Scale reading atlas for Atlantic salmon in the Barents Sea area

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Project report from the *Kolarctic salmon* project

Kolarctic ENPI CBC project *"Trilateral cooperation on our common resource; the Atlantic salmon in the Barents region* – Kolarctic salmon (KO197)".

Scientists, managers and commercial fishermen from Northern Norway, Finland and North-West Russia, White Sea area combined their efforts in the *Kolarctic salmon* project (2011-2013), with the aim of providing a better knowledge-base for the countries' management of the common Atlantic salmon stocks. Within this joint and unique effort bio-specimen were sampled along the North-Norwegian coast and in Russian Barents and White Seas generating the most comprehensive ecological and genetic datasets for Atlantic salmon.

The action was funded by the European Union, Kolarctic ENPI CBC programme and national funding from the participating countries and partners, 2011-2013.

You can read more about the project and its results:
https://prosjekt.fylkesmannen.no/Kolarcticsalmon/

Cover page photos:
Photo on the left - The biggest female previous spawned salmon (21.5 kg) known was caught 06.08.2008 from the River Tana/Norway (Photo: Erik Andreassen)
Photo on the right - Scale image from the same female salmon (juvenile age 4 years, sea-age 4S1S1+; total age 12 years) (Photo: Jorma Kuusela and Jari Haantie)

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1. Introduction

Atlantic salmon (*Salmo salar* L.) are known from their migratory behaviour and from their precise homing as mature fish to return to their natal river they left as smolts or as post spawners (kelts). Atlantic salmon are iteroparous; they have the potential to spawn repeatedly.Each river has its own salmon stock or stocks. This geographical isolation results in the subdivision of the species into a great number of discrete breeding subunits or stocks. In the Barents Sea area in Northern Norway, Northern Finland and in North-West Russia there are some hundreds of salmon stocks, which are genetically different from each other (Vähä *et al*. 2014). Also in the large boundary river Teno/Tana, between Norway and Finland, there are more than 30 genetically separate salmon stocks (Vähä *et al.* 2016 in press)

Environmental conditions in rivers in Barents Sea area are differing within the large area. These environmental factors are governing the time, which juvenile salmon needs before it reaches the smolt migration age and size.

The Atlantic salmon is a classic anadromous fish. An anadromous fish is one which migrates from the sea into the rivers to spawn. Juveniles of salmon are living in Barents Sea rivers their first two to eight years. Growth is slow in the freshwater environment but differs between rivers. In the beginning of their third to ninth year juveniles are migrating as smolts to the sea. After migrating as smolts downstream to sea their growth rate increases due to physiological changes and a greater abundance of food. At sea salmon is feeding from one to five years before homing migration. In Barents Sea area Atlantic salmon normally enters the rivers between the middle of May and end of August. Ice cover in the rivers in April and early May prevents or delays salmon to migrate into their home rivers although some salmon have already ascended to the coastal areas and fjords. Depending on the time of entry to a river, salmon are also classified as early-run or late-run fish. Usually the largest and oldest salmon are ascending first into the rivers followed by the fish which have been only one year at sea. Multiple spawning salmon is migrating into their home rivers also very early in the summer. Atlantic salmon normally survives the initial stress of at least one spawning. They are then known as kelts. These fish return to the sea, some immediately after the spawning, and others the following spring. By this time they have been in fresh water without feeding from o few months to almost one year. After reconditioning at sea, some will return to freshwater to spawn at least one more time. Others may spawn three or four times in subsequent seasons.

Salmon smolts are leaving the rivers during quite short time period which is called smolt window. This period is in Barents Sea rivers from the middle of June to the middle of July. There are, however, annual variations in all the rivers and between the rivers. Water temperature is affecting the start of the smolt migration as well as its duration. Smolts are migrating usually fast from the fjords out to open sea. The smolt migration time in early summer is affecting into the growth of salmon at sea during the first summer.

At sea salmon stocks are intermingling on the feeding grounds. Salmon from Barents Sea rivers have their growing areas within large area covering from Faroe Islands to east coast of Greenland and in Northern Norwegian Sea. Salmon spend 1 to 5 years in the sea before returning to the native river for spawning.

The use of salmon scales as a means to the study of the age and other biological conditions of the fish is due to establish the fact that periodic growth takes place in the salmon scales, and that groups of rings are formed in each year, and that it is possible by counting the number of these to ascertain the age of nearly every individual and to form an opinion regarding its life history.

Atlantic salmon scales have been used in the conventional approaches to age salmon (Malloch, 1912; Menzies, 1912; Calderwood, 1913; Nall, 1926; Menzies, 1927; Crichton, 1935; van Someren, 1937; Jones 1949; Anon. 1984; Shearer 1992; ICES 2011). The use of an image analysis microsystem with specially developed software have enabled scale image processing outline extraction and computation of features (Pontual & Prouzet, 1987; Pontual & Prouzet, 1988; ICES 2011). The image of salmon scales has been used in discriminant analysis to separate salmon stocks in mix stock fishery (Reddin, 1986).

Within the Kolarctic salmon research project in the years 2011-2012 it was collected juvenile salmon from all salmon rivers in Northern Norway for growth analysis as well as for baseline to be used in genetic analysis. In Kolarctic salmon project it was also collected scale material from the coastal salmon fishery in Northern Norway to analyse the genetic origin of salmon as well as smolt ages, adult ages and growth of fishes. Salmon scale data (life history of fishes) combined into the genetic analysis is contributing to a better understanding of the behavioural processes and stock dynamics that govern the run timing of various life-history stages of Atlantic salmon. This is fundamental to the successful conservation and management of wild Atlantic salmon stocks especially in outermost coastal areas as well as in fjords with high rates of exploitation towards mixed stocks.

To describe salmon ecology, to evaluate the reported salmon catch composition in relation to time and location and to describe the stock specific migration patterns in the Kolarctic salmon project it was arranged collection of the basic information on the salmon catches like scales for age determination, lengths and weights, sex and number of salmon lice.

Recently there have been produced recommendations which are including digital scale reading, detailing of characteristics and reference points, itemizing scale marks and issues in their separation (Antere & Ikonen, 1983; Lund *et al*. 1989; Lund & Hansen, 1991; Anon. 1991; Friedland *et al*. 1994; ICES 2011). Through these international recommendations it has been reached consensus on how the Atlantic salmon scale reading should happen and how the various life histories from scales should be interpreted. In ICES (2011) there has been presented examples from Atlantic salmon scales collected in rivers within a large area around North Atlantic. These scale features are including also information from the interpretation of the growth of salmon in fresh water and at sea.

This Atlantic salmon scale reading report was specific item mentioned in the Kolarctic salmon project. Scale images in this report are covering the entire life history of salmon from juvenile phase to maiden salmon, from kelt to previous spawners and from smolt released fish to escaped salmon. 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 consistently in interpretation be achieved. Earlier scale reading reports and articles from the growth observed in salmon scales are describing the methods for measurements from the scales and for identifying the various life history types of salmon. In this salmon scale reading report we present comprehensive figures from salmon scales as an advice to age salmon correctly originating from Barents Sea rivers.

2. Scale collection

Shearer (1992) and ICES (2011) recommended that scales should be collected from the left-hand side of the fish, 3–6 rows above the lateral line, on a diagonal between the anterior edge of the anal fin and the posterior edge of the dorsal fin, with approximately 20 scales placed into an appropriately labelled scale collection envelope. In the River Teno/Tana (since the year 1972) and in the Kolarctic salmon project (in the years 2011-2012) salmon scales have sampled from the location between the adipose fin and lateral line , close to lateral line, which is the area locating a little backwards from the above mentioned and internationally recommended area. Advantages to use that location used in Kolarctic salmon project are that this is the area where initial scale development in juveniles occurs, scale loss over the lifetime of the fish is limited and consequently occurrence of replacement scales is less and these scales are more coherent in denoting fish that are multiple spawning (ICES 2011).

Martynov (1983) showed that the further a scale is located from the lateral line, the later it is formed on the body, the lesser is 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 on the lateral line. In those cases when complete scale coverage takes 2 years to complete, the first annulus is missing on the scales distant from the lateral line rows. However, scales sampled from the rows 1–3 above the lateral line, have been found to include unacceptably high proportion of unreadable (regenerated) scales although they have complete juvenile ages. There are many other reports indicating that the first annulus is lacking from juvenile salmon scales (Dannevik 1928; Power 1969). Jensen and Johnsen (1982) concluded that the first annulus in juvenile salmon scales from cold waters consists of a few narrow circuli close to the center of the scale, or is missing. Therefore the site to collect scales from adult salmon should be quite close to the lateral line and site should situate close the area between adipose fin and lateral line where also the proportions of regenerated scales is low. Scales in the figures 1–3 are collected from 4–5 different sites in salmon. Especially figures 2 and 3 are indicating that scales located further from the lateral line are smaller than scales located between adipose fin and lateral line.

Photo 1. Scale collection.
Photo: Eero Niemelä

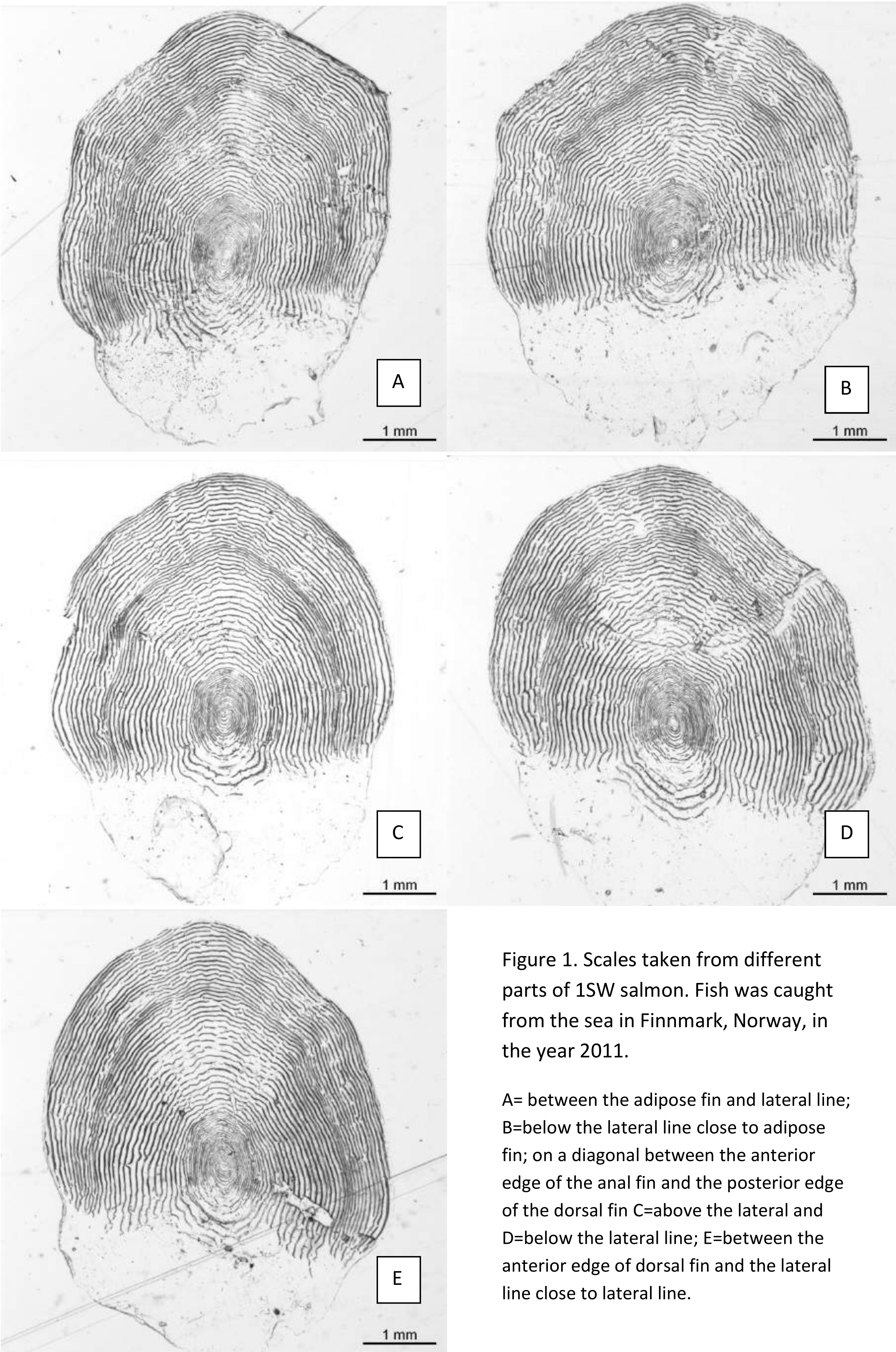


Figure 1. Scales taken from different parts of 1SW salmon. Fish was caught from the sea in Finnmark, Norway, in the year 2011.

A= between the adipose fin and lateral line; B=below the lateral line close to adipose fin; on a diagonal between the anterior edge of the anal fin and the posterior edge of the dorsal fin C=above the lateral and D=below the lateral line; E=between the anterior edge of dorsal fin and the lateral line close to lateral line.

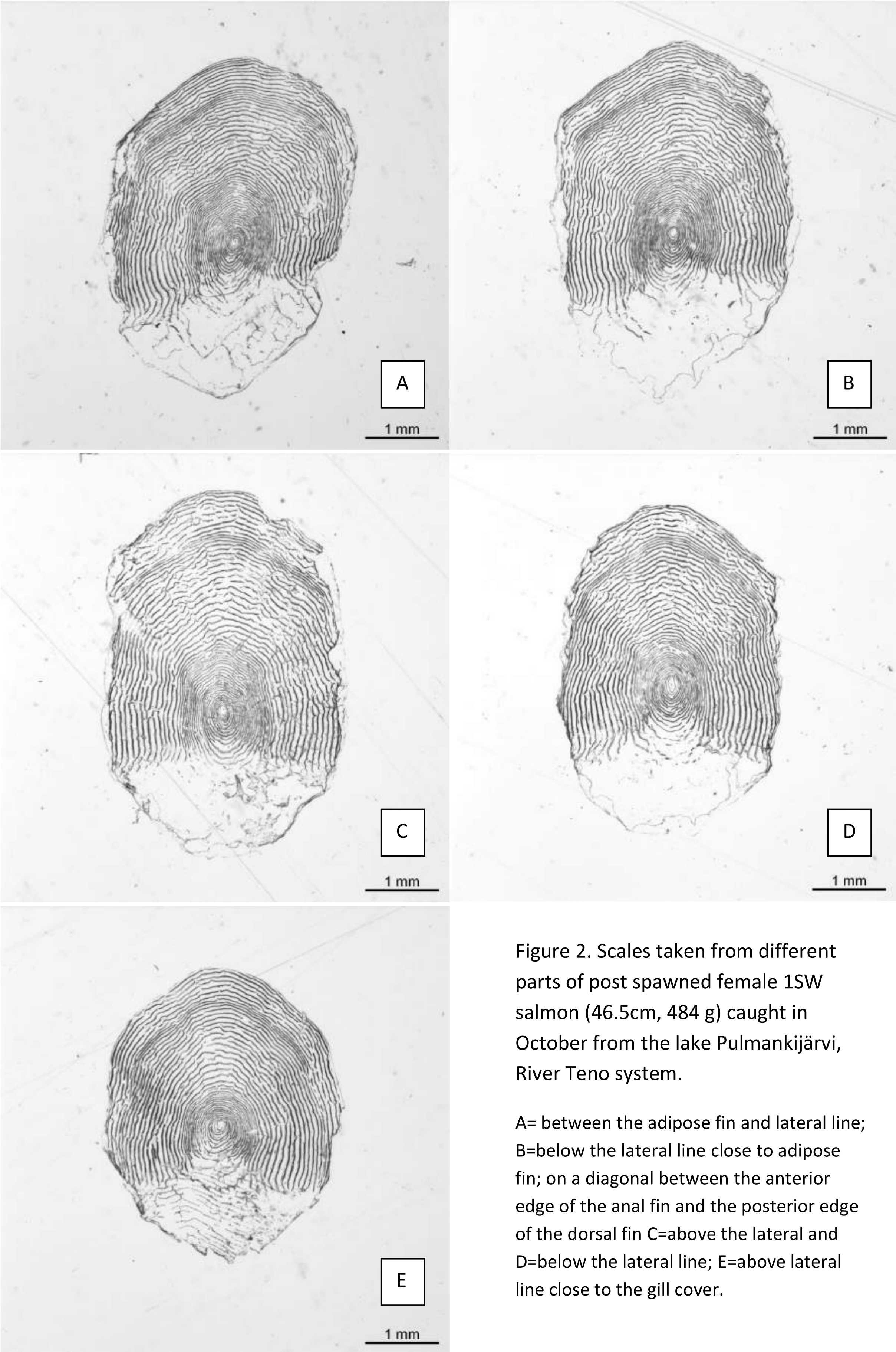


Figure 2. Scales taken from different parts of post spawned female 1SW salmon (46.5cm, 484 g) caught in October from the lake Pulmankijärvi, River Teno system.

A= between the adipose fin and lateral line; B=below the lateral line close to adipose fin; on a diagonal between the anterior edge of the anal fin and the posterior edge of the dorsal fin C=above the lateral and D=below the lateral line; E=above lateral line close to the gill cover.

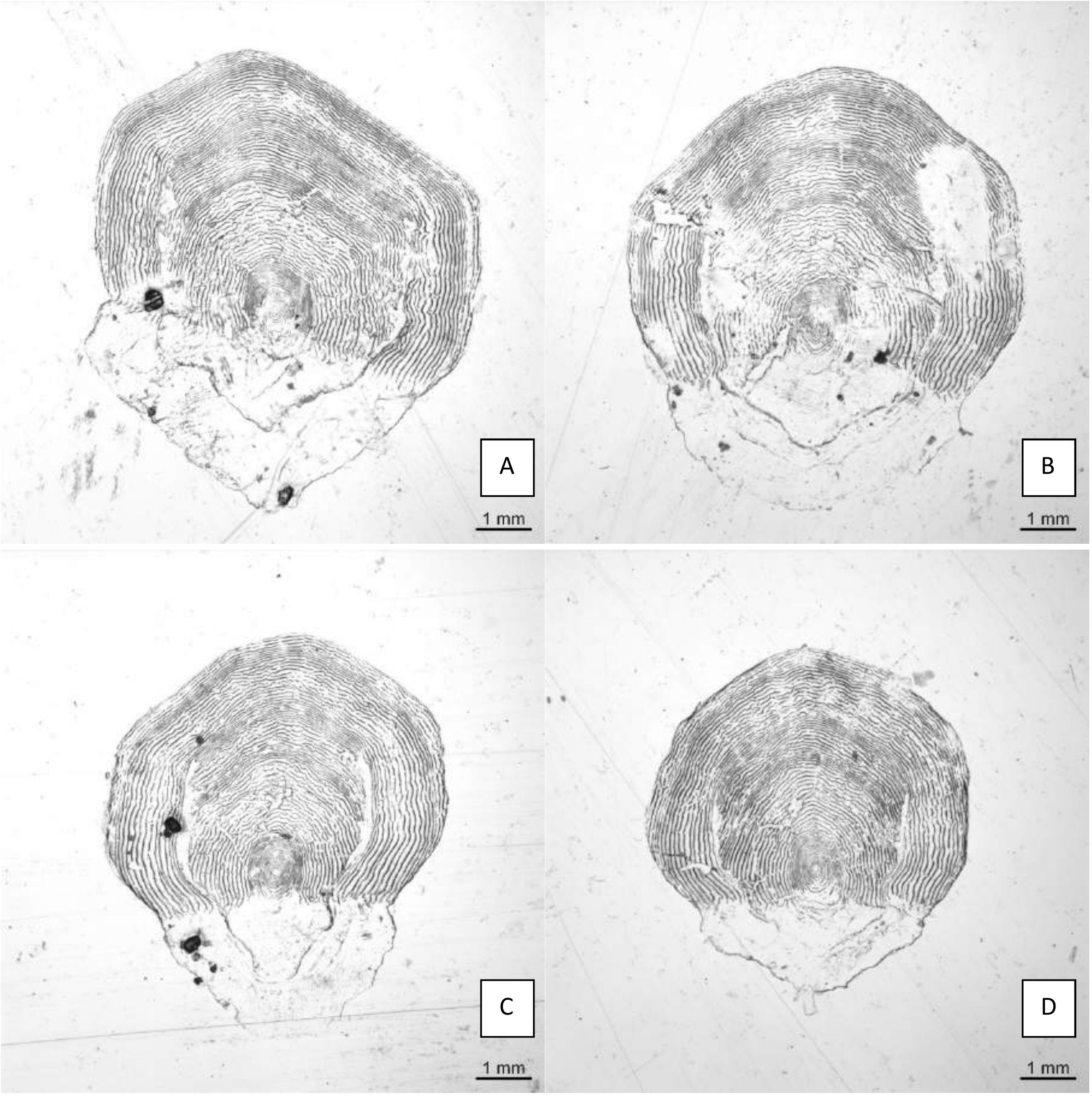


Figure 3. Scales taken from different parts of previous spawning salmon (sea-age 1S1+) (85.7 cm, 5900 g) caught in July in the River Teno.

A= between the adipose fin and lateral line; B=below the lateral line close to adipose fin; on a diagonal between the anterior edge of the anal fin and the posterior edge of the dorsal fin C=above the lateral and D=below the lateral line

3. Scales collected throughout the summer

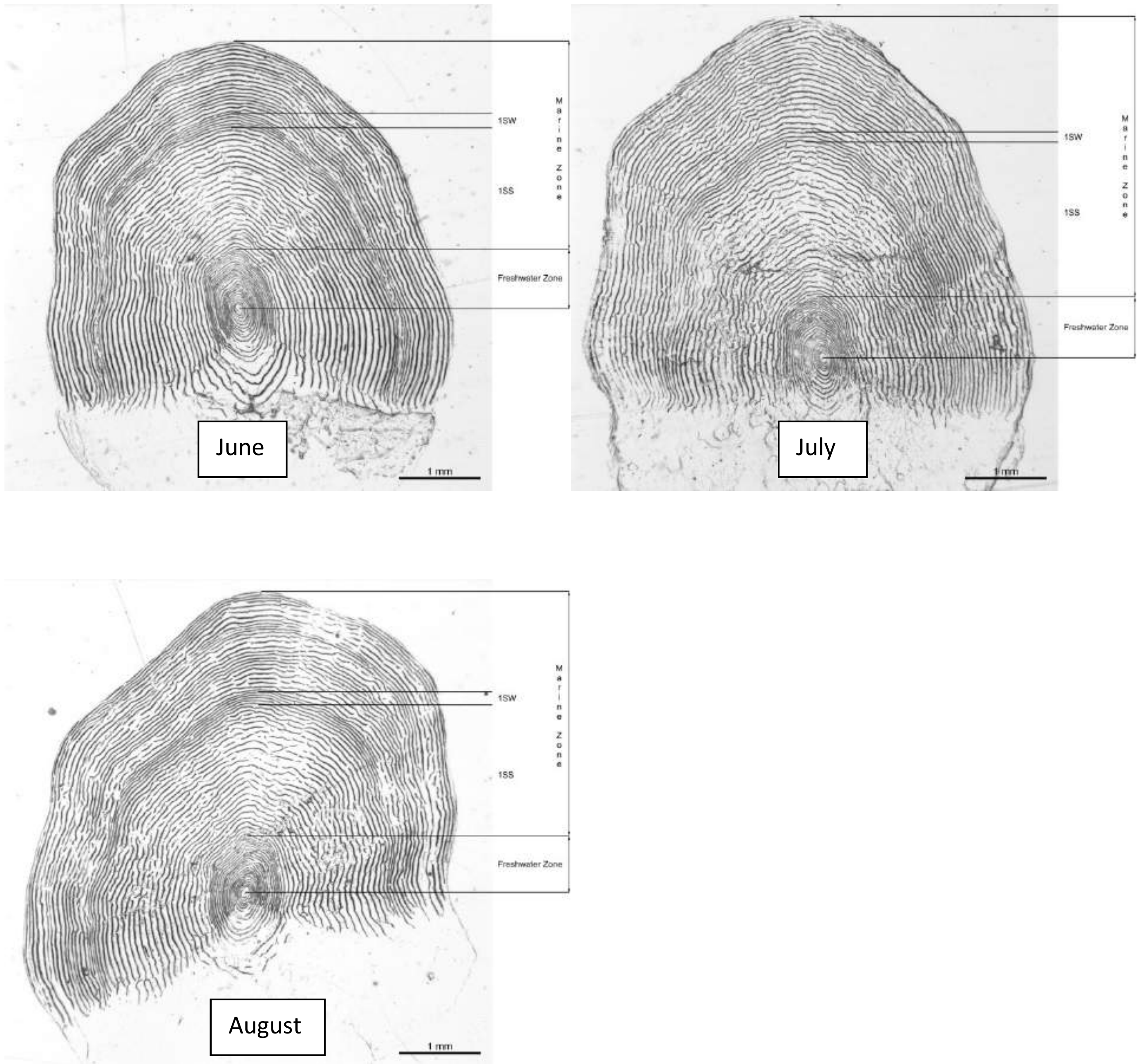


Figure 4. 1SW salmon from the River Målselva stock caught at sea.

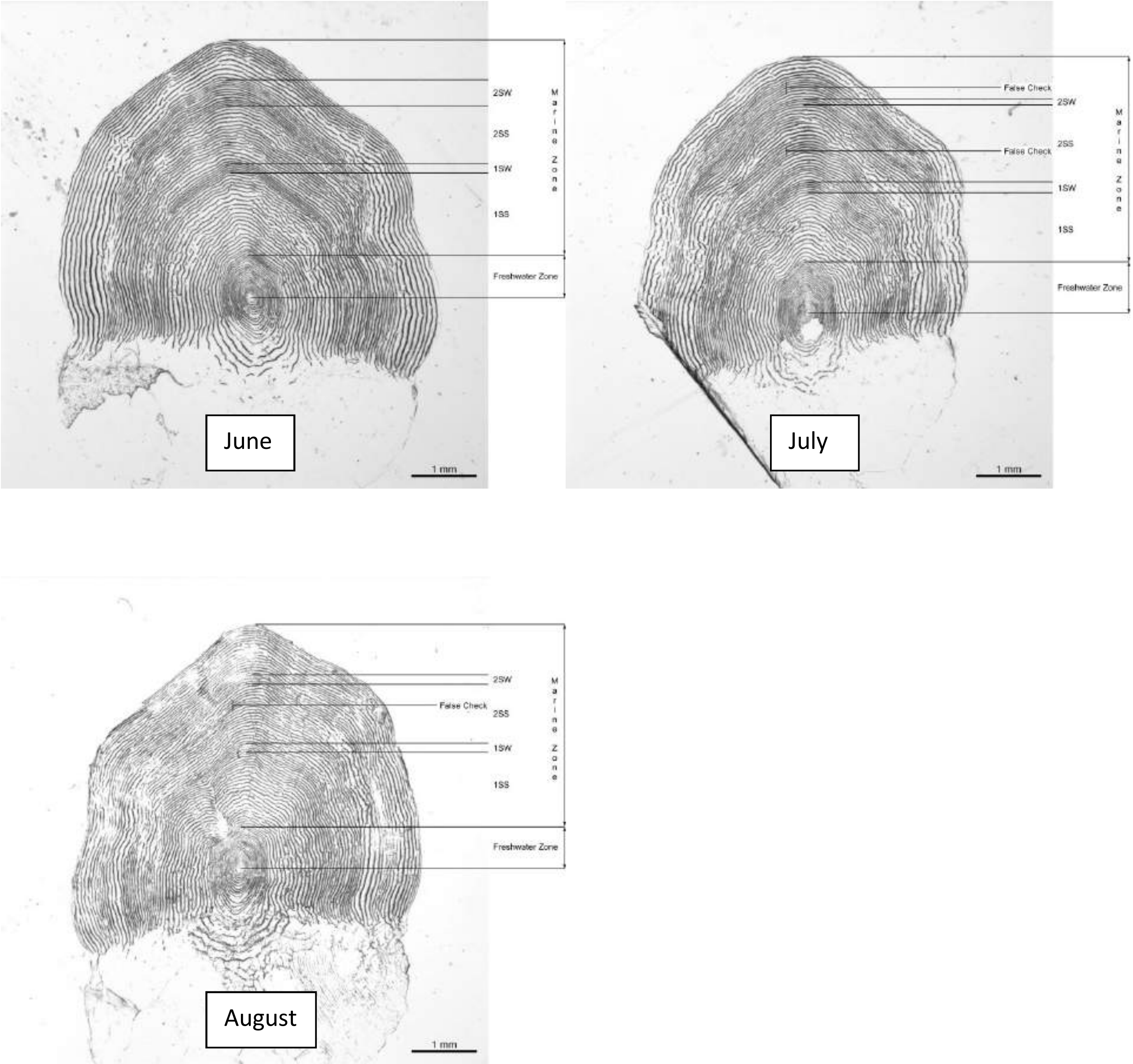


Figure 5. 2SW salmon from the Målselva stock caught at sea.

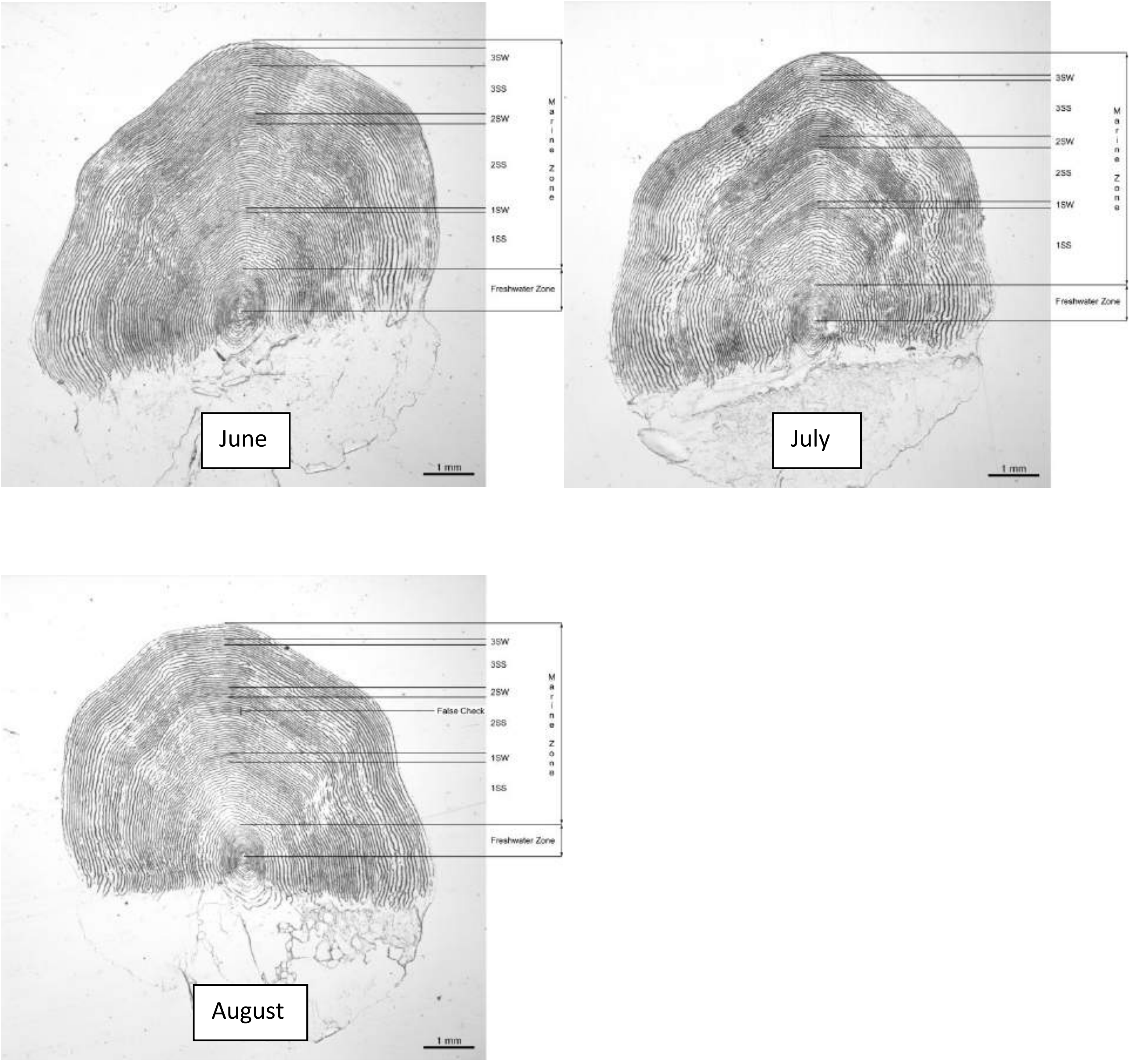


Figure 6. 3SW salmon from the Målselva stock caught at sea.

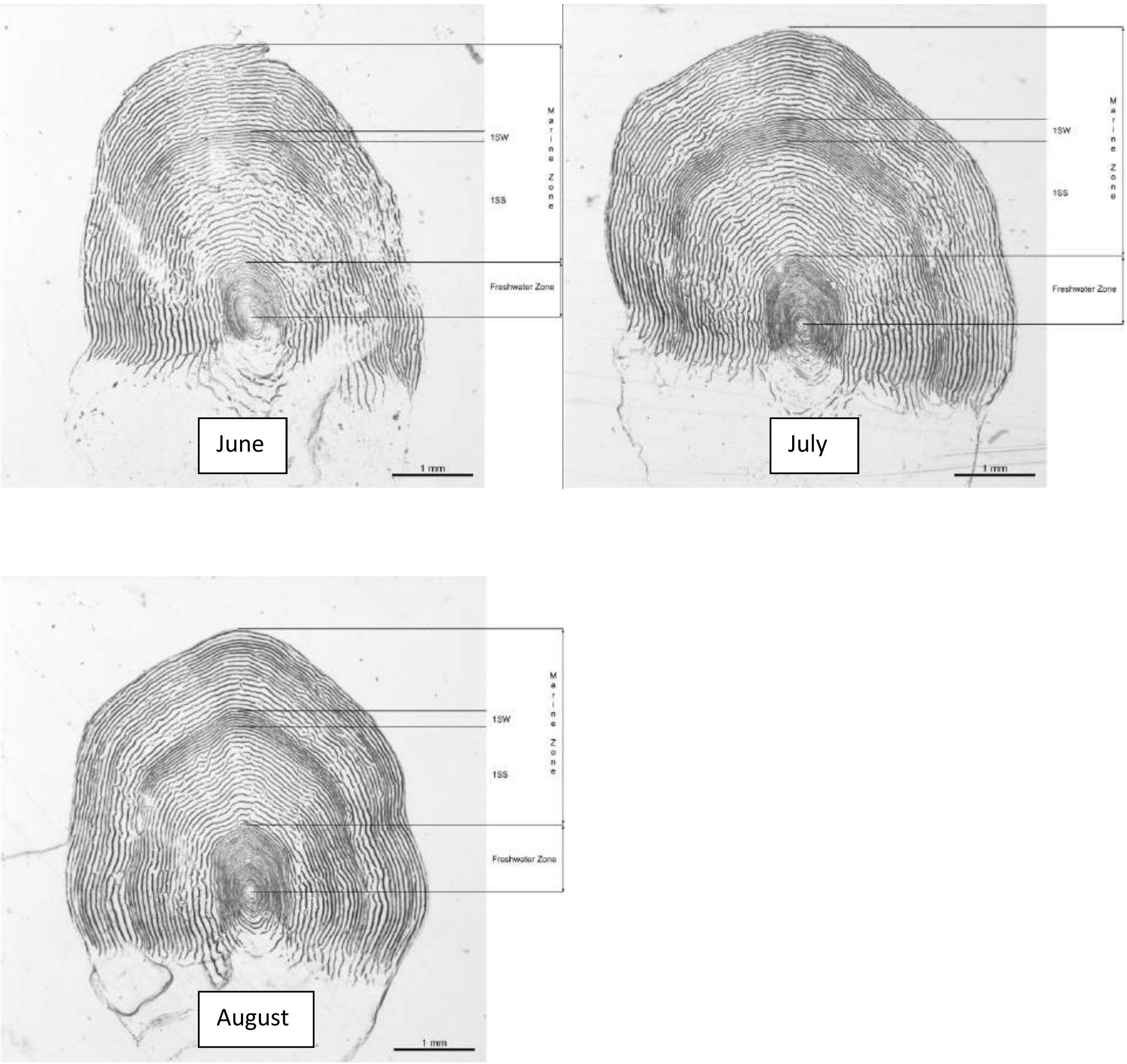


Figure 7. 1SW salmon from the River Alta stock caught at sea.

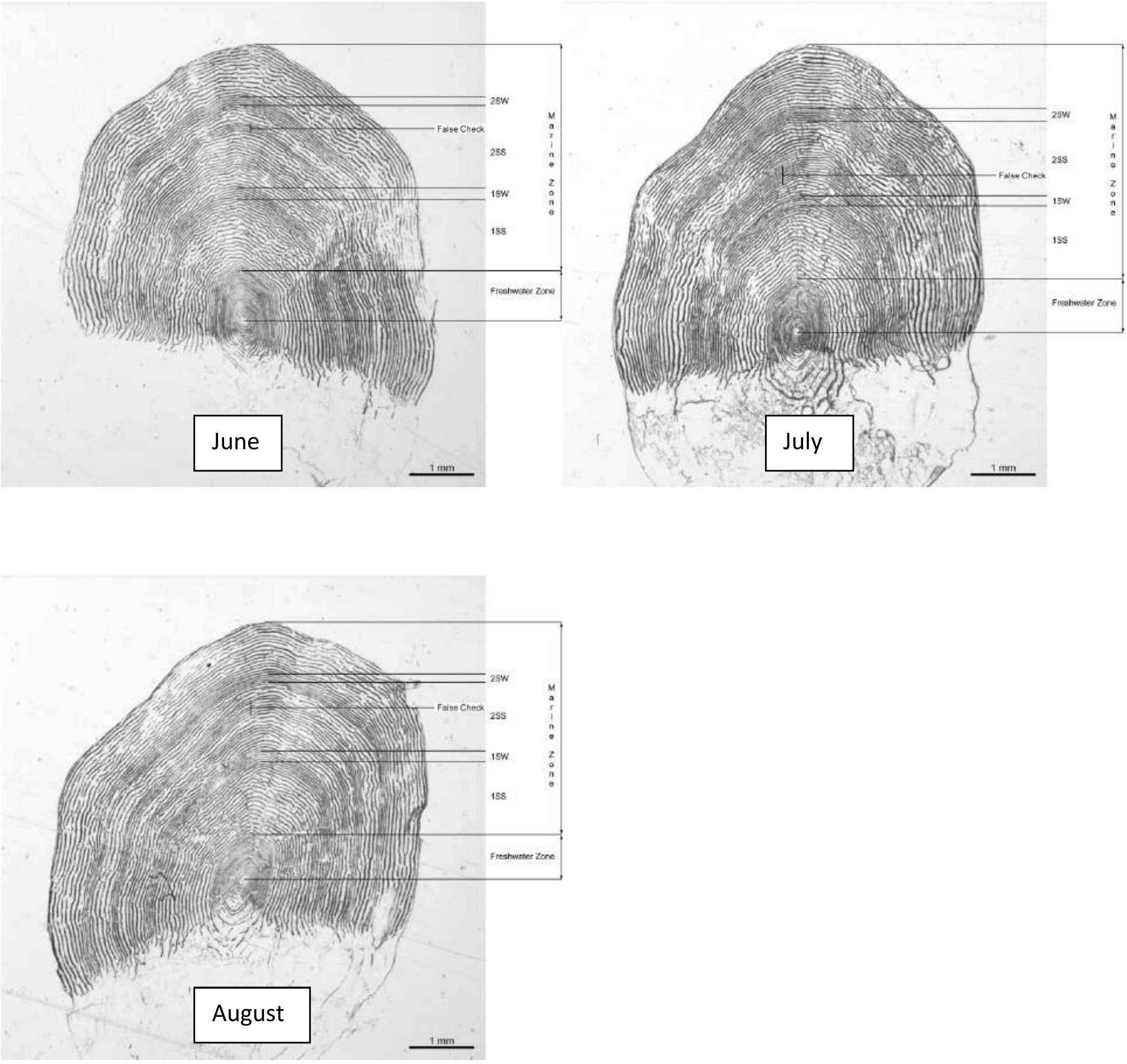


Figure 8. 2SW salmon from the River Alta stock caught at sea.

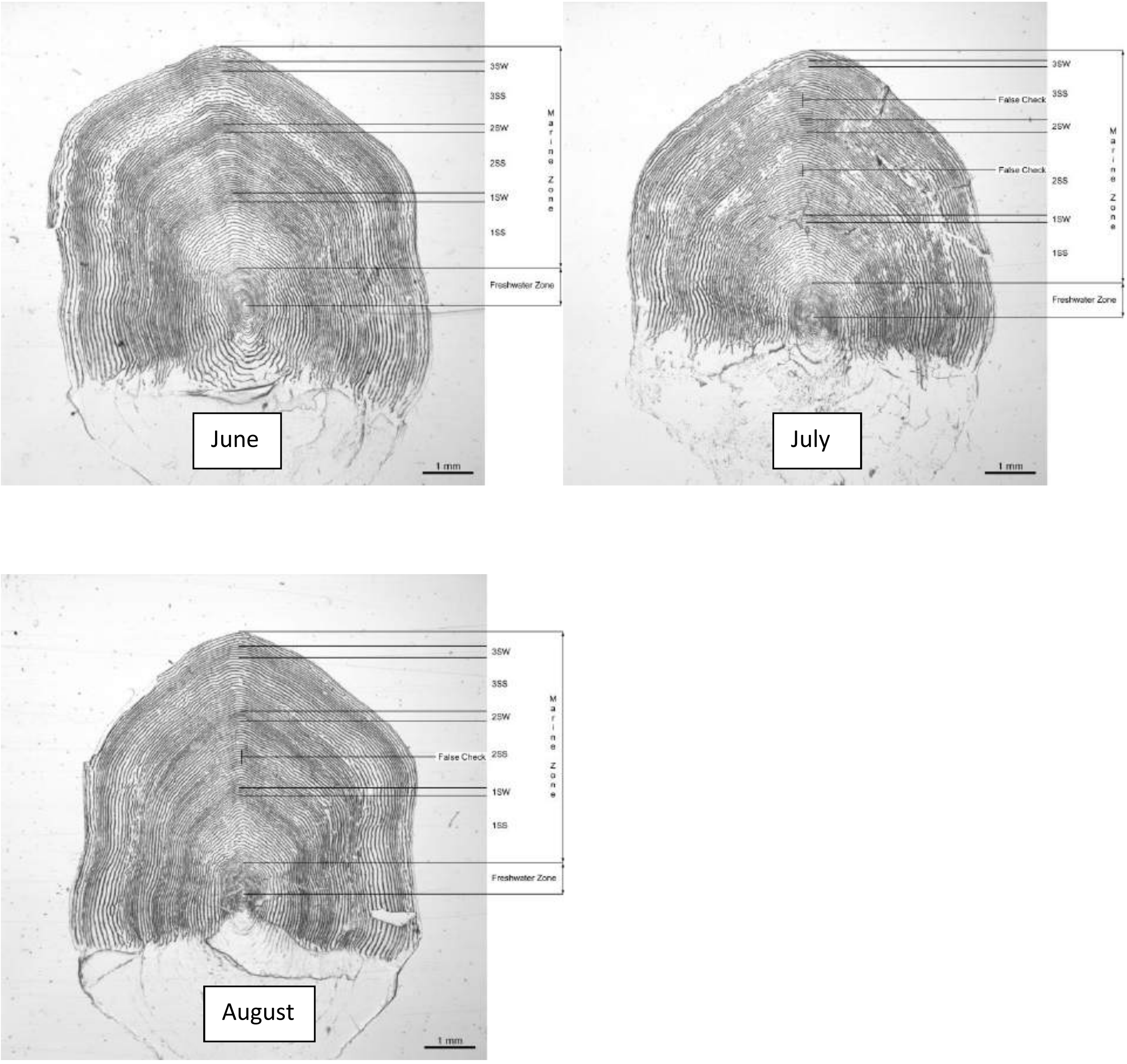


Figure 9. 3SW salmon from the River Alta stock caught at sea.

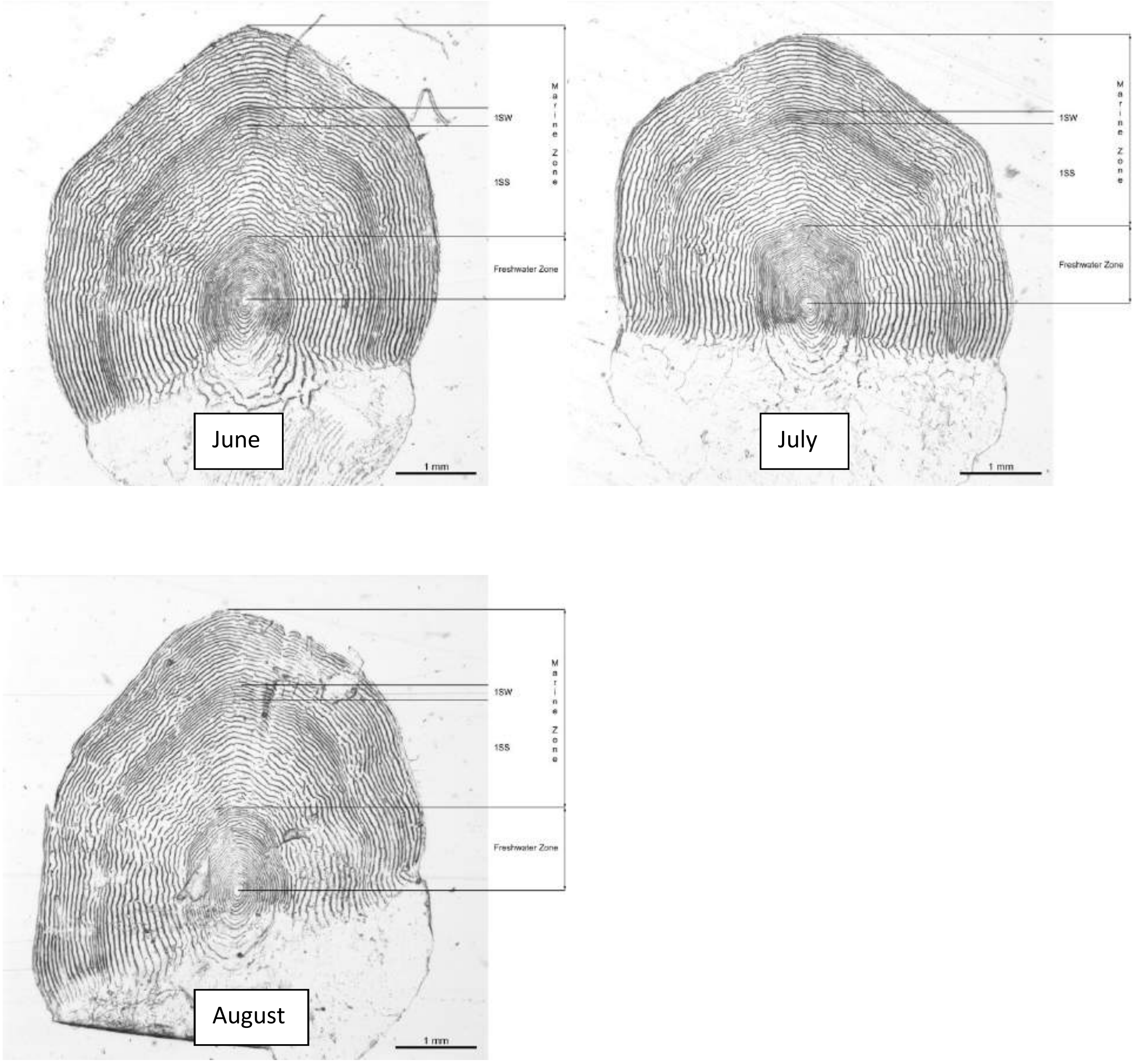


Figure 10. Male 1SW salmon from the river Teno/Tana mainstream stock caught at sea.

