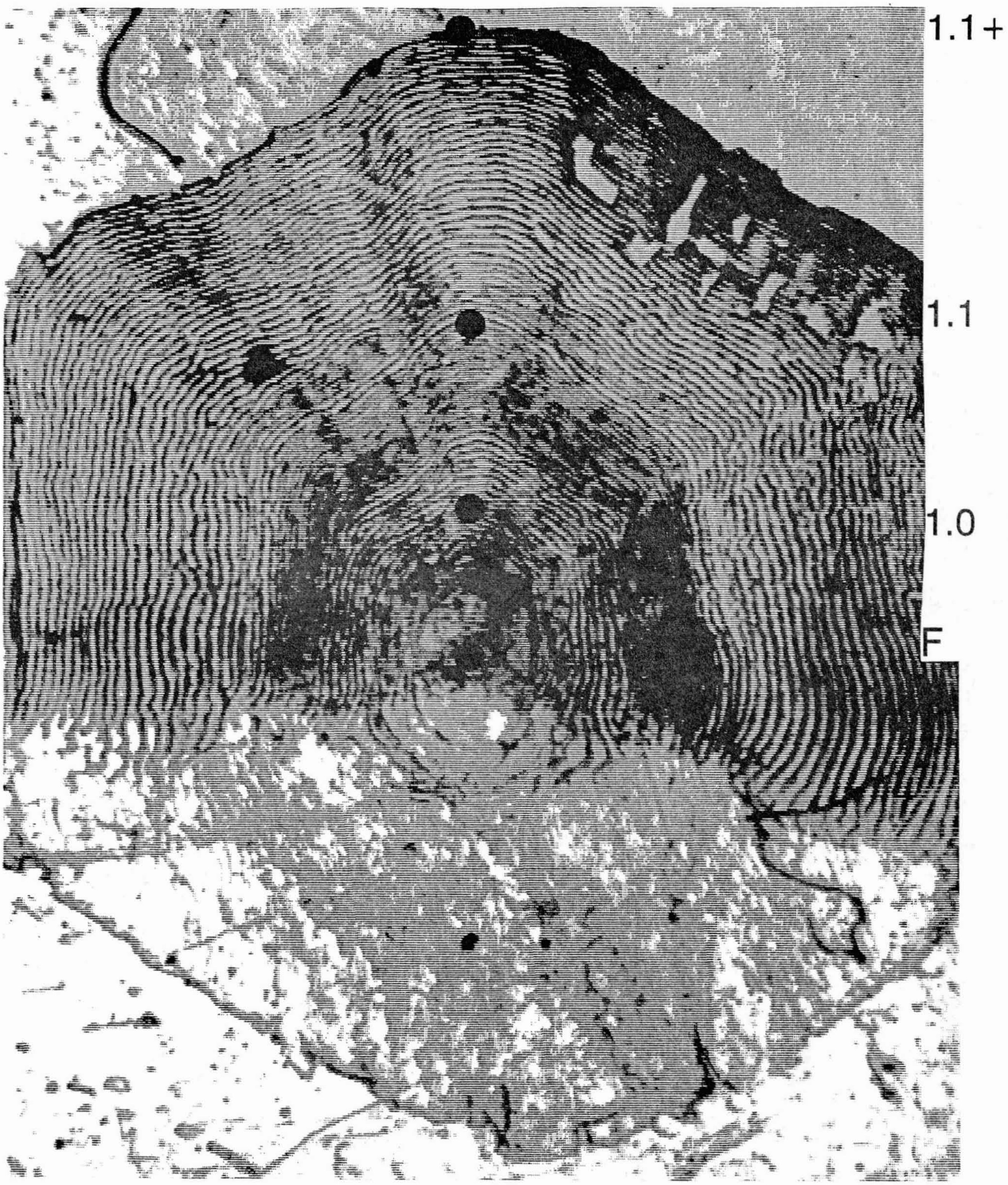


Figure 31b. Sub-division 25, river Mörrum stock

Date of capture 16.12. 1966
Age 1.1+ wild
length 68 cm weight 2.4 kg

Analysis:

	River zone	Sea zone	
Age	1.0	1.1	1.1+
Length (in mm)	0.711	2.15	4.06
Circuli	29	28	37