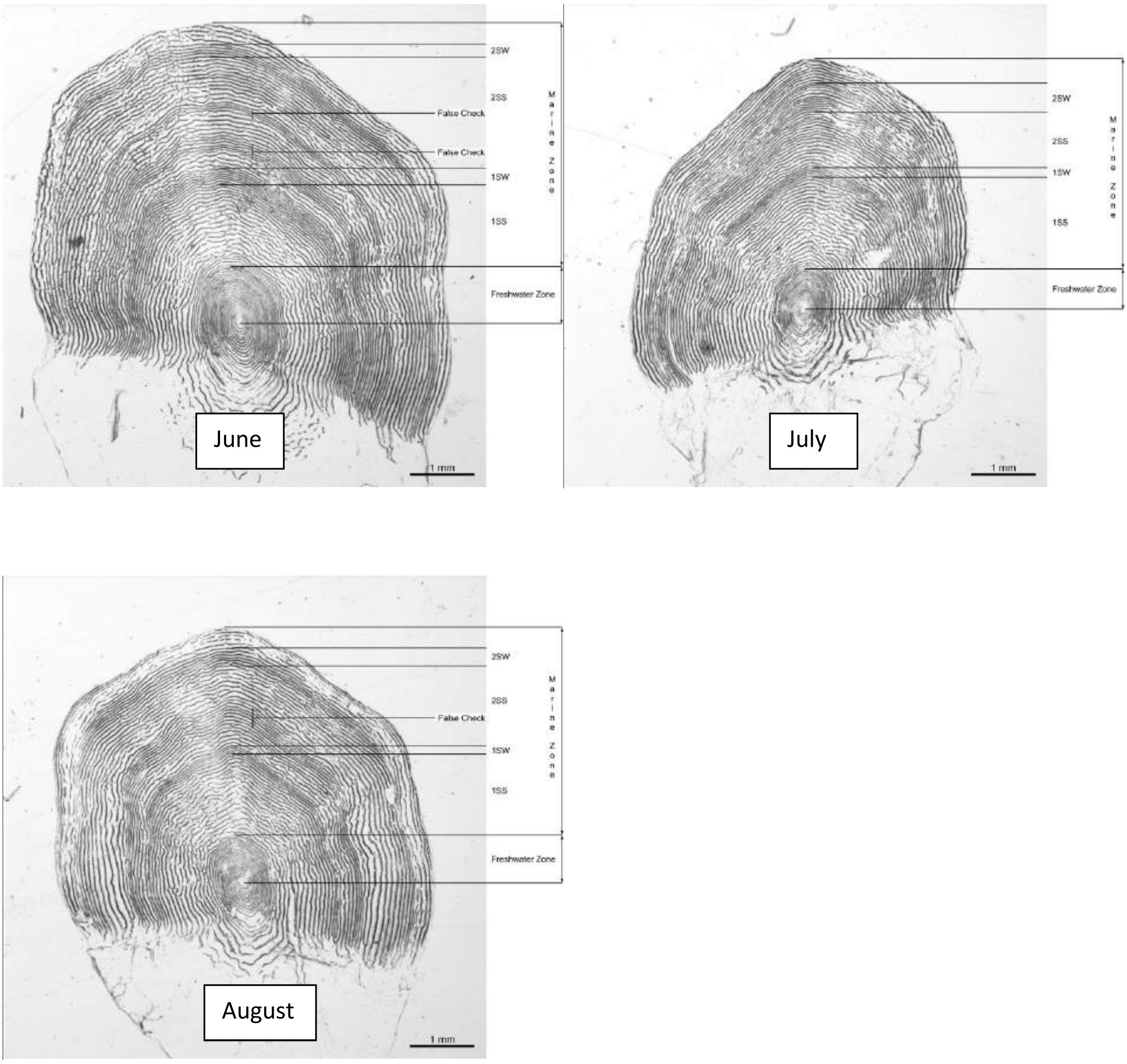


Figure 11. Male 2SW salmon from the River Teno/Tana mainstream stock caught at sea.

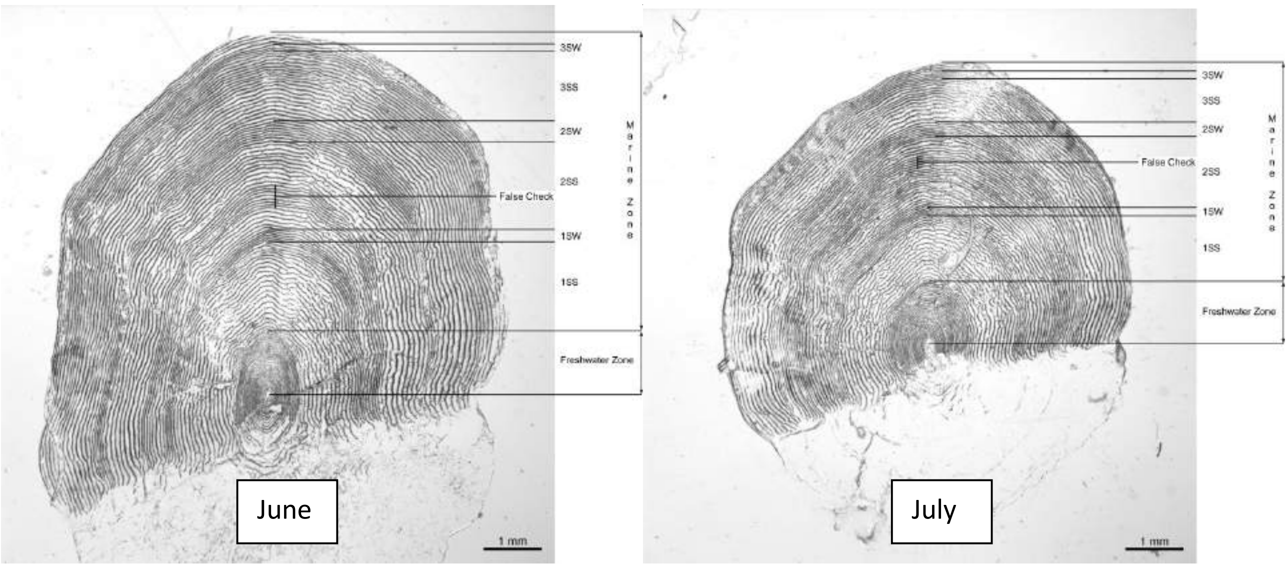


Figure 12. Male 3SW salmon from the River Teno/Tana mainstream stock caught at sea.

4. Preparing scales for analysis

There is always mucus on the scales which has not been removed before scales have stored into scale envelope. This mucus can make the scale analysis and ageing difficult especially for those adult fish which have been many months in fresh water before to be caught. If scales need to be cleaned, they should be placed in a petri dish with soapy water and then rubbed between the fingers. Figures 13–14, 15–16, 17–18 and 19–20 are demonstrating the scales for 1SW, 2SW, 3SW and previous spawner salmon, respectively, how does the scale look like before cleaning with soap, mounting before cleaning, after the cleaning with soap and after the cleaned scale was mounted. Salmon scales which have not been cleaned can not be recommended to use in ageing and in scale measurement analysis. Cleaned scales with soap and water are almost as good for analysis as mounted scales. There are no remarkable differences in the images from dirty or cleaned scales after mounting. Scales from previous spawned salmon should always mount which helps to observe all the previous spawning marks (Figures 19–20).

Scales to be read may be mounted. The use of unmounted scales is fast but when scales are also being used for exact growth 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. The scale sample to be mounted should include 10-20 scales to be sure that there are enough scales with all the annulus. Figures 21–24 demonstrate the process to make scale impression using jeveller press in mounting.

Photo 2. Scales on the plate on the way to mounting. Photo: Eero Niemelä

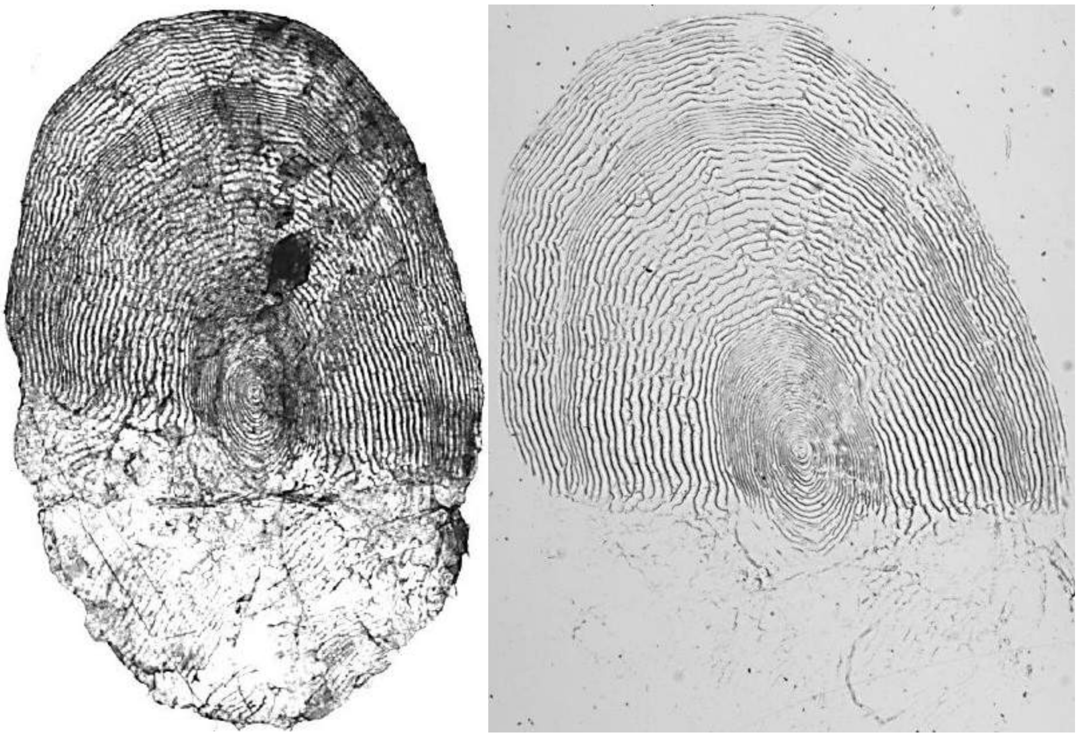


Figure 13. Figure on the left is from dirty and not pressed 1SW (one-sea-winter) salmon scale and figure on the right is from the same dirty but pressed scale. The scale image on the right is that one which is most often used for salmon scale ageing and growth analysis.

Figure 14. Figure on the left is from washed and not pressed 1SW (one-sea-winter) salmon scale and figure on the right is from the same washed but pressed scale.

Figure 15. Figure on the left is from dirty and not pressed 2SW (two-sea-winter) salmon scale and figure on the right is from the same dirty but pressed scale.

Figure 16. Figure on the left is from washed and not pressed 2SW (two-sea-winter) salmon scale and figure on the right is from the same washed but pressed scale.

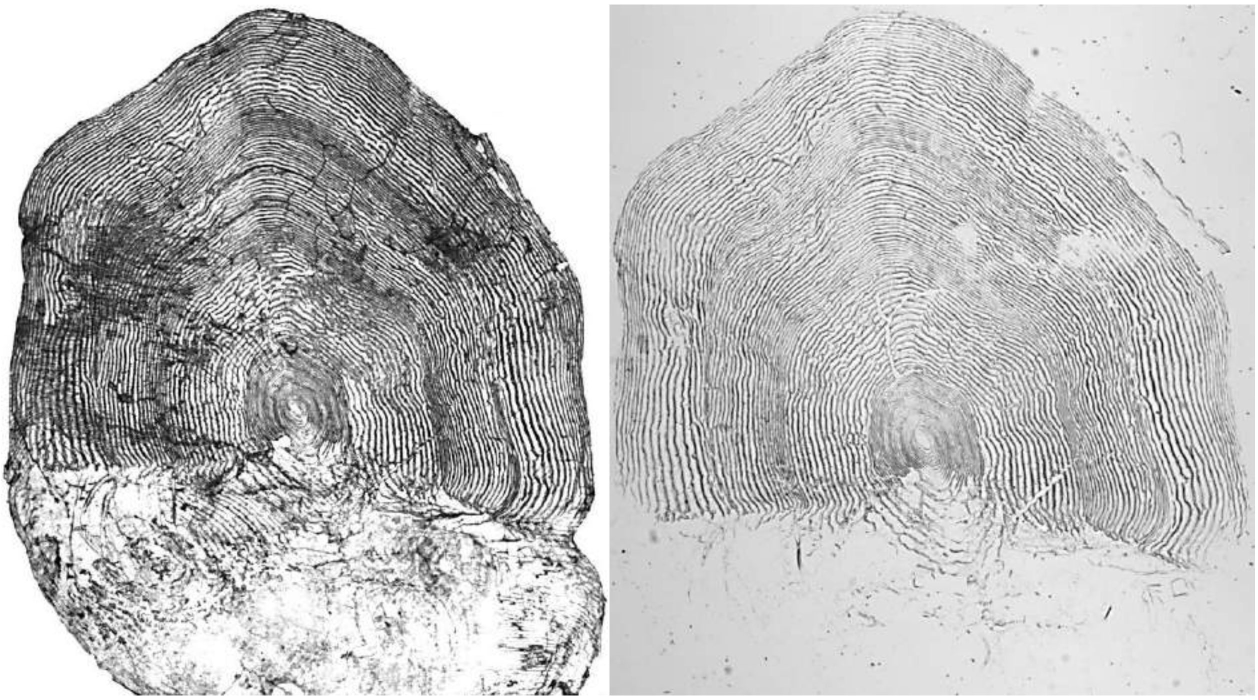


Figure 17. Figure on the left is from dirty and not pressed 3SW (three-sea-winter) salmon scale and figure on the right is from the same dirty but pressed scale.

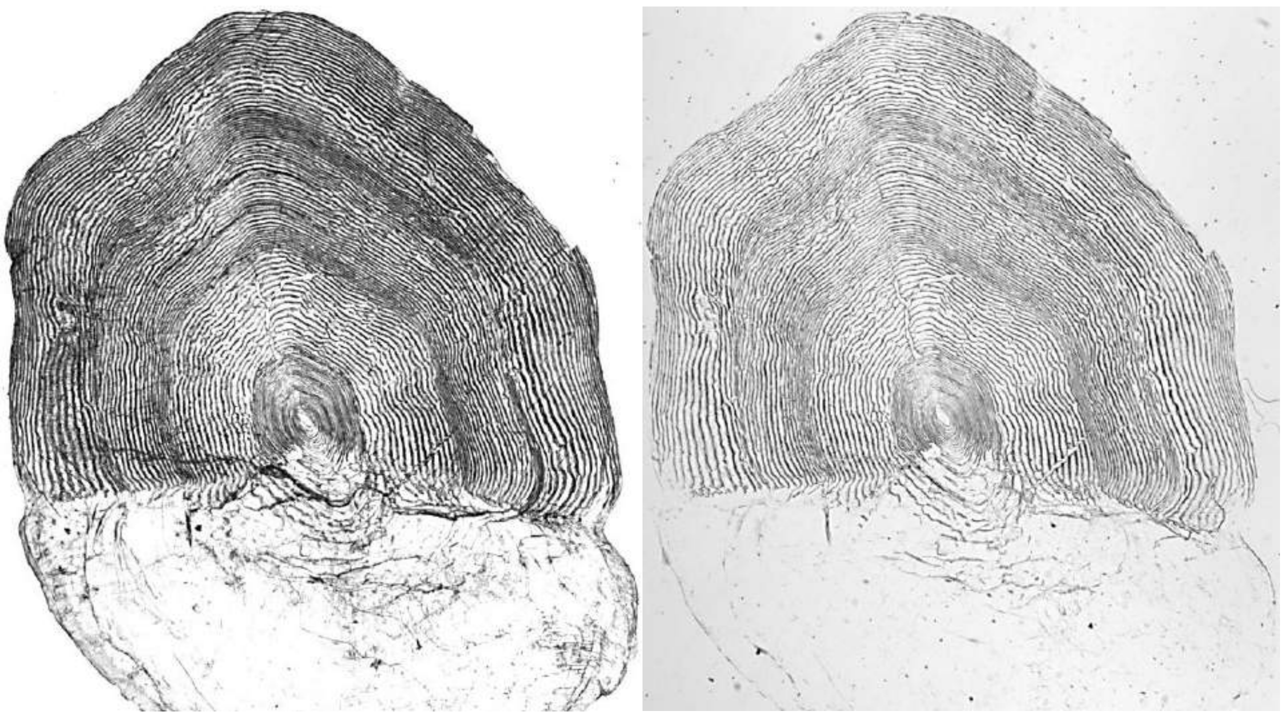


Figure 18. Figure on the left is from washed and not pressed 3SW (three-sea-winter) salmon scale and figure on the right is from the same washed but pressed scale.

Figure 19. Figure on the left is from dirty and not pressed 2S1S+ SW (Previous spawner) salmon scale and figure on the right is from the same dirty but pressed scale.

Figure 20. Figure on the left is from washed and not pressed 2S1S+ SW (Previous spawner) salmon scale and figure on the right is from the same washed but pressed scale.

Figure 21. Salmon scales are usually fastened into each other when stored in the scale envelopes (figure on the left). Scales must be separated from each other and see which is the glossy side.

Figure 22. Scales will be put in rows on the plate glossy side up.

Figure 23. Plate with scales will be put into squeezer.

Figure 24. Scale imprints can be seen in the plate.

5. Typical scale features

Salmon scales are often used in age and growth studies because they reflect growth at the different life stages of fish (Tesh 1968). Growth patterns differ between salmon stocks, and detailed scale patterns have been used to distinguish between different groups of salmon, e.g. separation of salmon of European and North American origin in the high seas salmon fishery (Reddin 1986). Fish and scale growth are influenced by environmental conditions such as water temperature, length of growing season, and food availability, and may be influenced by genetic factors. The scale characters used in the most recent works are typically either count of measurements of growth rings from the freshwater and marine zones. This method is quite subjective in that it may be sensitive to the scale readers's interpretation.

Under magnification, salmon scales display numerous concentric rings, called *circuli (=rings, sclerites)*, radiating outwards from a central focal area (*focus*) (Figure 25). Circuli appear on the surface of the scale as dark concentric lines. In all the scales there is the focus (=nucleus) or center of the scale. A freshwater growth zone of narrowly spaced circuli (Figure 25) is clearly distinguishable from a zone of more widely spaced saltwater growth circuli in scales of salmon. Fish age is determined by counting *annuli*, the zones of closely spaced circuli formed yearly during winter and early spring periods of slow growth.

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

- River Zone: the period spent in freshwater up to the last river annulus. The freshwater annulus position marker is placed beside the last circuli in the freshwater annulus and the saltwater entry marker is placed immediately after the first circuli in the saltwater growth zone.
- Sea Zone: the period from the onset of sea growth; it may include time spent in freshwater as an adult (Figures 25, 32, 33).

On some scales there is a third distinct part which occurs between the river and sea zones. This zone is called Run -out period: a period of intermediate growth between the last river annulus and the start of the sea growth

During the sea phase of scale growth, 3 types of dark 'band' may be observed (ICES 1984, ICES 1992):

1. Winter band; a dark band through to be associated with slow growth during the cold period of the year
2. Summer check
3. Closing at the edge of the scale: this is not necessarily associated with winter growth but may occur in response to maturation, homeward migration and cessation of feeding

There are also 4 types of light band, which are:

1. Summer band; a light band through to be associated with rapid growth during the warmer period of the year
2. Winter check
3. Spawning mark
4. Plus growth

End of the winter bands are indicating the annulus. The transition from one annual zone to the next may be identified by the first continuous circuli of the new growth season cutting over the lst incomplete circuli of the preceding season or identified by increased growth from narrow to wide spaced circuli.

End of the summer growth indicates end in the growth during each summer. At the end of the summer growth, a notable reduction in the circuli spacing occurs as the salmon goes into winter, these often become progressively closer together as winter progresses.

6. Identifying spawning marks

In scale examinations, counts are made of spawning marks (regions of discontinuity of growth circuli) to determine the number of times salmon has spawned. These marks develop in two stages: (1) while the fish is in freshwater, parts of the marginal growth circuli and parts of previous spawning marks, at and near the scale edge, may disappear (”erode”) ; and (2) when the fish returns to the sea and scale growth resumes, new marginal circuli are usually discontinuous with the eroded circuli. They do not join them and there is often an area of scar tissue between old and new circuli. These areas of disjunction are the spawning marks (White & Medcof, 1968).

In ICES (2011) salmon spawning marks has identified as follows. A spawning mark results from scale edge erosion caused by material being reabsorbed from the scale when the fish is in freshwater. Complete winter bands may be eroded where the fish has been in freshwater for several months. These marks are indicated by irregular, broken circuli with larger irregular gaps between circuli orrur when salmon spawn.

Spawning marks occur in Atlantic salmon scales after spawning has taken place in the ages of 1SW–4SW. Repeated spawning can take place in consecutive years or in alternate years. Consecutive spawning can take place over many years, while alternate spawners undergo reconditioning of 1 to 3 years between spawning events.

When salmon ascended into their spawning river after 1 to 5 years at sea they cease feeding and therefore scale growth stops. Erosion takes place around the sides of the scales and in the posterior area of the scale (in the scale pocket). After spawning salmon descend the river as kelts back to the sea, feeding resumes and the growth of the scale continues. Between the new growth at sea and the old growth before spawning a “spawning mark” can usually be observed.

The spawning marks are evident along the lateral margins of the scale and can display as an absence of circuli along a section of the scale, often providing a sharply defined linear scale profile compared to the typical ovoid shaped scale from an unspawned fish. Spawning marks can be observed in the uppermost (anterior) area of the scale but are less pronounced.

Clear identification of spawning marks is not always easy. The contrast between post spawning growth and a spawning mark may highlight the latter. A view of the scales leading edge, usually overlapped by the proceeding scale can aid identification. Such scales tend to be large so it is important when they are first encountered to ensure that the entire scale is viewed at its image saved. Spawning marks may be more apparent on both sides of the scale if they are collected from the location above the anal fin. Spawning marks may mask (by effectively removing) an annulus so sea age should be carefully categorized.

Reconditioning should be carefully checked for, watching for check marks before a second spawning, while taking care not to read such a check as a winter band.

If there is little annual scale growth and much erosion during a spawning period like it is the case for consecutive spawning salmon in Barents Sea rivers, one or more previous spawning marks and annual rings could be completely obliterated. For alternate spawning salmon the annual growth zone in scales between the repeated spawnings is usually large and clear.

7. Check marks

In ICES (2011) check marks occurrence is described in details. Checks can be characterized as groupings of circuli that present like an annulus (or an age defining feature) leading to potential ageing and growth calculation errors (Figure 25). These are exhibited as 'notable irregularities' in circuli spacing's, consisting of 2 to 5 circuli, uncharacteristically narrowly or widely spaced but not constituting a winter or summer band. A check may be observed in a period of fast growth in a summer band (between widely space circuli) as a series of narrowly spaced circuli, constituting a summer check, showing a notable reduction growth. A series of widely spaced circuli in a winter band constitutes a winter check and represents a notable increase in rate of winter growth. In extreme northern latitudes checks manifesting as a continuation of a winter band (winter check) have been observed. All checks may be theoretically related to changes in the immediate environment in time of the salmon, giving rise to decrease of increased growth.

As a general rule, where a candidate annulus is identified by a dense grouping of circuli in the long axis of the scale it can be deemed a check if there is no evidence of circuli grouping in the latera margins of the scale.

8. Salmon ages

Salmon caught in Barents Sea area have the freshwater ages from 2 to 8 years. Adult salmon ages are from 1SW (sea-winter) to 5 SW. In addition to maiden salmon there are a lot of previous spawning salmon which have been spawning and thereafter they have reconditioned at sea for the next spawning.

The salmon age terminology reported in Shearer (1992) is standard, a single digit indicating freshwater age prior to smolting, which may be followed by a "+" indicating run-out, a decimal point as separator, a second single digit indicating years at sea, which may be followed by "+" to indicate 'plus growth', followed by "S" indicating a spawning mark, followed by digits indicating subsequent years at sea, spawning marks and plus growth.

Figures 25–33 are presenting some examples from the wide variety of the ages in maiden Atlantic salmon scales, from kelts and previous spawners.

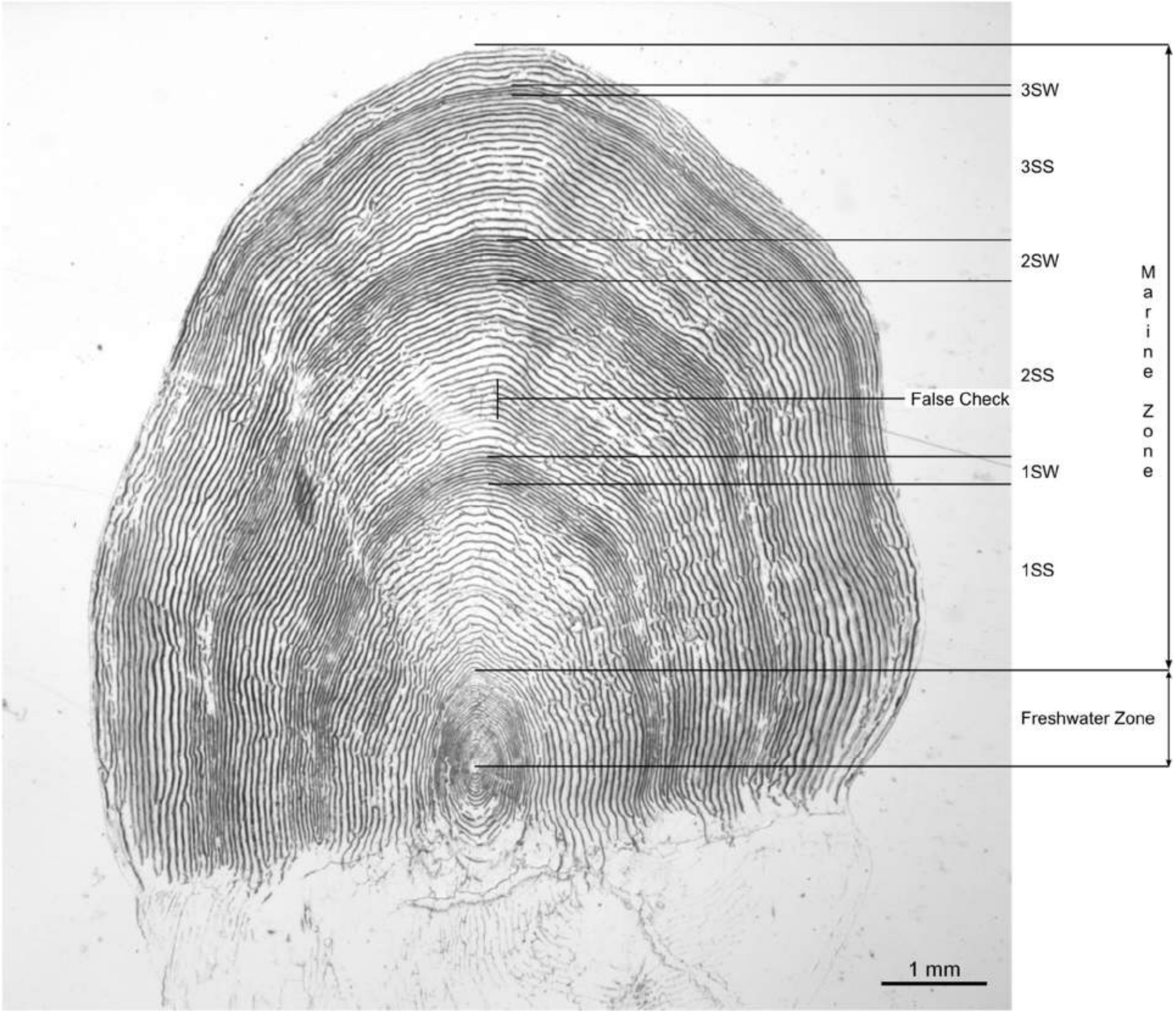


Figure 25. Scale from maiden 3SW old Atlantic salmon. Freshwater zone indicates the period which salmon has spent in river. After migrating to sea there are three summer growth bands (1SS, 2SS, 3SS ; first sea summer etc.) and three winter growth bands (1SW, 2SW, 3SW ; first sea winter etc.).

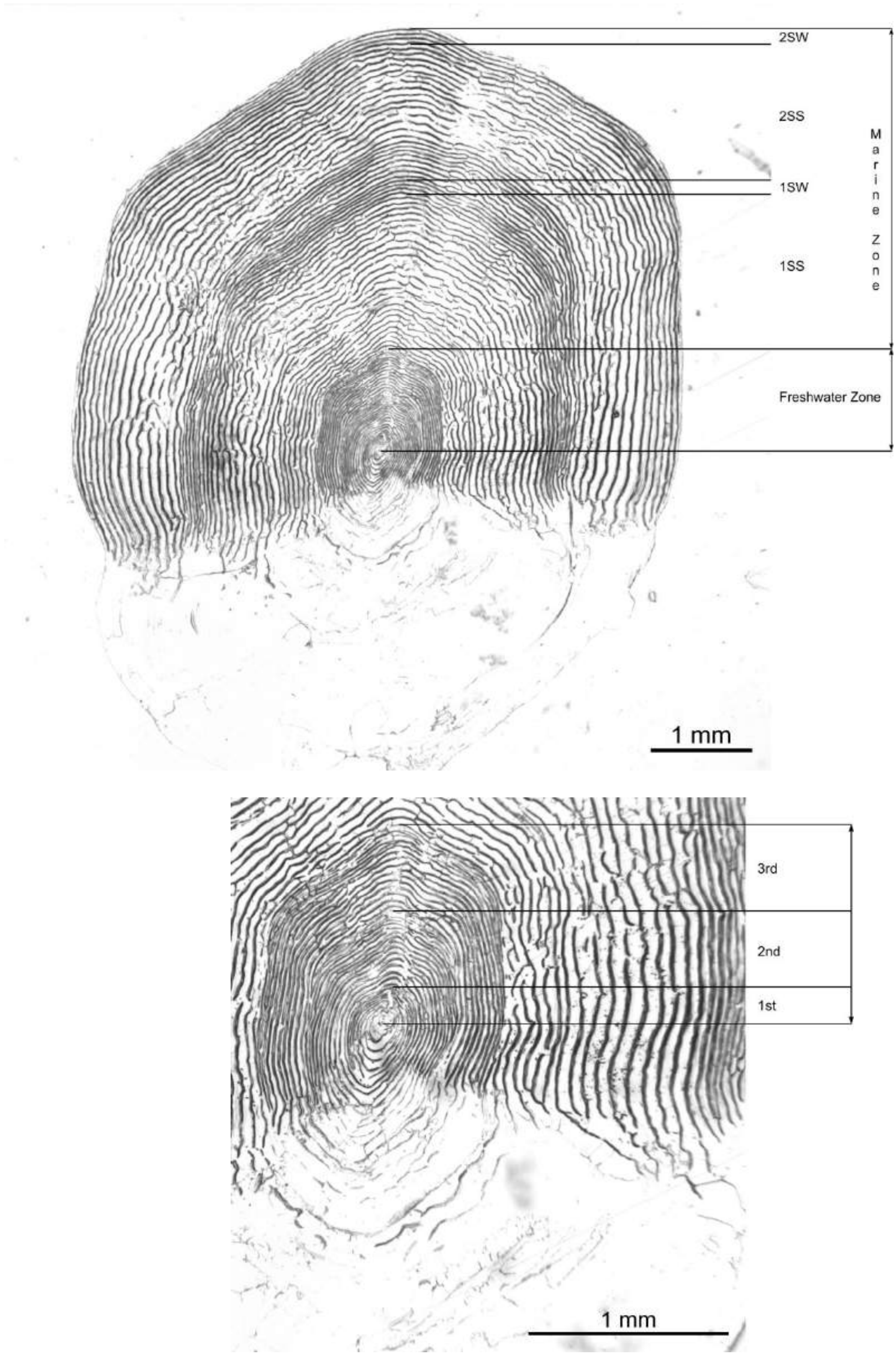


Figure 26. Two sea winter salmon (74,5cm and 4300g) caught from Jarfjord in East-Finnmark on 28.2.2008. In the beginning of the second sea summer growth a check can be observed. In the smaller figure the freshwater growth indicates the smolt age of three years.

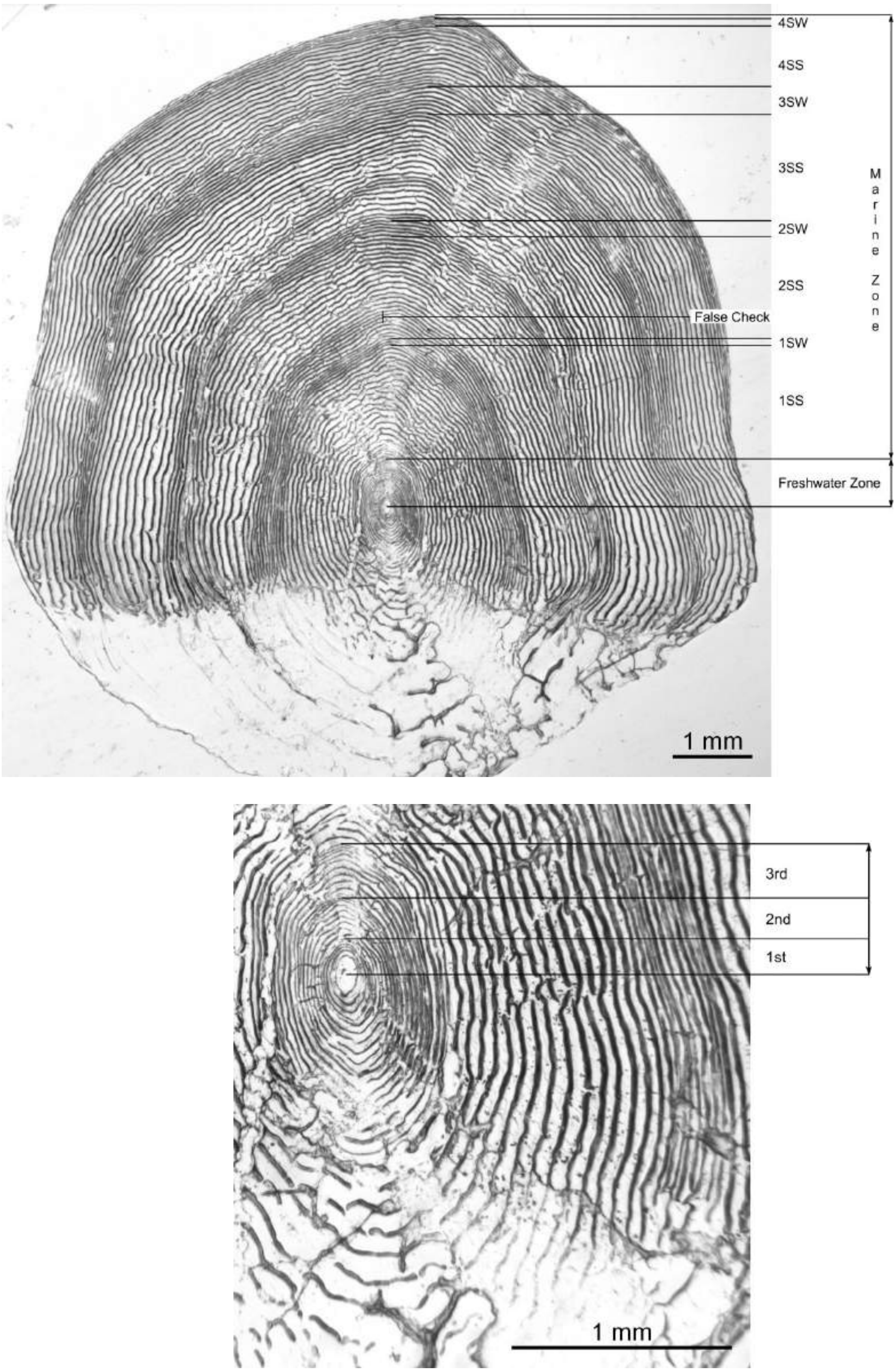


Figure 27. Four sea winter male salmon (137cm and 24.7 kg) caught from Revøysund in East-Finnmark on 26.6.2010. After migrating to sea there are four summer growth bands (1SS, 2SS, 3SS, 4SS ; first sea summer etc.) and four winter growth bands (1SW, 2SW, 3SW, 4SW ; first sea winter etc.). During second and third summer there are checks in the growth. In the smaller figure the freshwater growth indicates the smolt age of three years.

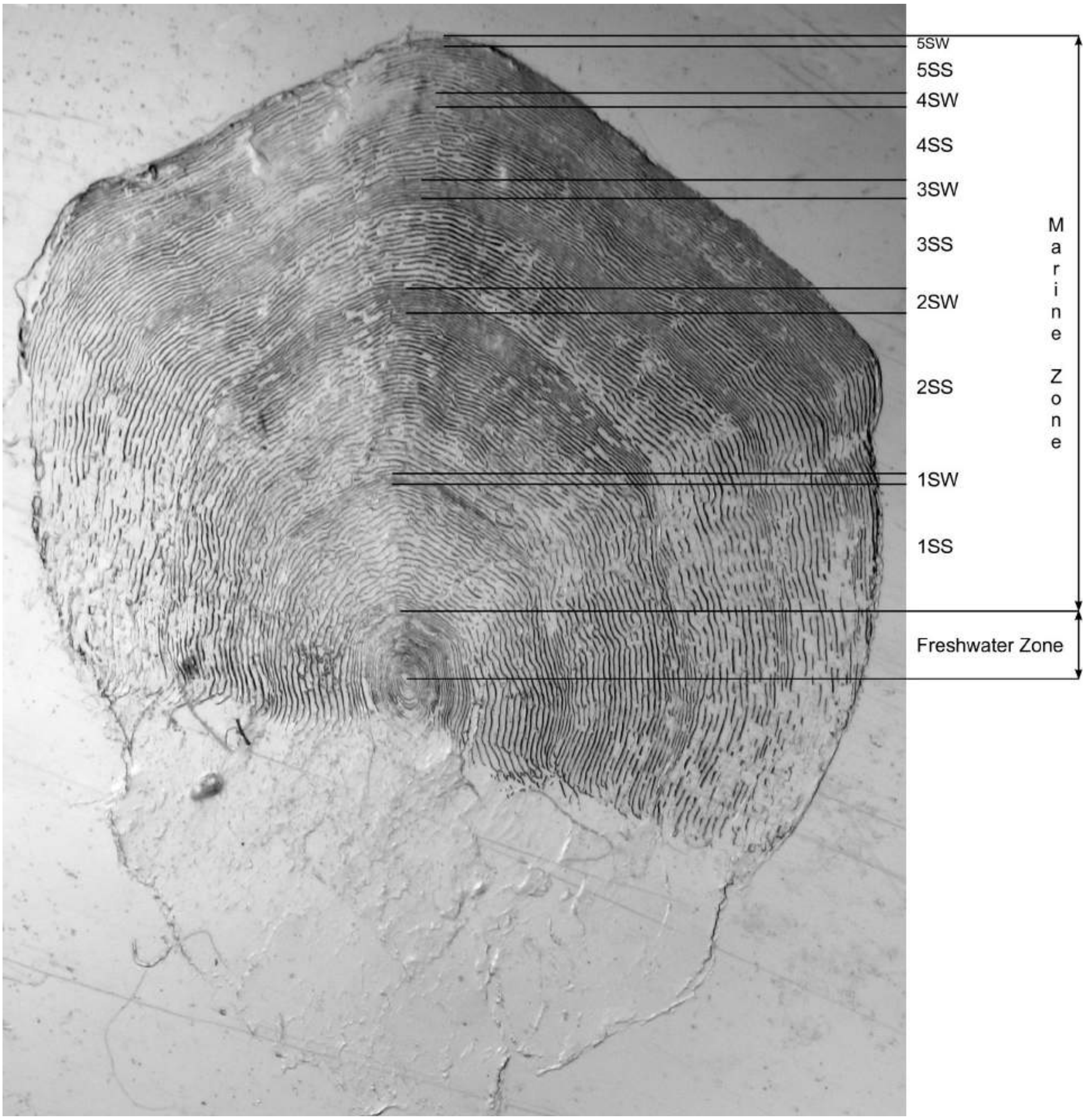
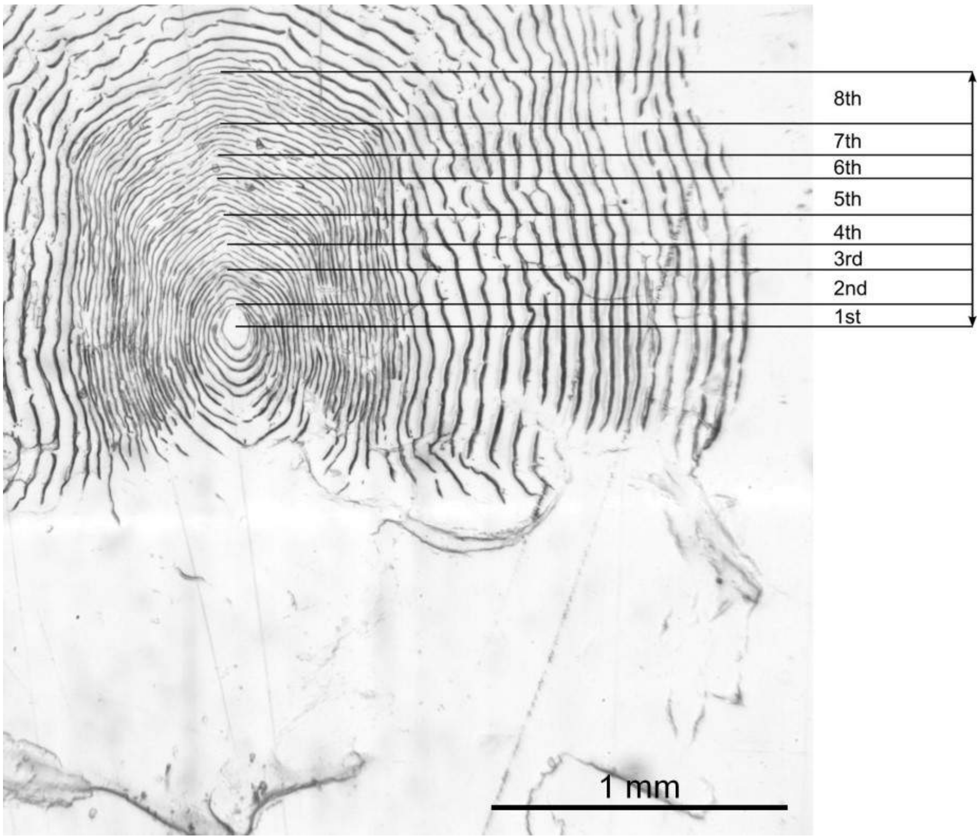


Figure 28. Five sea winter male salmon (127cm) caught from the River Teno/Tana. Smolt age is 4+ years.



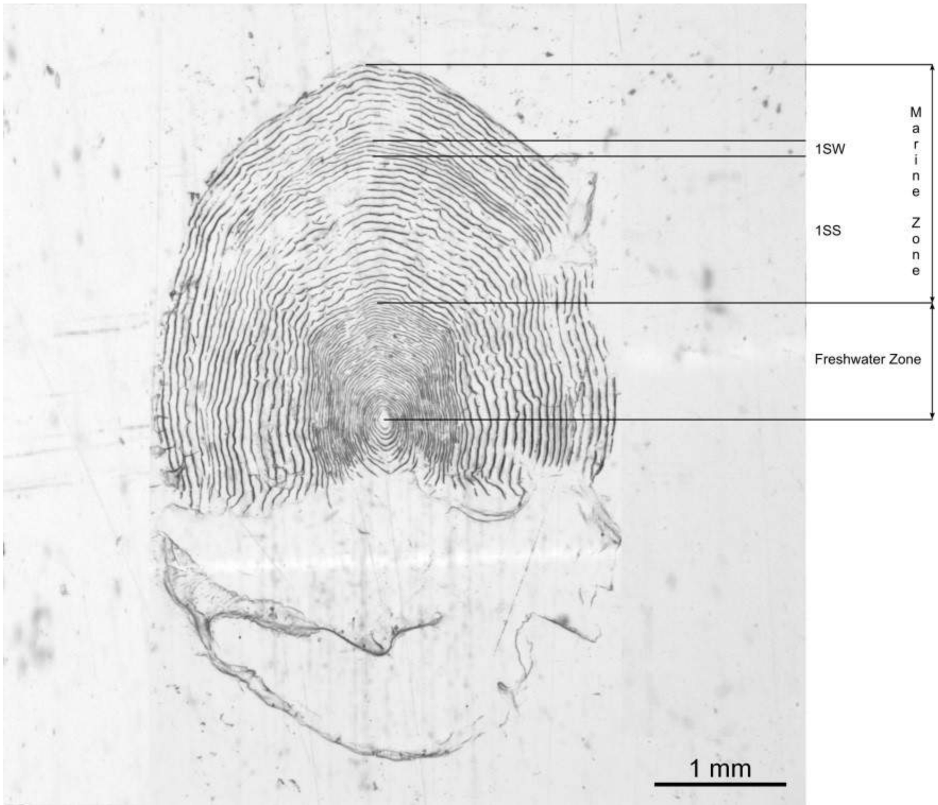


Figure 29. One sea winter salmon with the smolt age of 8 years caught from the River Tsarsjohka (Tributary of the River Teno/Tana).

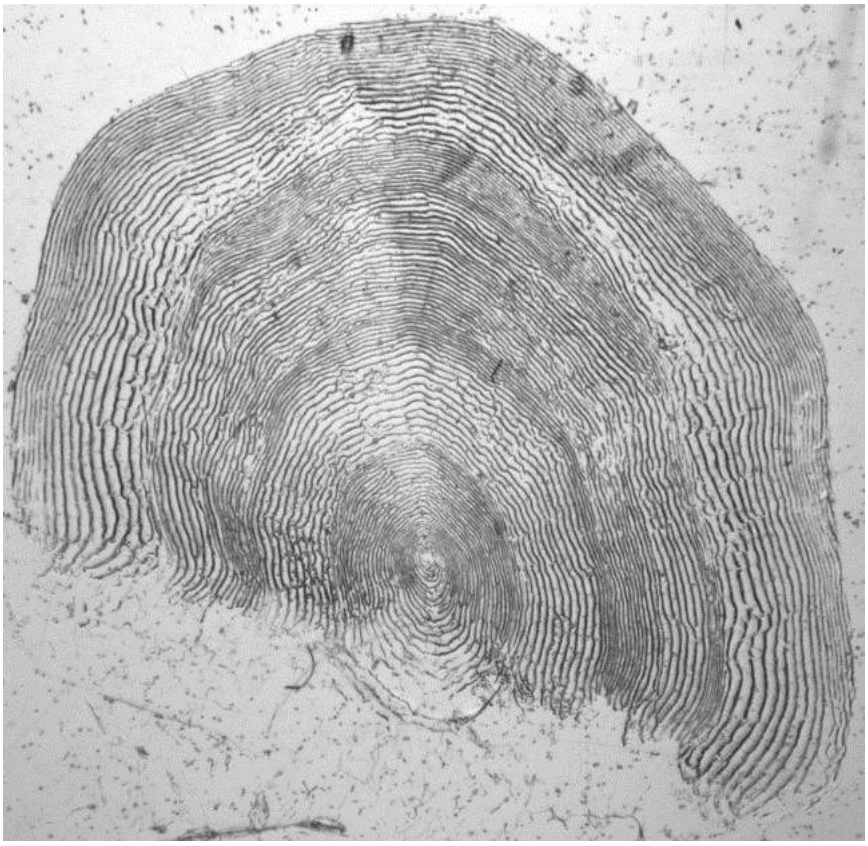


Figure 30. Three sea winter salmon with the smolt age of 2 years caught from the sea in Finnmark in Northern Norway. There are three checks during the second sea summer growth.

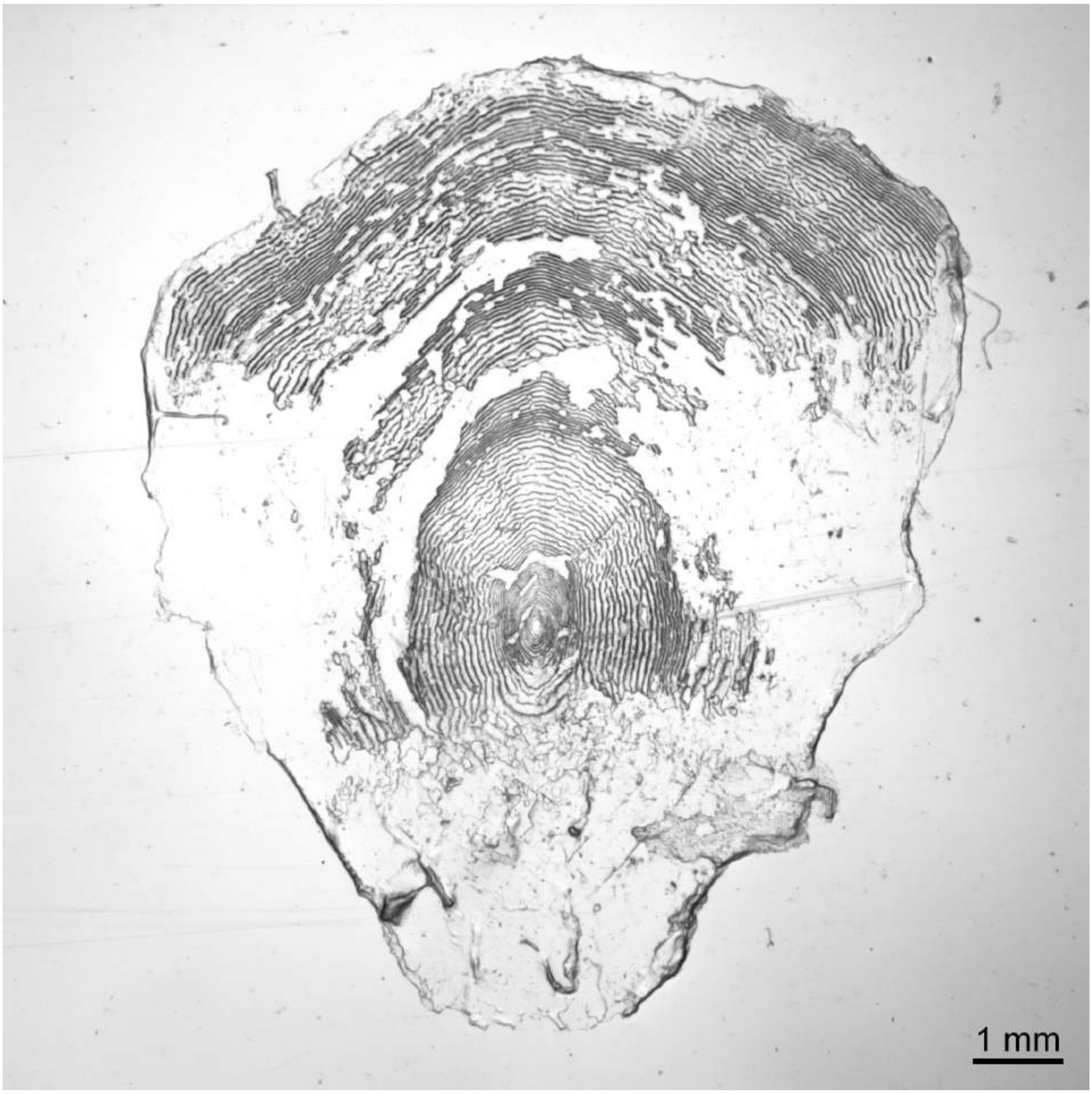


Figure 31. Dead male 5SW salmon (131cm) found from the River Teno/Tana (Kuoppilassuvanto) on 10.10.2010. Scale has large erosions.

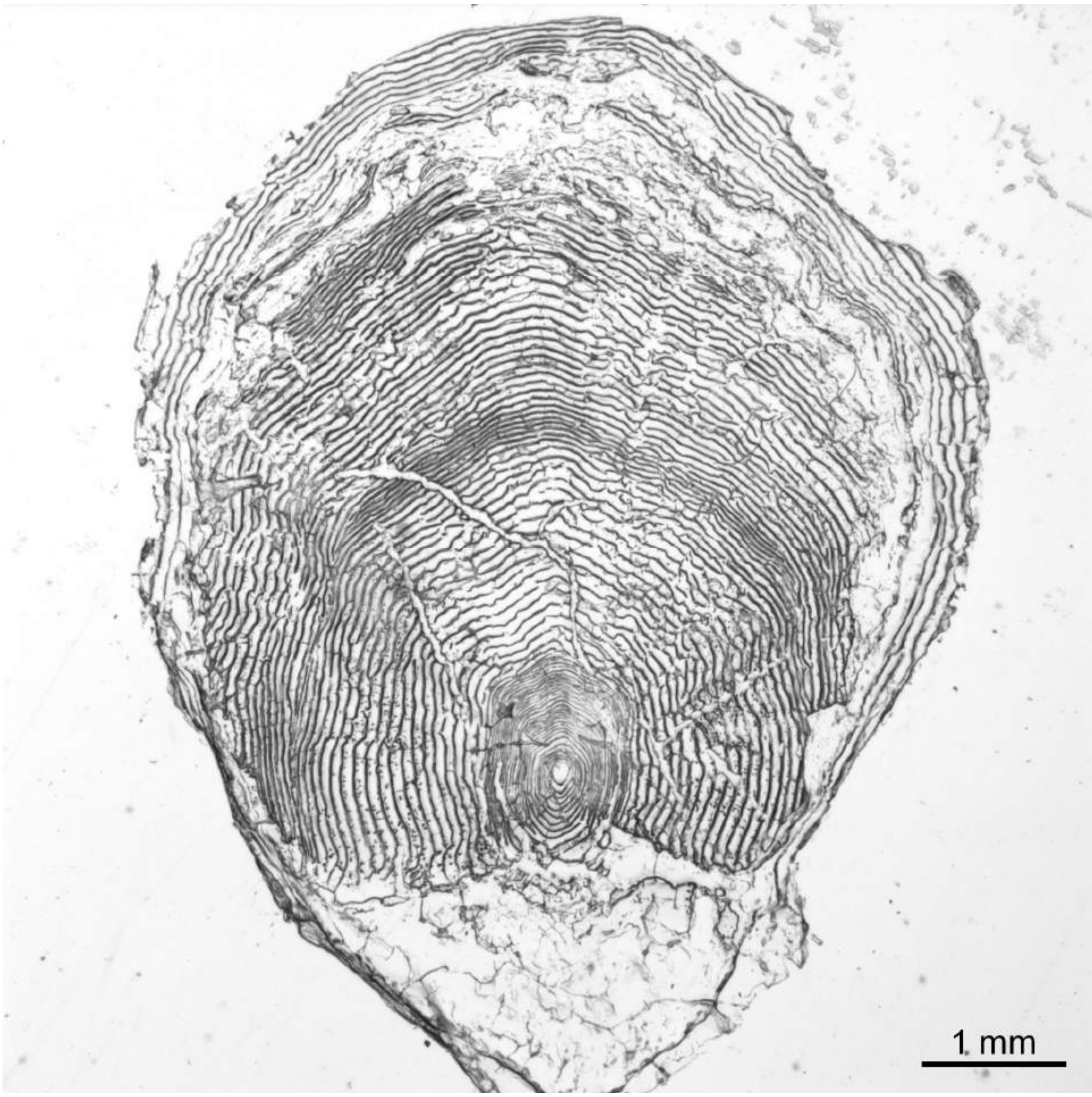


Figure 32. Previous spawning female salmon (90cm, 4900g) of the age 2S1S1S. The first spawning took place during the third sea year (after the second sea winter). Thereafter fish needed always one year between repeated spawnings. Smolt age was 4 years. Fish was caught 21.7.2009 in the River Teno/Tana. Some residual eggs were still in the body cavity.

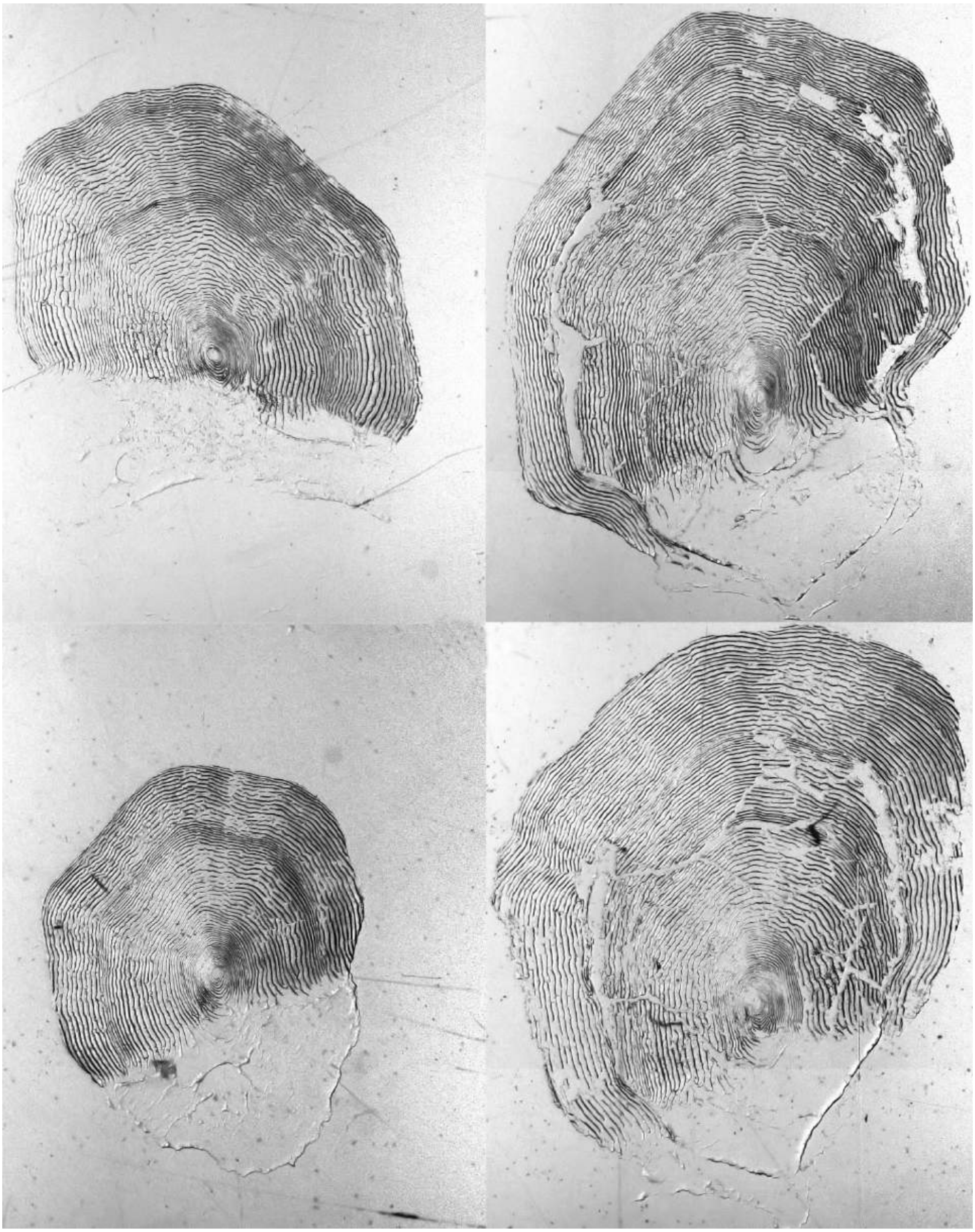


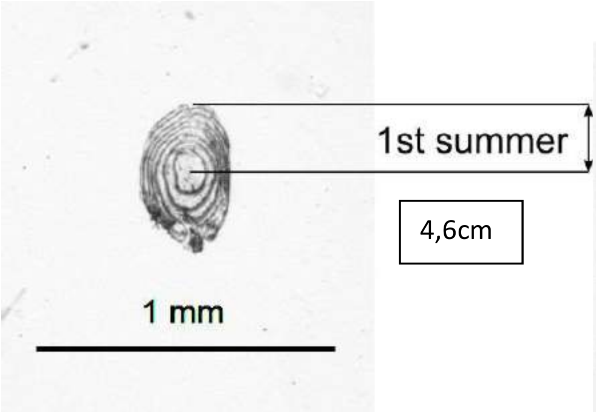
Figure 33. Scales on the left (below; first time spawner of the sea-age 1SW salmon, above; first time spawner of the sea-age 2SW salmon) and on the right (below; previous spawner of the sea-age 1S1 SW salmon, above; previous spawner of the sea-age 2S1 salmon) are indicating differences in scale structures.

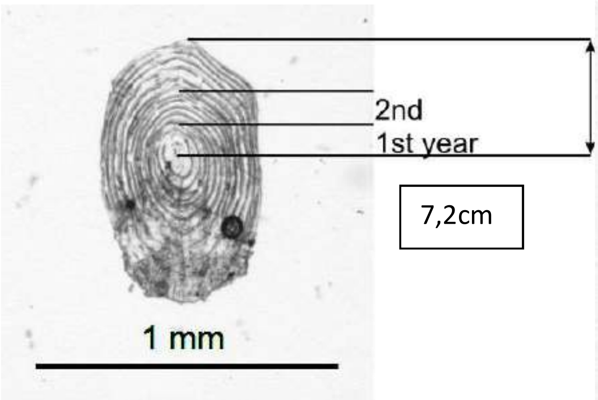
9. Juvenile scales

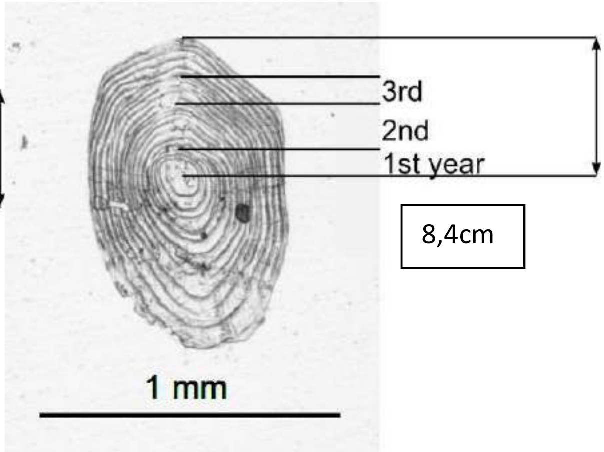
Growth rings (strias) on juvenile salmon scales are of two types. The widely spaced rings are produced in summer and the less widely spaced rings are produced in winter. The main difference between summer and winter rings are the narrower spacing and broken nature of the smaller number of winter rings, whereas the summer rings are more numerous, widely spaced and generally unbroken. Sometimes a band of narrowly spaced rings may be seen in the middle of a band of normal summer rings. This band, often called the “summer check”, is presumably the result of a temporary slowing down of the growth rate and it can be induced by too warm or too cold water temperatures combined to poor food availability. ”Summer check” can usually be distinguished from winter rings by the absence of any gradual narrowing of the spacing of the normal summer rings preceding the formation of these check rings (Jones 1949).

Dahl (1910) described in details the development of juvenile salmon scales as follows. When examining the scale of a smolt or parr under the microscope it can be seen at once that it consists of a transparent plate of an irregular elliptical shape, and that the under surface is smooth. The anterior portion, which is embedded in a pocket of fold of the skin, is characterized on the outer surface by a series of concentric elliptical rings, which are parallel with the outer edge of the scale. On the posterior or exposed portion of the scale, and which is the only portion that is visible the removal of the adjacent and overlapping scales, these concentric lines or rings become, and especially with increasing age, most irregular and indistinct. As a rule rings formed in the summer are unbroken around the circumference of the whole of the scale, though occasionally one may meet with scales of which the summer rings are not always complete. This probably arises from the fact that all growths do not proceed simultaneously, and that therefore the different portions of the scale have not always the same uniform rate of growth. It is more than likely that this is due to some variation in the date of growth in length. In autumn and winter the growth generally decreases or ceases entirely, and all the scales show a similar edge. This character is also retained during the whole of the winter, and such little growth as does take place is shown in the production of narrower rings close to the edge of the scale. After the winter, when development begins again, the ring formation of the new season does not entirely coincide with the last formed rings of the preceding season, and the new growth is shown by the formation again of entire and unbroken rings. It is therefore as a rule easy to recognize the winter rings formed during the period of stagnation between the two growth-zones. The chief characteristics of this period of stagnation are the pronounced branching or ramification of the rings, and also the fact that they are narrower and lie closer together, so that a magnified representation of a scale shows a narrow and more darkly shaded belt. This narrow winter-band has also a different optical refractive power, as will be seen with a microscope by using different methods of illumination.

Juvenile scales in this report are presenting the growth during the freshwater period. Growth is presented for the rivers where the growth was classified as slow growth, quite slow growth, fast growth and fastest growth.







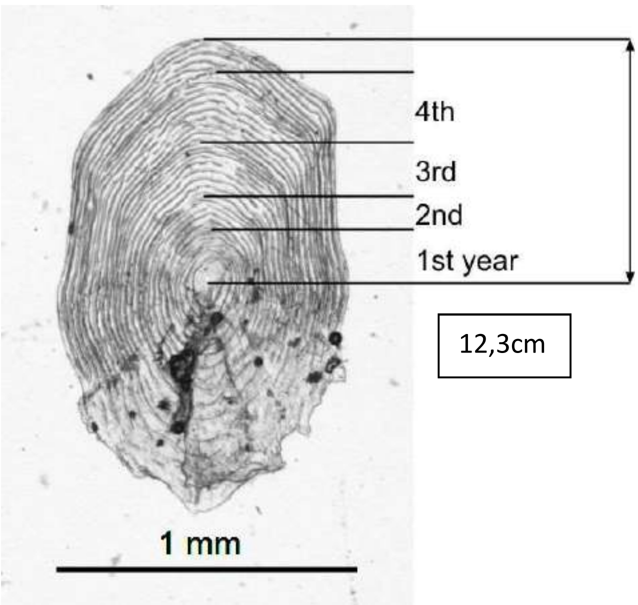


Figure 34. Grense Jakobselva. Slow growth. Caught in September 2010.

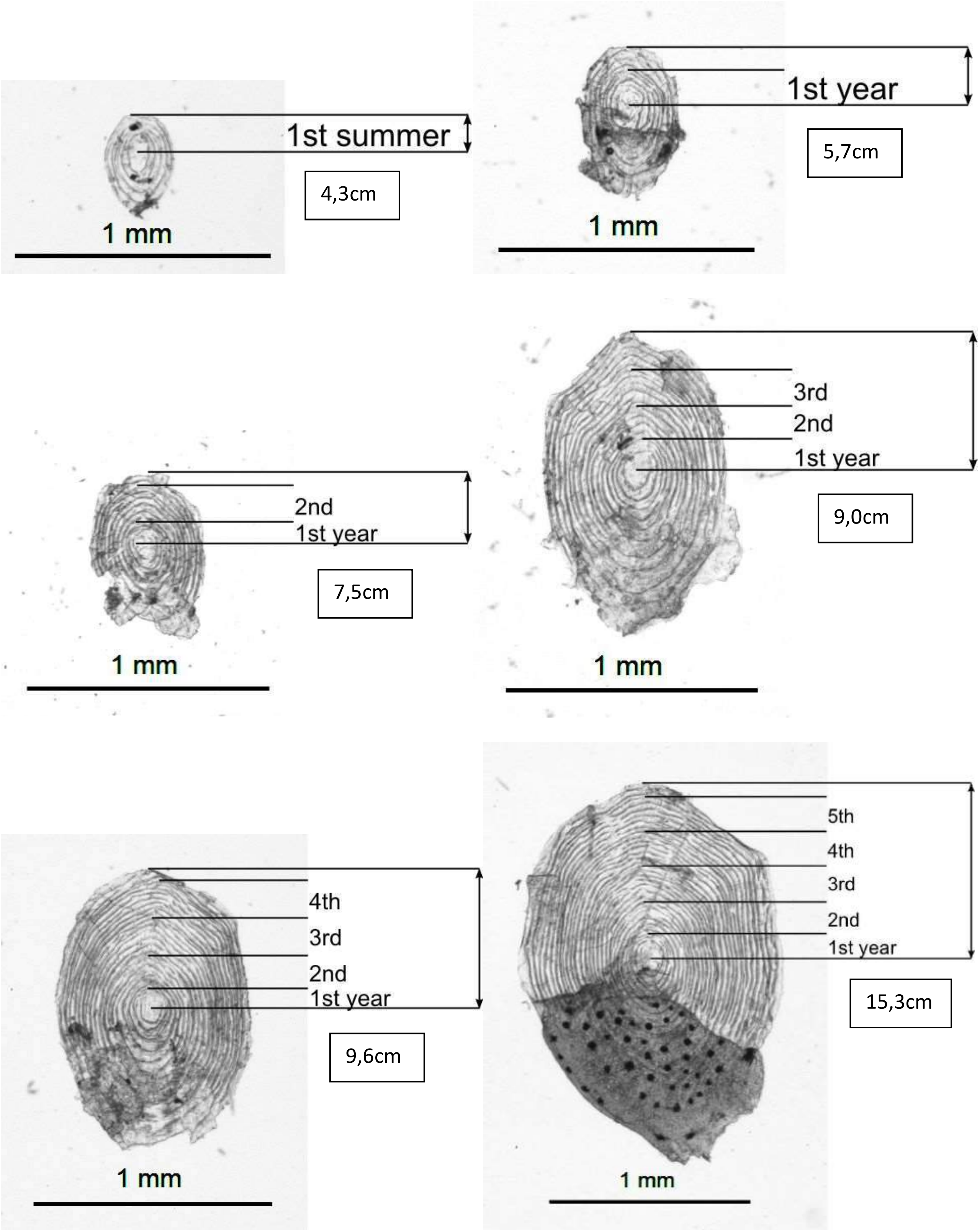


Figure 35. Risfjordelva. Slow growth. Caught in September 2012.

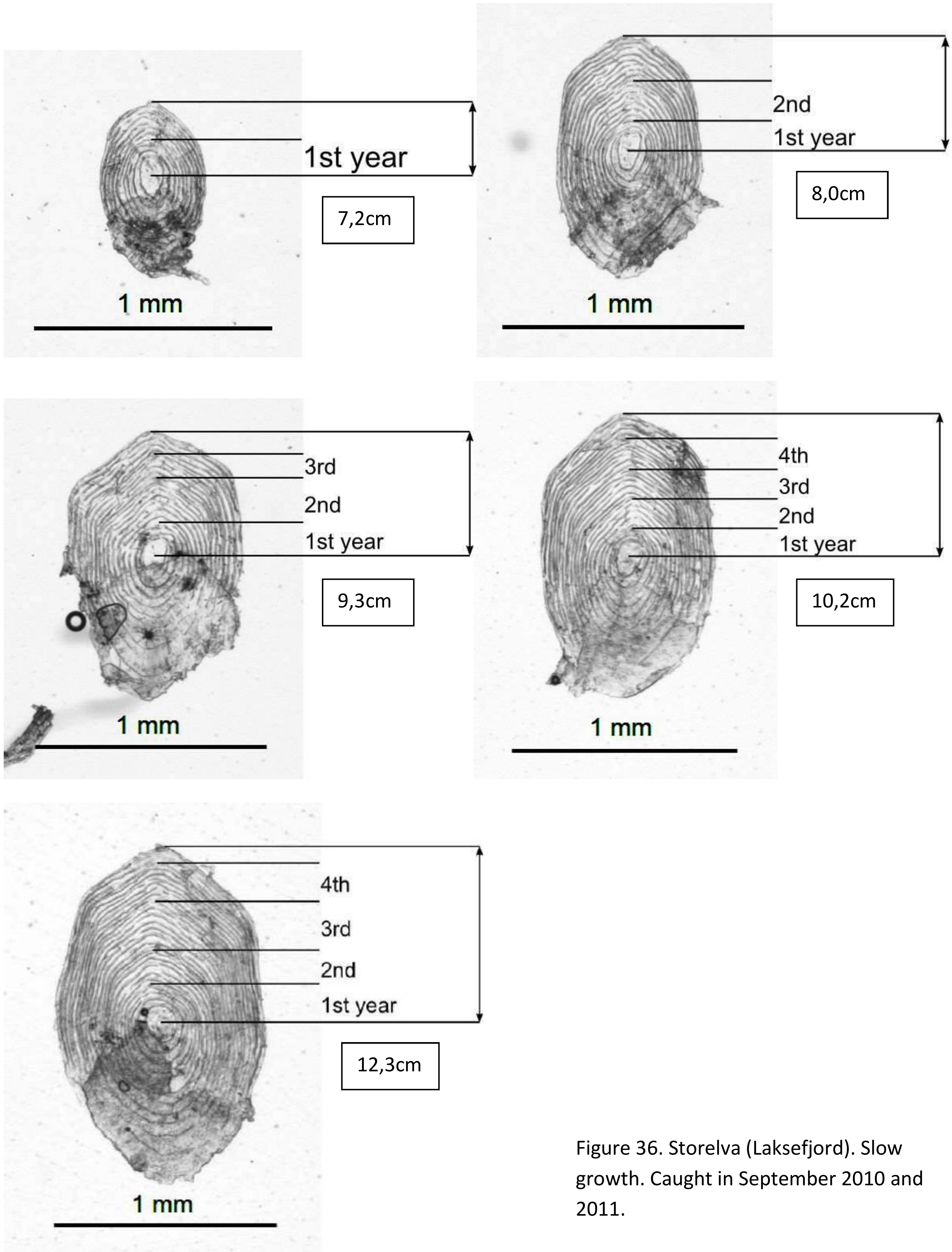
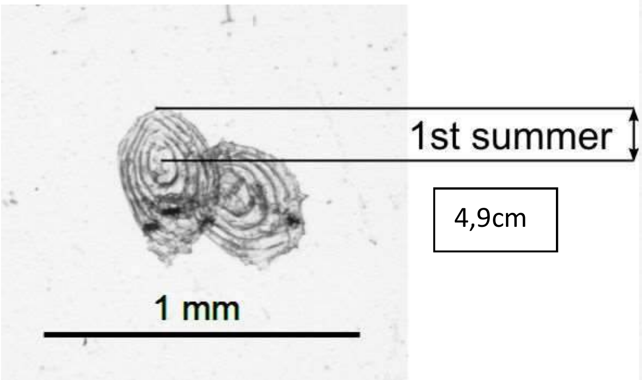
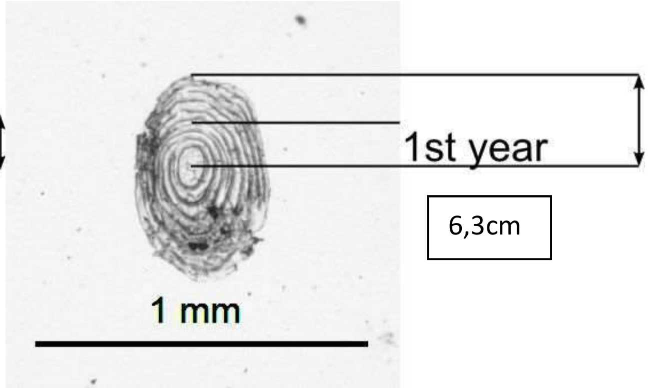
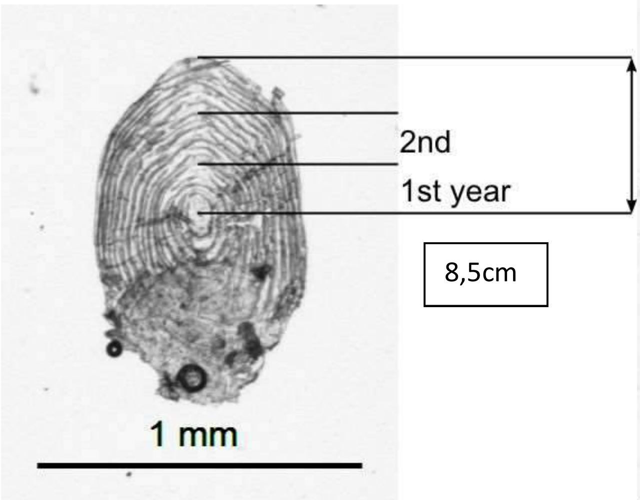
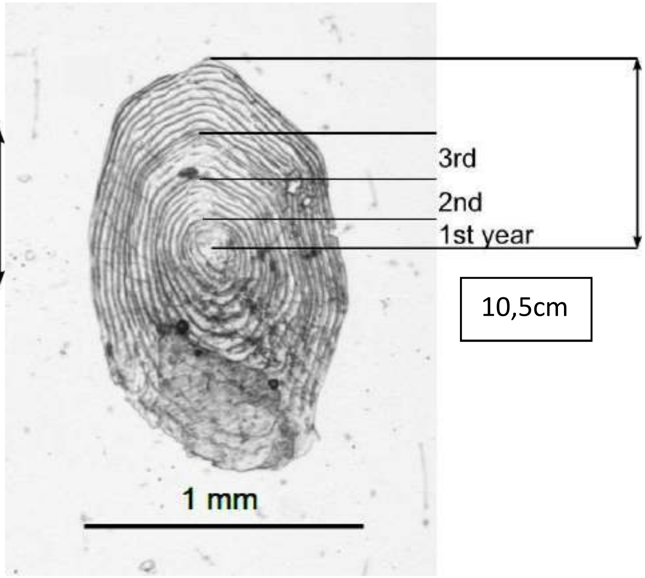


Figure 36. Storelva (Laksefjord). Slow growth. Caught in September 2010 and 2011.









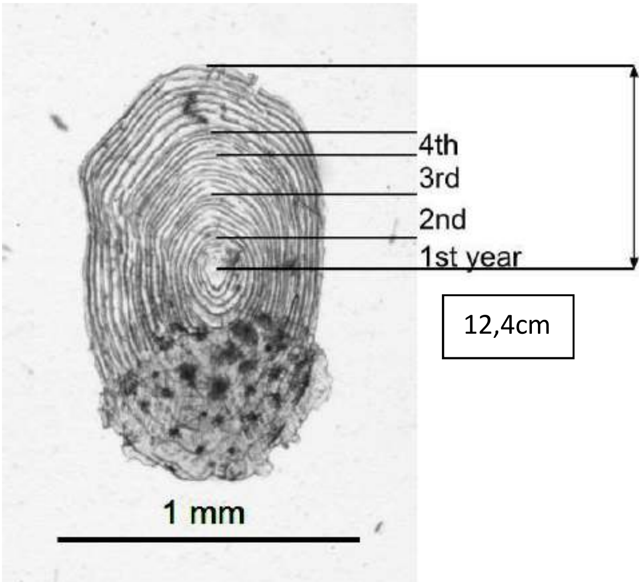


Figure 37. Stabburselva. Slow growth.
Caught in September 2010 and 2011.

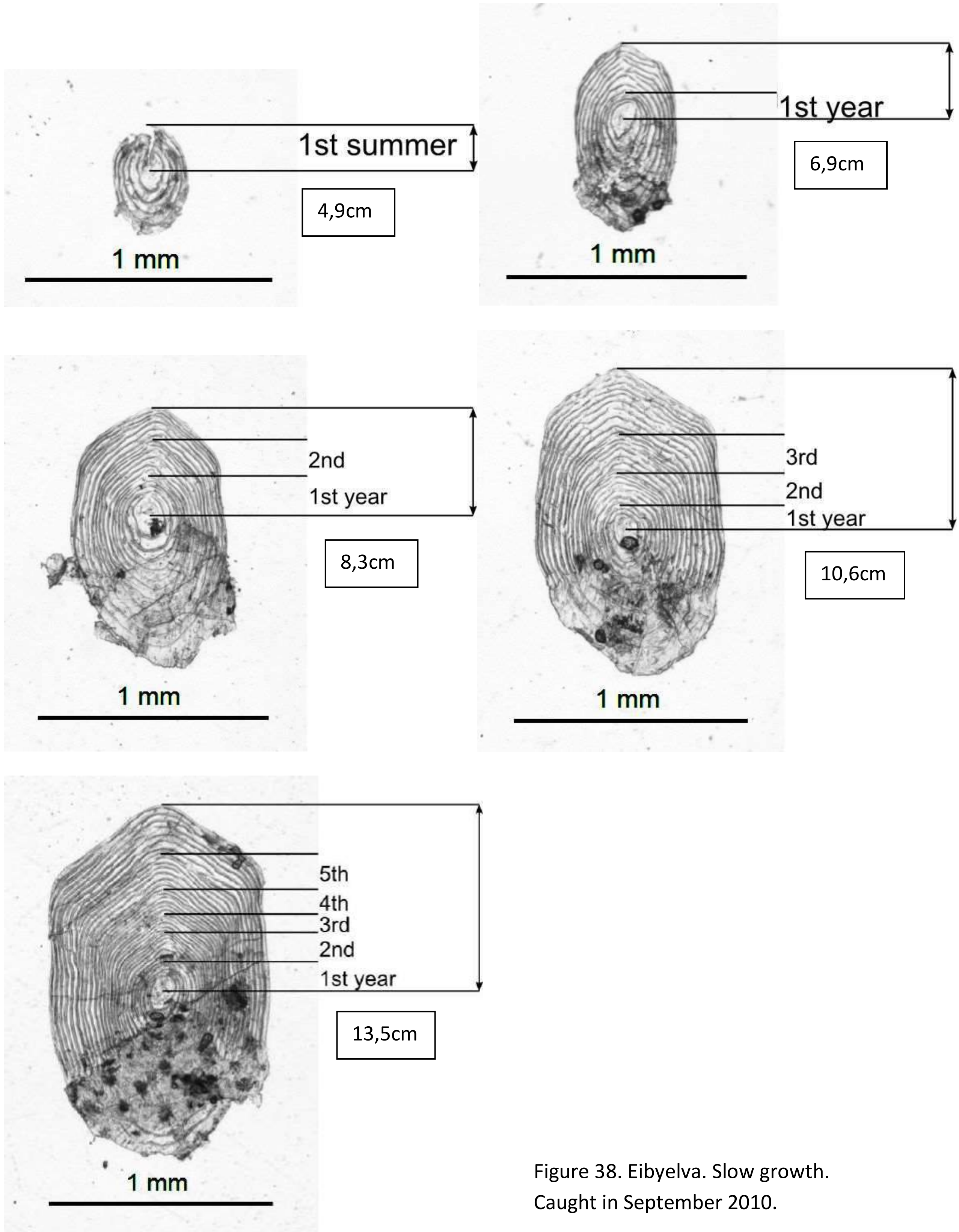


Figure 38. Eibyelva. Slow growth.
Caught in September 2010.

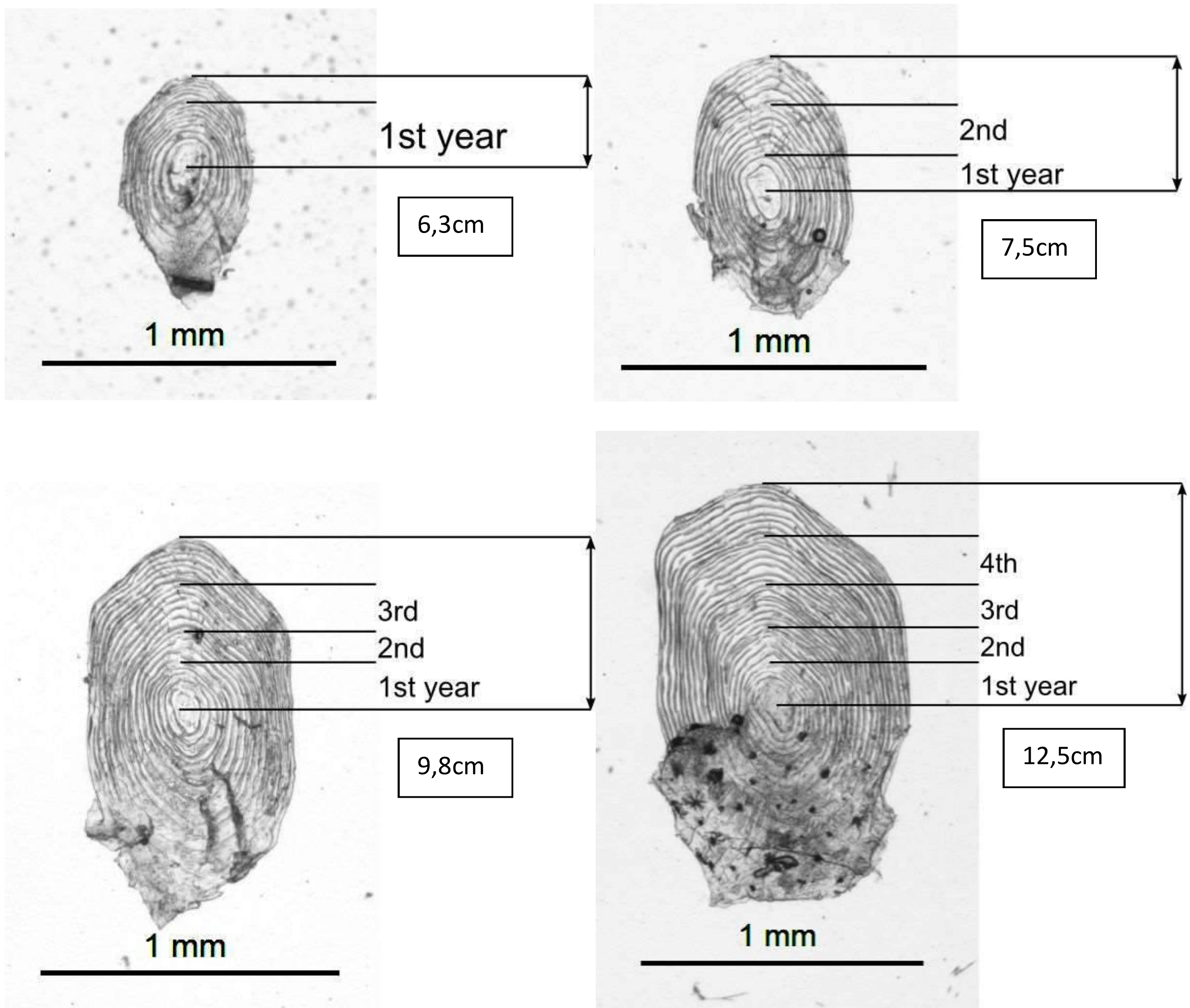


Figure 39. Neidenelva. Quite slow growth. Caught in September 2011.

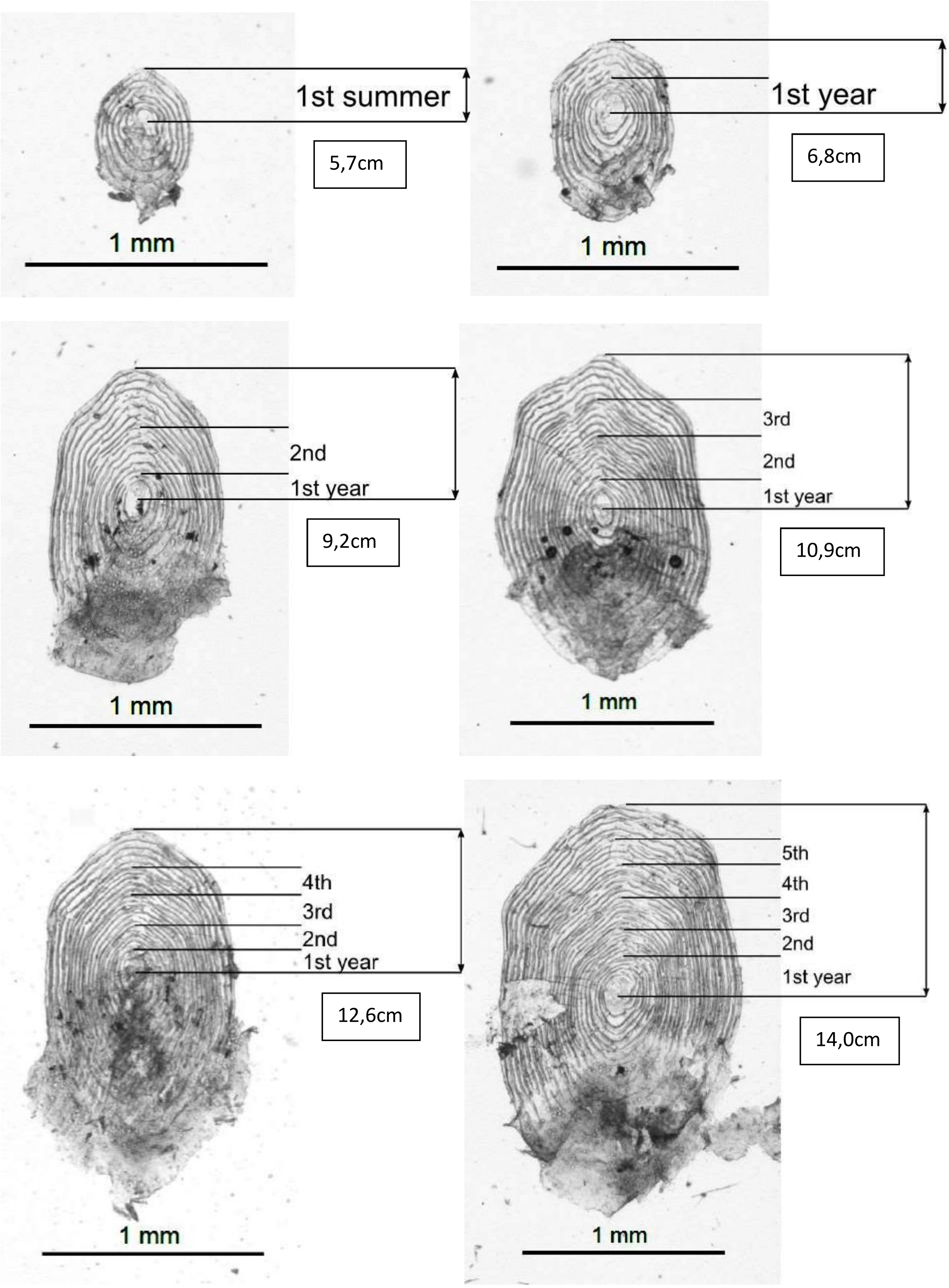
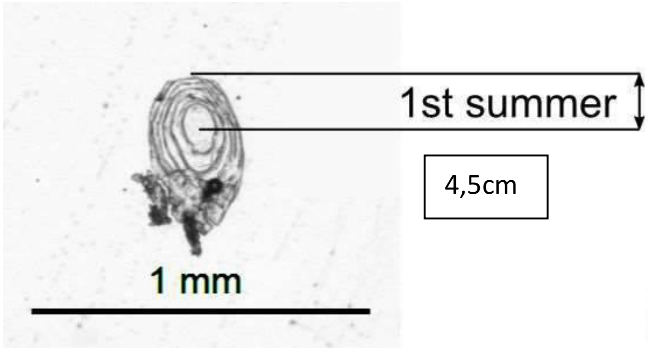
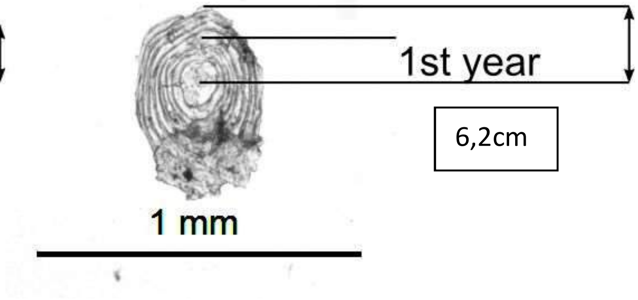
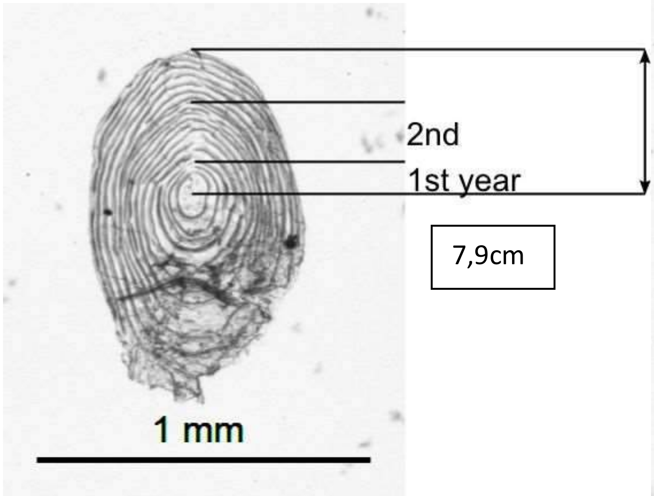


Figure 40. Tømmervikelva. Quite slow growth. Caught in September 2010.







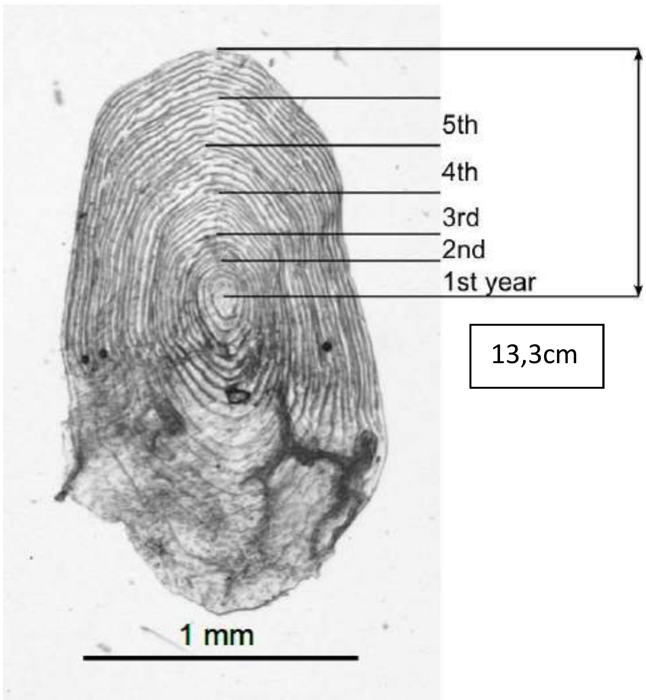


Figure 41. Kvalsundelva. Quite slow growth. Caught in September 2010.

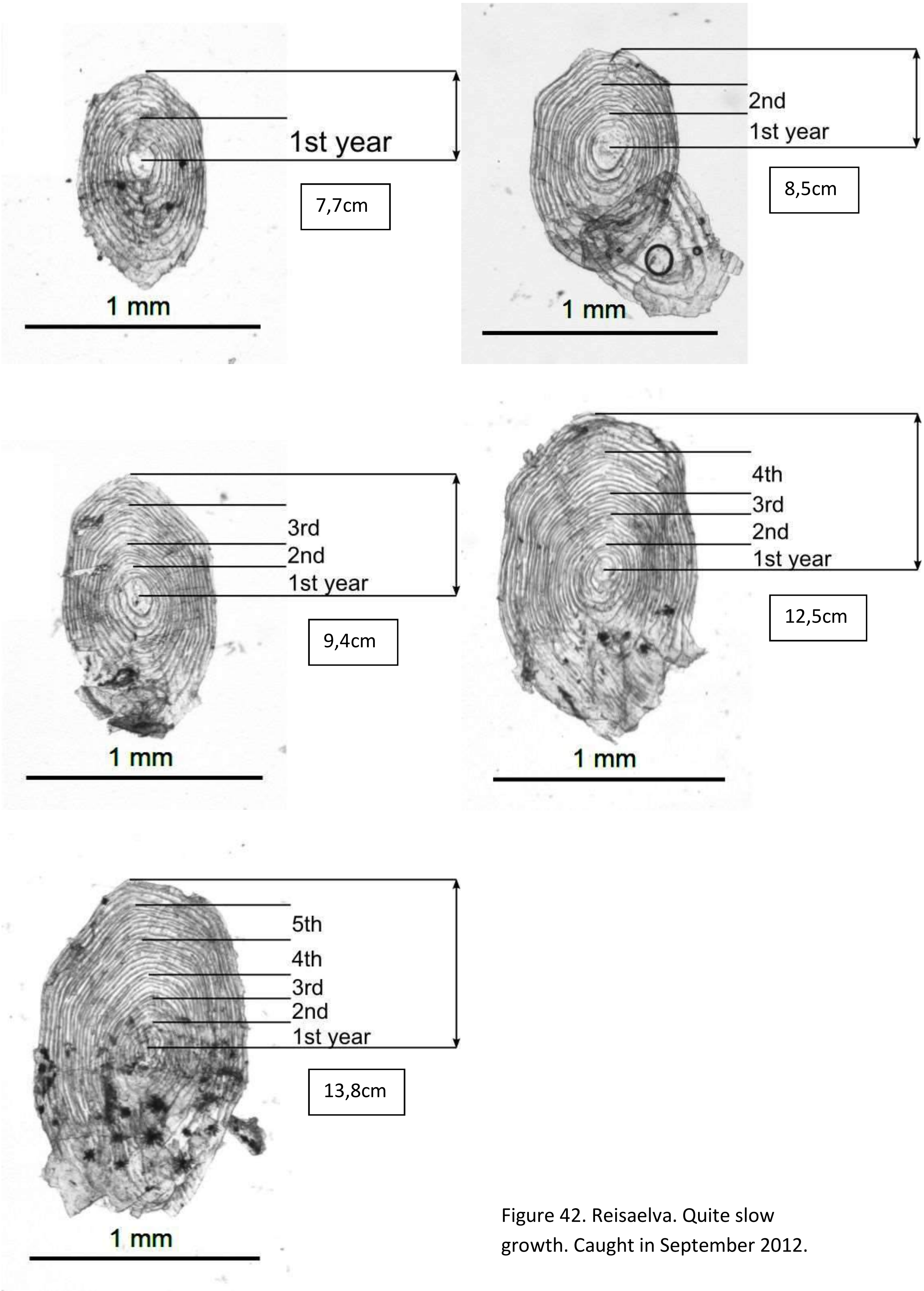
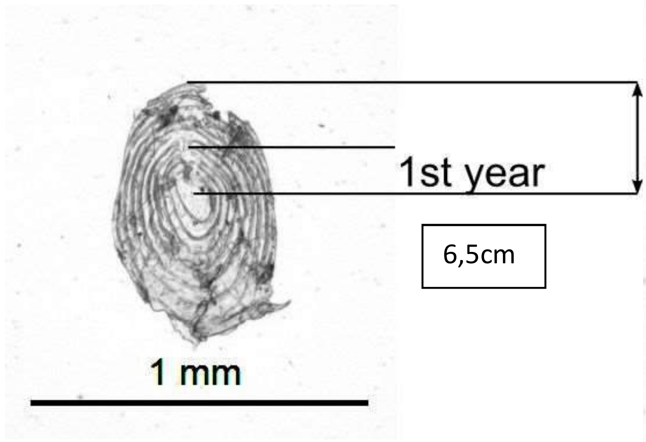
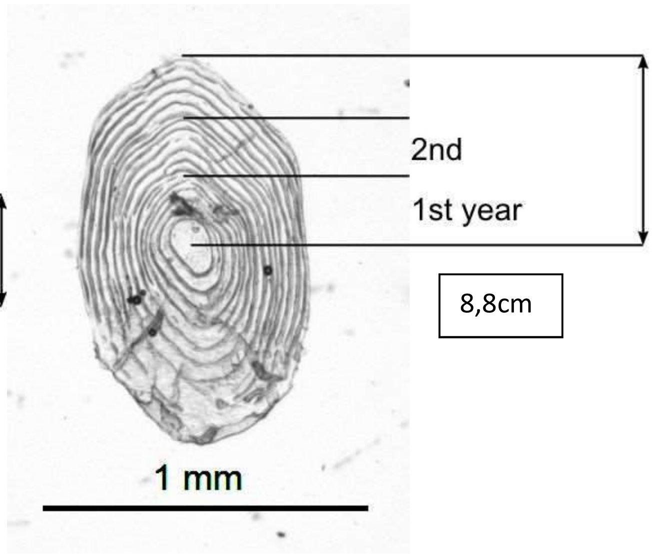
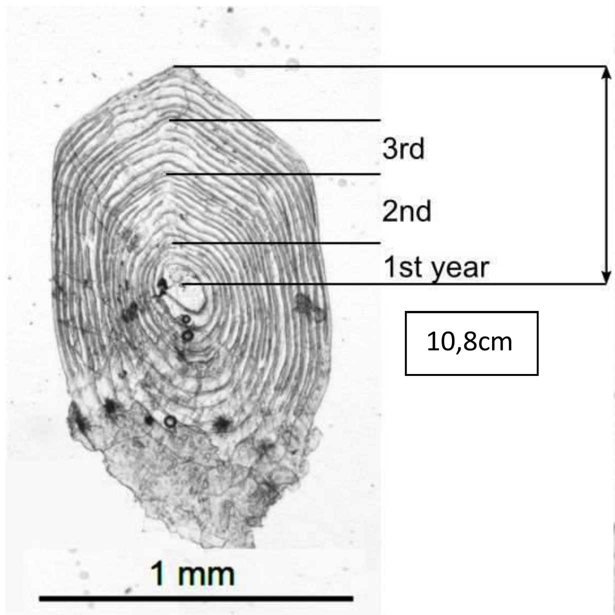
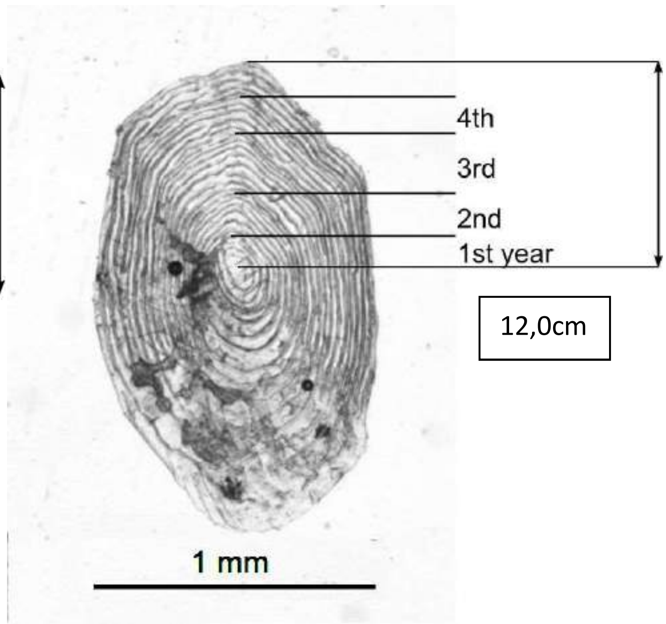


Figure 42. Reisaelva. Quite slow growth. Caught in September 2012.