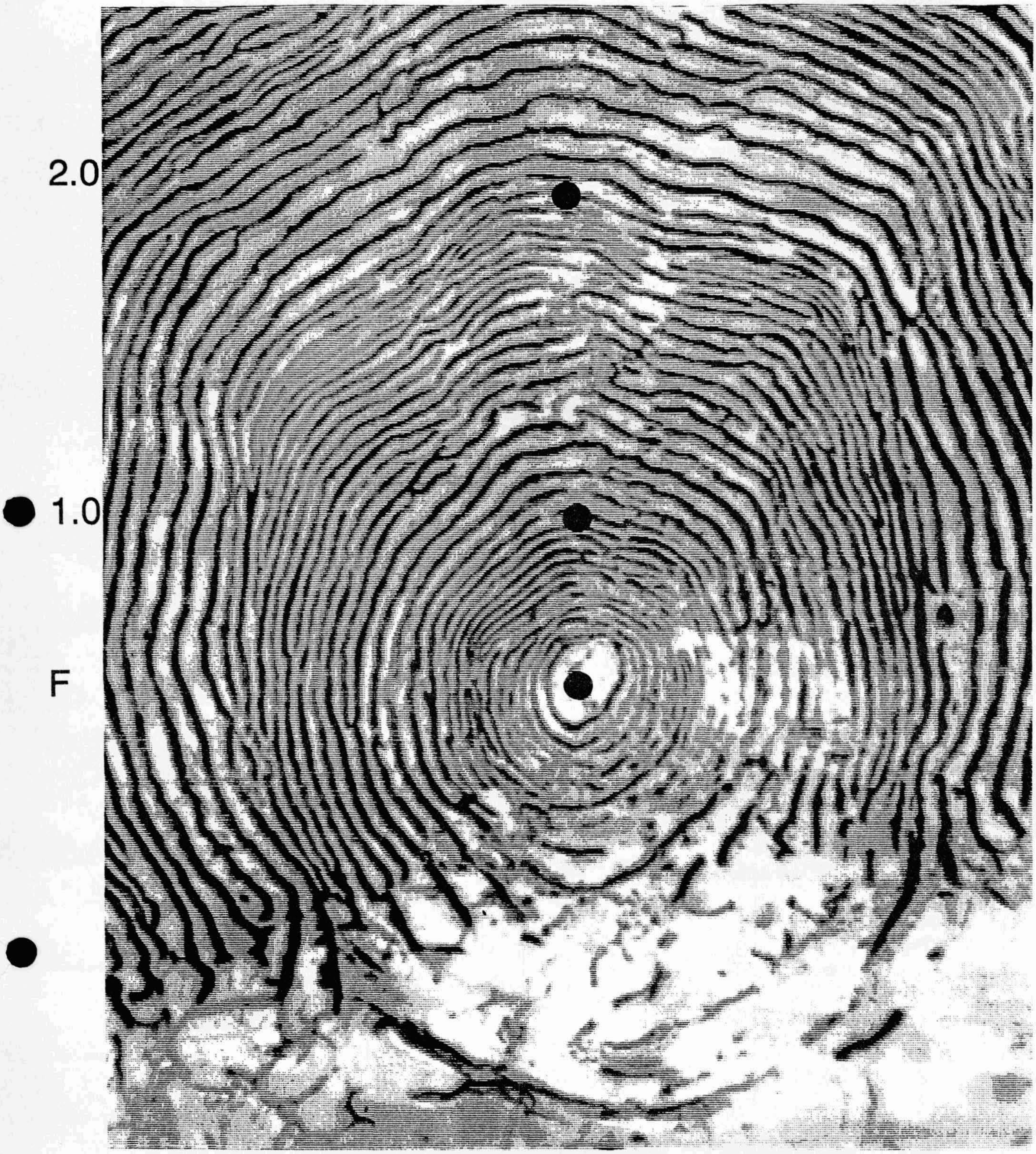


Figure 32a. Sub-division 25, river Mörrum stock

Date of capture 25.08. 1967
Age 2.2+ wild
length 80 cm weight 6.6 kg

Analysis:

	River zone		Sea zone		
Age	1.0	2.0	2.1	2.2	2.2+
Length (in mm)	0.23	0.814	2.15	3.72	4.14
Circuli	8	22	28	25	9