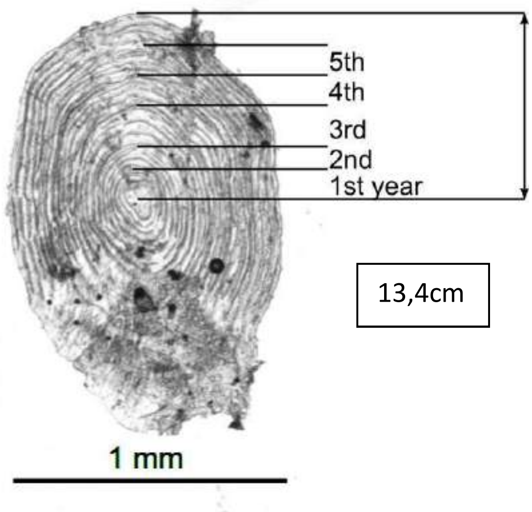


Figure 43. Målselva. Quite slow growth.
Caught in September 2012.

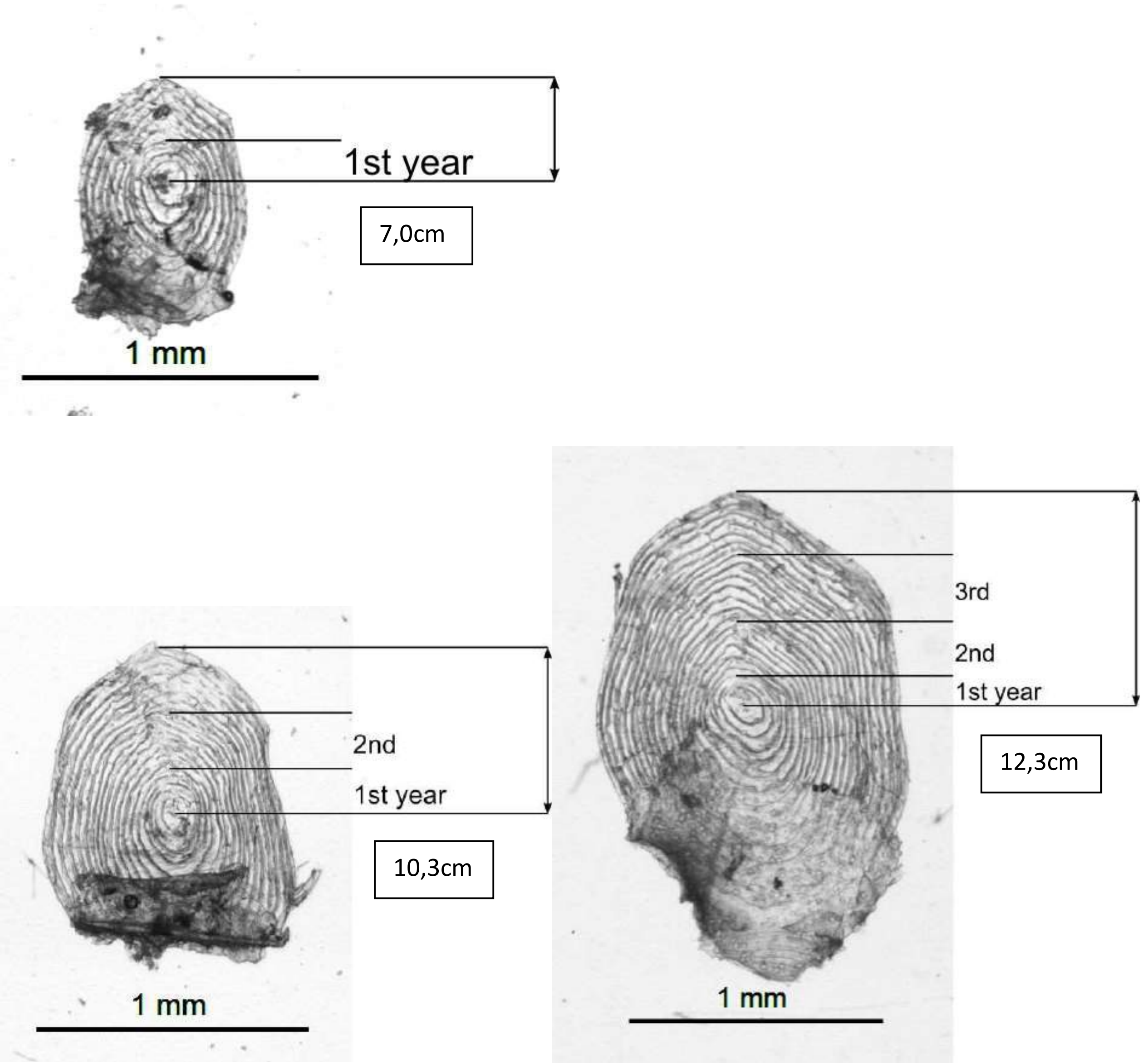


Figure 44. Storelva (Båtsfjord). Fast growth. Caught in September 2010.

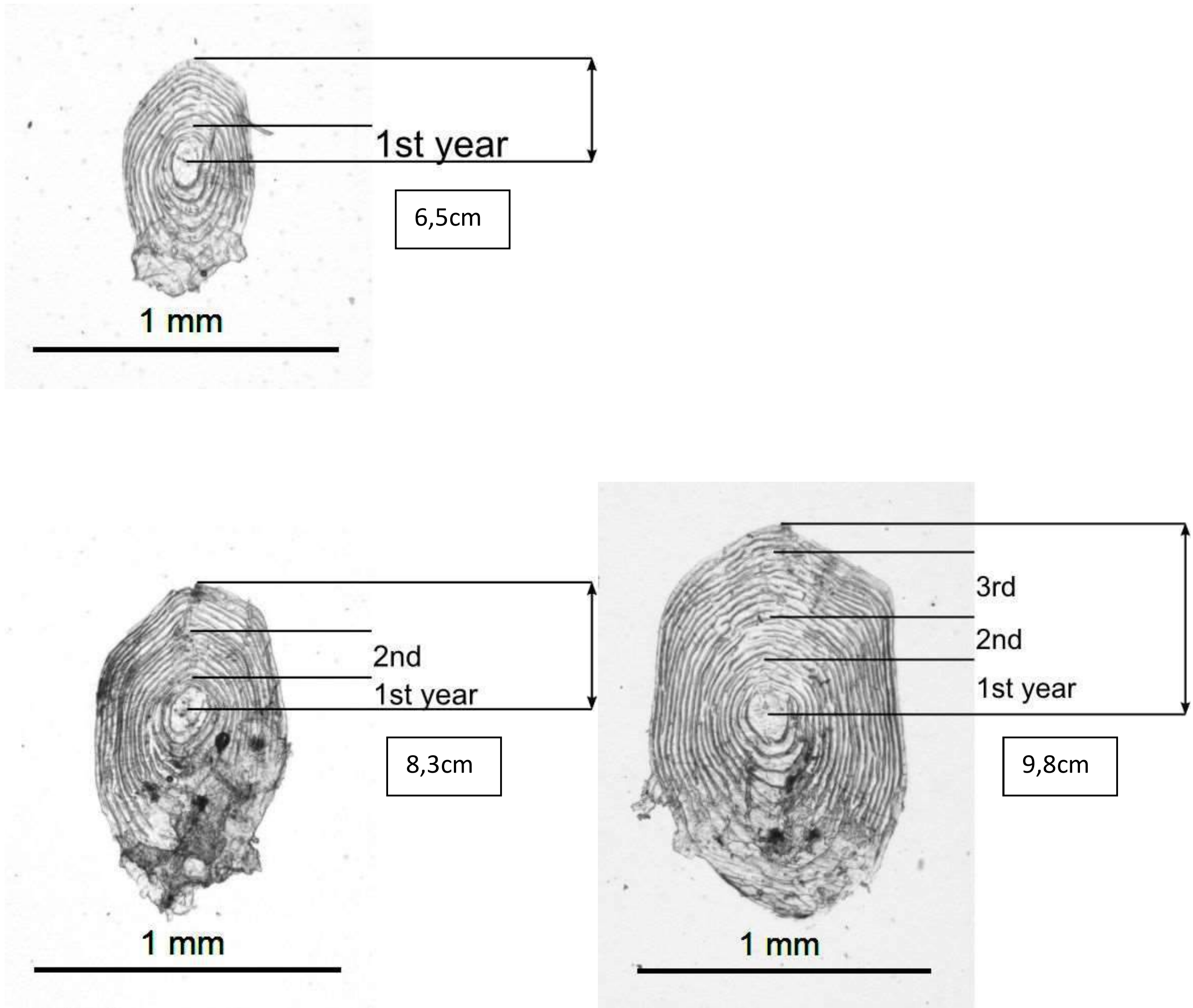


Figure 45. Skaidielva (Repparfjord). Fast growth. Caught in September 2010.

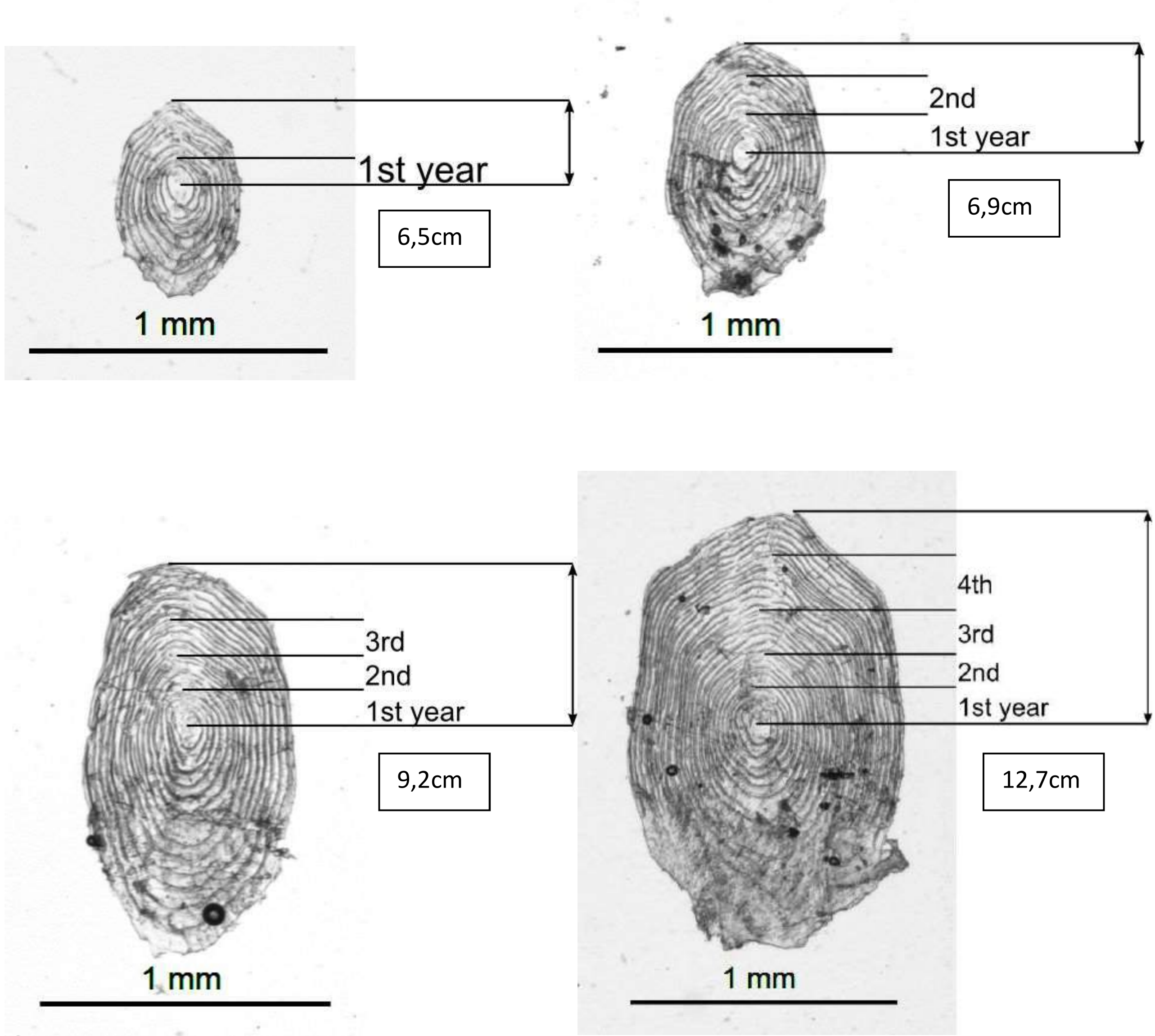


Figure 46. Kvænangselva. Fast growth. Caught in September 2011.

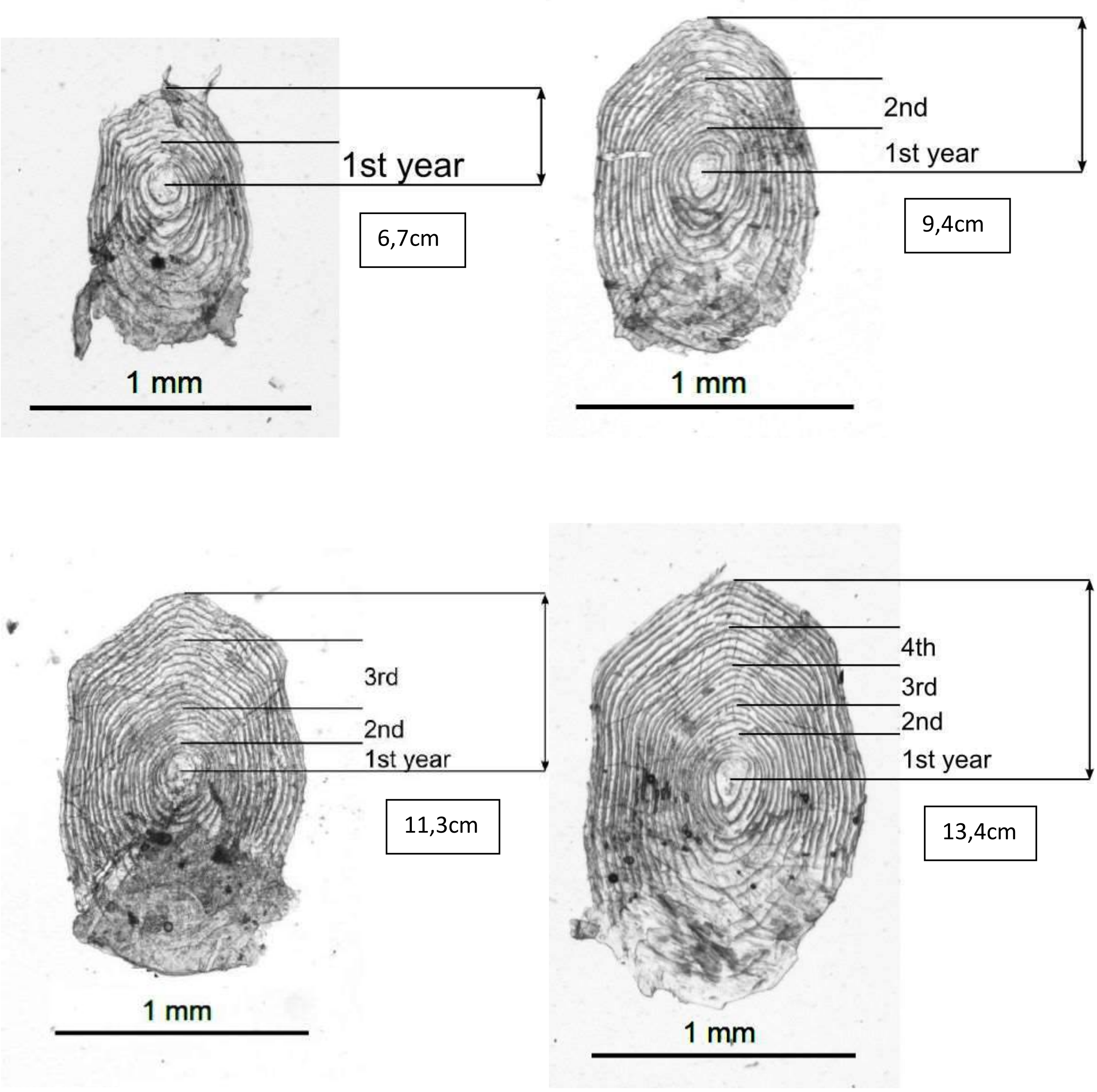
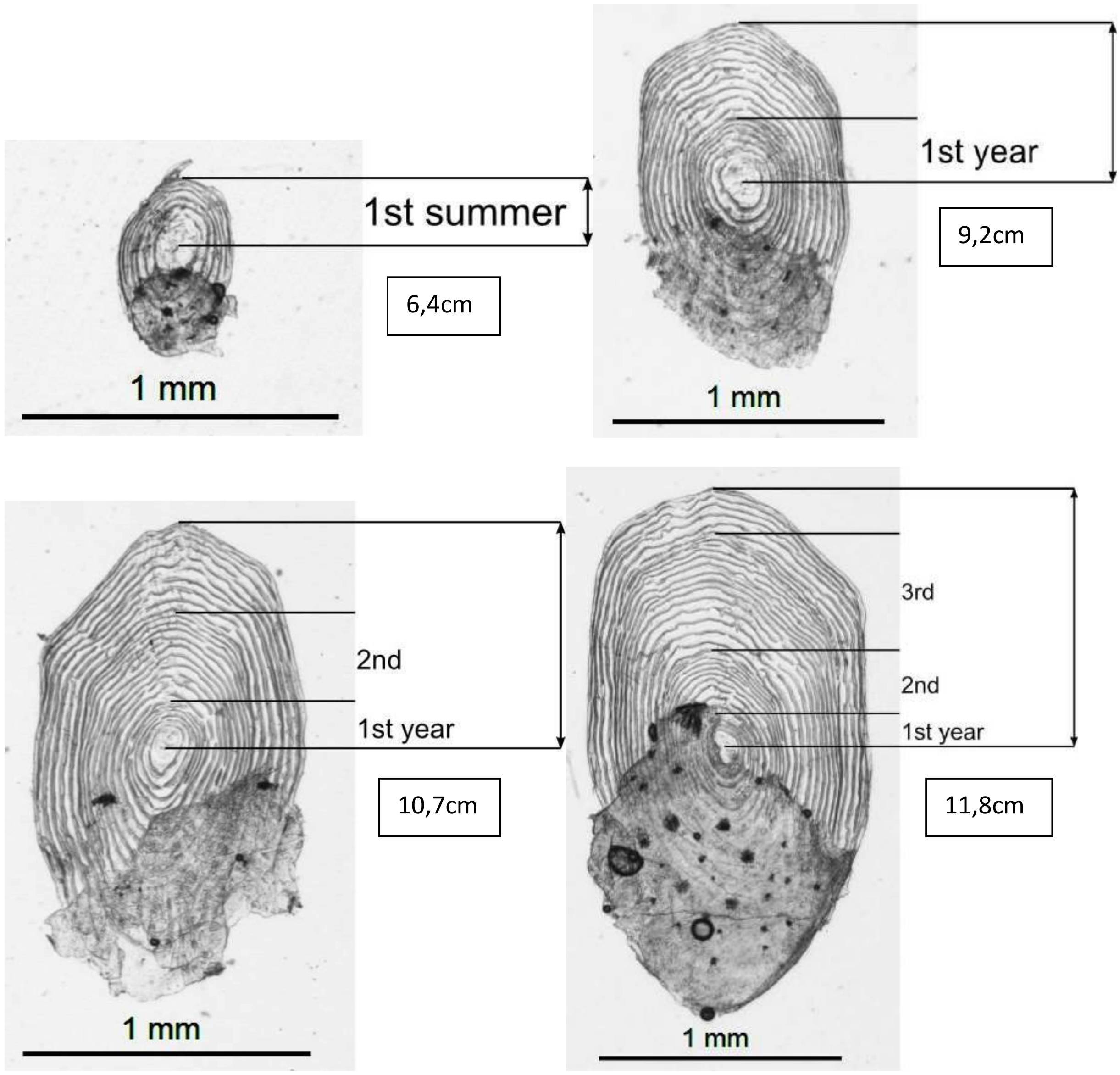


Figure 47. Kåfjordelva. Fast growth. Caught in September 2011.



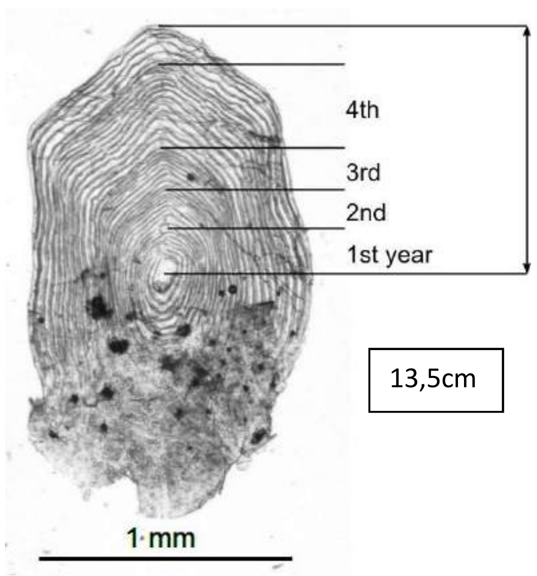


Figure 48. Laukhelle. Fast growth.
Caught in September 2011.

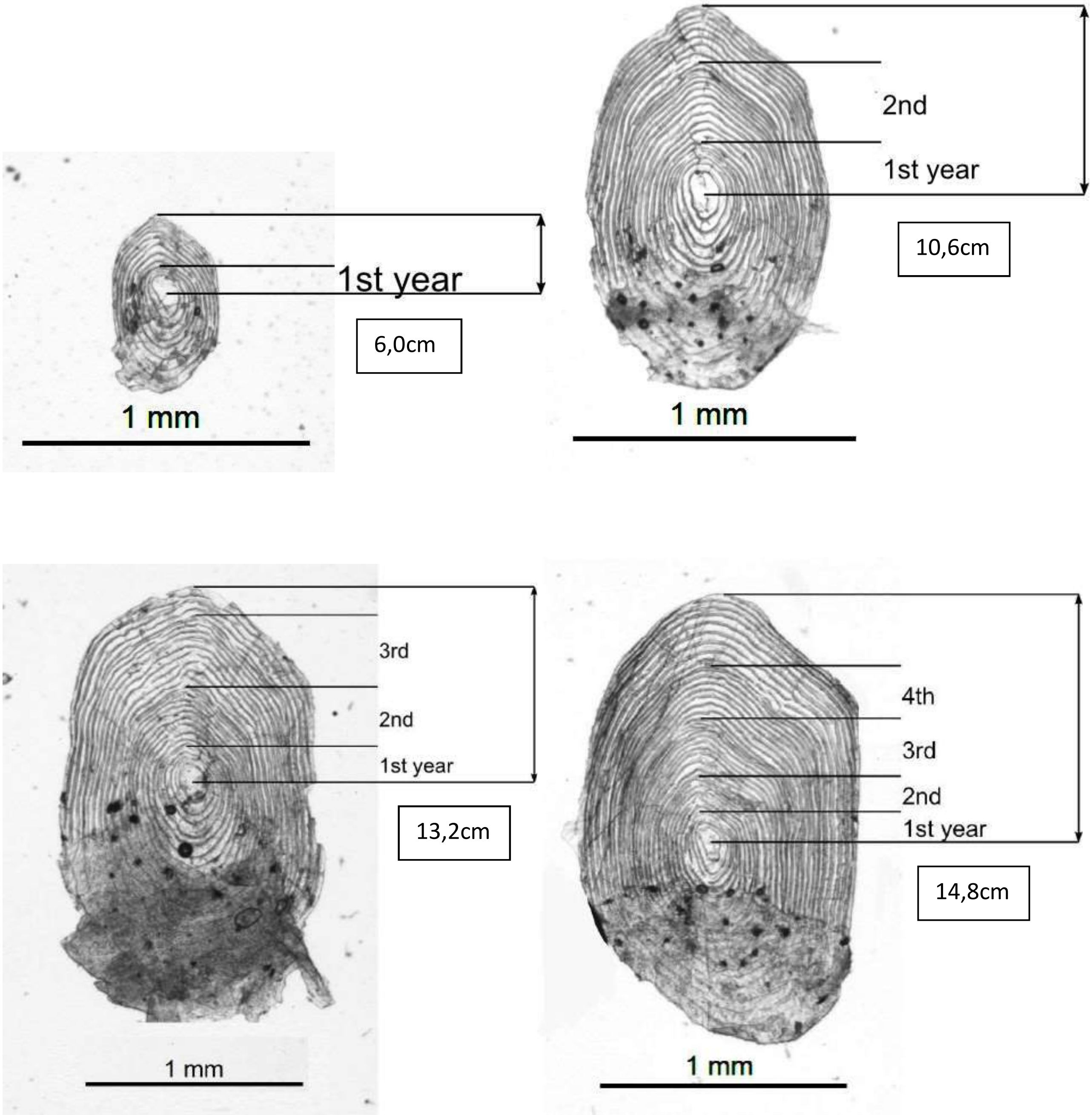


Figure 49. Halselva. Fastest growth. Caught in September 2011.

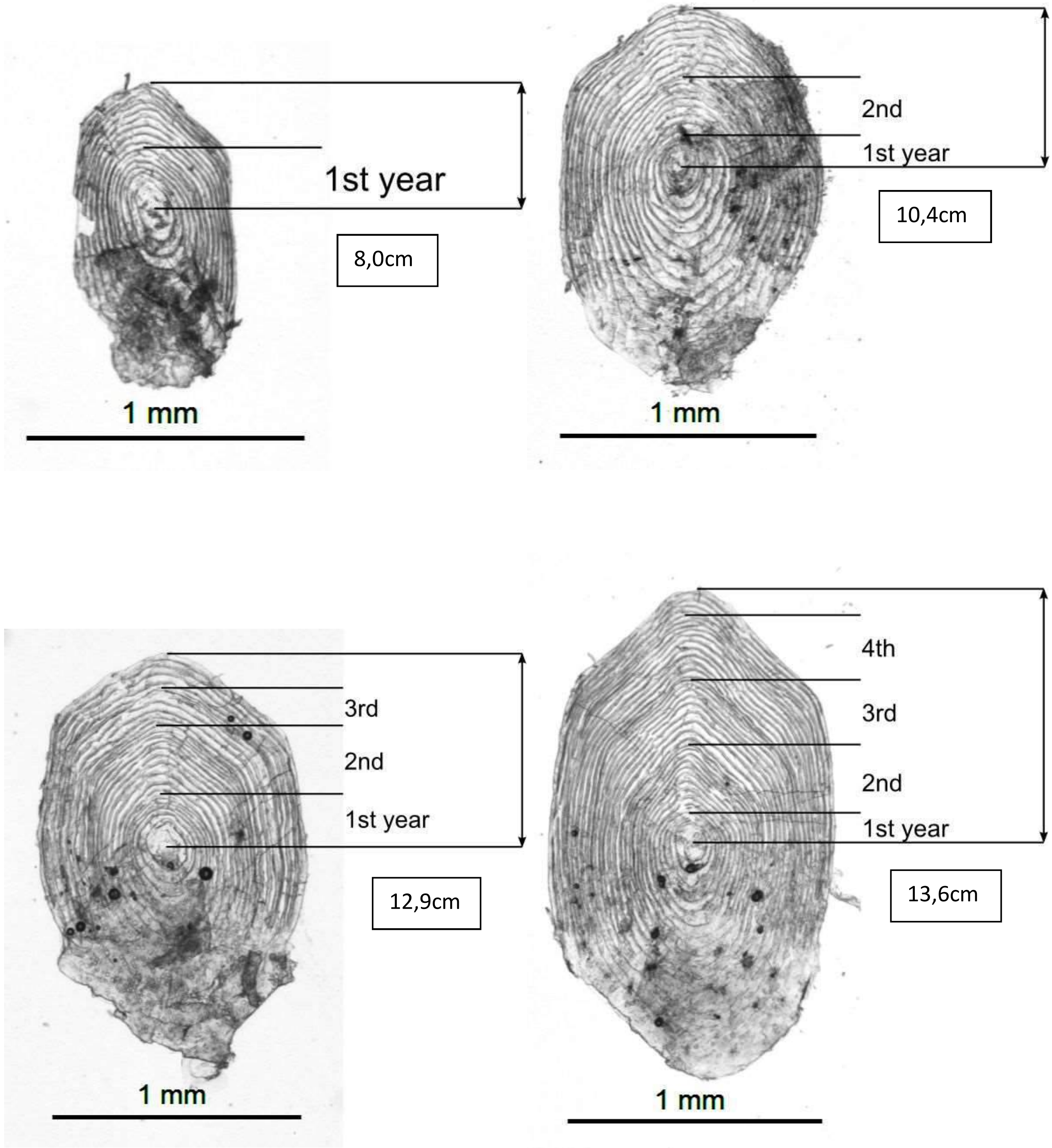


Figure 50. Lakselva (Ausfjord). Fastest growth. Caught in September 2011.

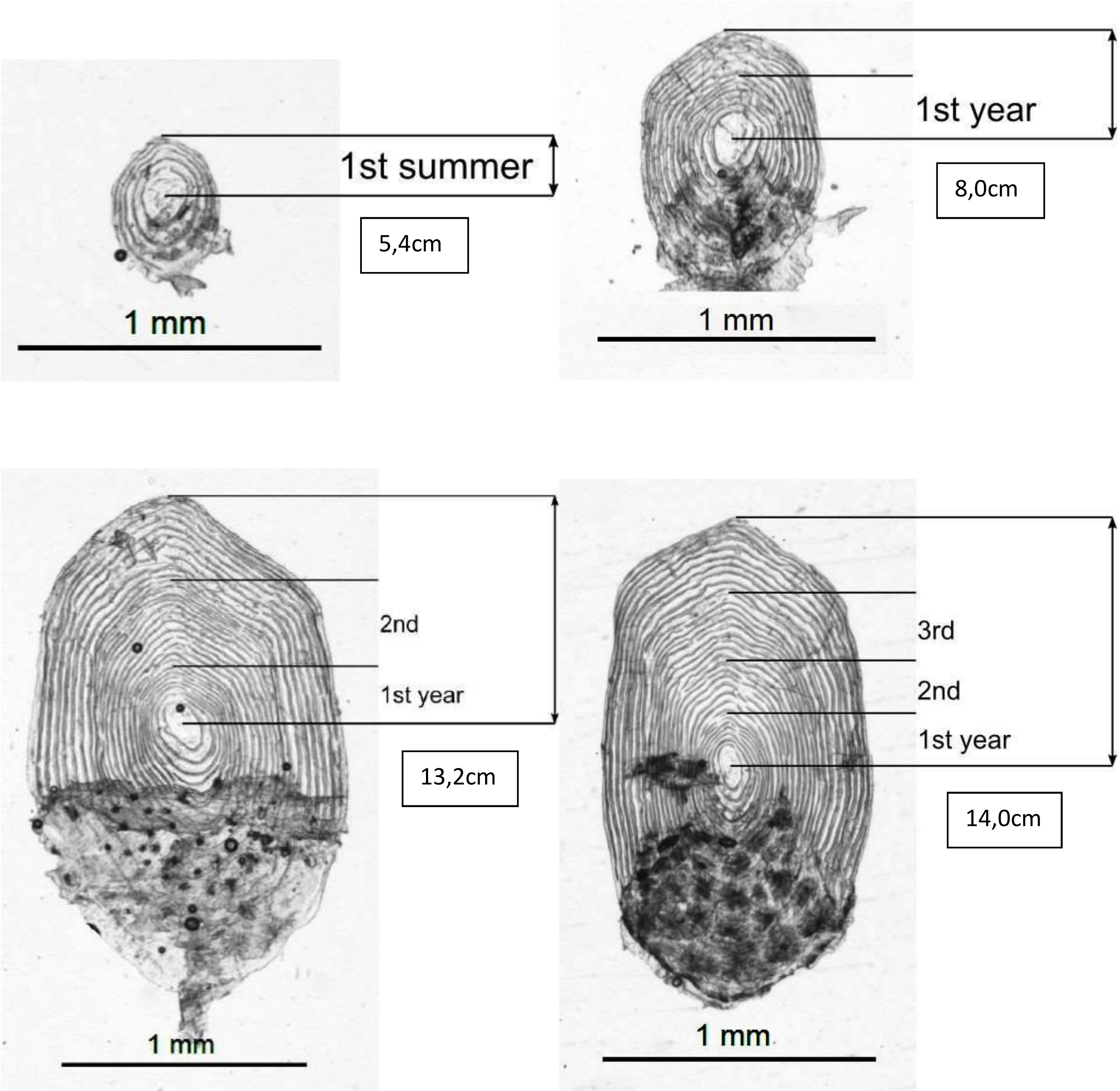


Figure 51. Lyselva (Lysbotnvassdraget). Fastest growth. Caught in September 2011.

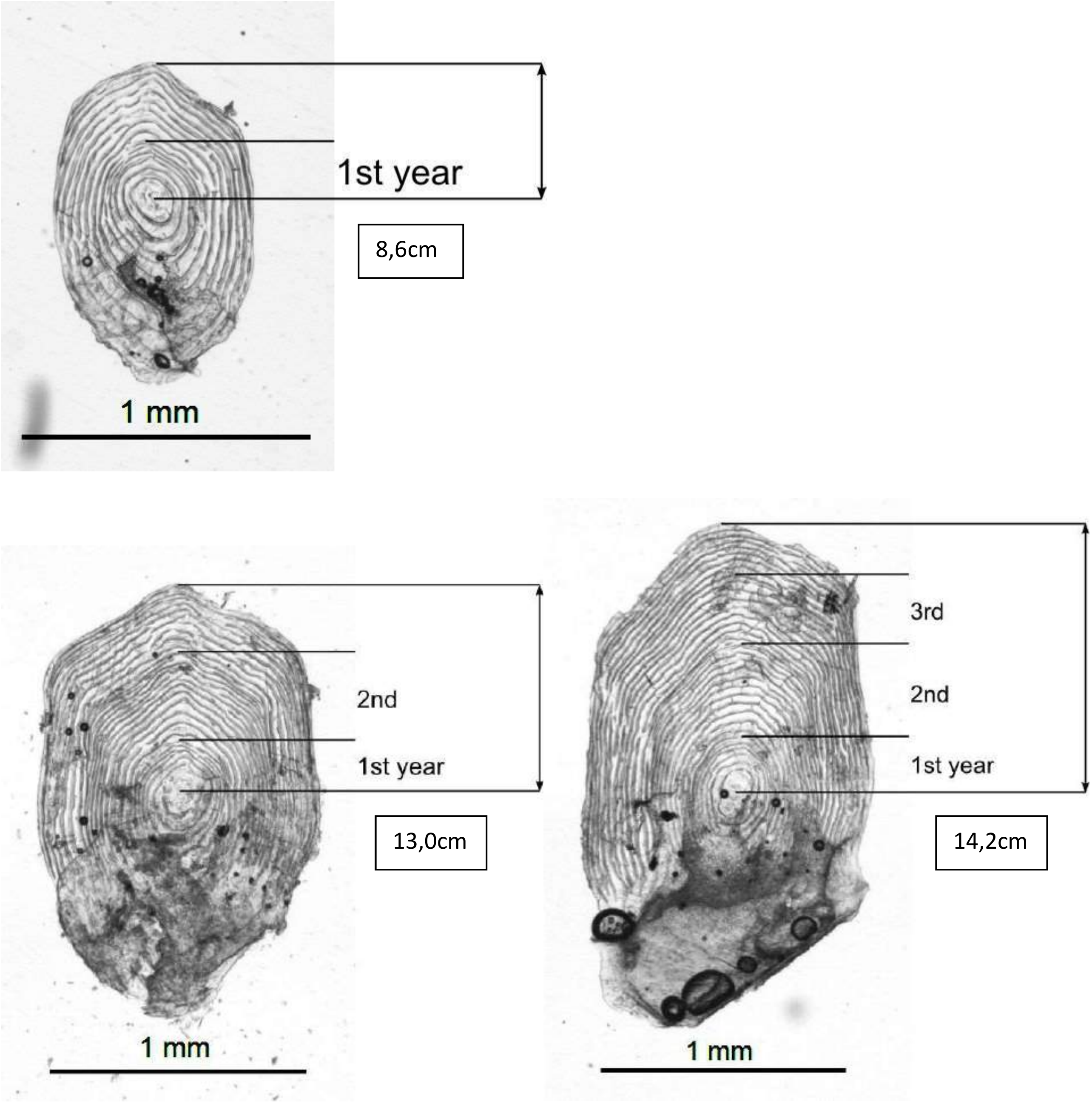


Figure 52. Tennelvvassdraget. Fastest growth. Caught in September 2011.

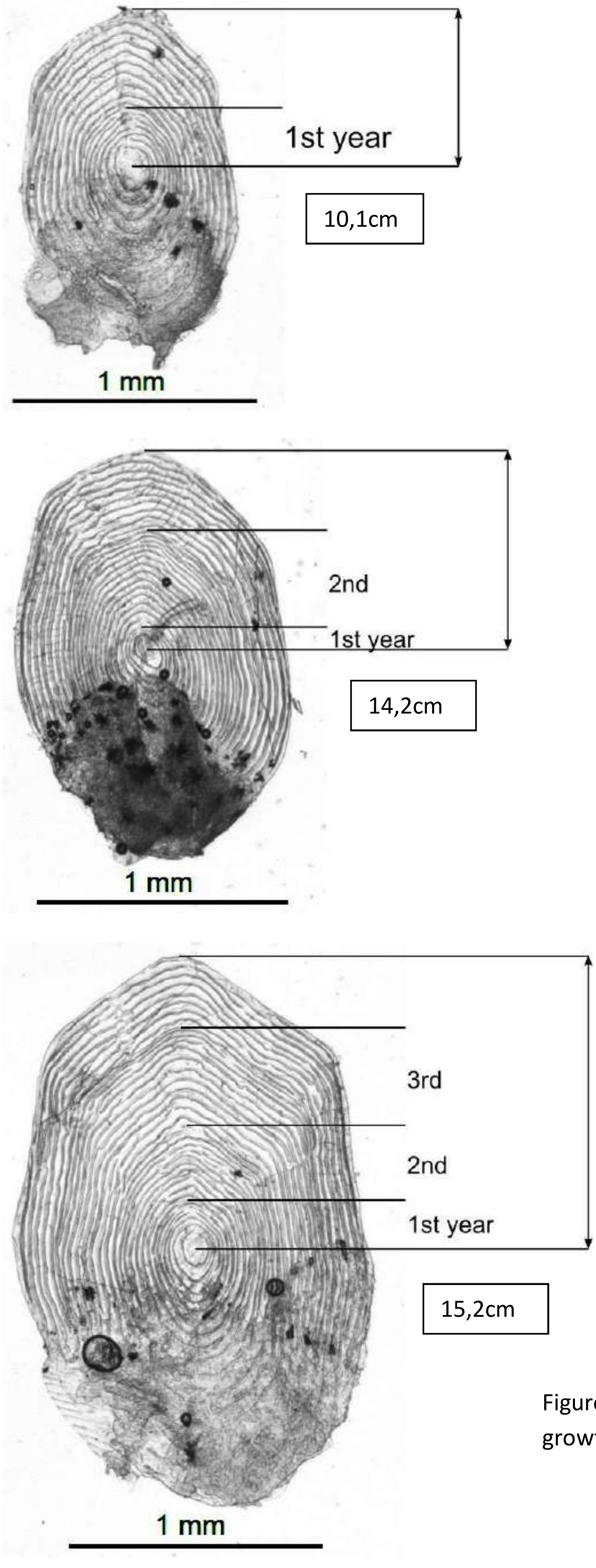


Figure 53. Iversfjordelva. Fastest growth.

10. First time spawners

The scale growth at sea and in the freshwater period for maiden salmon is presented for some Barents Sea salmon stocks. In the figures the summer bands (sea summer) and the winter bands (sea winter) are presented. Smolt age in the figures is four except for the River Teno/Tana stocks where smolt ages are 3, 4 and 5 for 1–3SW salmon.

Photo 3. Meiden salmon in River Tana/ Teno. Photo: Eero Niemelä

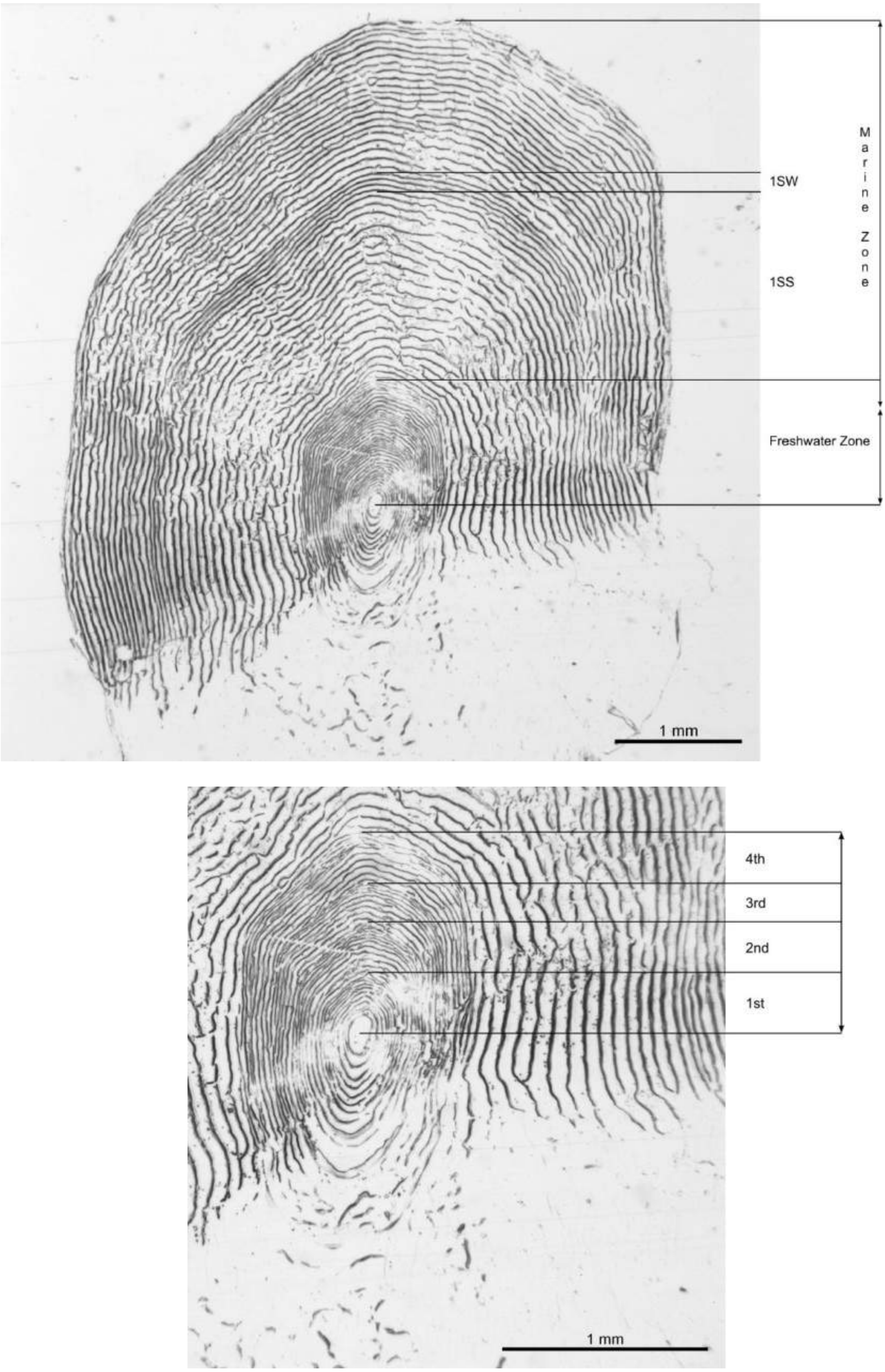


Figure 54. River Ura 4.1SW. In the age 4 is smolt age and 1 is years at sea.

Figure 55. River Ura 4.2SW.