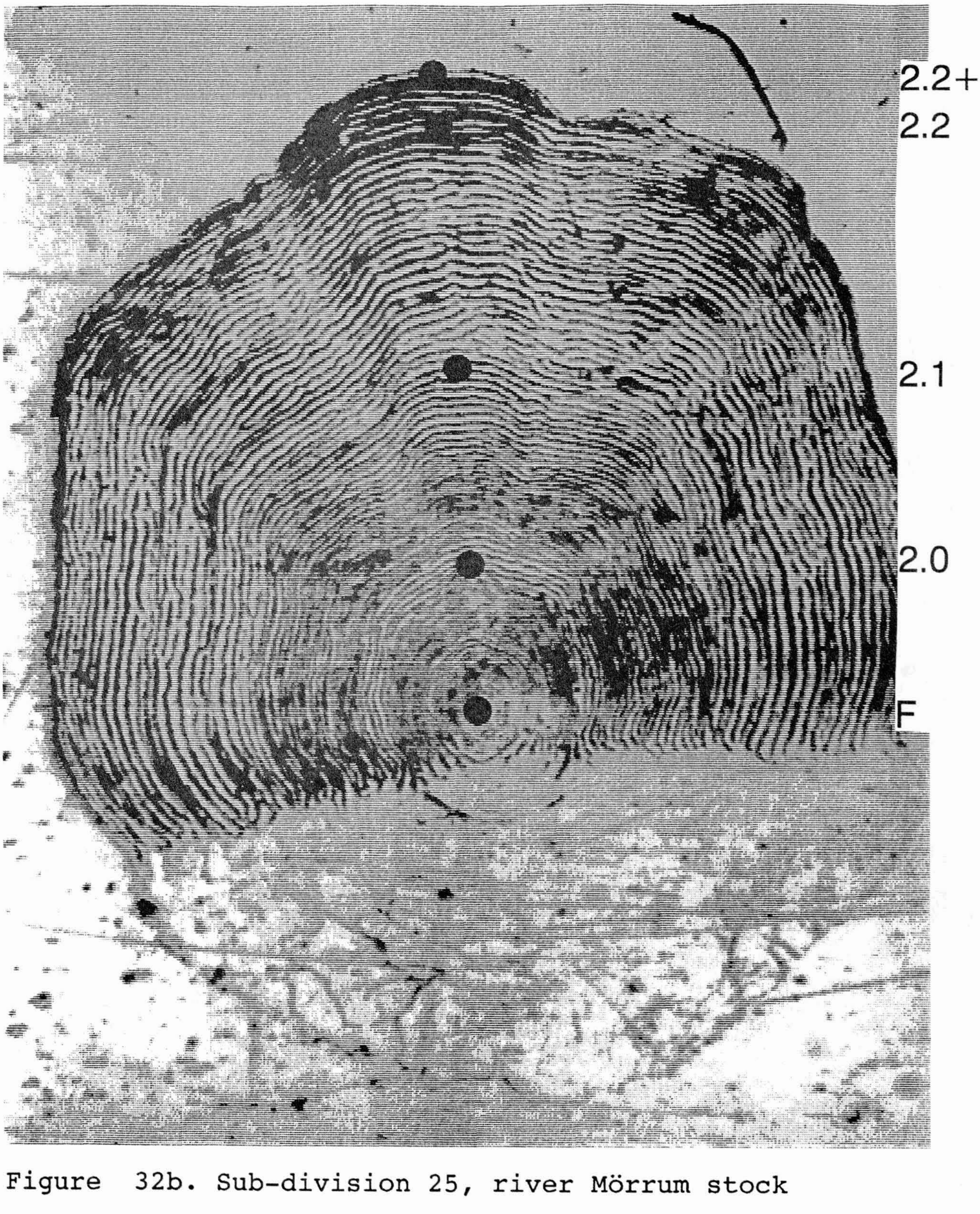


Figure 32b. Sub-division 25, river Mörrum stock

Date of capture 25.08. 1967
Age 2.2+ wild
length 80 cm weight 6.6 kg

Analysis:

	River zone		Sea zone		
Age	1.0	2.0	2.1	2.2	2.2+
Length (in mm)	0.23	0.814	2.15	3.72	4.14
Circuli	8	22	28	25	9