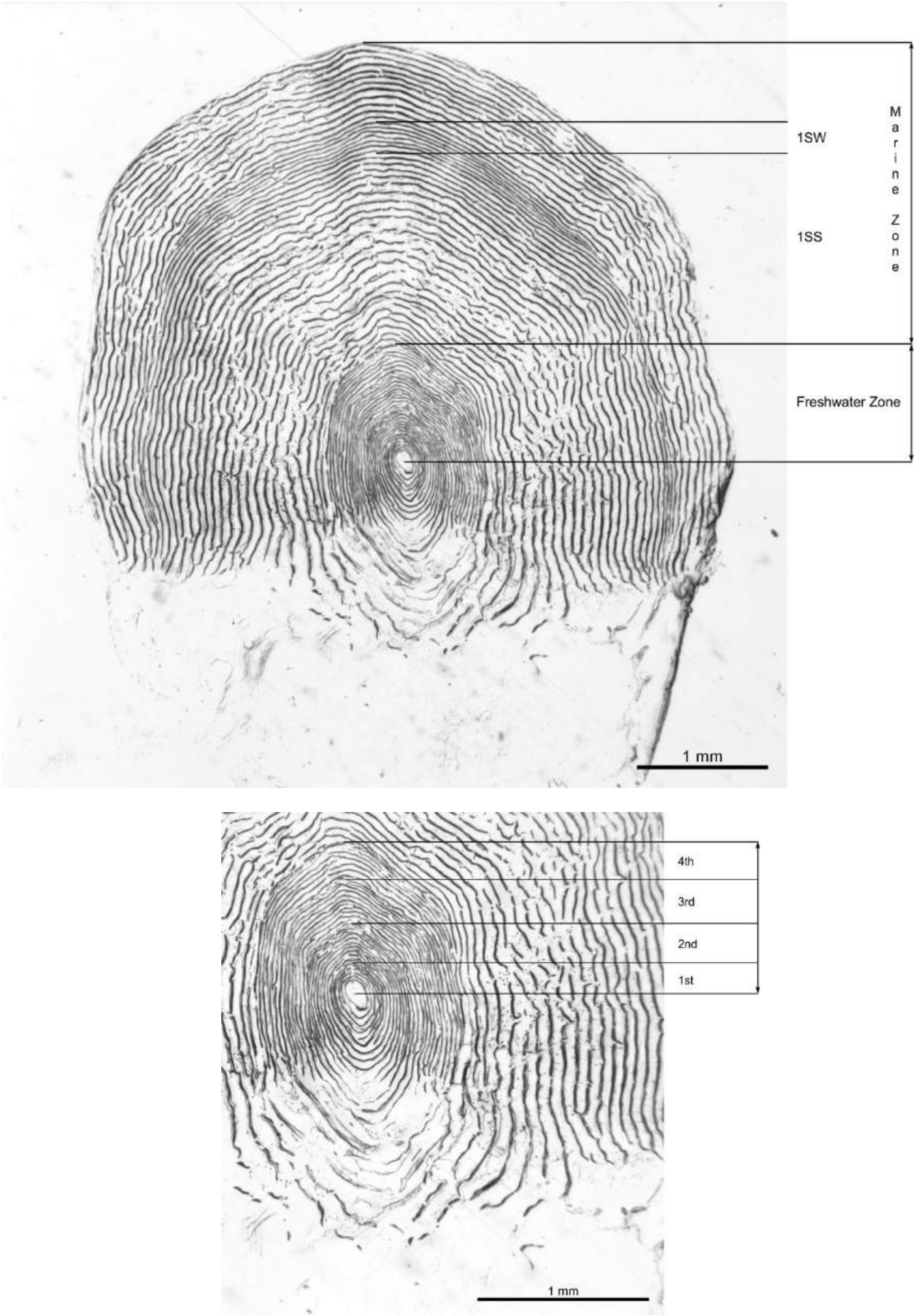
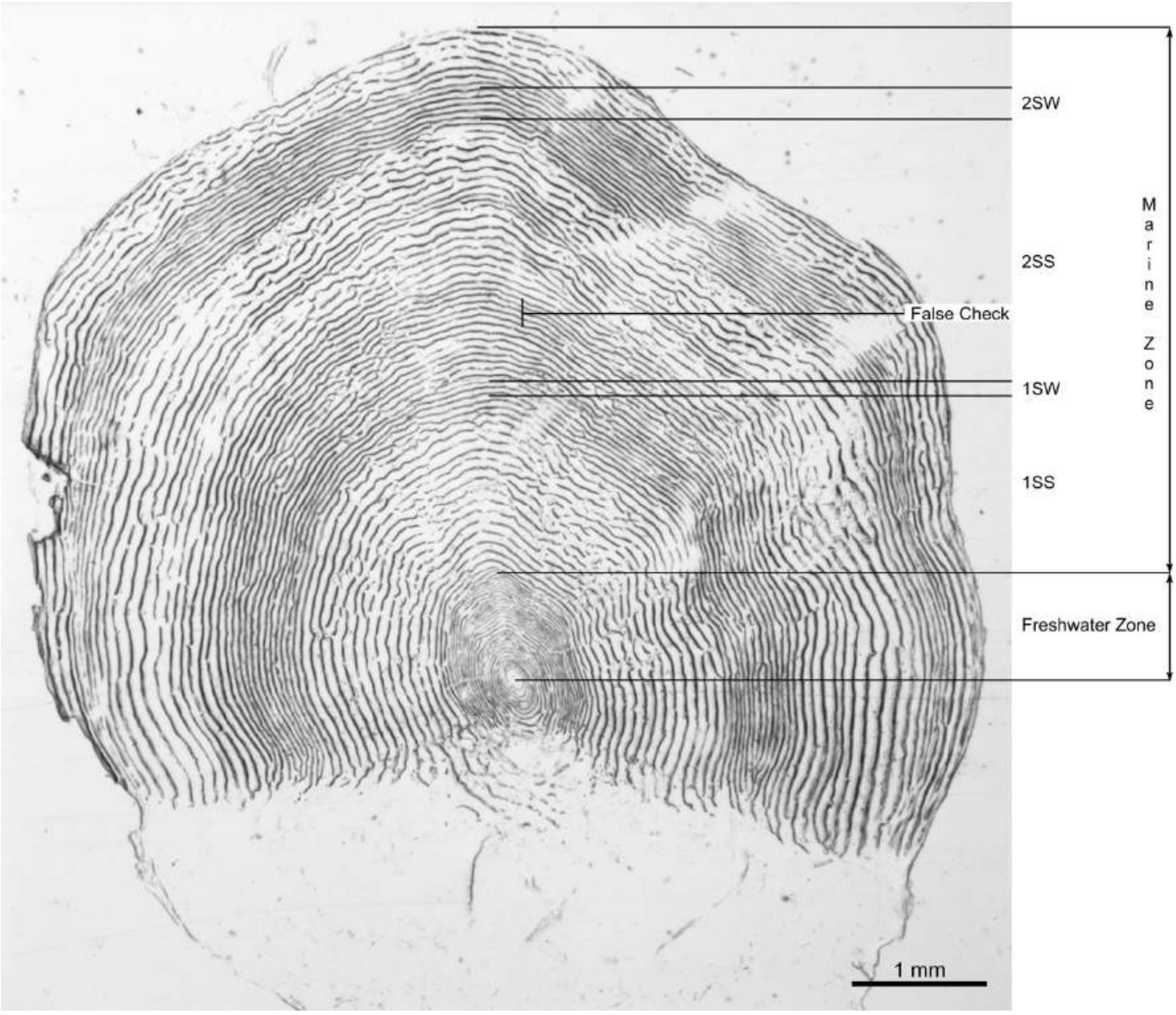


Figure 56. River Bolshaya Zapadnaya Litsa 4.1SW.



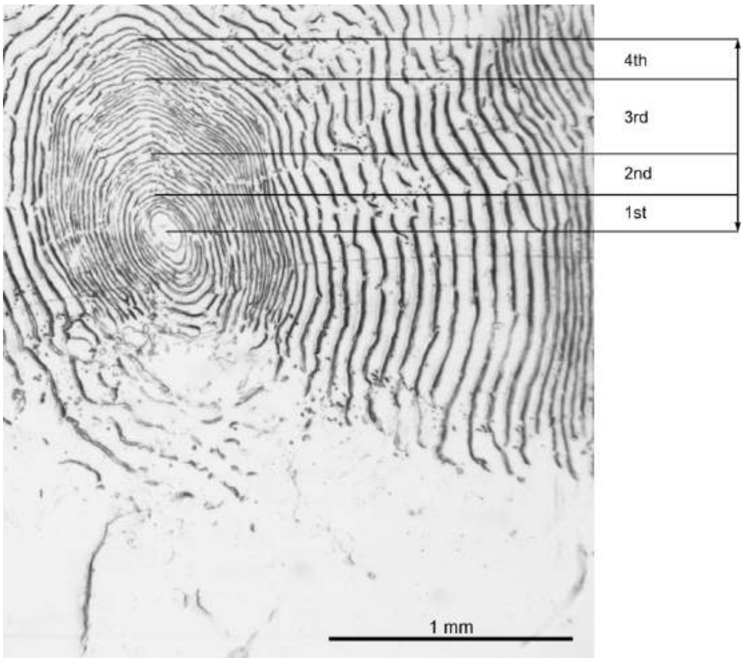
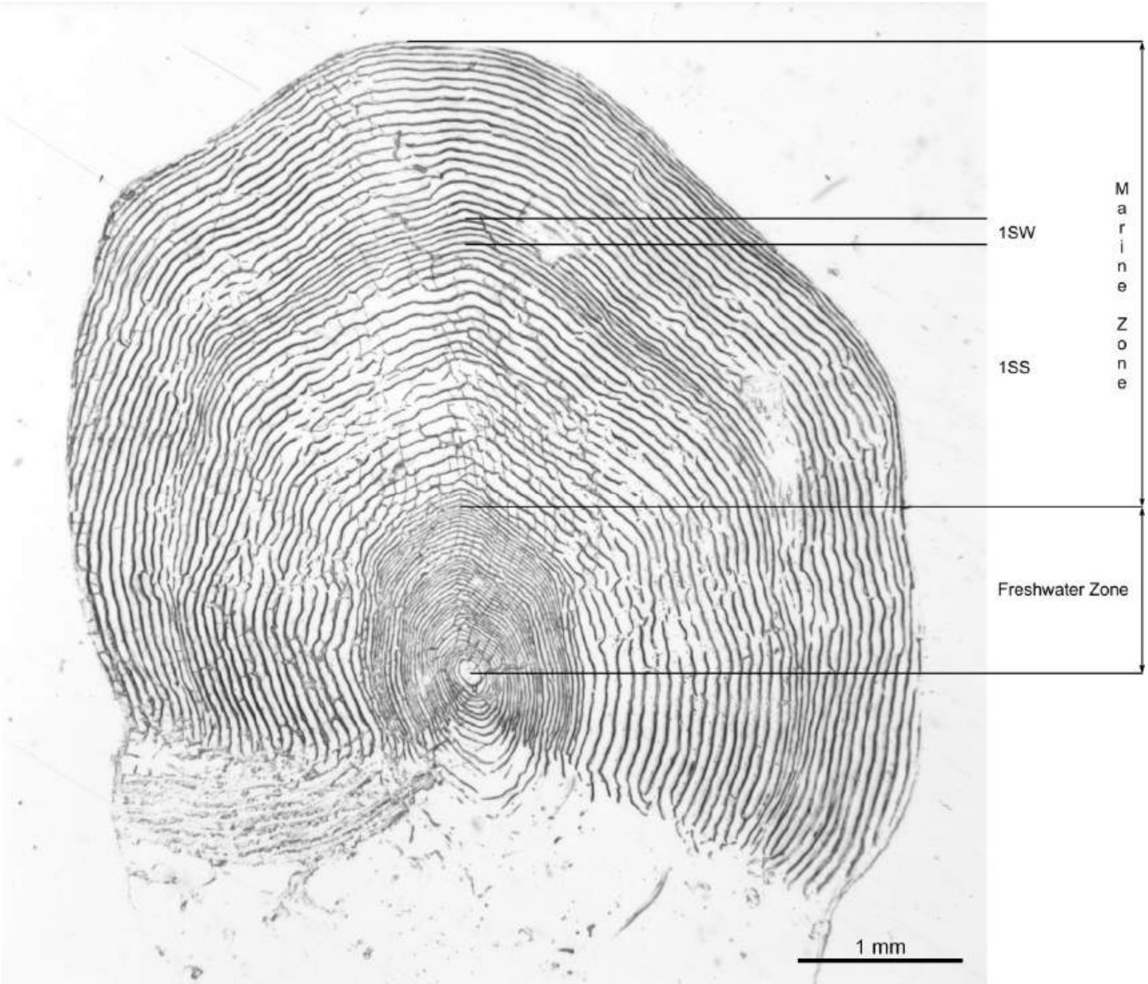


Figure 57. River Bolshaya Zapadnaya Litsa 4.2SW.



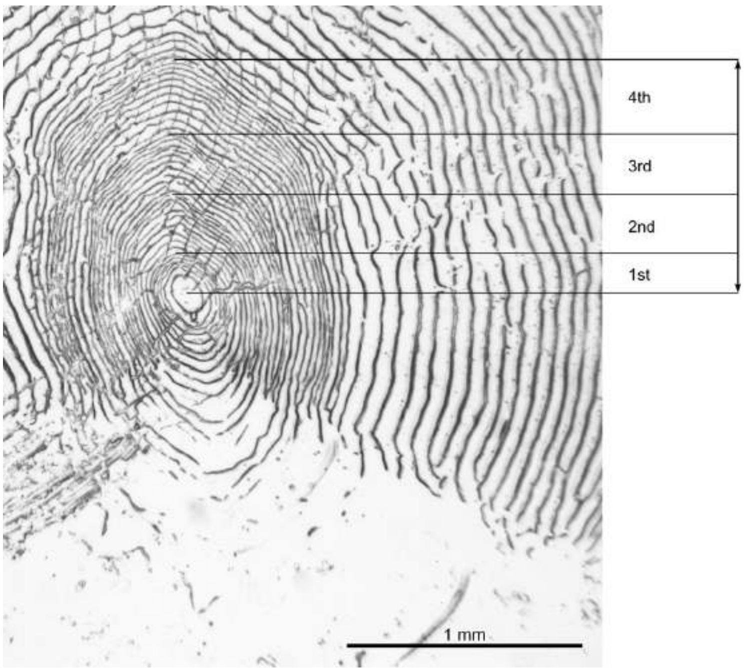
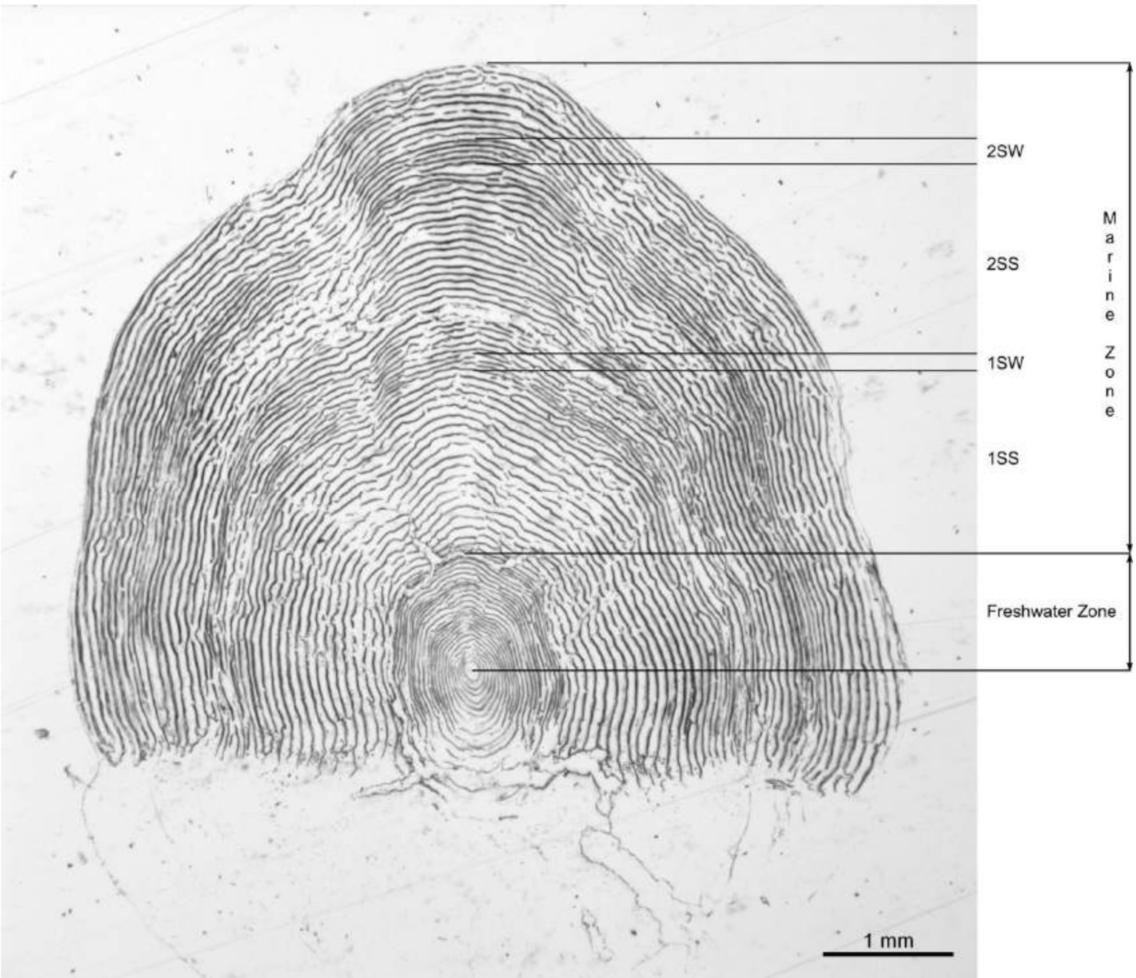


Figure 58. River Titovka 4.1SW.



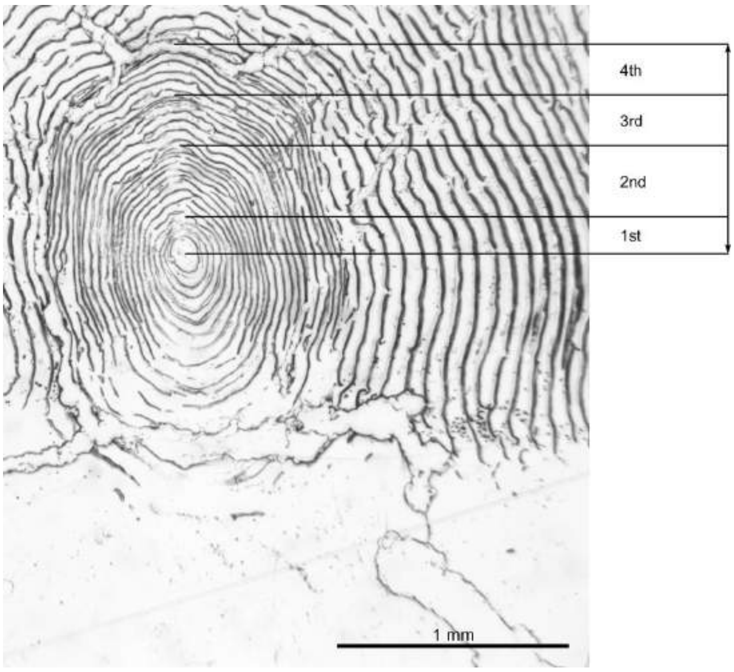
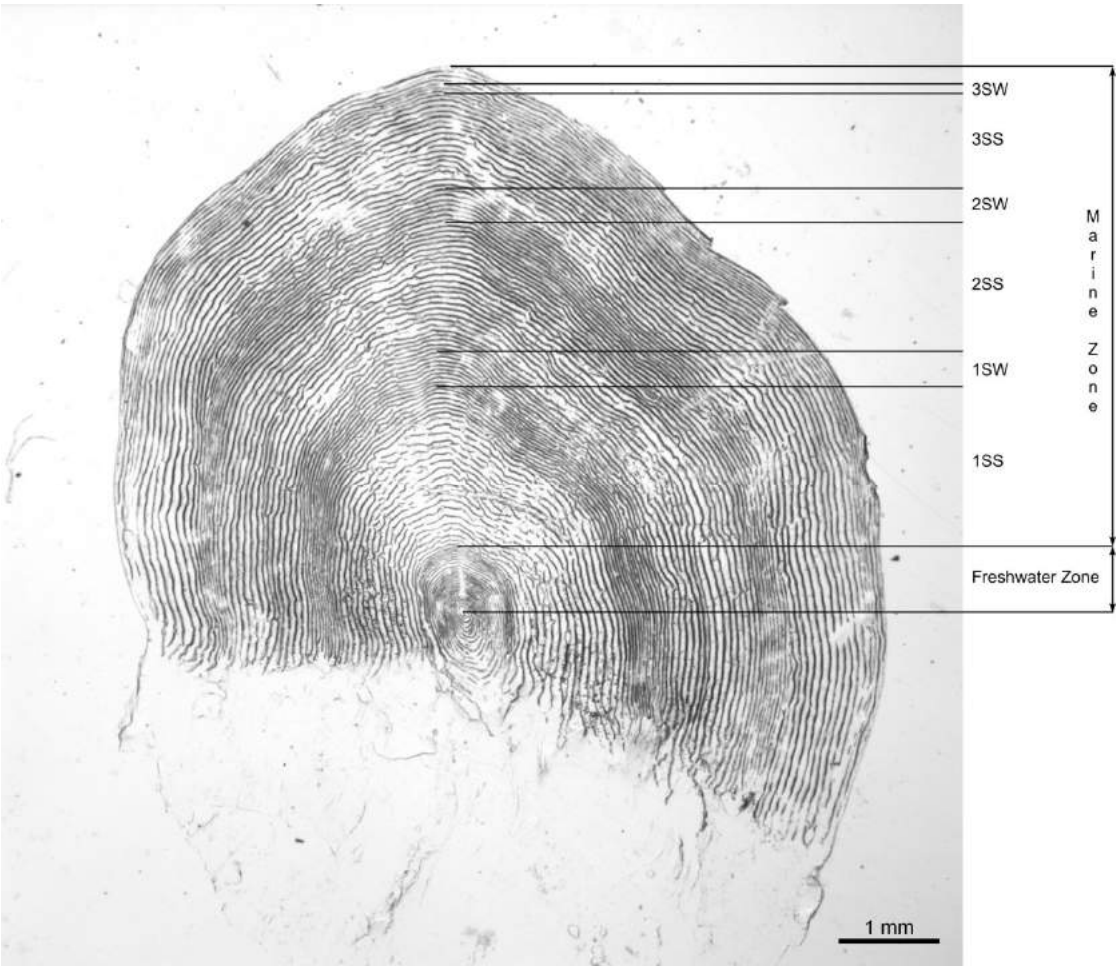


Figure 59. River Titovka 4.2SW.



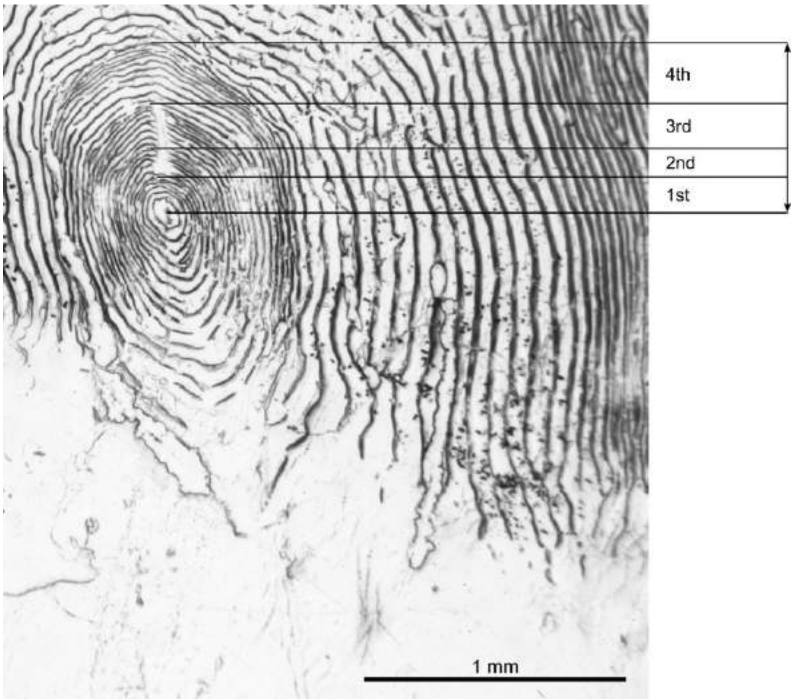
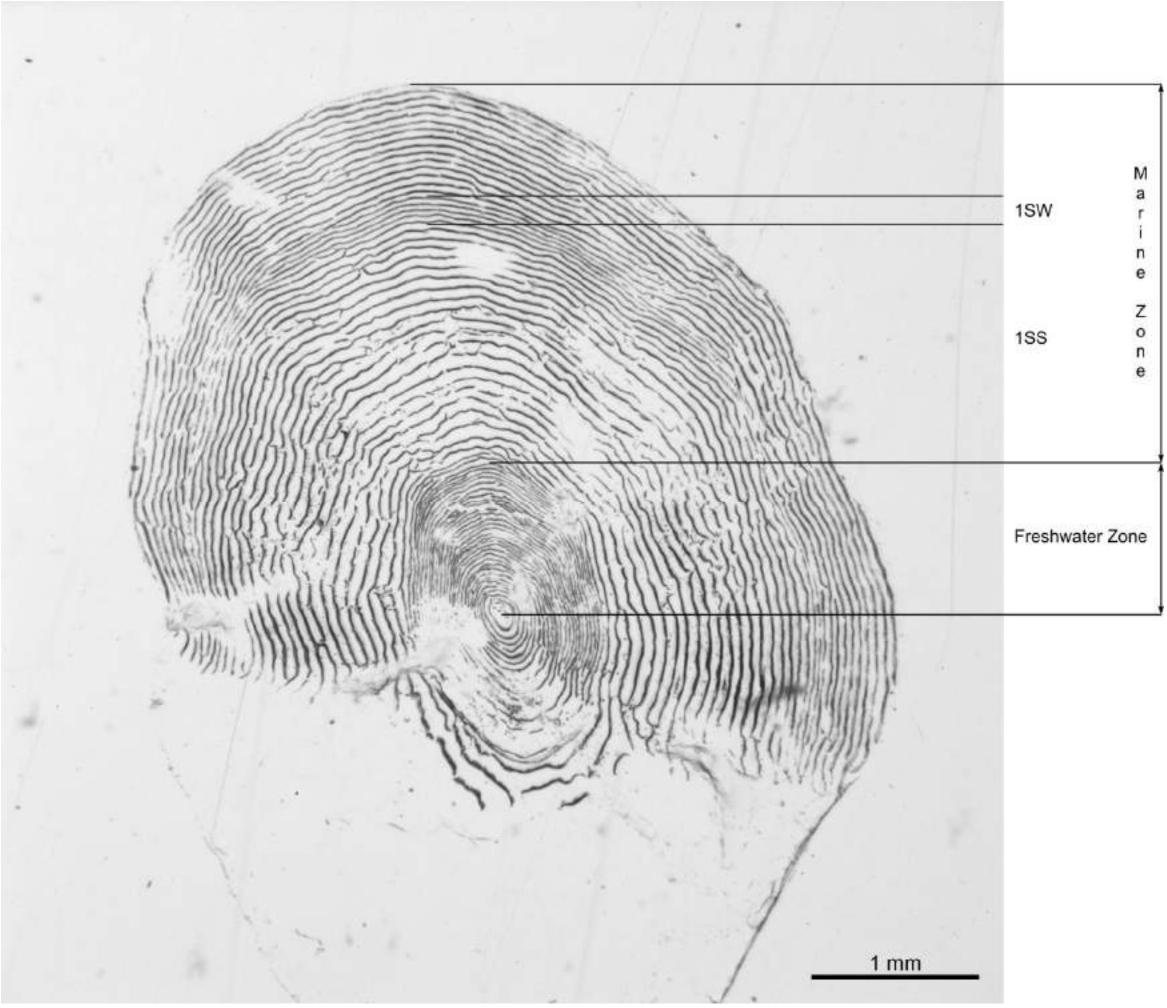


Figure 60. River Titovka 4.3SW.



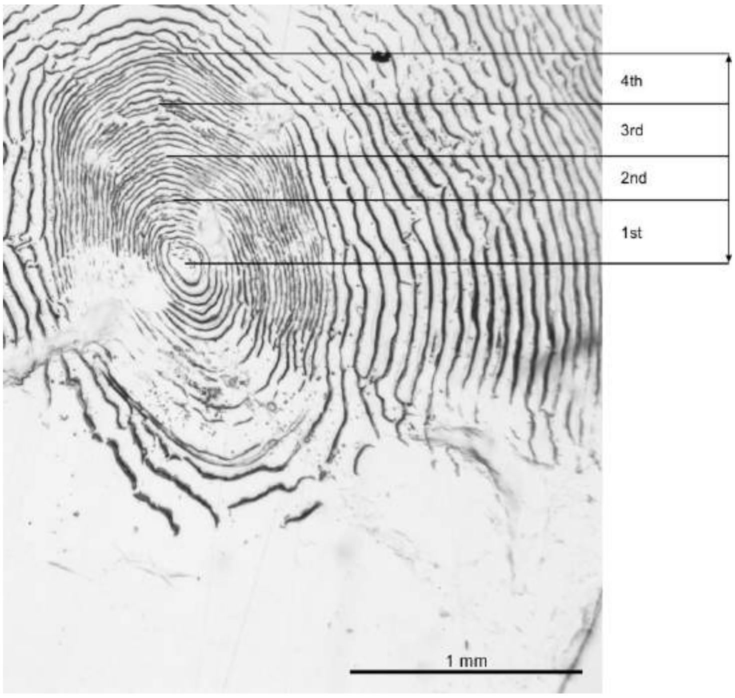
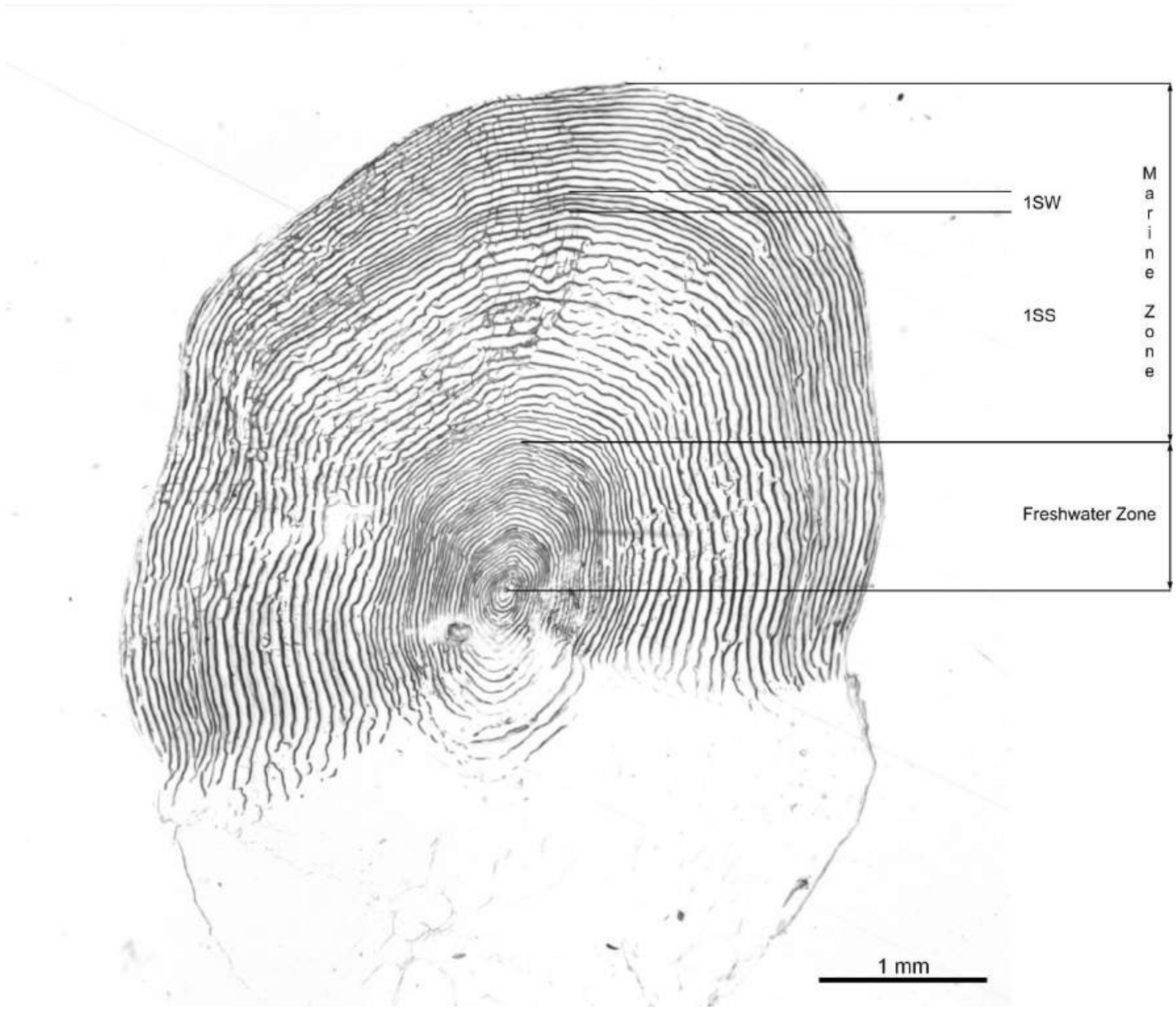


Figure 61. River Pyave 4.1SW.



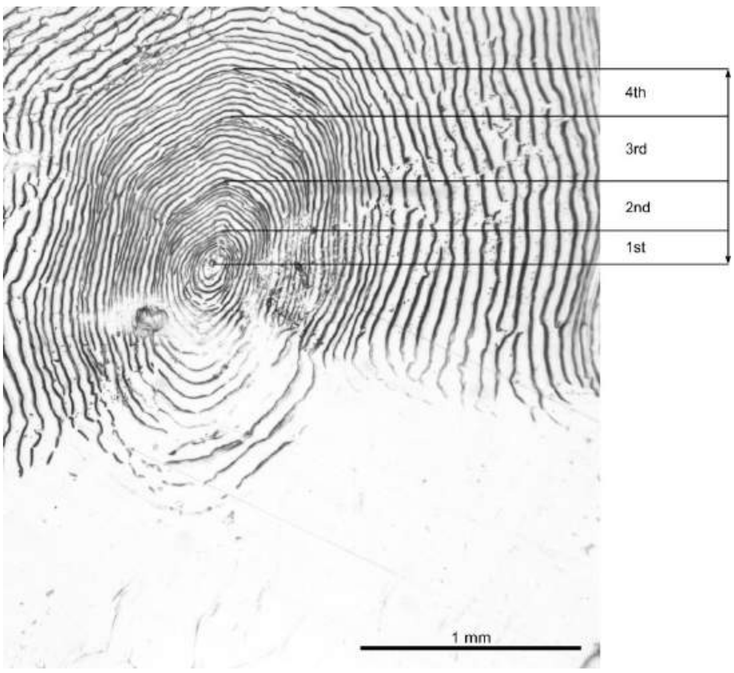
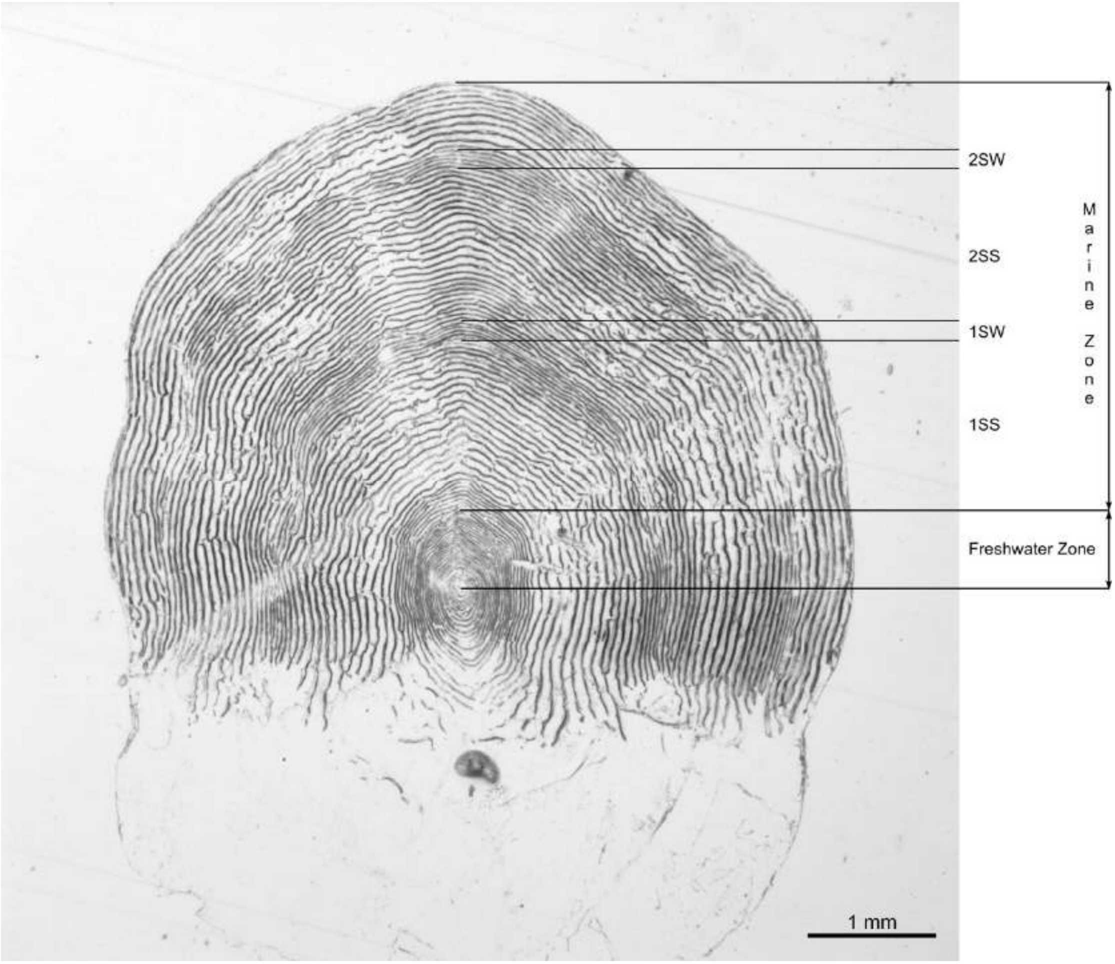


Figure 62. River Neiden 4.1SW.



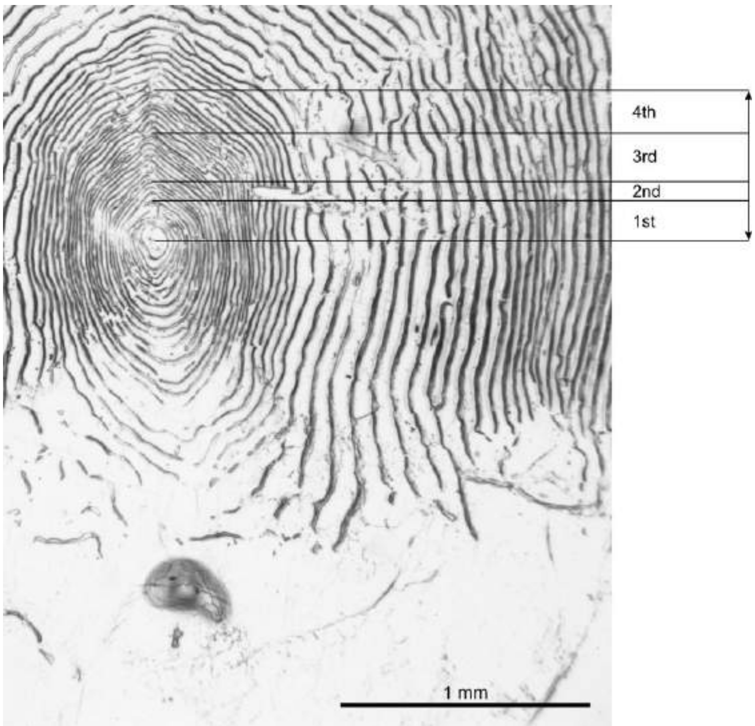
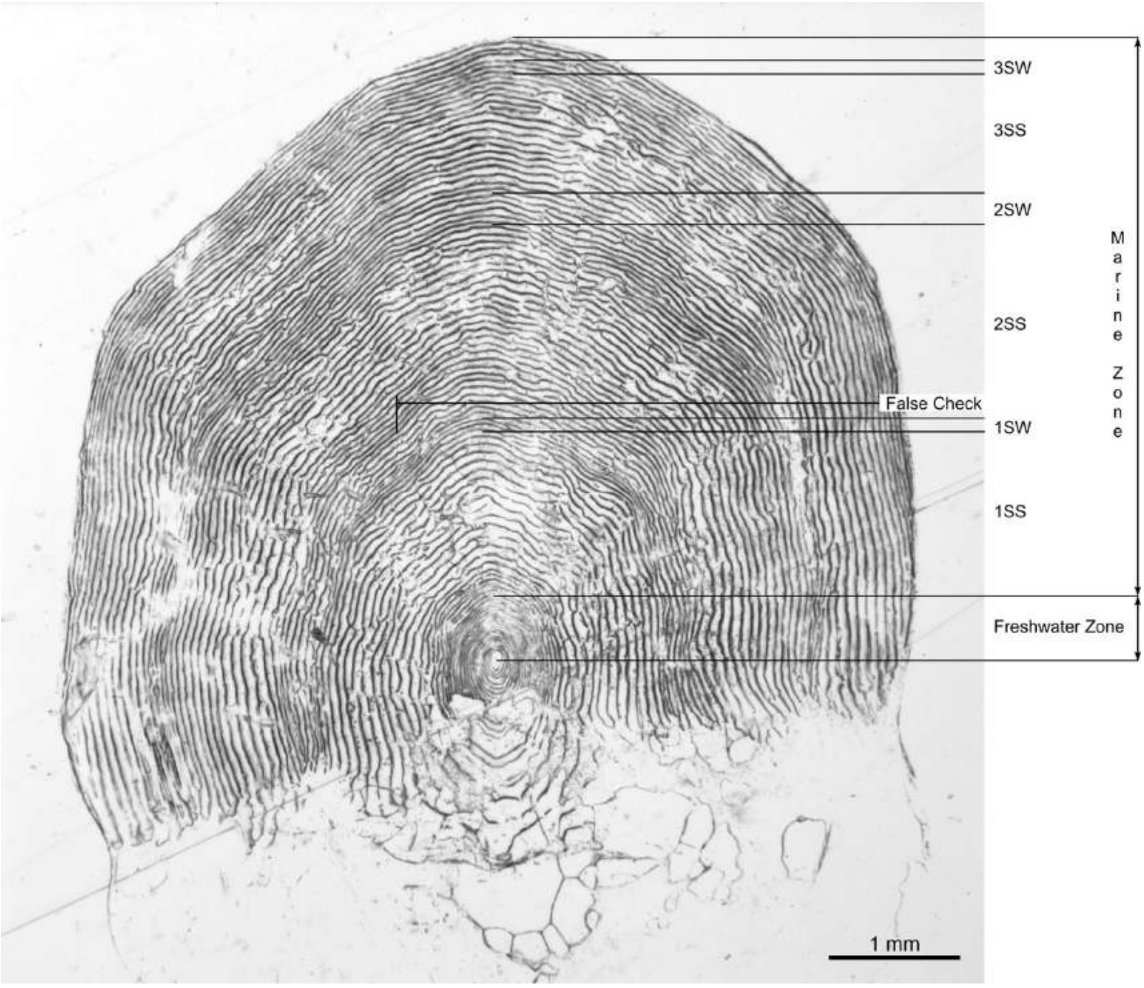


Figure 63. River Neiden 4.2SW.



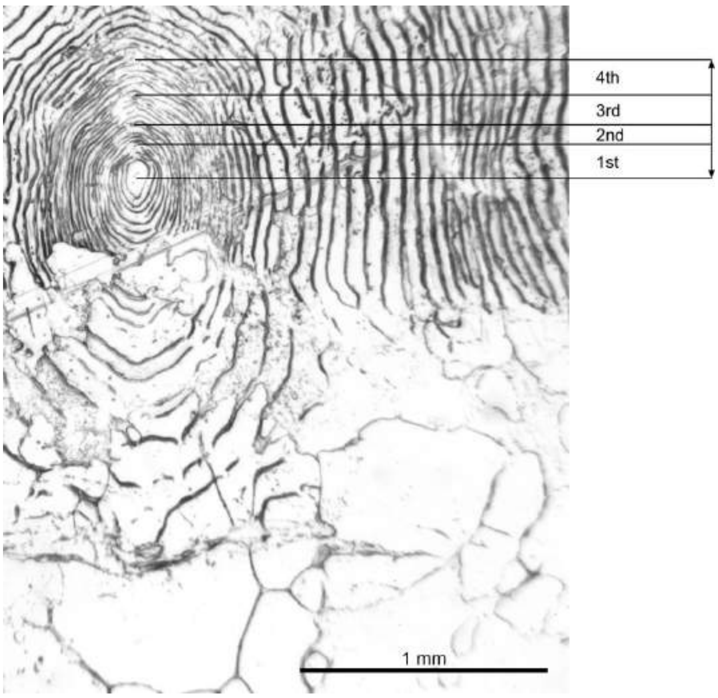
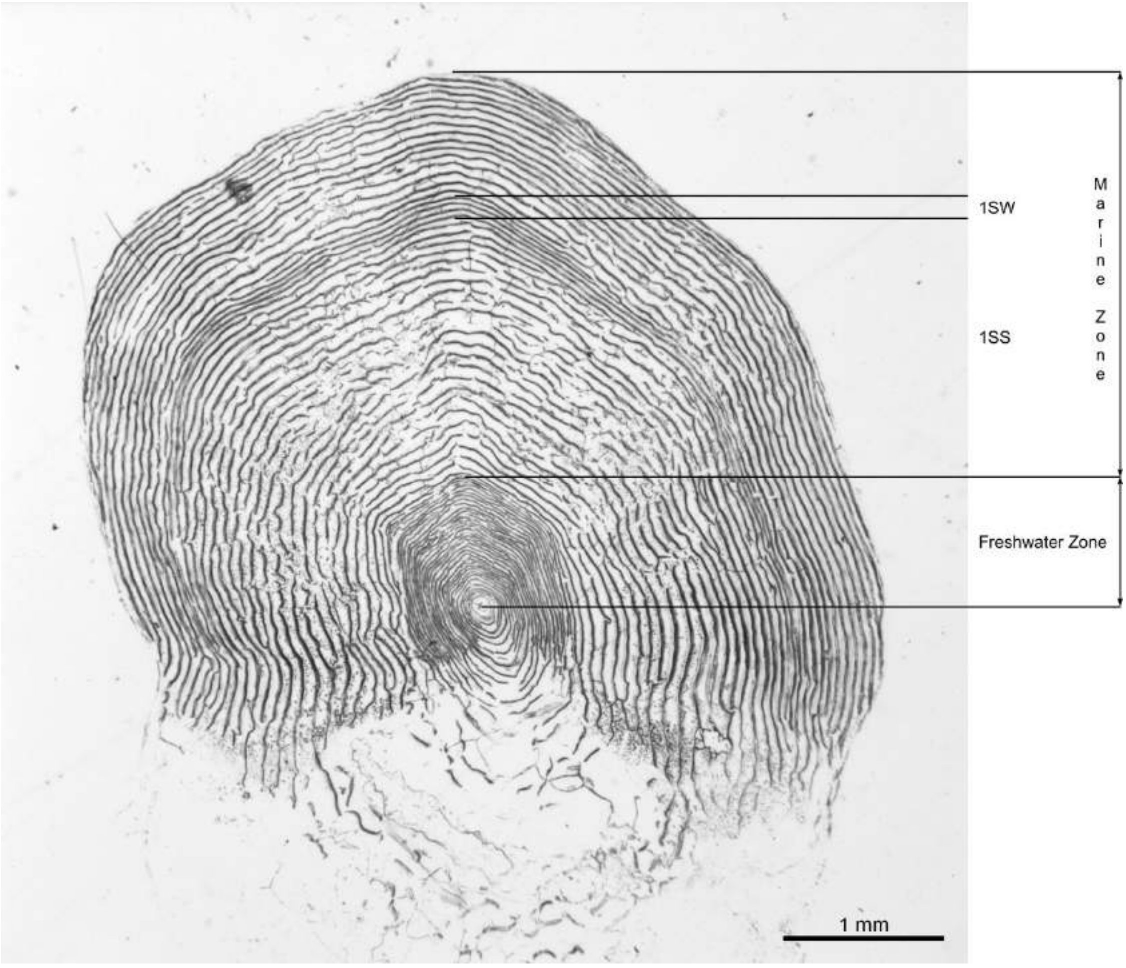


Figure 64. River Neiden 4.3SW.



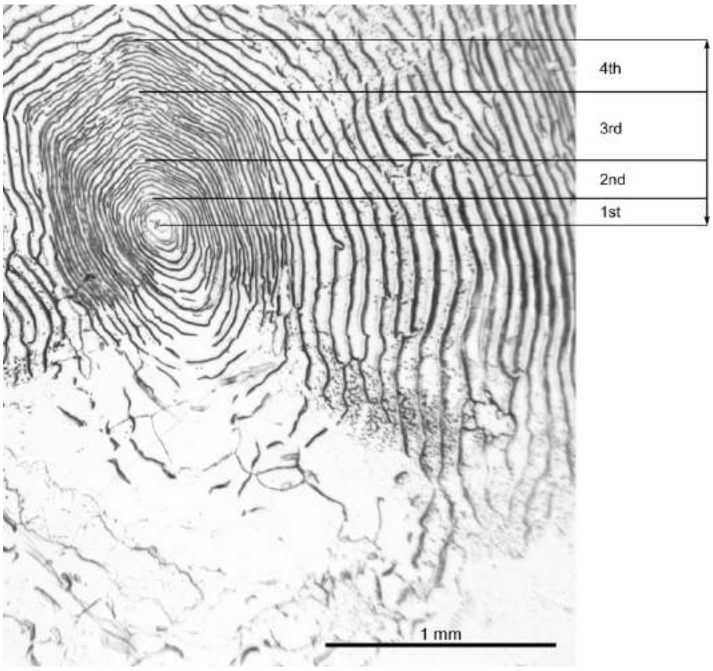


Figure 65. River Vesterelva 4.1SW.

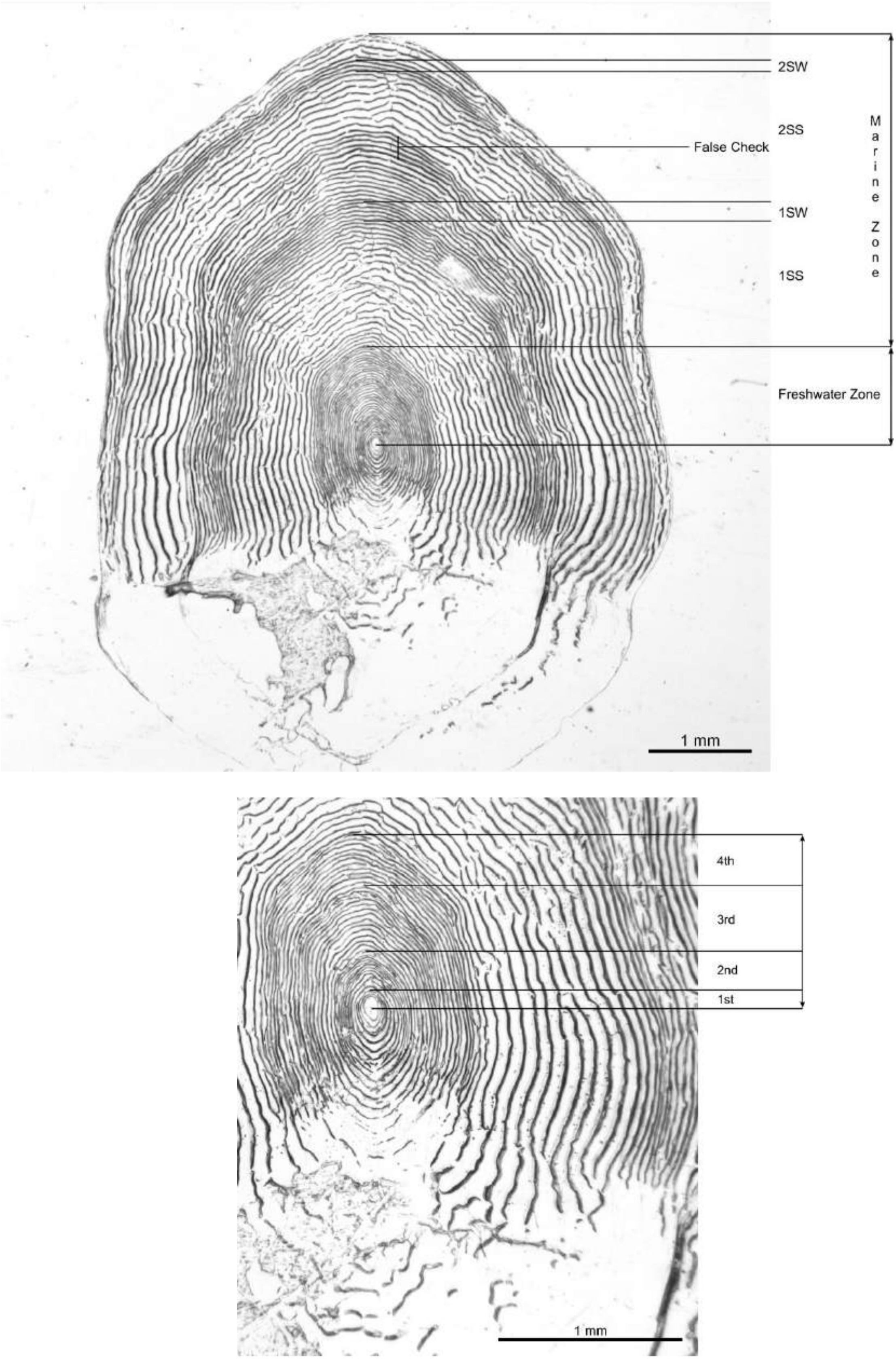
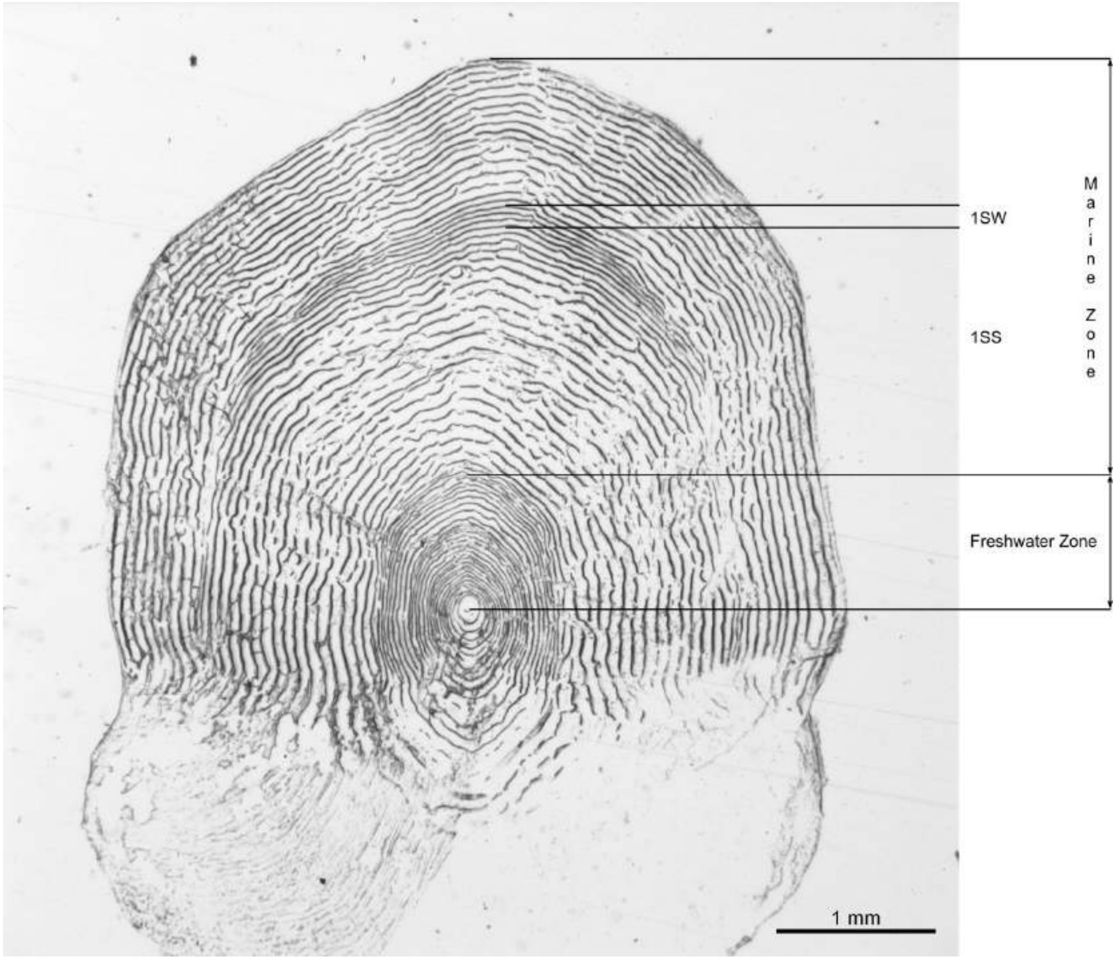


Figure 66. River Vesterelva 4.2SW.



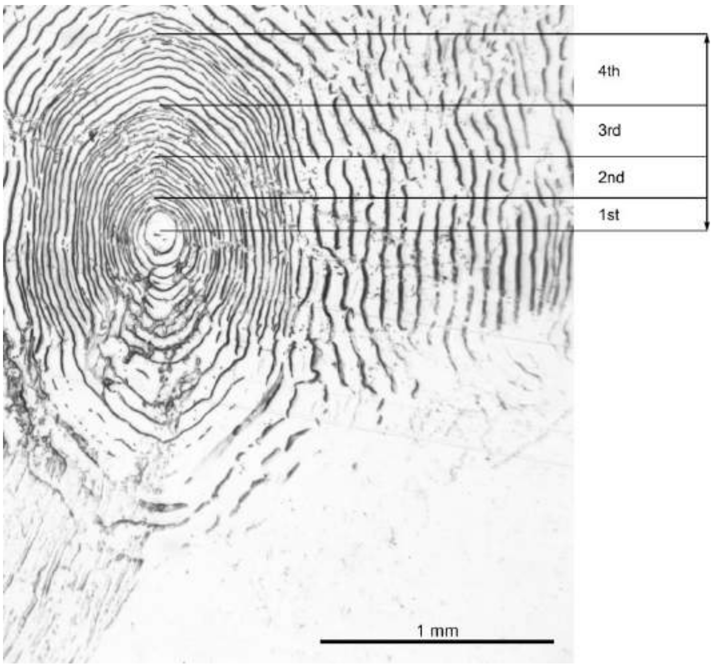
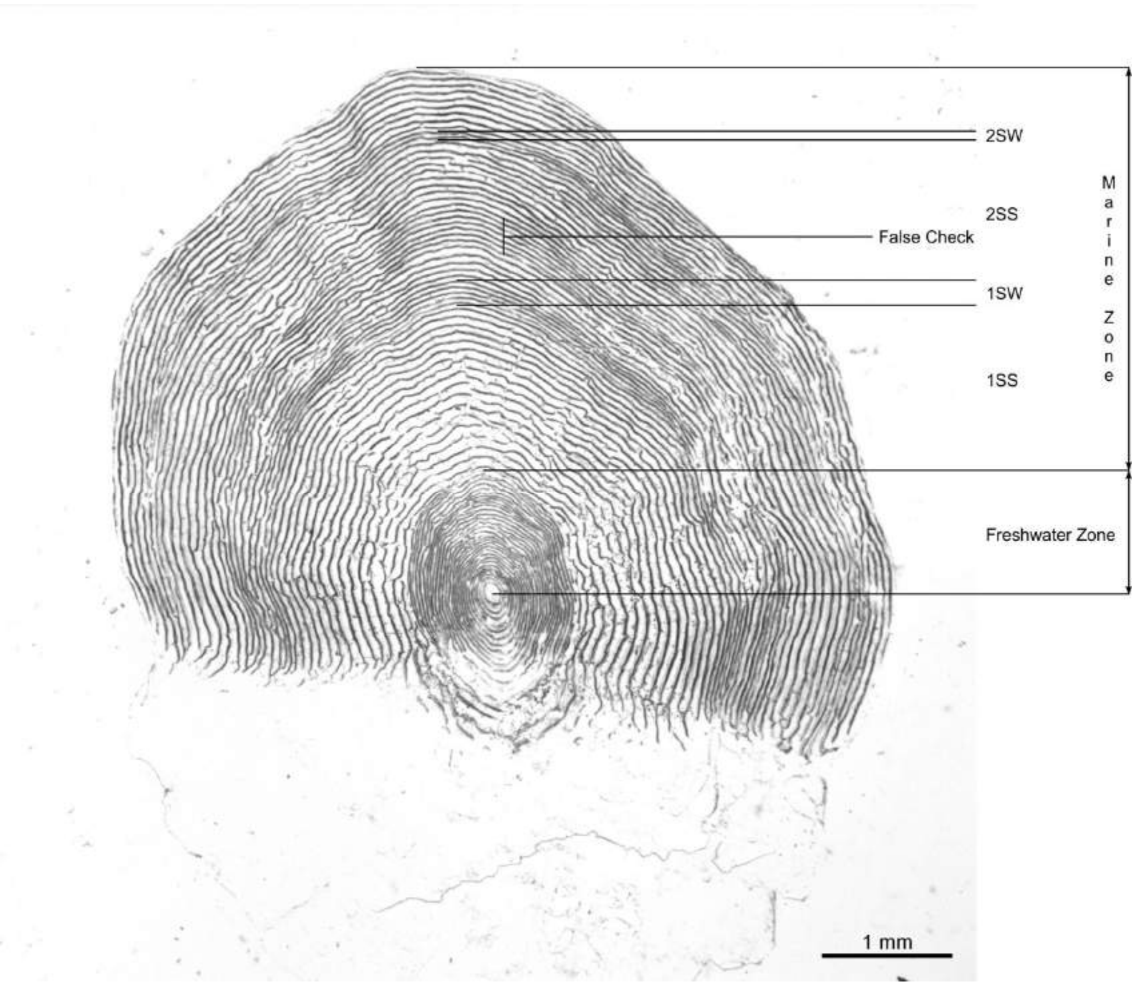


Figure 67. River Bergebyelva 4.1SW.



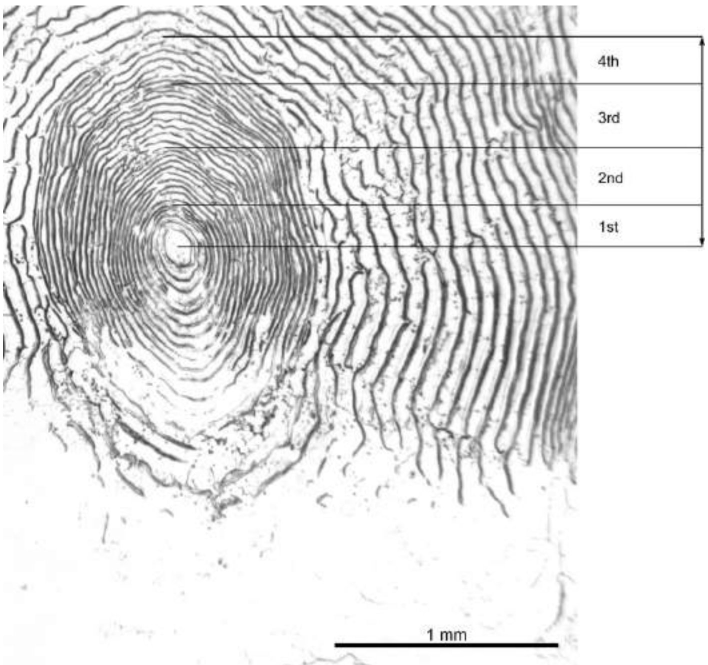
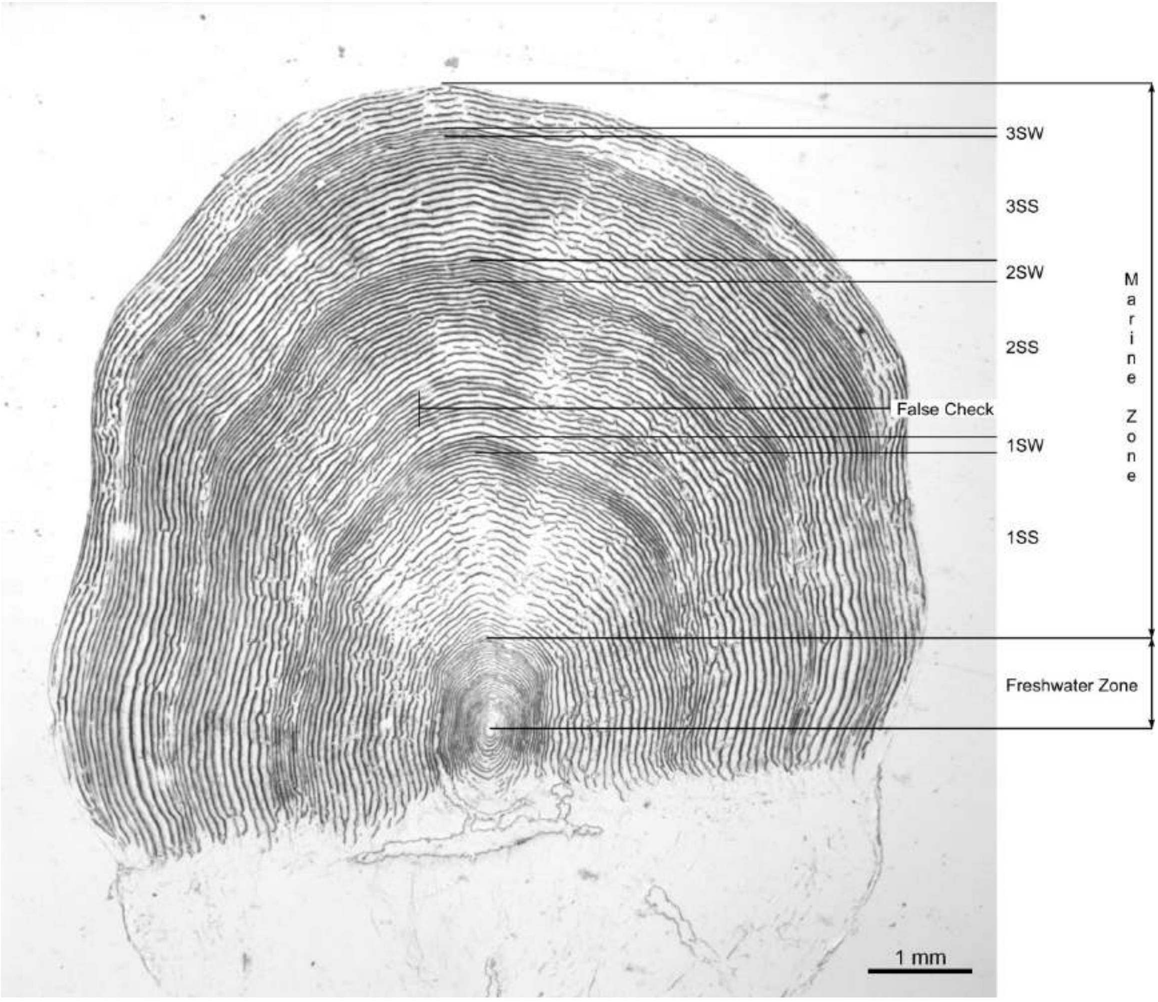


Figure 68. River Bergebyelva 4.2SW.



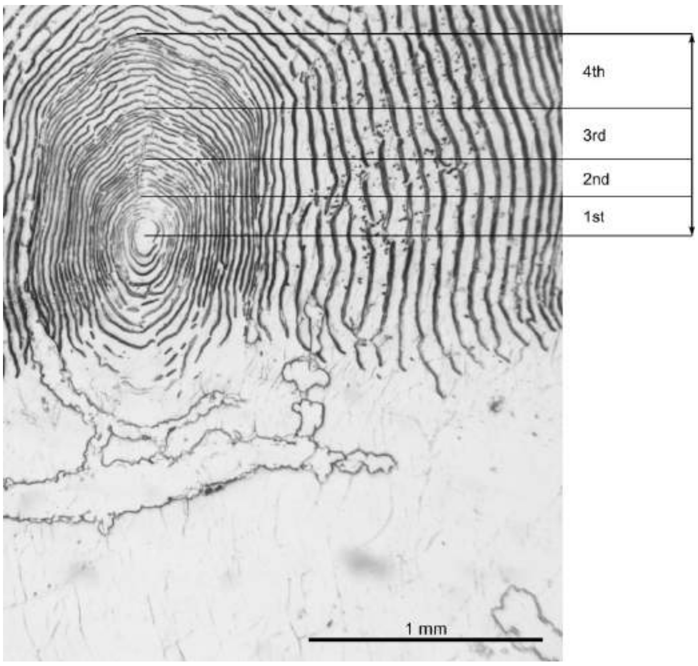


Figure 69. River Bergebyelva 4.3SW.

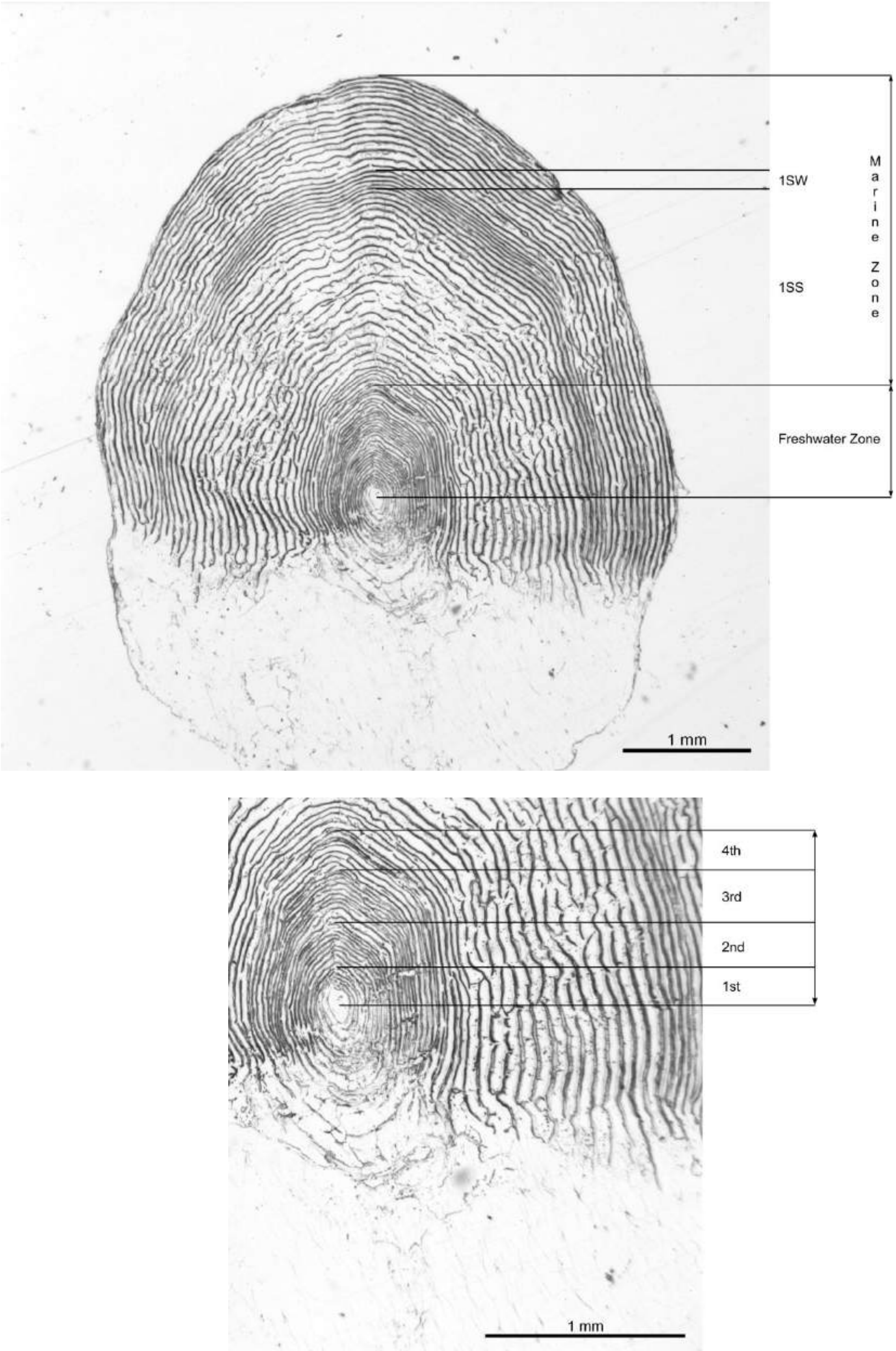
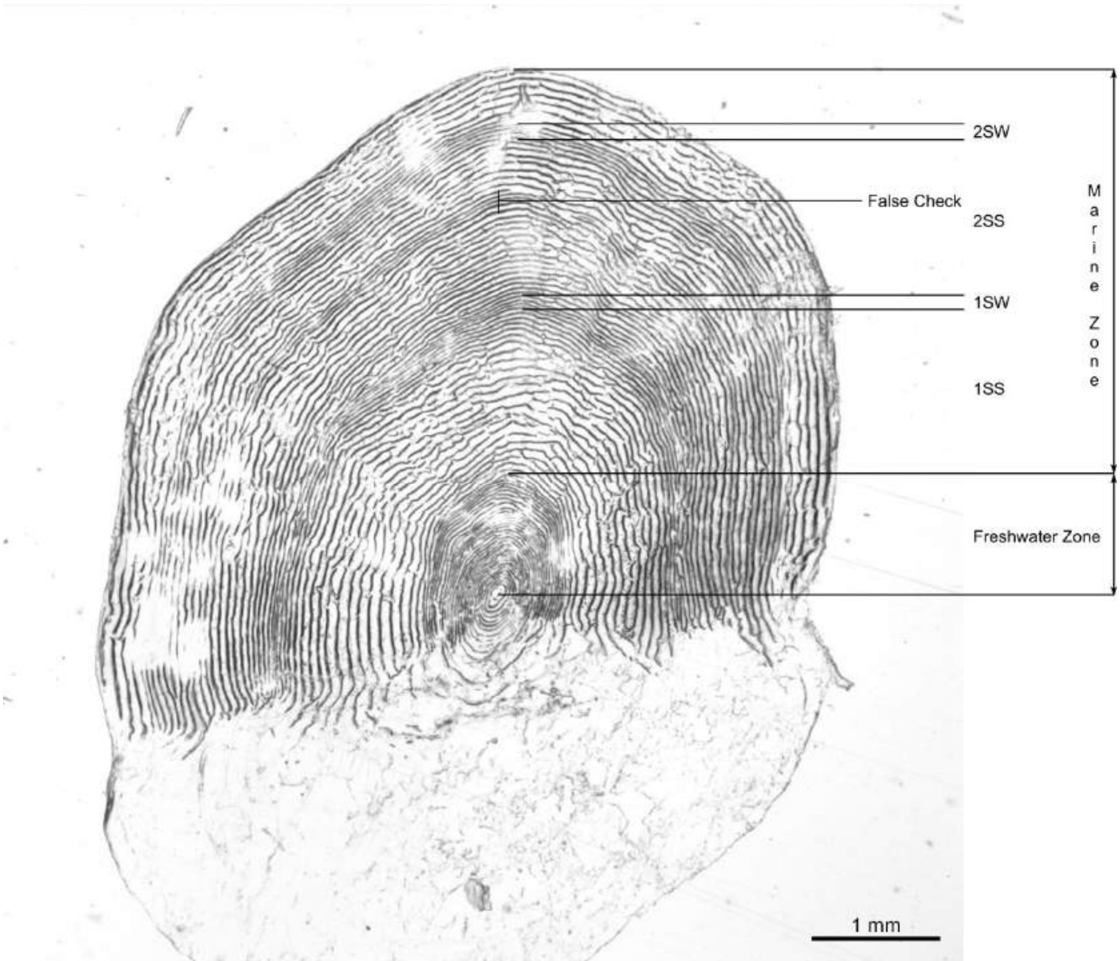


Figure 70. River Vestre Jakobselva 4.1SW.



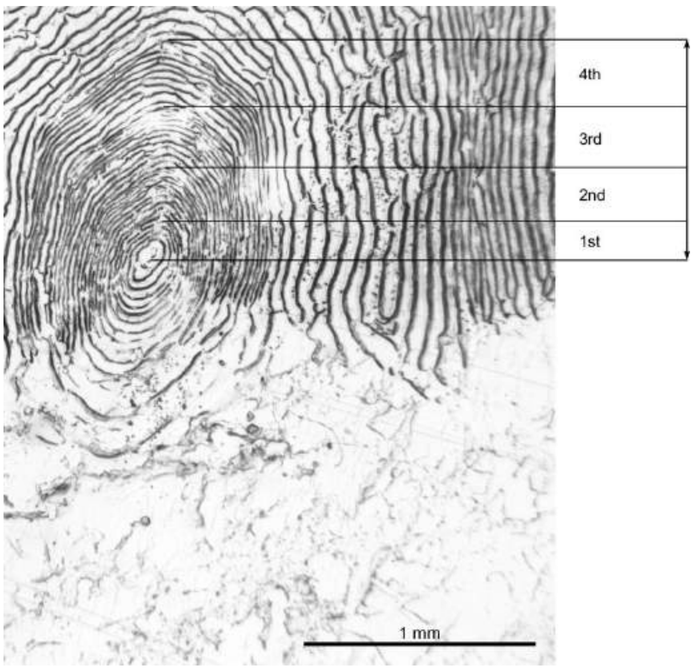
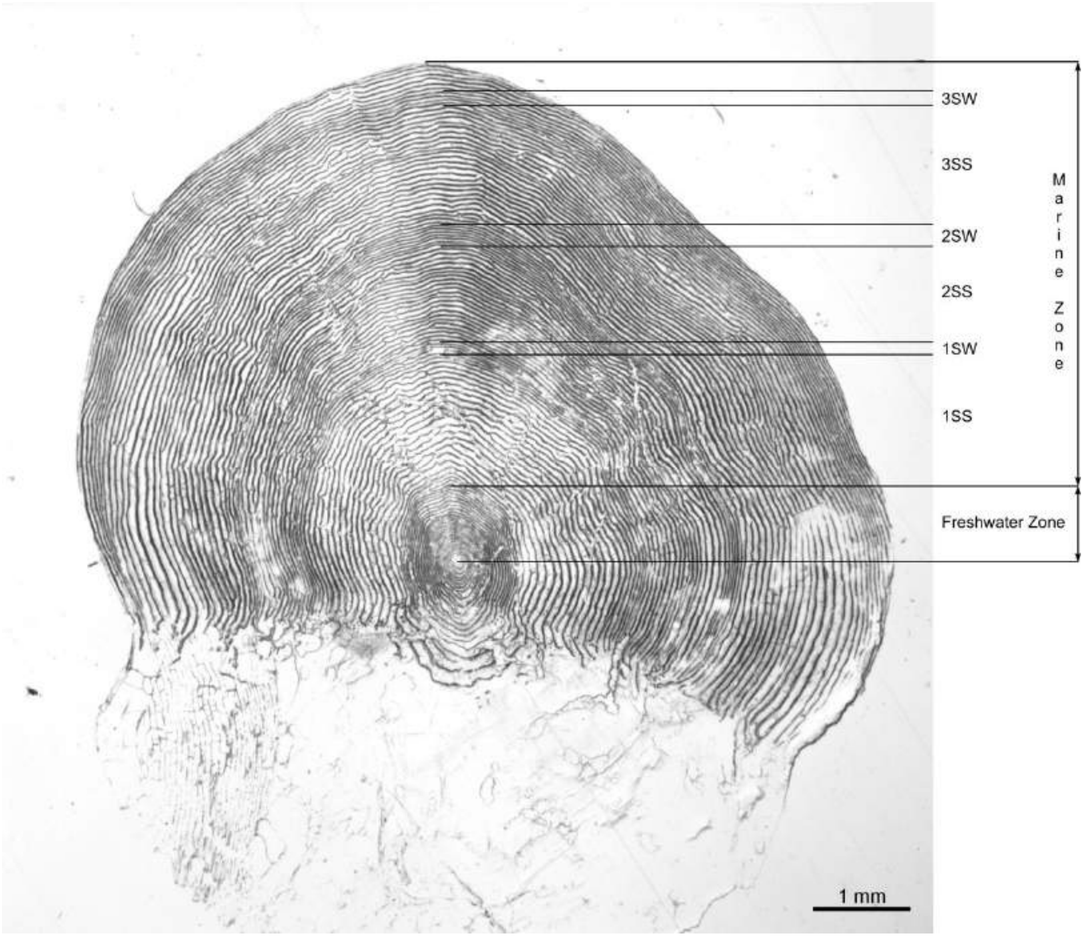


Figure 71. River Vestre Jakobselva 4.2SW.



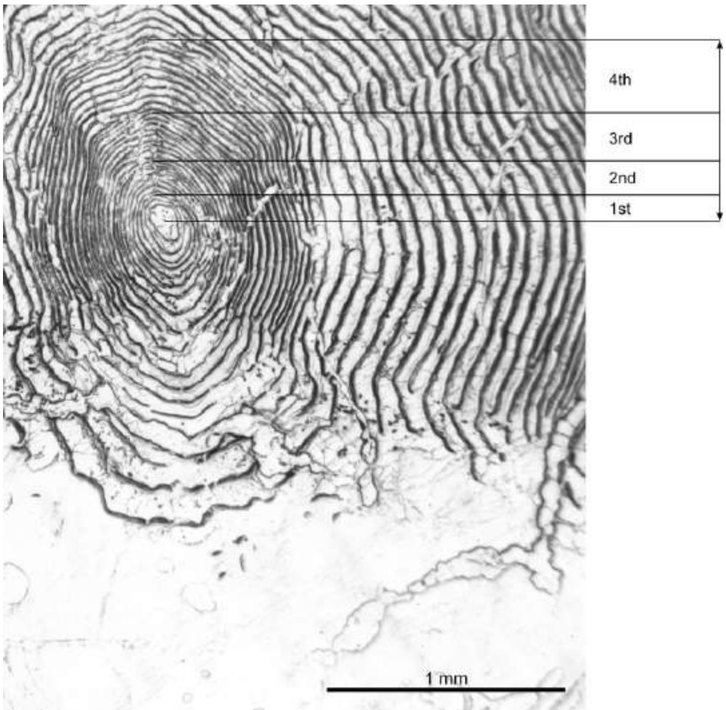
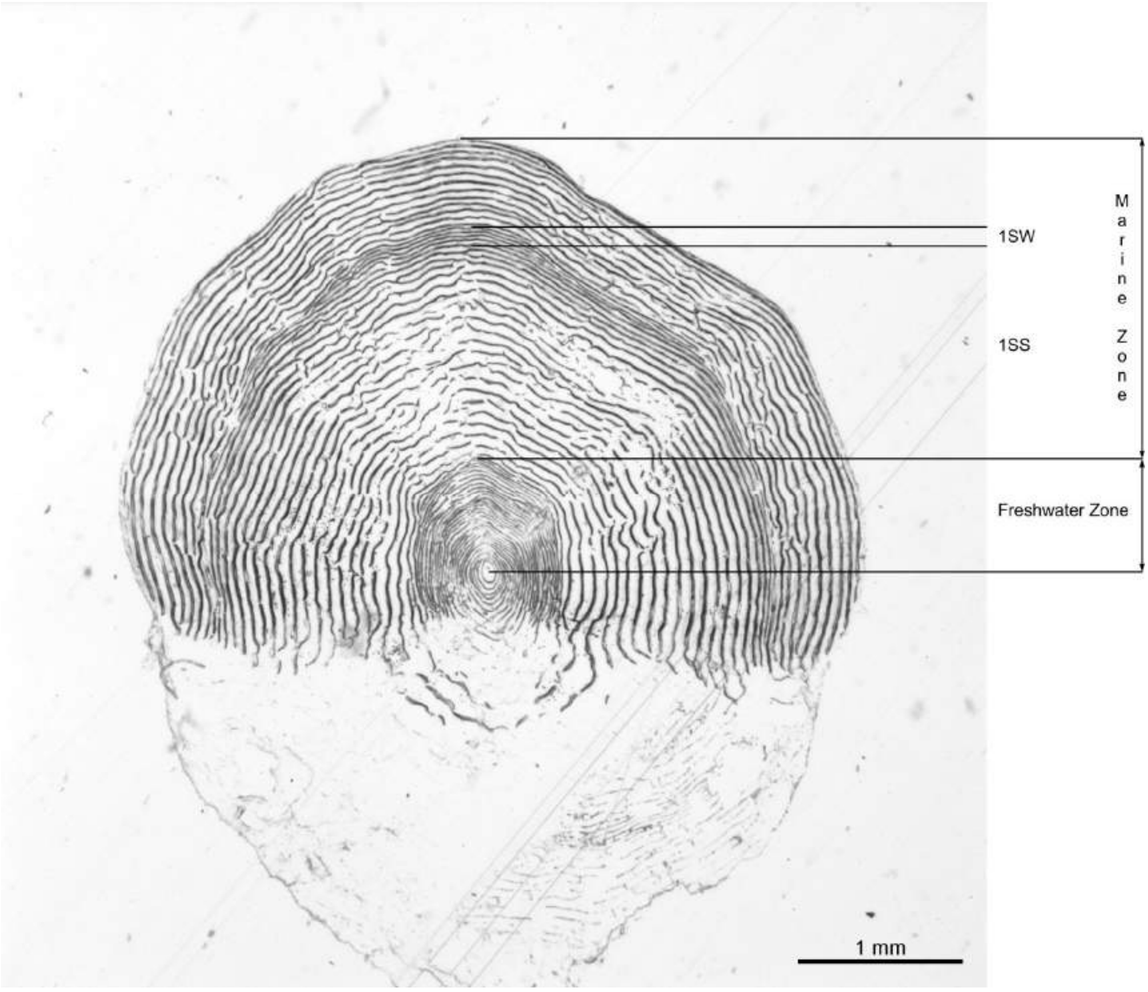


Figure 72. River Vestre Jakobselva 4.3SW.



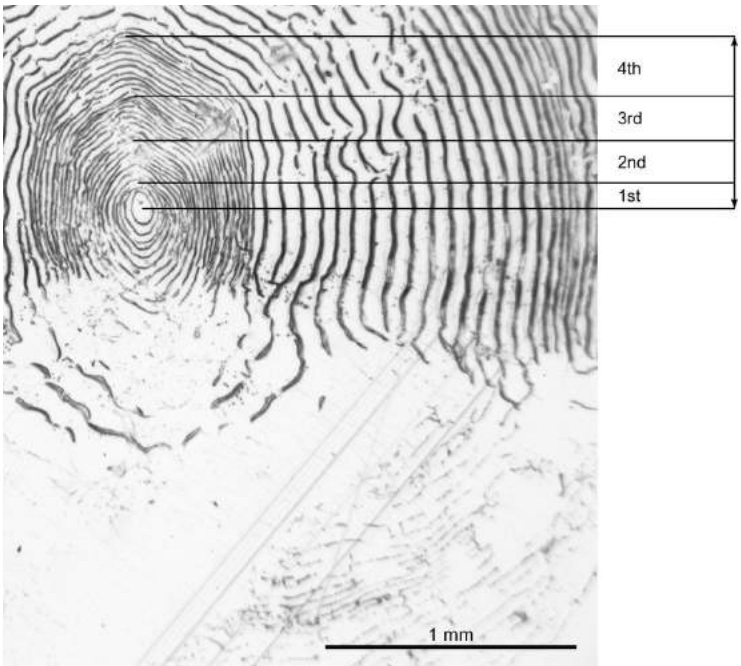
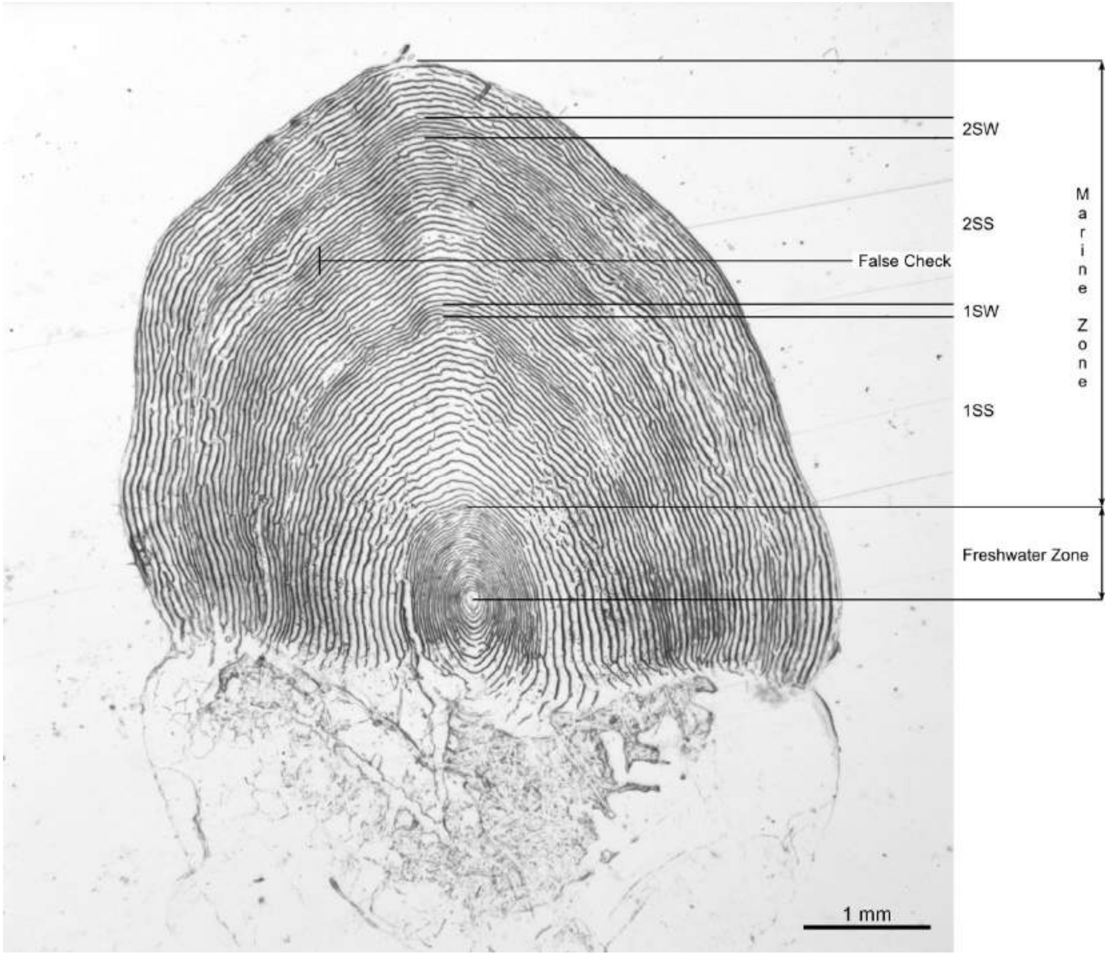


Figure 73. River Komagelva 4.1SW.



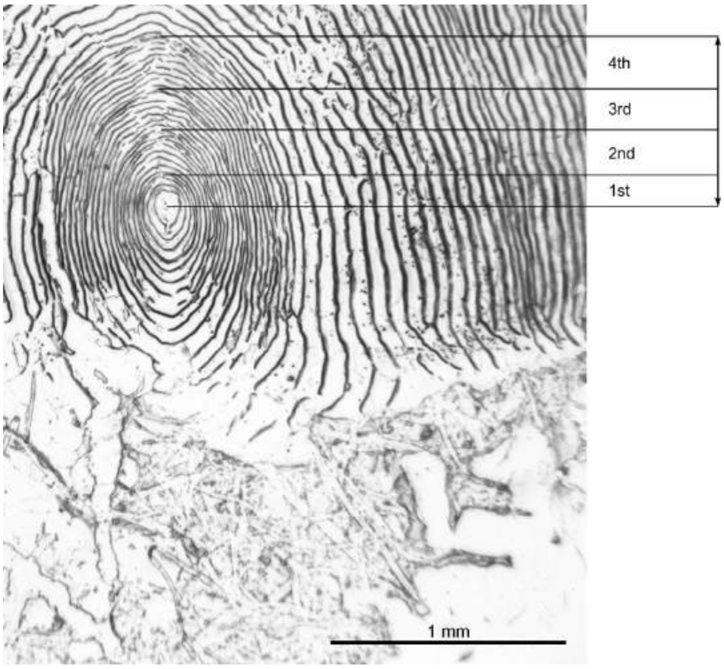
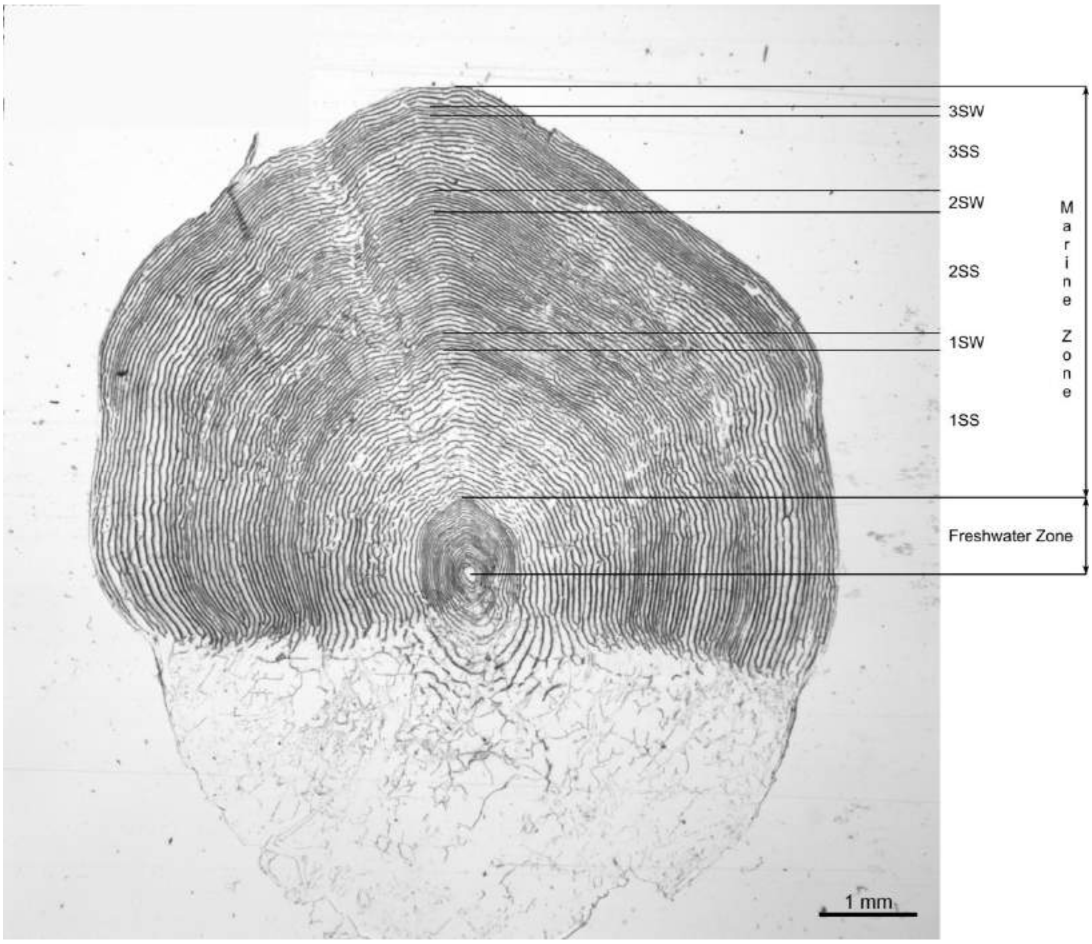


Figure 74. River Komagelva 4.2SW.



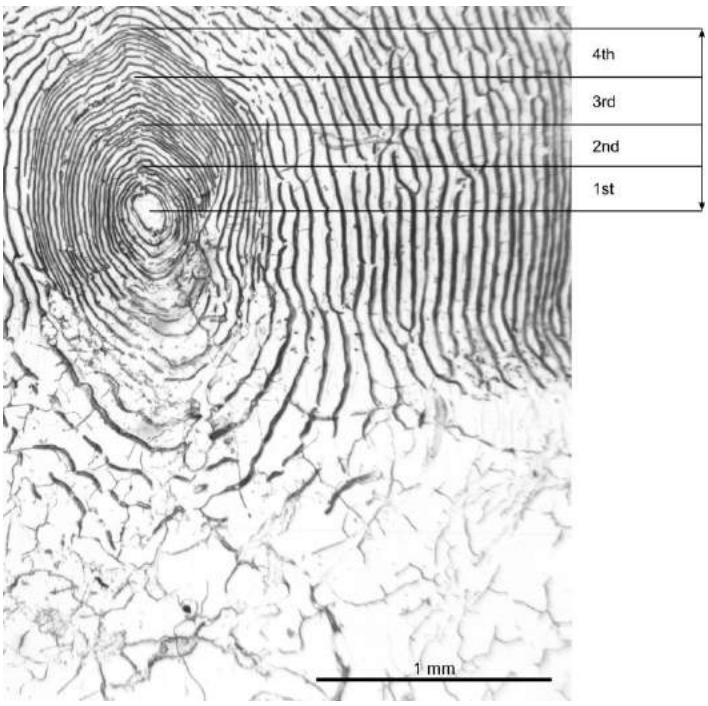
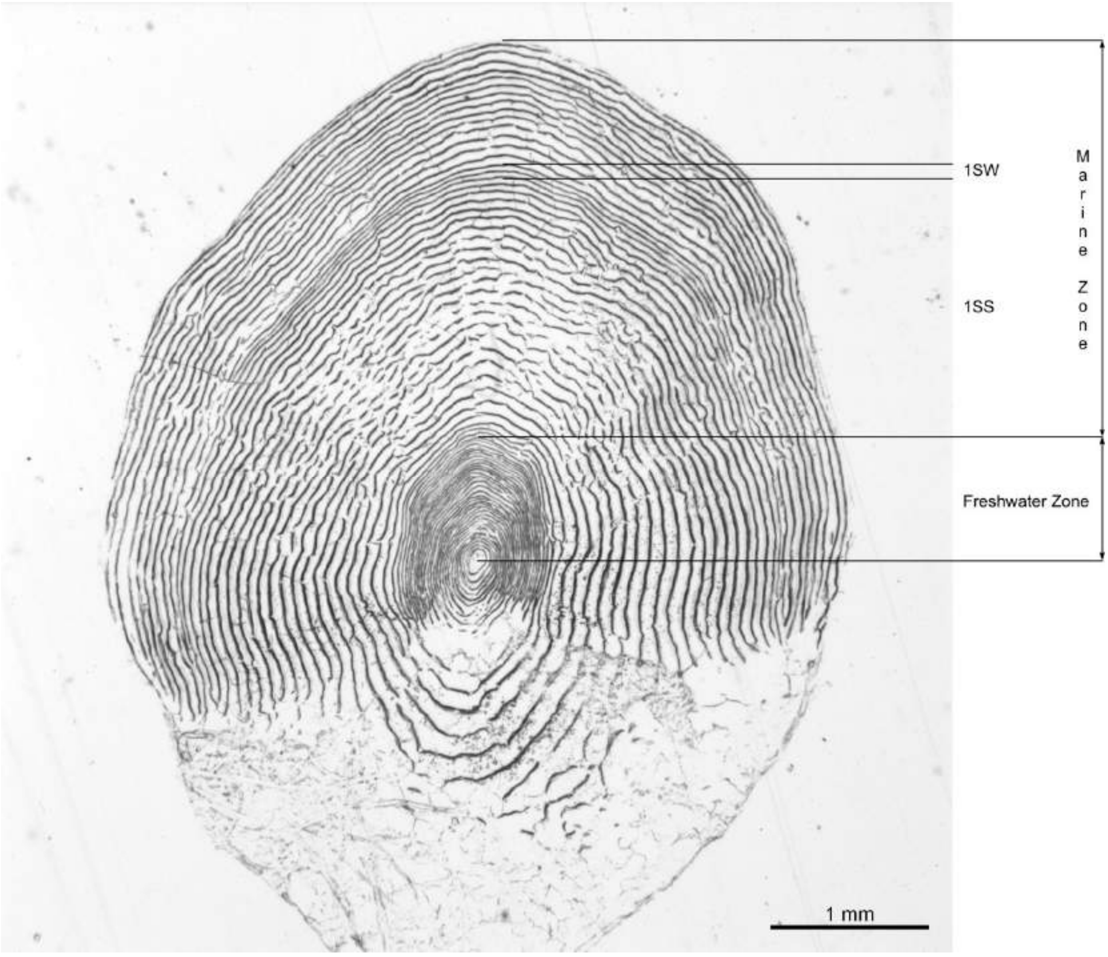


Figure 75. River Komagelva 4.3SW.