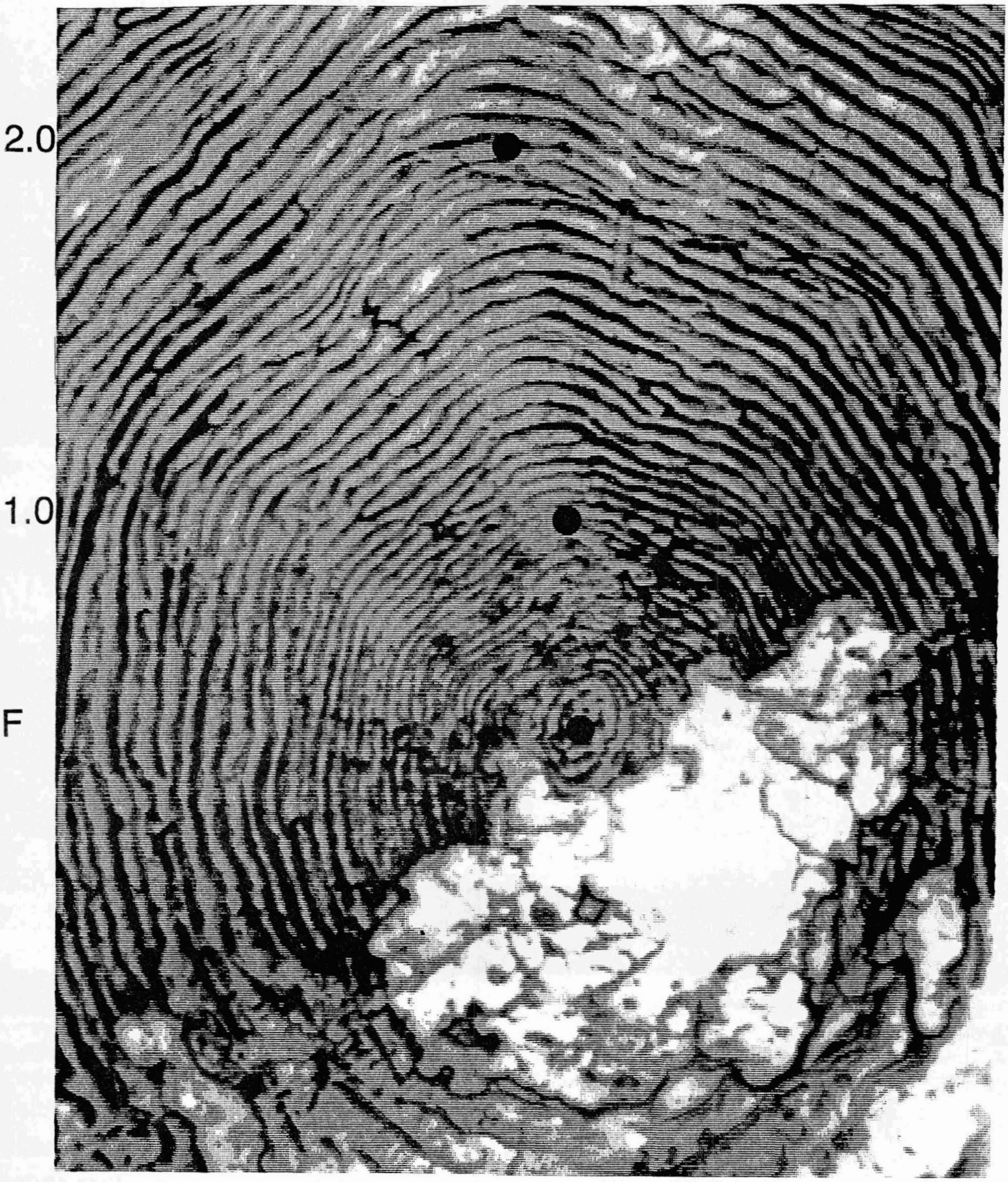


Figure 33a. Sub-division 25, river Mörrum stock

Date of capture 11.09. 1989
Age 2.2+ hatchery-reared
length 91 cm weight 9.7 kg

Analysis:

	River zone		Sea zone		
Age	1.0	2.0	2.1	2.2	2.2+
Length (in mm)	0.416	0.909	2.5	4.5	5.34
Circuli	16	14	29	33	17

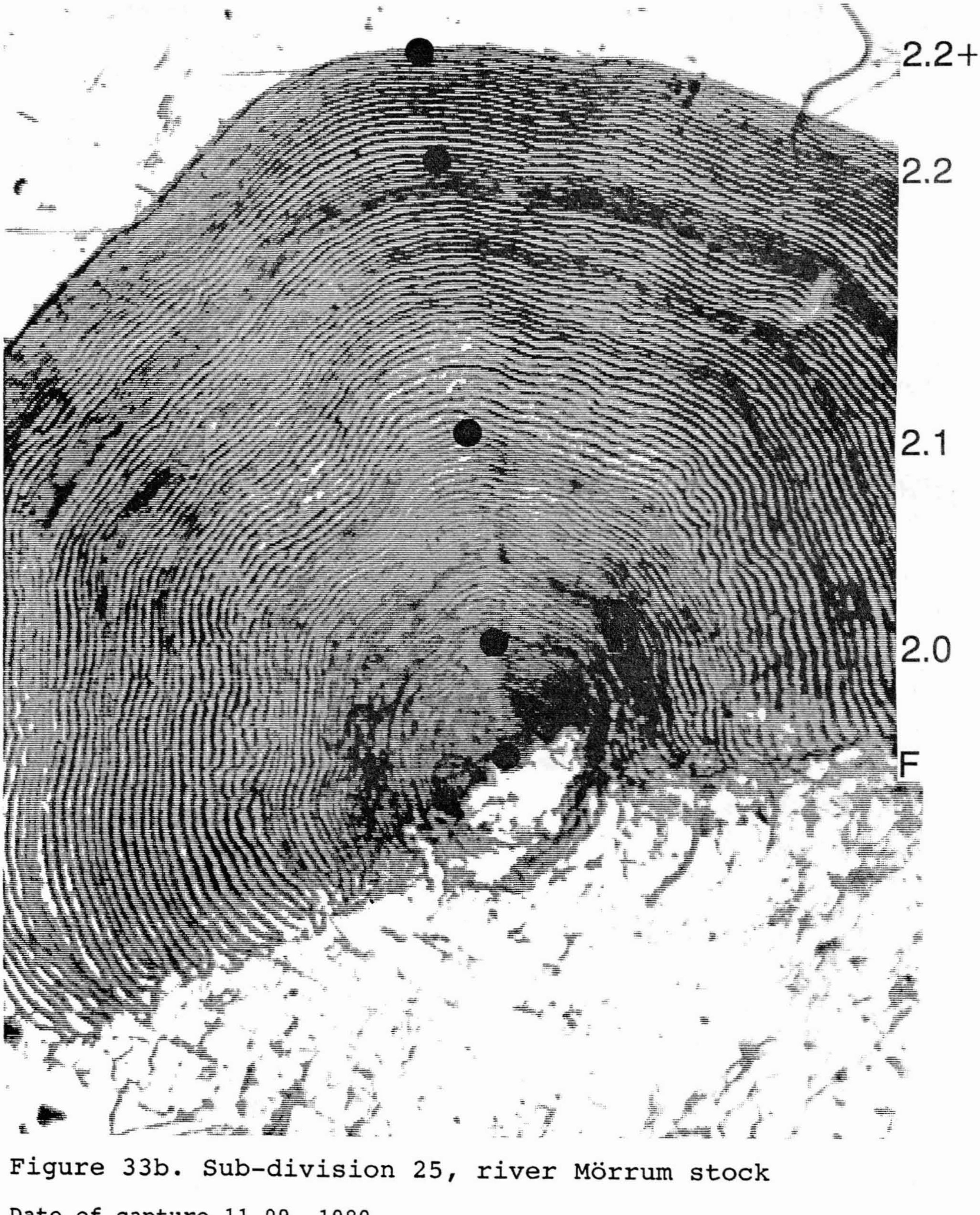


Figure 33b. Sub-division 25, river Mörrum stock

Date of capture 11.09. 1989
Age 2.2+ hatchery-reared
length 91 cm weight 9.7 kg

Analysis:

	River zone		Sea zone		
Age	1.0	2.0	2.1	2.2	2.2+
Length (in mm)	0.416	0.909	2.5	4.5	5.34
Circuli	16	14	29	33	17

Report to the ICES
Workshop on Scale Reading
for Baltic Salmon, Utsjoki,
Finland, 15-17 January 1991

Using of discriminant function to distinguish between the wild and hatchery-reared Baltic Salmon - review of initial Finnish-Polish cooperative works

prepared by Irena Borzęcka
Inland Fisheries Institute, River Fishery Department,
Żabieniec, 05-500 Piaseczno, Poland

In 1988 the attempts of using a linear discriminant function to distinguish between wild and hatchery-reared salmon were undertaken in Polish Inland Fisheries Institute, River Fishery Department with cooperation of Finnish Game and Fisheries Research Institute. The plastic scale impressions were delivered from Finland together with age and fish origin determination. In addition, a routine scale sample of fish without information about their actual origin was available. Those samples were used to establish the scale characters, wich served as a base to derivation of discriminant function. They were as follows:

- width of consecutive annual zones of fish scale in fresh water
- number of circuli in the consecutive annual zones of fish scale in fresh water
- width of the first annual zone of fish scale in the sea
- number of circuli in the first annual zone of fish scale in the sea

- age of fish at the smolt stage.

The discriminant function derived on standard scale samples classified the fish to suitable groups, wild or reared ones, with an accuracy about 90%. This function was then used to separate the wild and reared fish from commercial catches. The result differed, however, from this one obtained by the Finnish investigators, who applied their "visual" method based on appearance of scale fresh water zone in wild and reared salmon. The reasons of this discrepancy could be varied. The routine sample used to verify the discriminant function came from catches in which origin of fish was unknown. The standard samples, on which the function was derived were not randomly taken, only some "easier" scales were selected to them. Finally, the disagreements in scale reading between the Finnish and Polish scale readers might occur. More detailed results of that part of task can be find in paper prepared by Ikonen, Torvi, Borzęcka - submitted to the Anadromous and Catadromous Fish Committee ICES in 1990.

In 1989 the next scale plastic impressions were delivered from Finland. It was a catch sample of fish caught at Simo. Apart from their lenghts /lt/ and weights, other pieces of information about the fish were given: age of fish, widths of the freshwater zone and the first sea zone on the scale and width of the whole scale from focus to the edge. The "visual" scale estimations of fish origin made by skilful Finnish investigator had to be used as "actual" data in this case. This set of information proposed and prepared by the Finnish reasearch workers, followed their sugestion to construct a discriminant function that would be based on quite different characters. This discriminant function assumed following form

$$/1/\ Y = -1{,}20859 - 0{,}01727W_f - 0{,}00057W_{s1} + 0{,}00256W_{sc} + 0{,}68092A - 0{,}05306B$$

$$\bar{Y}_I = 0{,}4146 \qquad \bar{Y}_{II} = -0{,}4146$$

W_f - width of freshwater zone

W_{s1} - width of the first sea zone

W_{sc} - width of the whole scale from focus to the edge

A - age in the fresh water

B - age in the sea

This function separeted the fish from standard samples with an accuracy 98 %. However, in this case, the scale samples became differentiated by themselves: smolt age of salmon "visually"determined as hatchery-reared was equal to two years Meanwhile, 94% of "visually" wild fish consisted of not younger smolts than three years old.
The next function was constructed, therefore, without the ages of fish

$$/2/\ Y = 0{,}46132 - 0{,}02354W_f - 0{,}0032W_{s1} + 0{,}000434W_{sc}$$

$$\bar{Y}_I = 0{,}1046 \qquad \bar{Y}_{II} = -0{,}1046$$

Accordance of this function with the "visual" classification of fish approached 76%. This result seems to be unsatisfied. One can doubt in correctness of some used characters. For example, the width of whole scale is certainly correlated with the age of fish. On the other hand a proportion of regenerated scale, which was proposed by the Finnish partners, should have played an important role. It is a well-known fact, that the scales are more exposed to damage during the farming process, and therefore, their regeneration is more frequent in this fish group. However, it should be agreed how to measure the scale regeneration / width of field of regeneration, frequency of regeneration in the scale sample, a.s.o/.