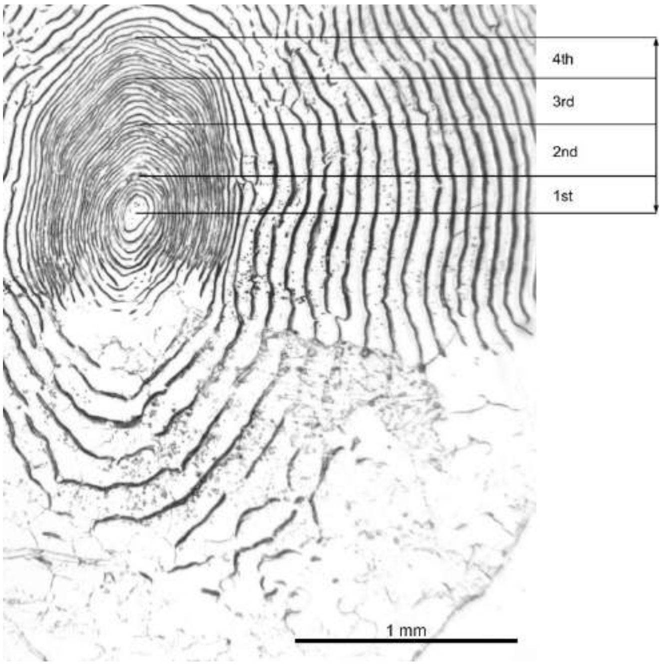
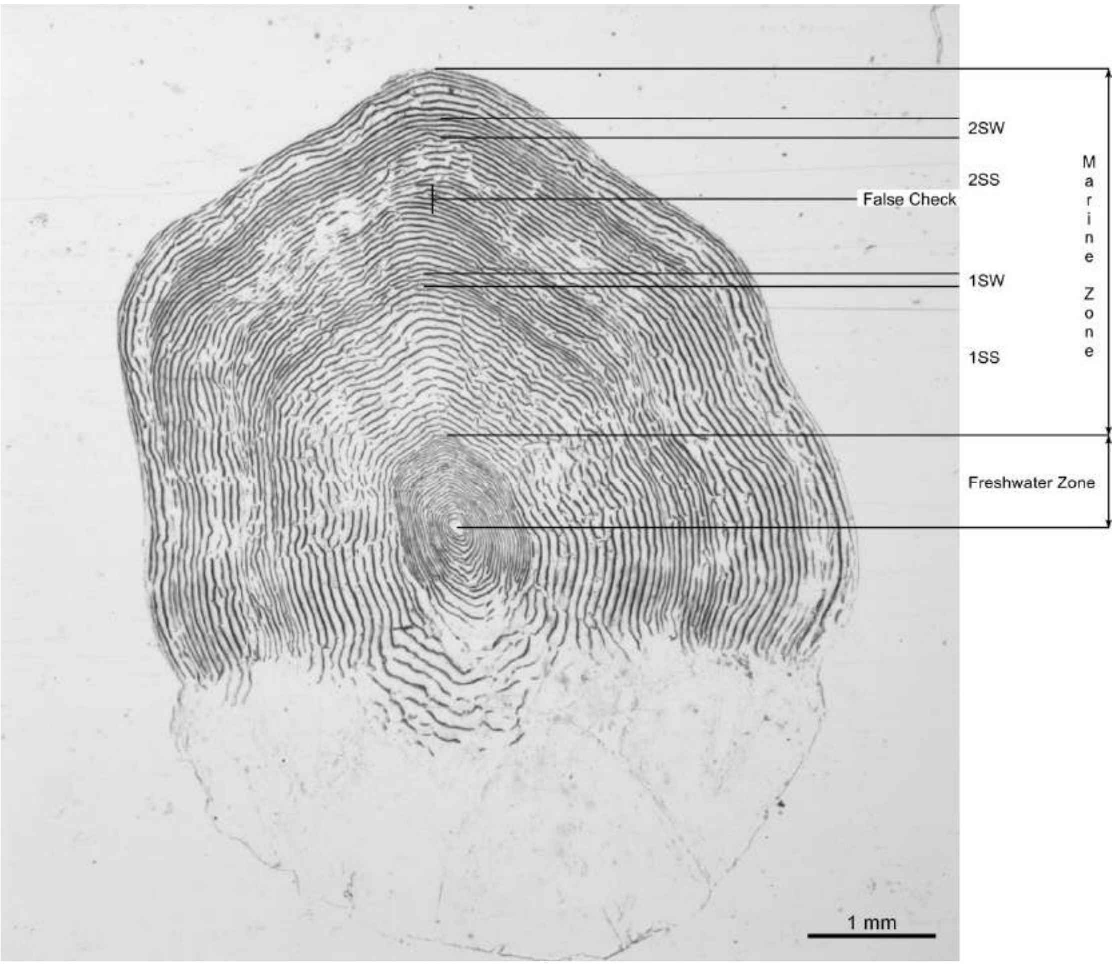


Figure 76. River Syltefjordelva 4.1SW.



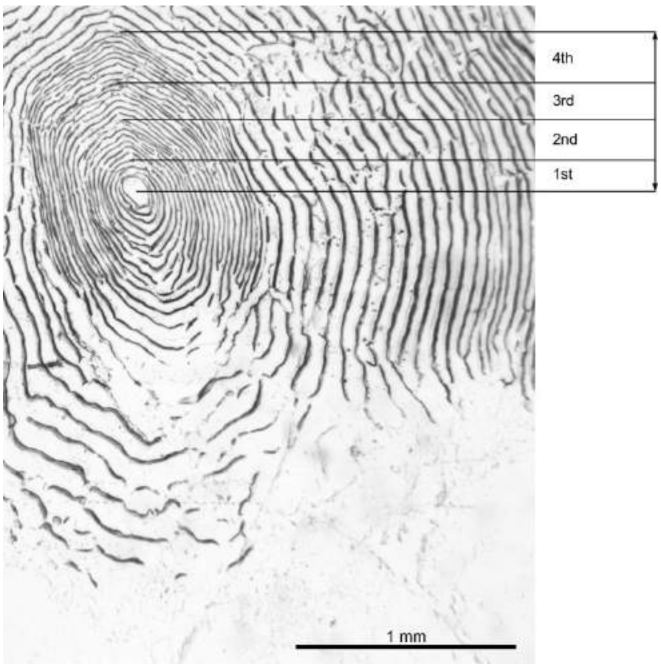


Figure 77. River Syltefjordelva 4.2SW.

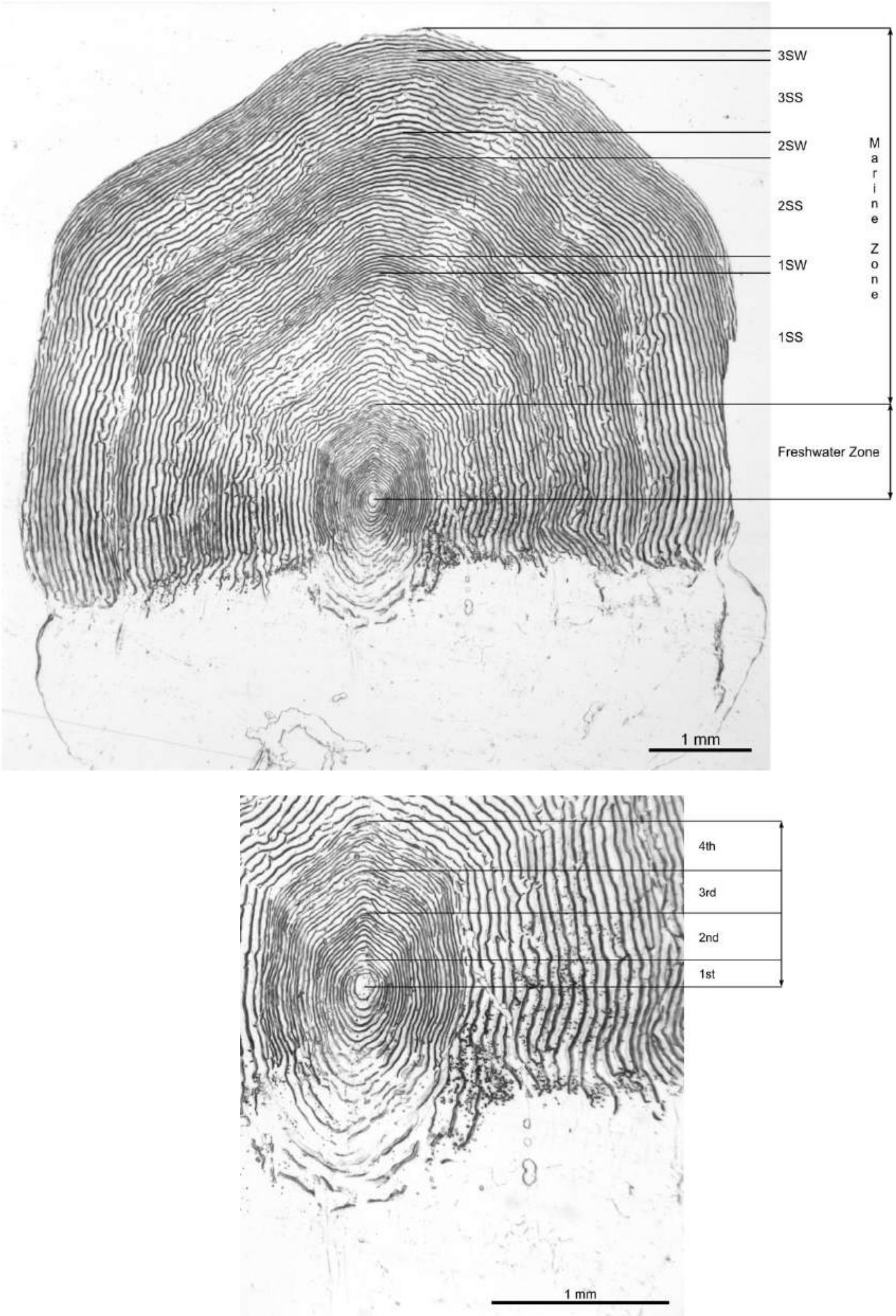
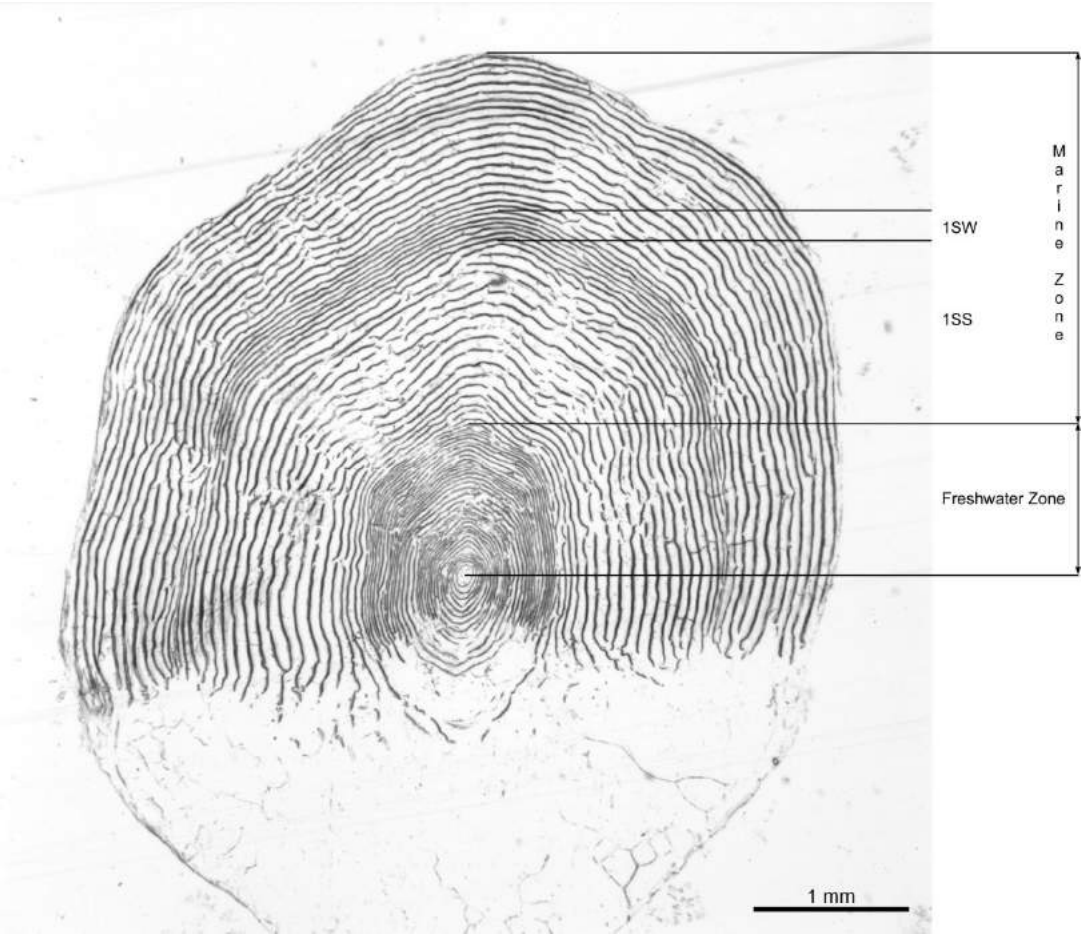


Figure 78. River Syltefjordelva 4.3SW.



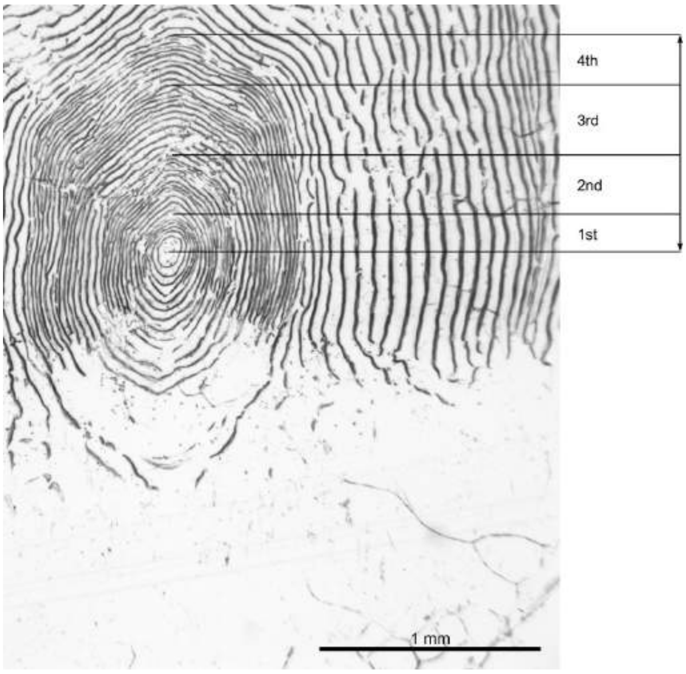
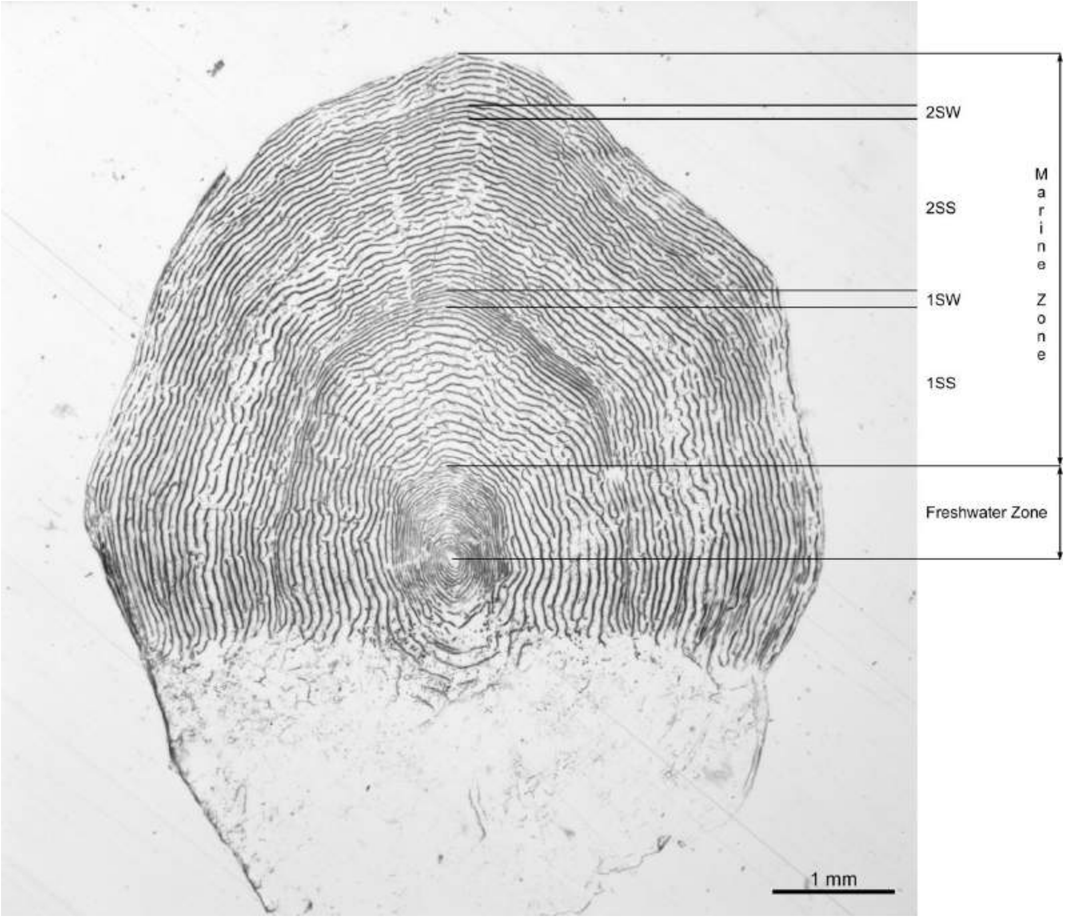


Figure 79. River Kongsfjordelva 4.1SW.



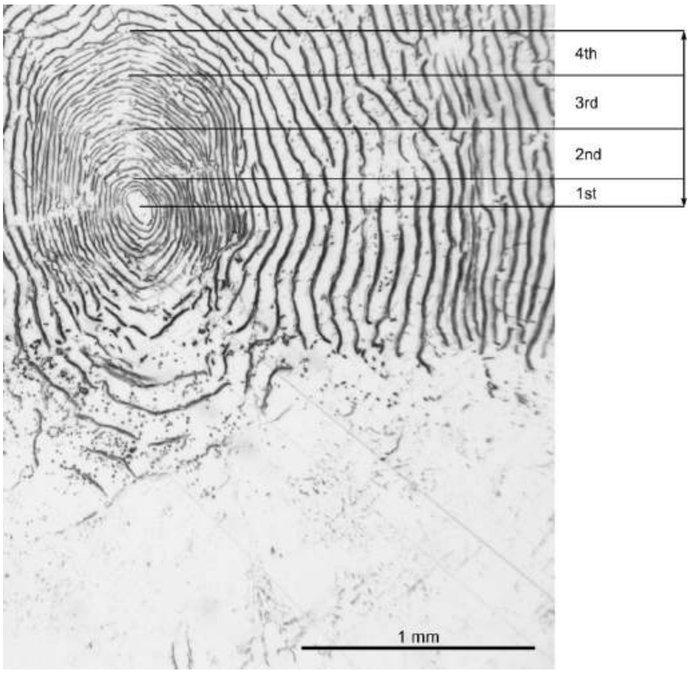


Figure 80. River Kongsfjordelva 4.2SW.

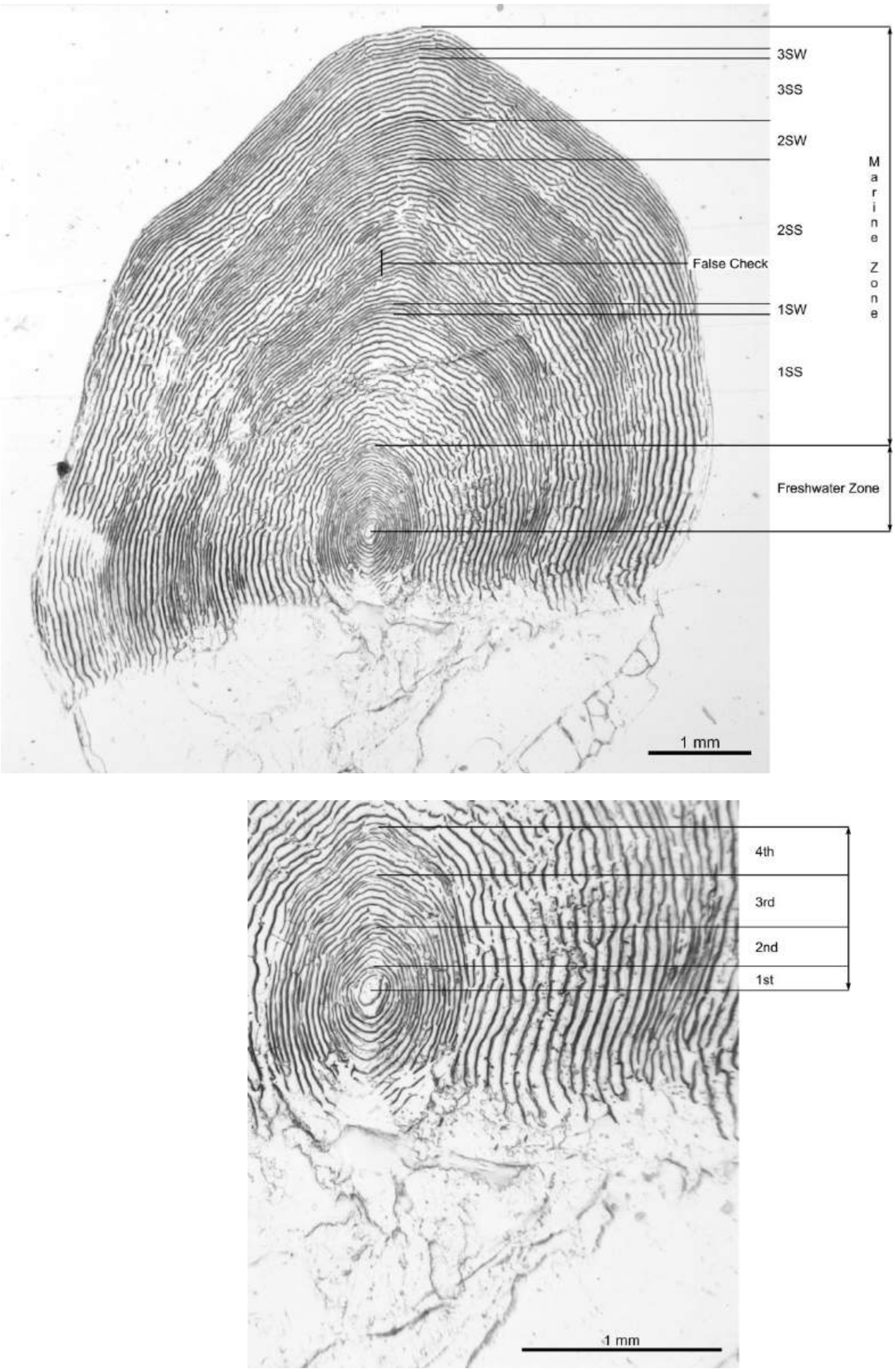


Figure 81. River Kongsfjordelva 4.3SW.

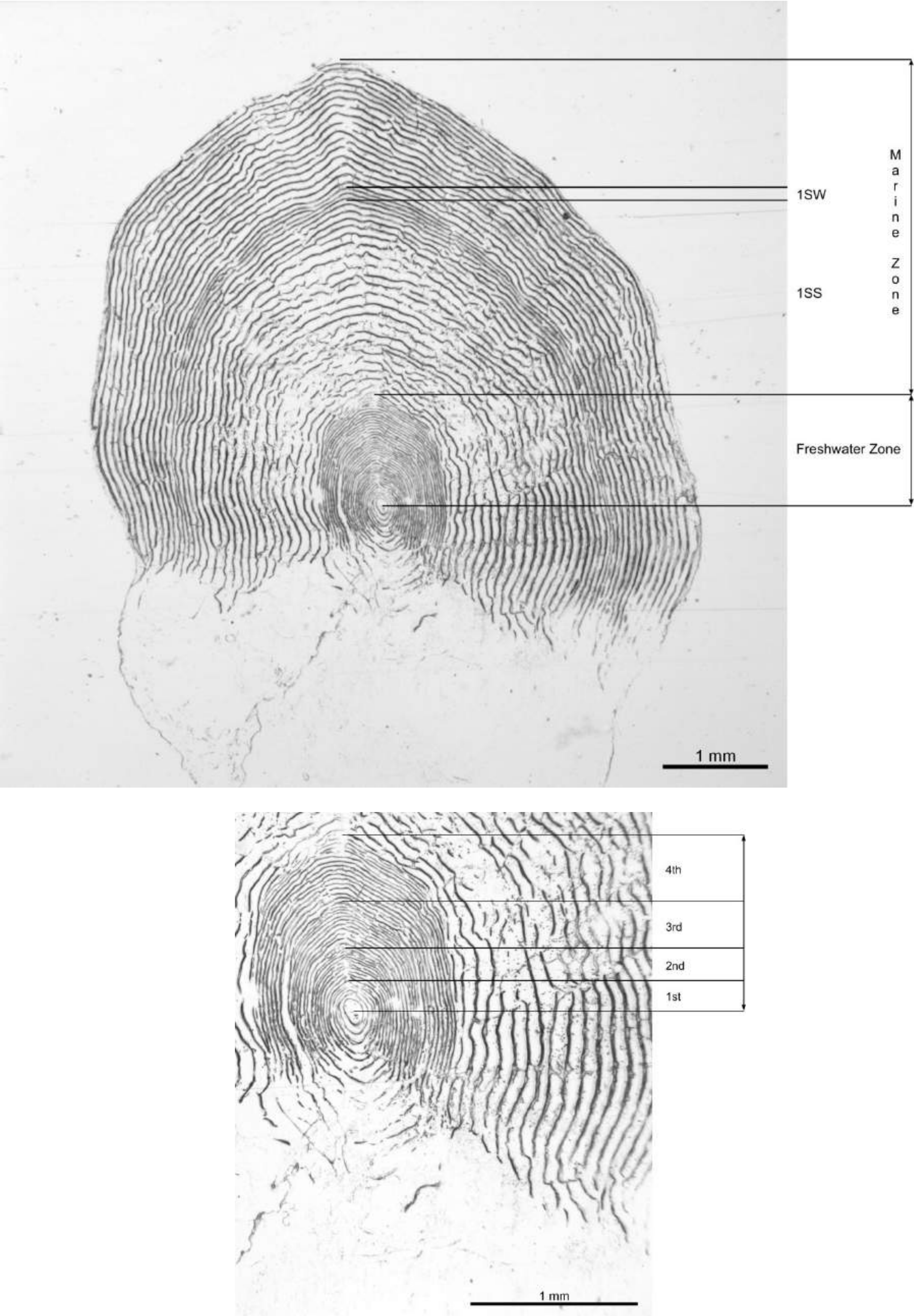


Figure 82. River Iesjohka 4.1SW. Tributary of the River Teno/Tana.

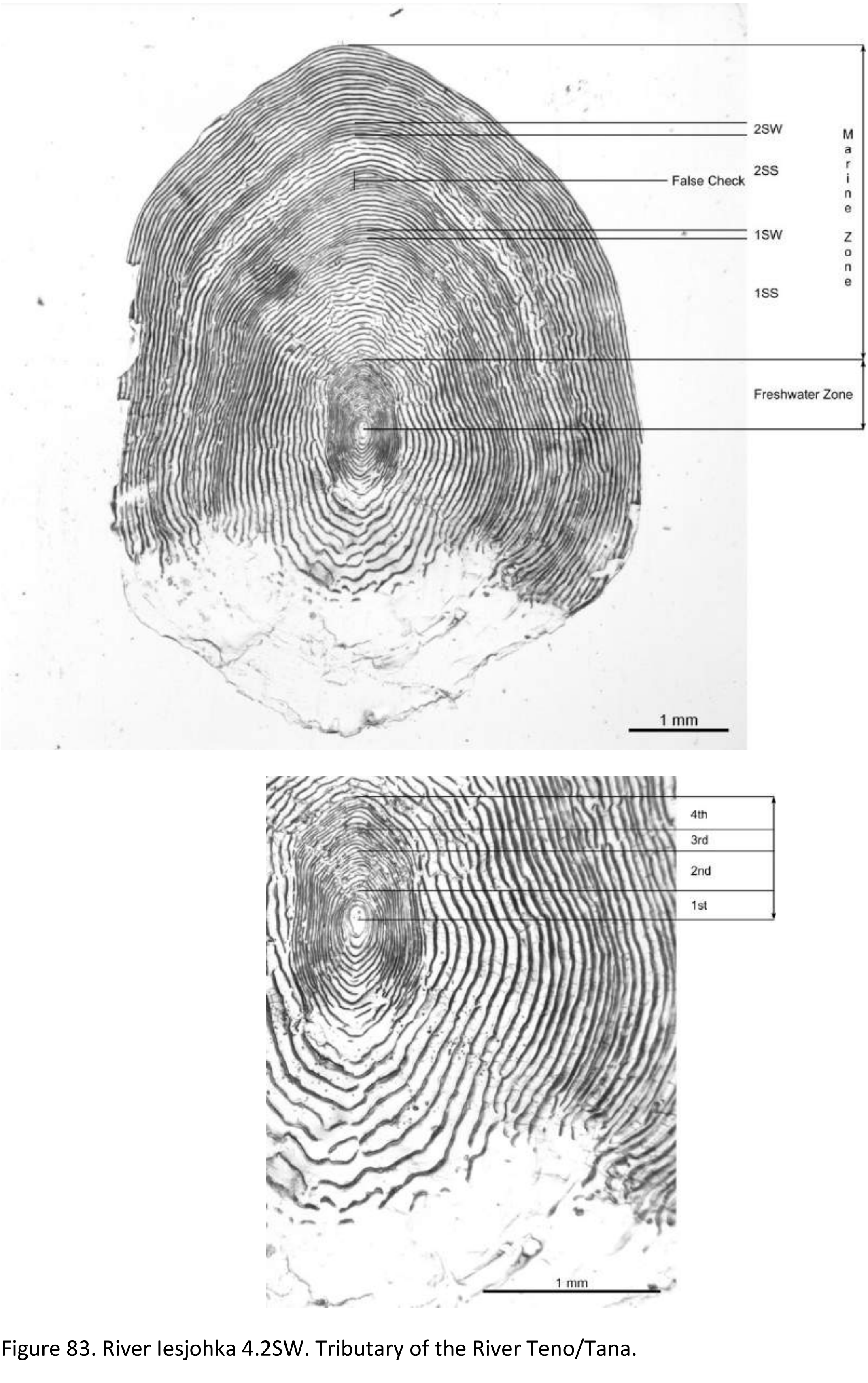


Figure 83. River Iesjohka 4.2SW. Tributary of the River Teno/Tana.

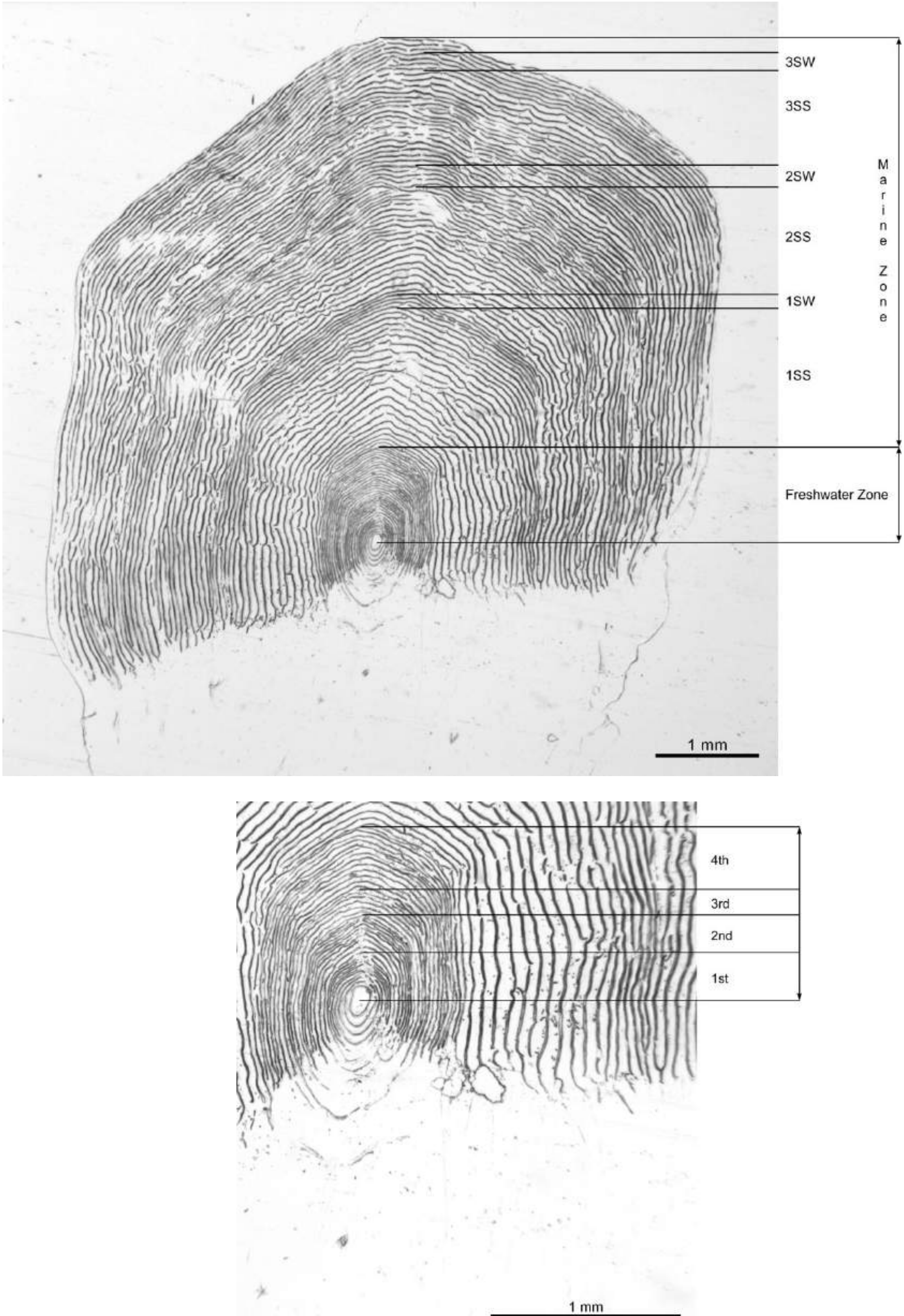
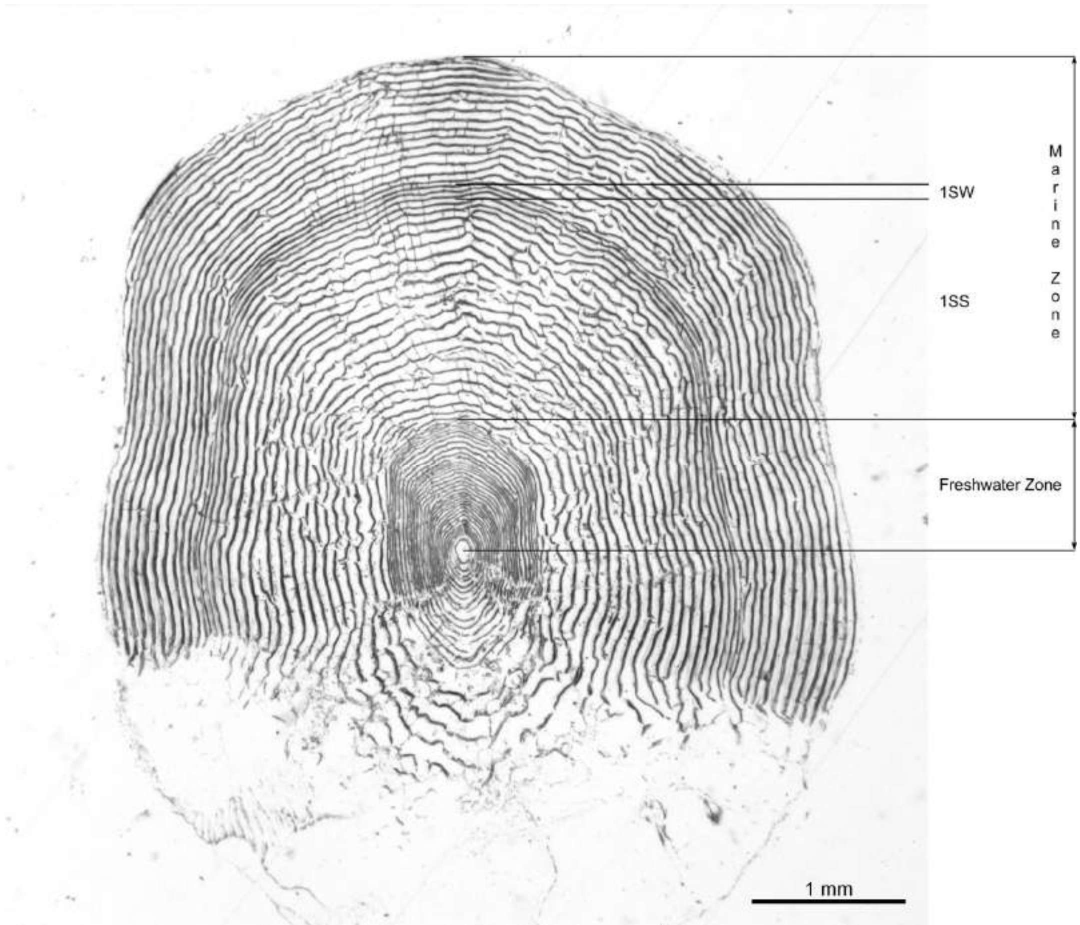


Figure 84. River Iesjohka 4.3SW. Tributary of the River Teno/Tana.



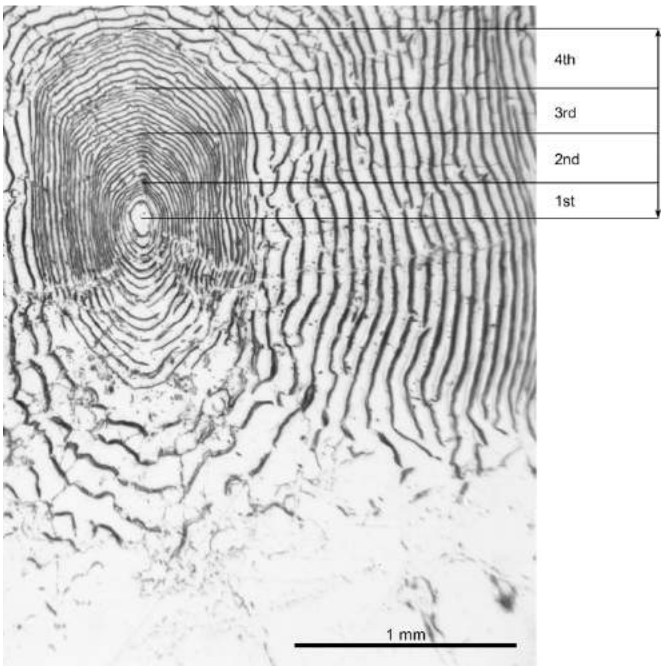
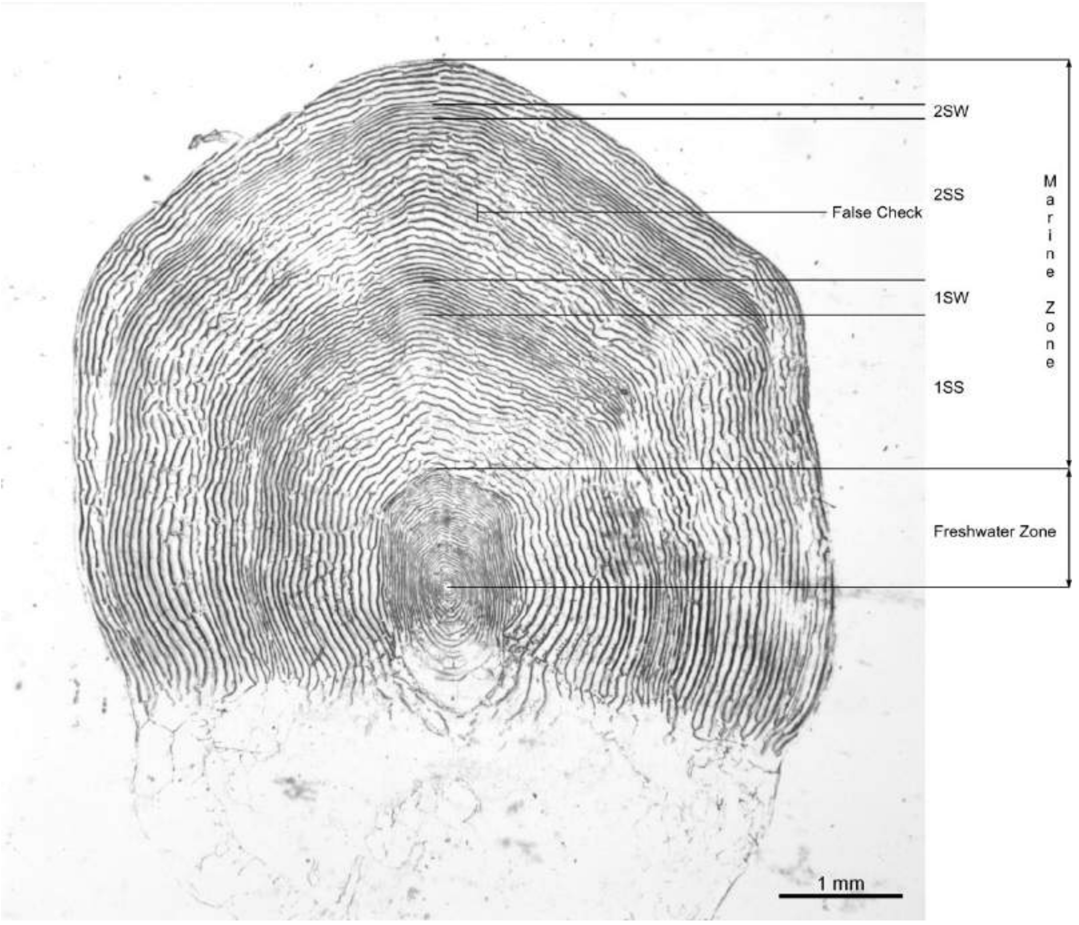


Figure 85. River Karasjohka 4.1SW. Tributary of the River Teno/Tana.



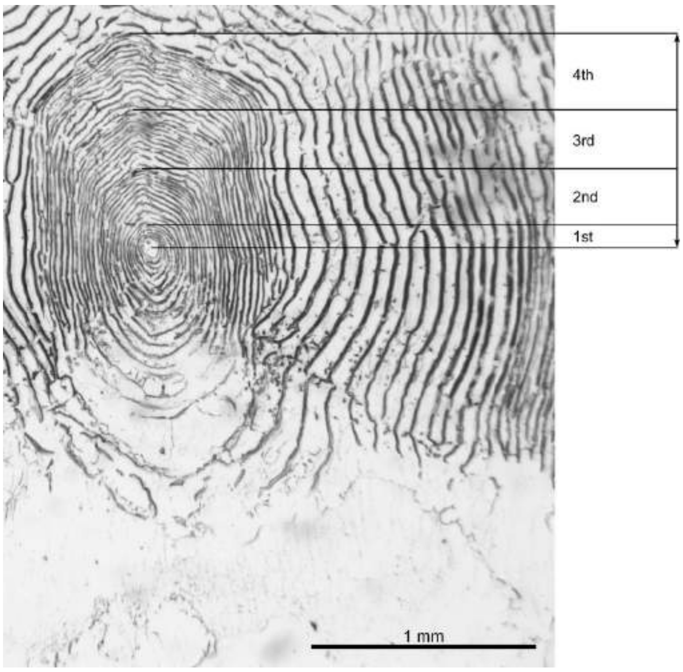


Figure 86. River Karasjohka 4.2SW. Tributary of the River Teno/Tana.

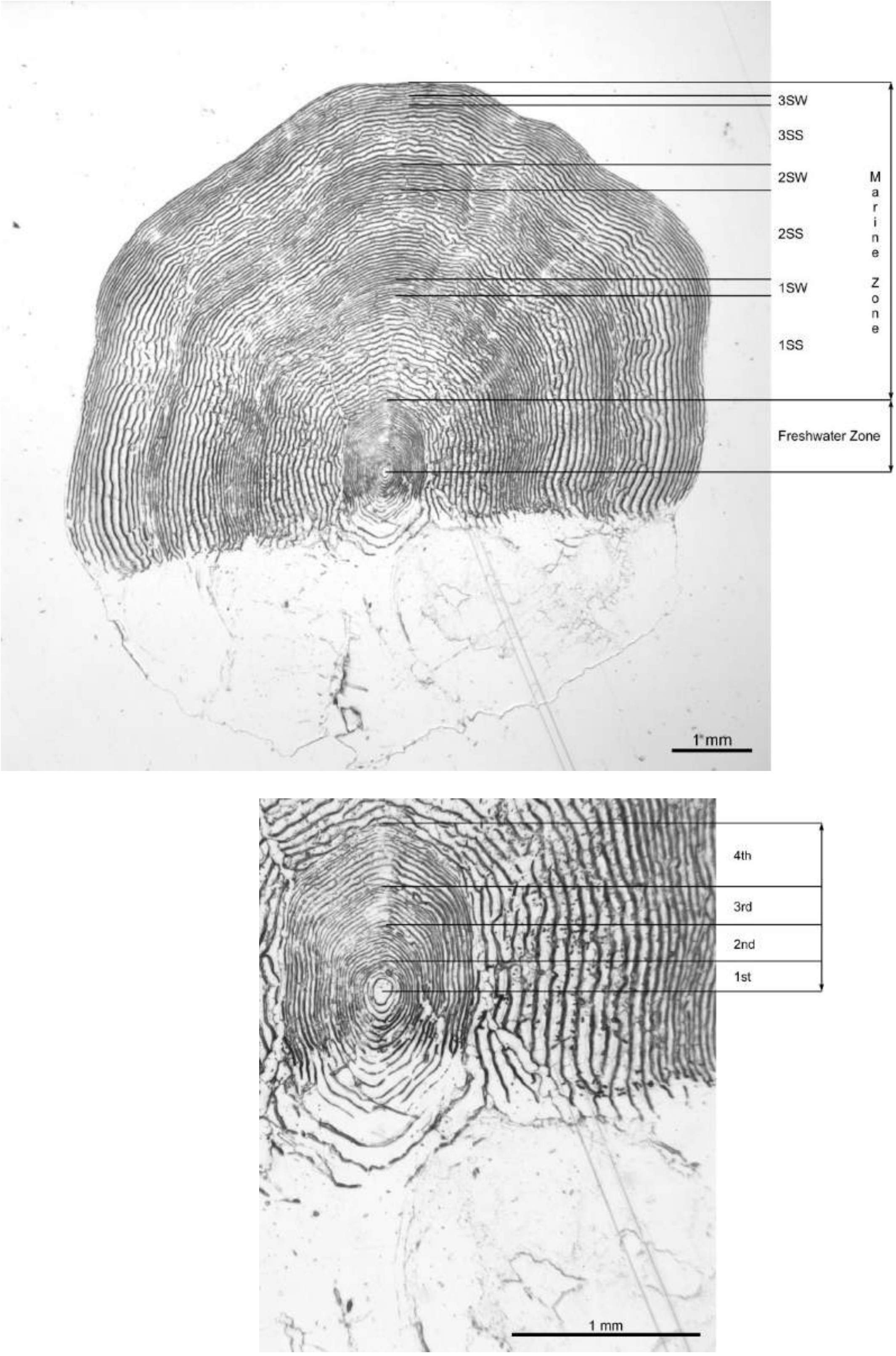
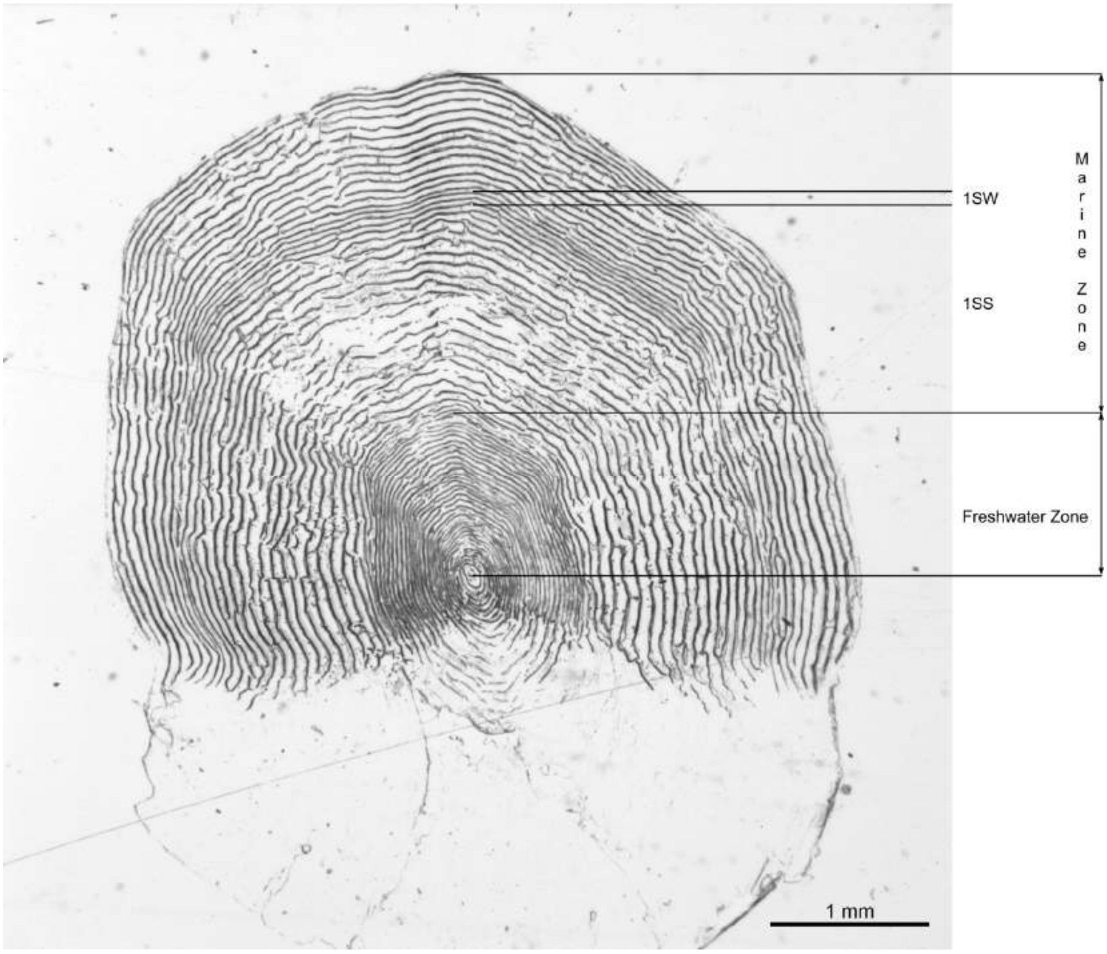


Figure 87. River Karasjohka 4.3SW. Tributary of the River Teno/Tana.