Finally, the most important condition is to have a series of suitable standard samples at disposal, which might serve both for derivation and verification of discriminant functions. The functions must be derived on scale materials in which the origin of fish is really known, but not determined by another method only. Every new character used to form a modified function should be precisely defined and translated into a "mathematical language", this concerns e.g. a distinctness of annuli.

Those initial results of applying the discriminant analyses to distinguish between the wild and hatchery-reared salmon should yet be discussed in details and continued as a hopful, rational approach to the problem.

Literature

Antere I. and Ikonen E. 1983. A method of distinguishing wild salmon from those originating from fish farms on the basis of scale structure. ICES, C.M. 1983/M:26

Borzęcka I. 1988. Preliminary information on the test of discrimination between the wild and hatchery-reared salmon by discriminant function. ICES,C.M. 1988/Assess:19 Appendix 1

Borzęcka I., Ikonen E., Torvi I., 1990. Attempts of using the discriminant function based on scale structure of Baltic Salmon to distinguish between the wild and hatchery-reared smolts

Appendix 2.

Working document
to the ICES Workshop
on Scale Reading for
Baltic Salmon, Utsjoki,
Finland, 15-17 January
1991

A methodical problem of ageing salmon and sea trout in the spawning season

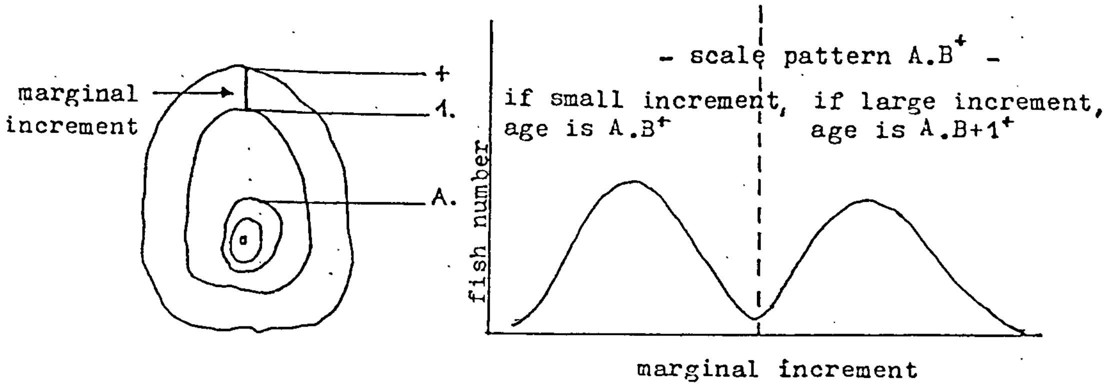
by

Irena Borzęcka
Inland Fisheries Institute,
River Fishery Department,
Żabieniec, 05-500 Piaseczno, Poland

Annotations to Figure 1

This methodical problem refers to classical interpretation of scale "marginal increment" of sea trout migrants entering river in spring and summer /Sych 1967, 1970/. Distance between the last annual ring and scale margin has been called the marginal increment, which may also be expressed by number of circuli /CK/.

The distribution of marginal increments is considered to be bimodal in sample of spring-summer fish. Some of them had not yet a small this year's growth before entering. Large marginal increments correspond to the body growth of previous calendar year in this part of fish, and one must be added to the scale pattern when ageing:



However, those fish can meet some late autumnal migrants already having a large marginal increment of this year during the spawning season. The fish age is equal to scale pattern against the increment division in this case. Such examples taken from spawning grounds in river Drwęca, the Lower Vistula tributary, are shown in Figure 1. Scale impressions related to these facts may be demonstrated and discussed at the Meeting.

L i t e r a t u r e

Sych R.,1967. Age determination of sea trout during formation of annual rings /Polish, with English and Russian Summary/. Roczniki Nauk Rolniczych,90-H-2:305-325.

Sych R.,1970. Some considerations on the theory of age determination of fish from their scales - finding proofs of reliability.
EIFAC Technical Paper N13.

Figure 1

An example of difficulty in ageing of sea trout spawners in the Drwęca River. Scale sampled in October 1988 and 1989, before spawning. The marginal increment of scales, presented as number of circuli /CK/, can overlap in both ages of the same scale pattern: see /+/ in ages A.1$^+$ and A.2$^+$, N-number of fish