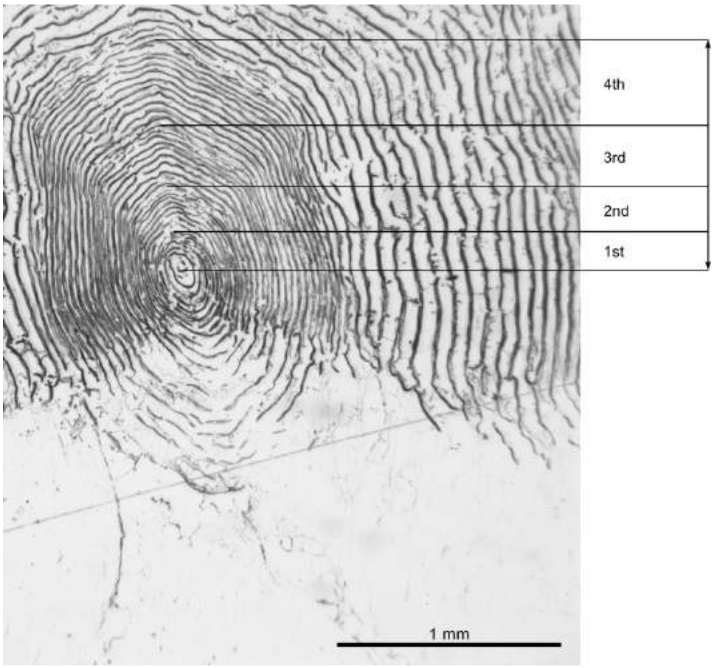


Figure 88. River Anarjohka 4.1SW. Tributary of the River Teno/Tana.

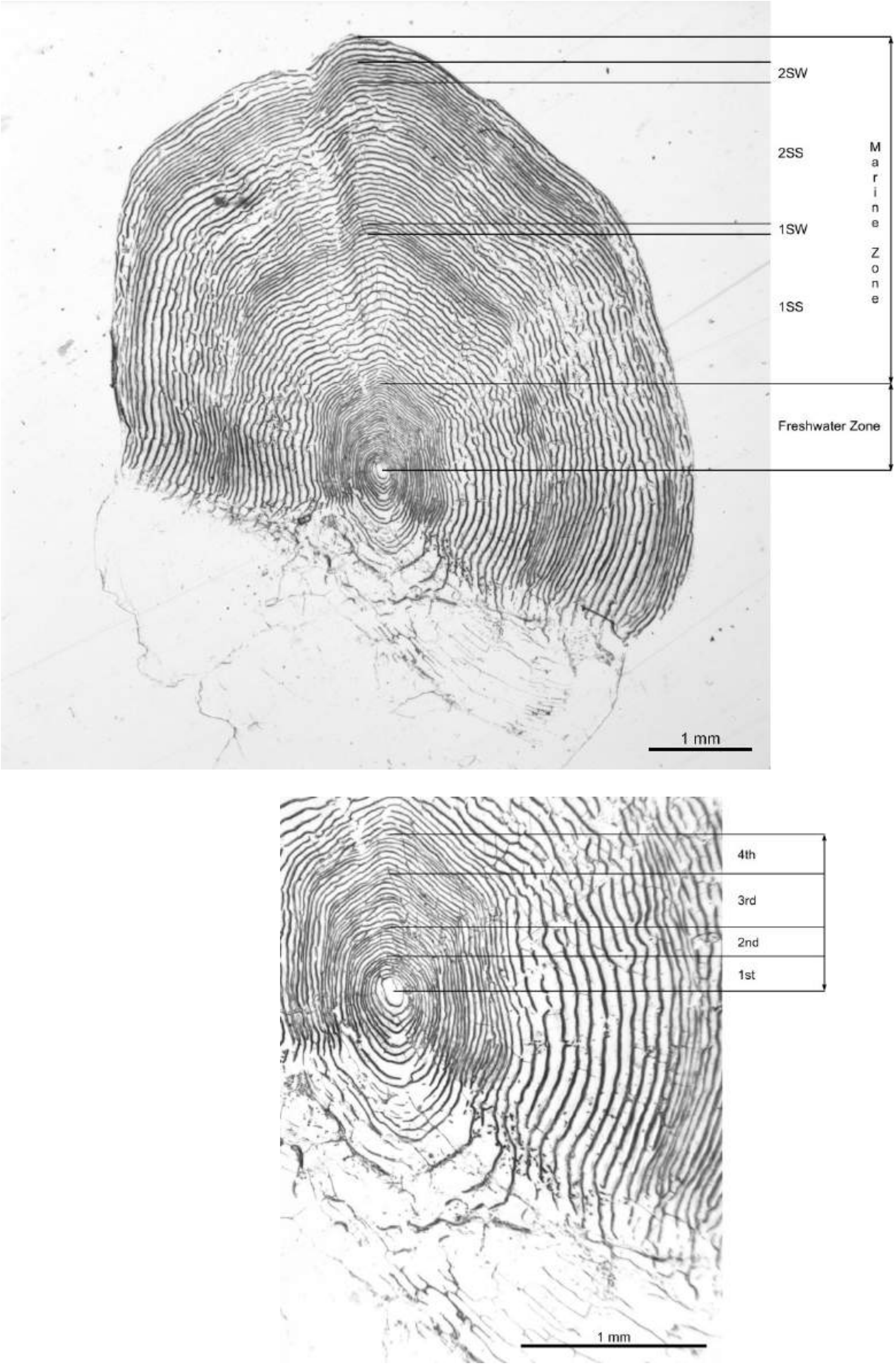


Figure 89. River Anarjohka 4.2SW. Tributary of the River Teno/Tana.

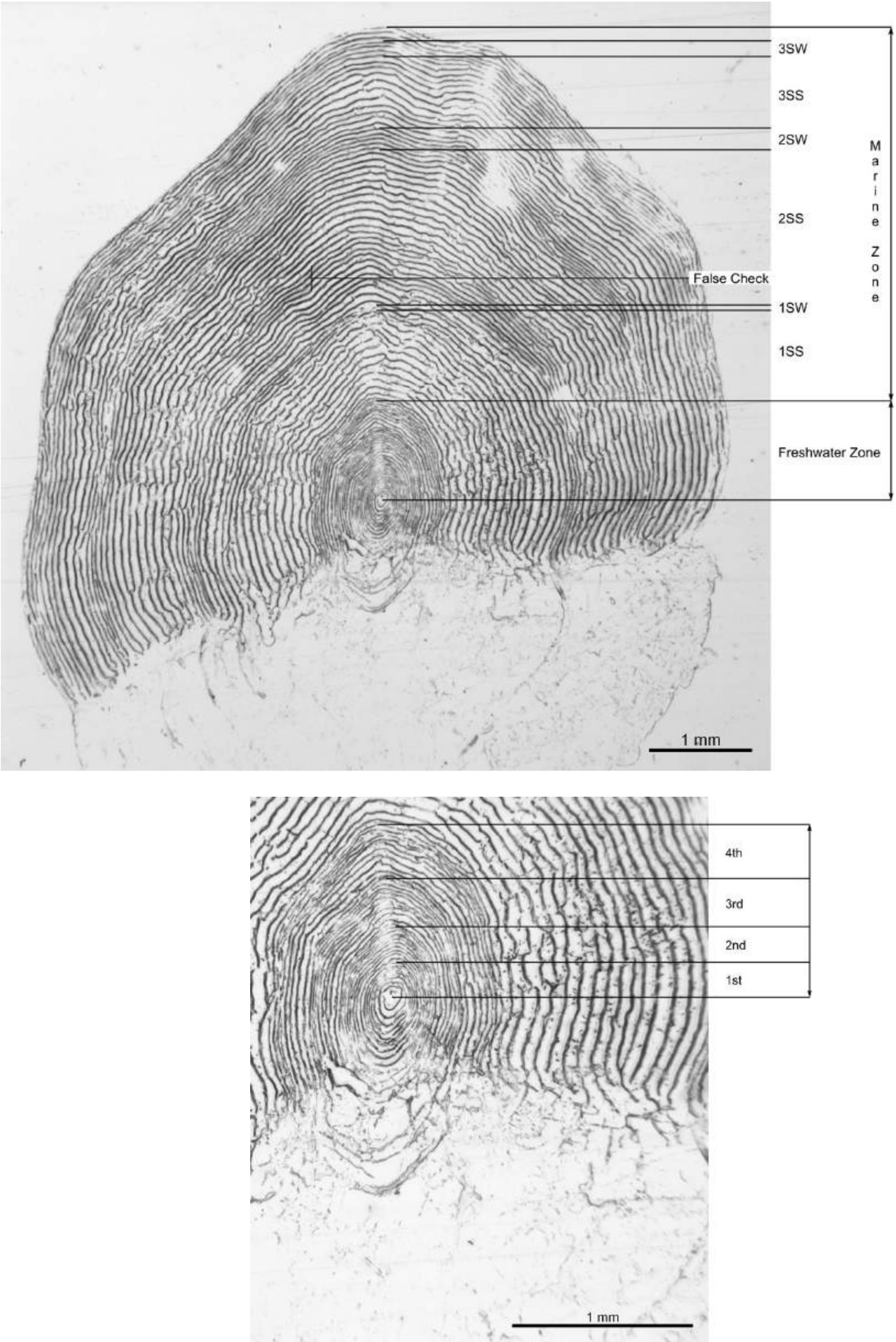


Figure 90. River Anarjohka 4.3SW. Tributary of the River Teno/Tana.

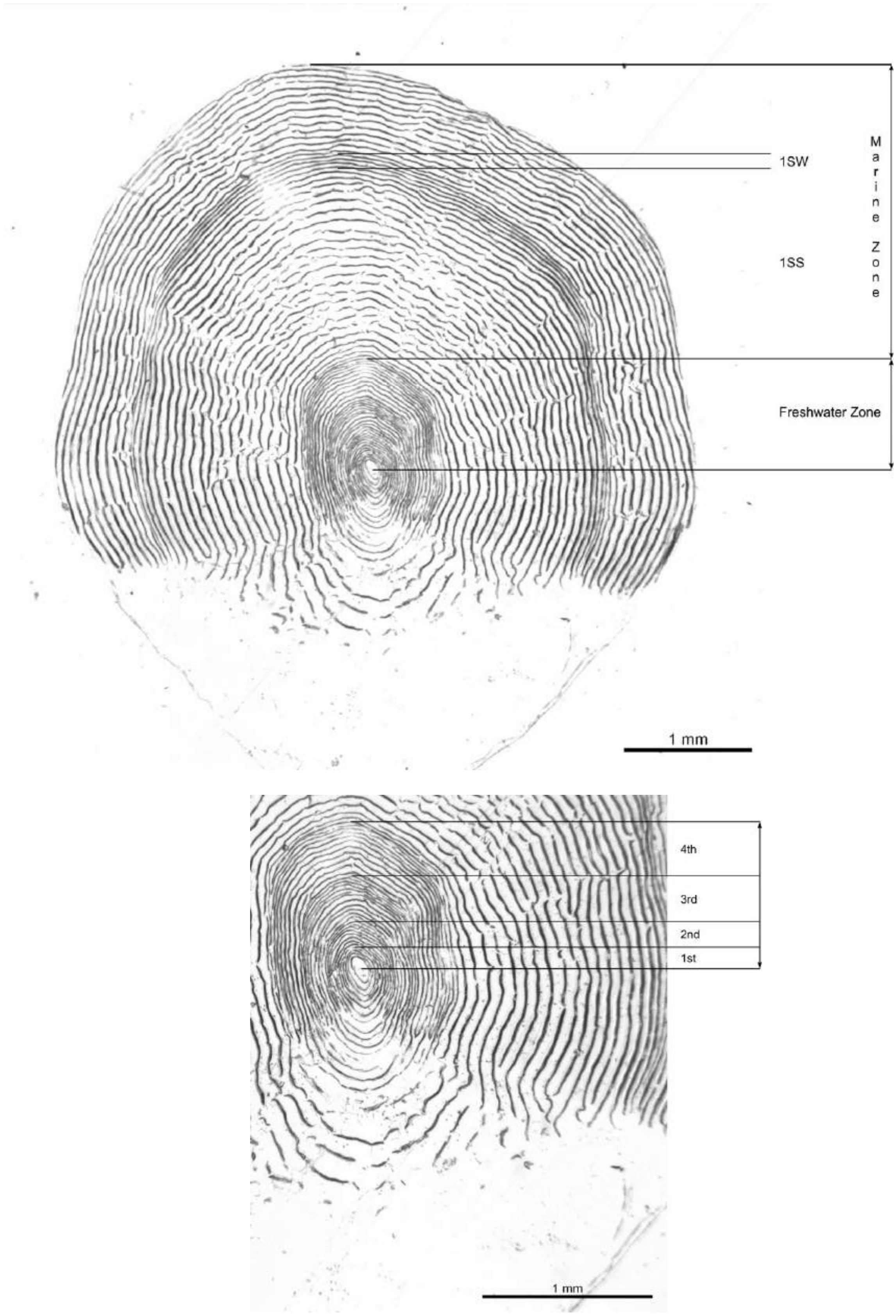


Figure 91. River Maskejohka 4.1SW. Tributary of the River Teno/Tana.

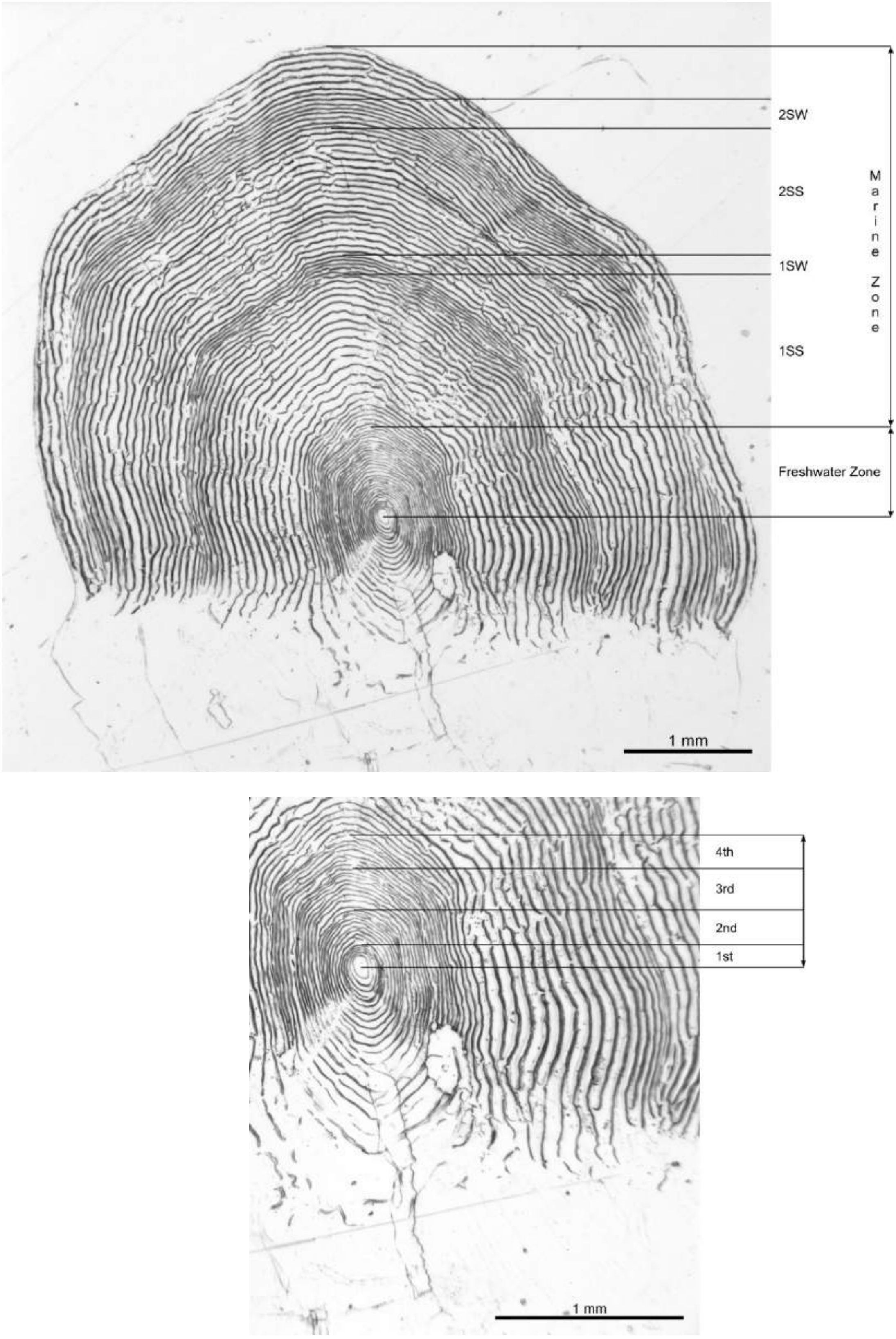


Figure 92. River Maskejohka 4.2SW. Tributary of the River Teno/Tana.

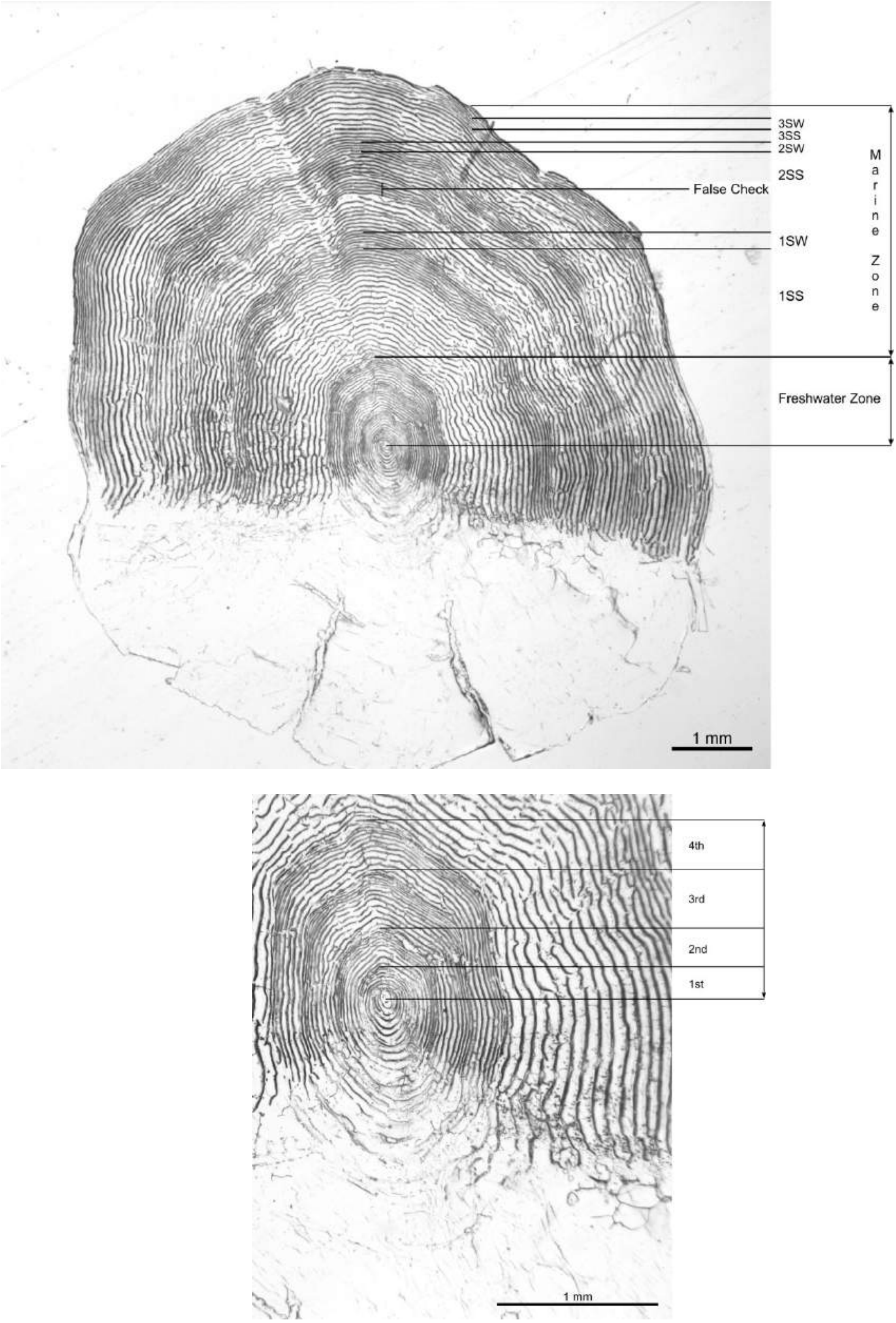


Figure 93. River Maskejohka 4.3SW. Tributary of the River Teno/Tana.

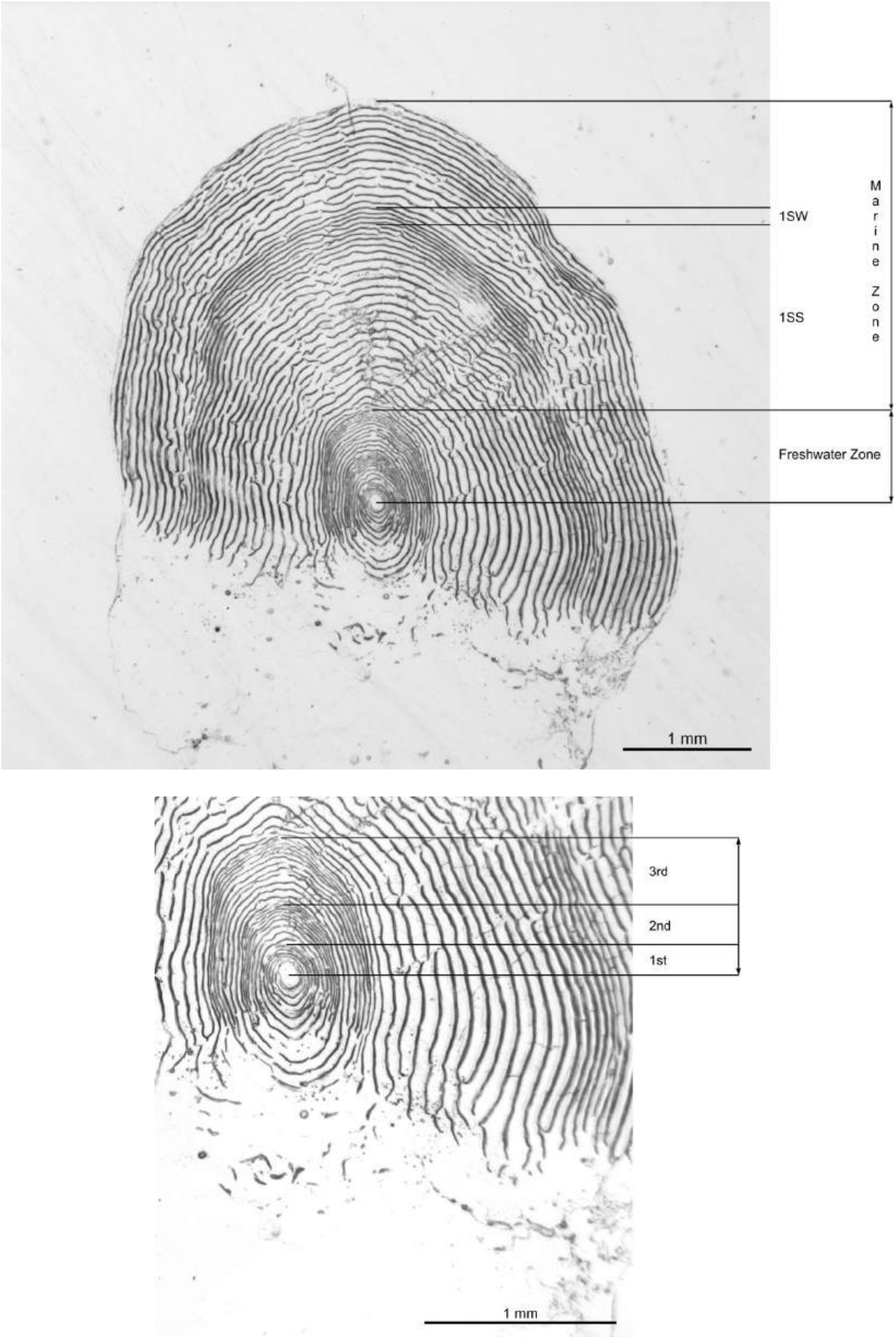
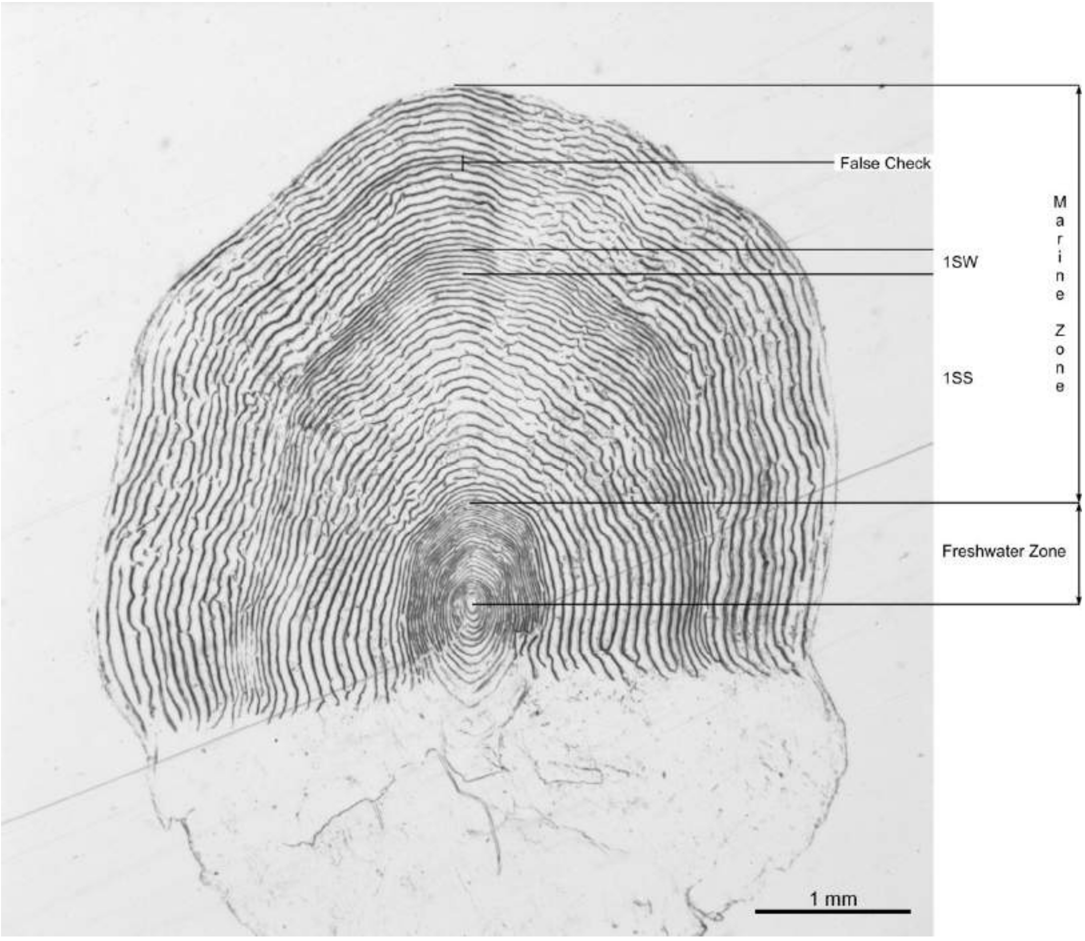


Figure 94. River Teno/Tana mainstream. 3.1SW.



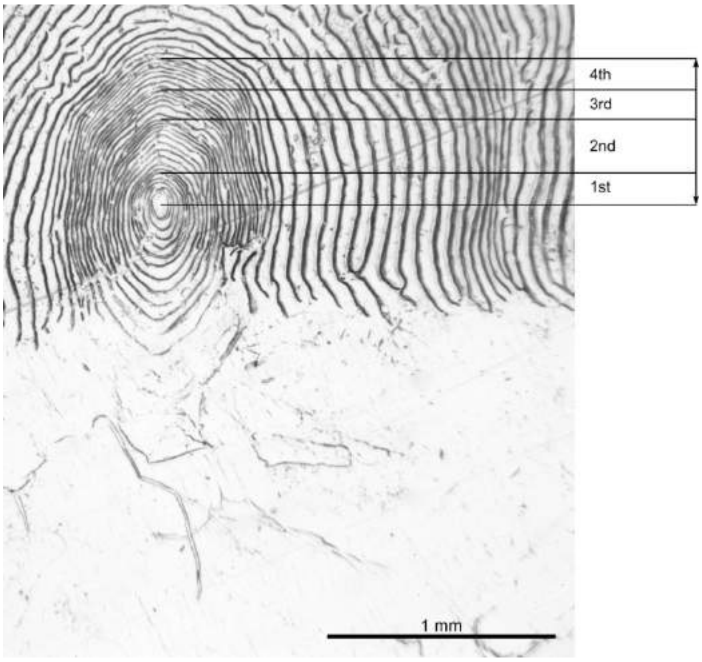


Figure 95. River Teno/Tana mainstream. 4.1SW.

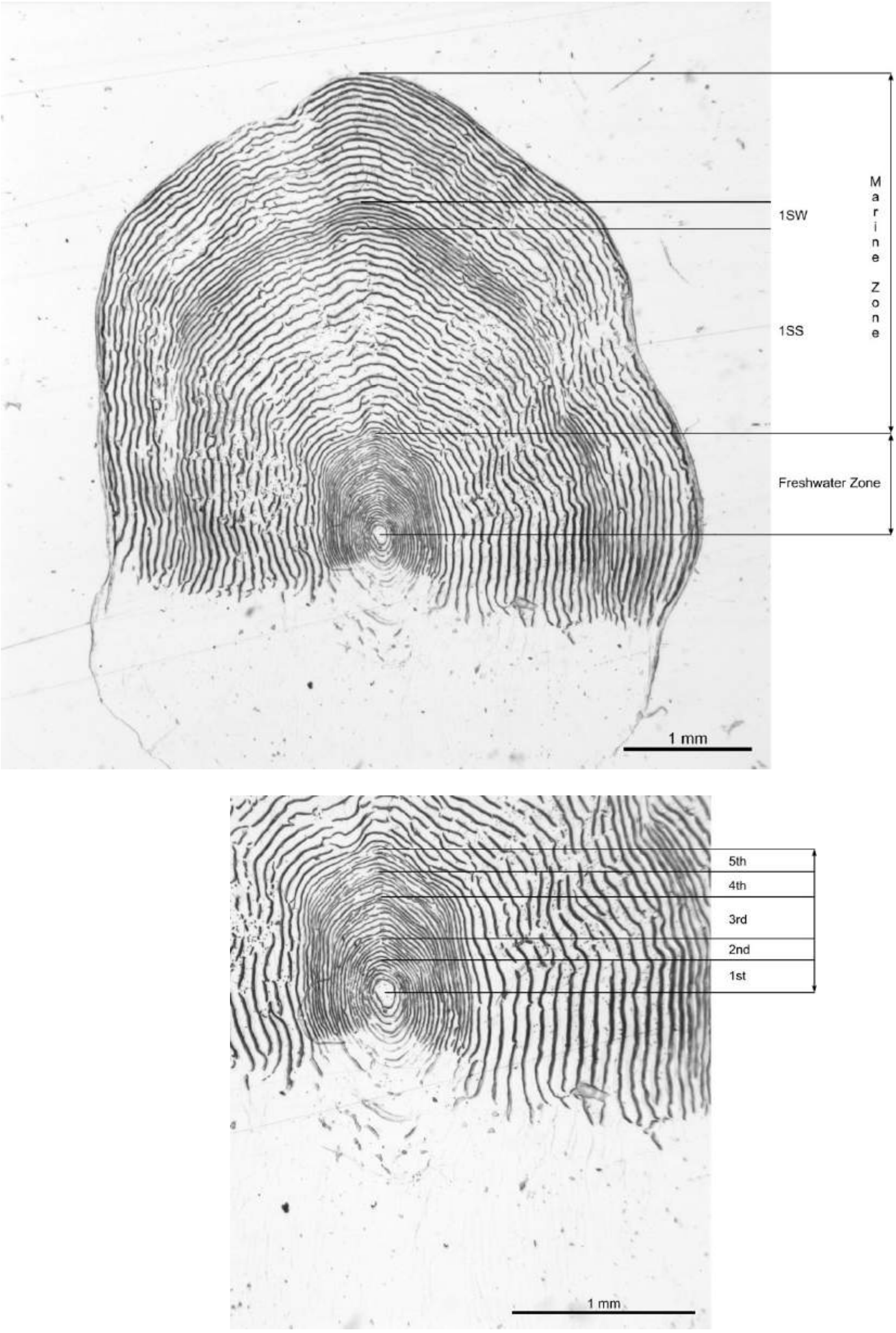


Figure 96. River Teno/Tana mainstream. 5.1SW.

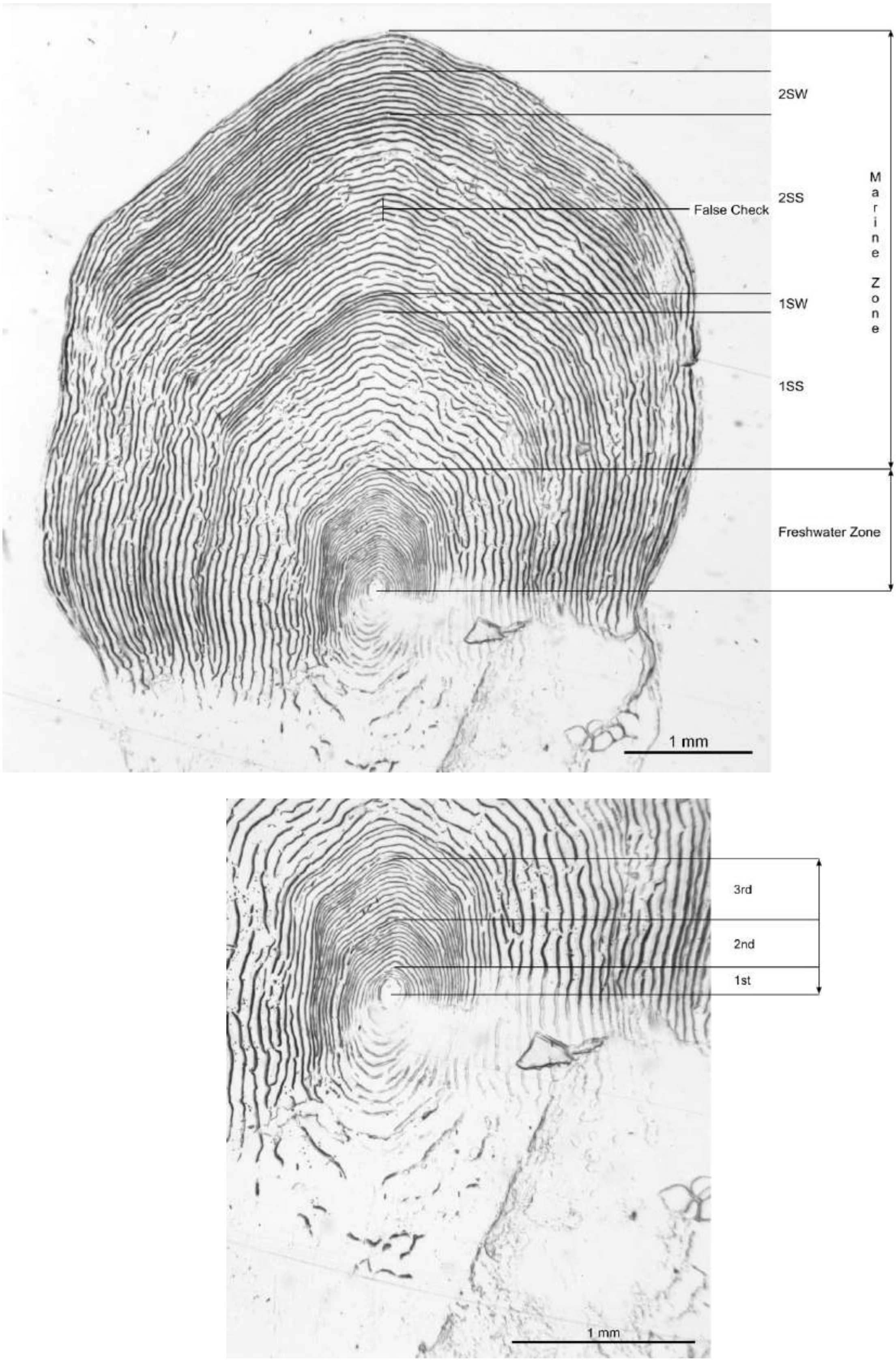
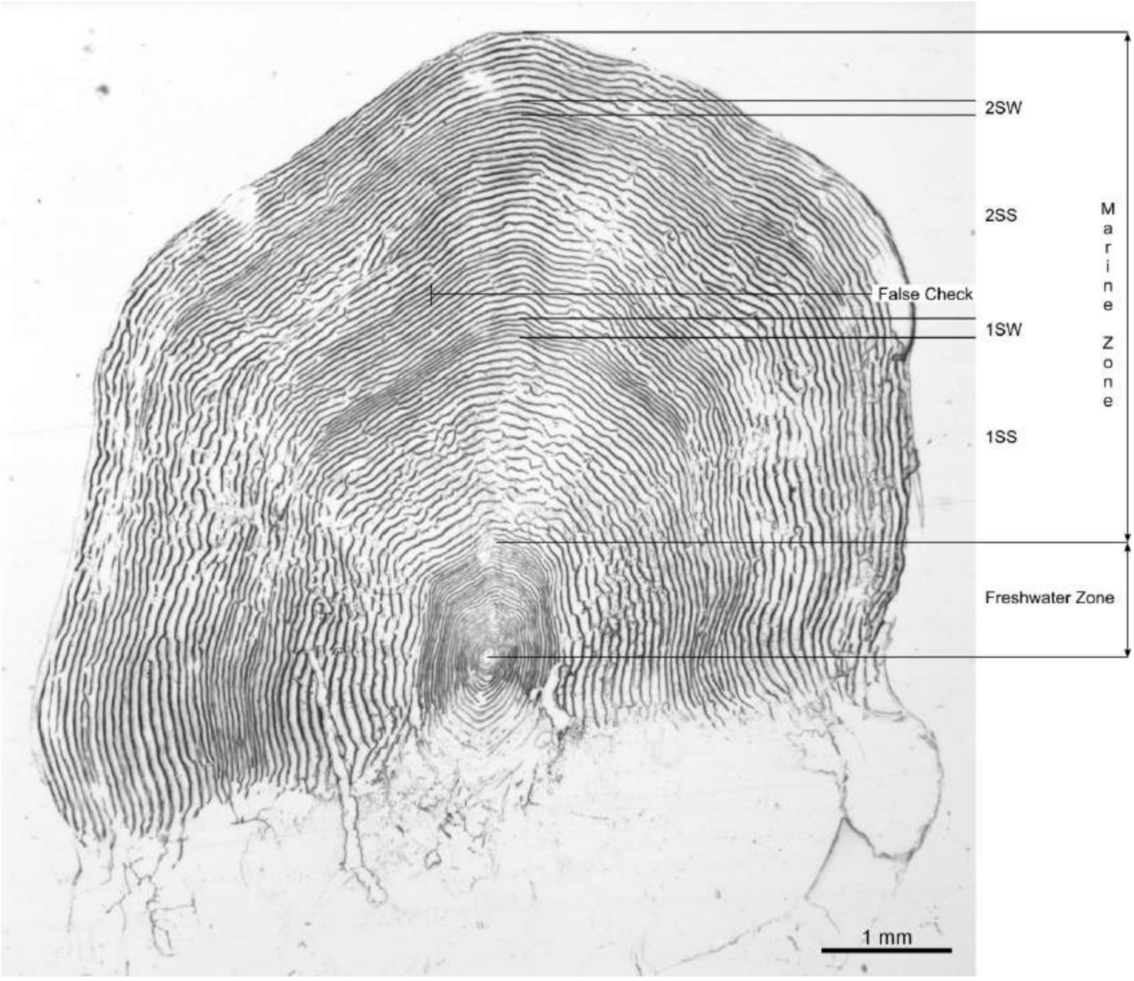


Figure 97. River Teno/Tana mainstream. 3.2SW.



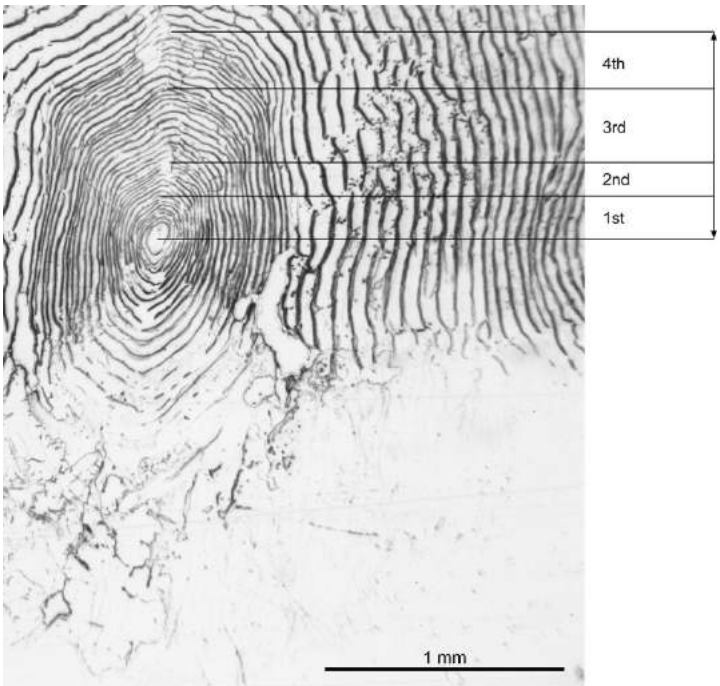


Figure 98. River Teno/Tana mainstream 4.2SW.

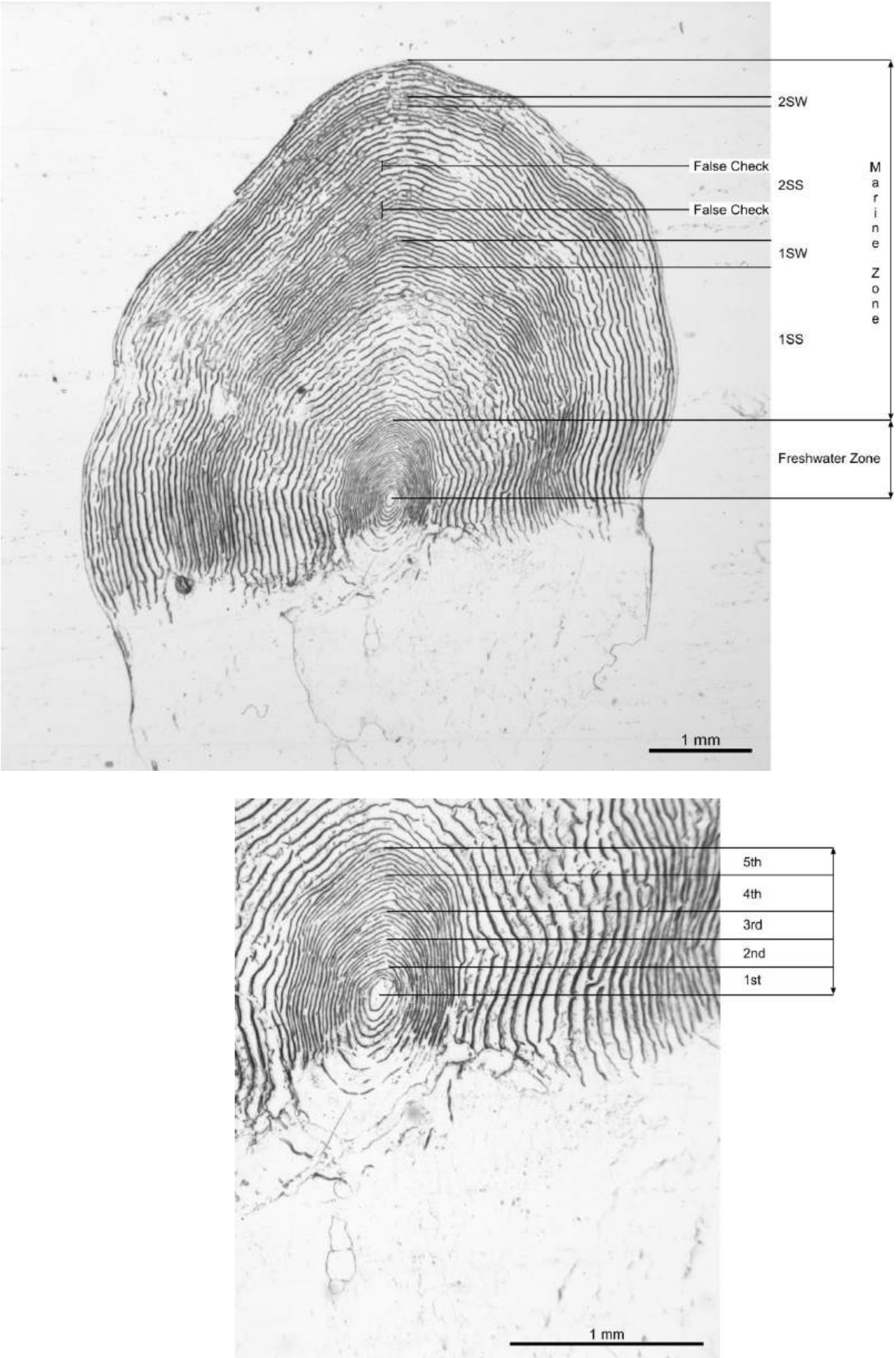


Figure 99. River Teno/Tana mainstream. 5.2SW.

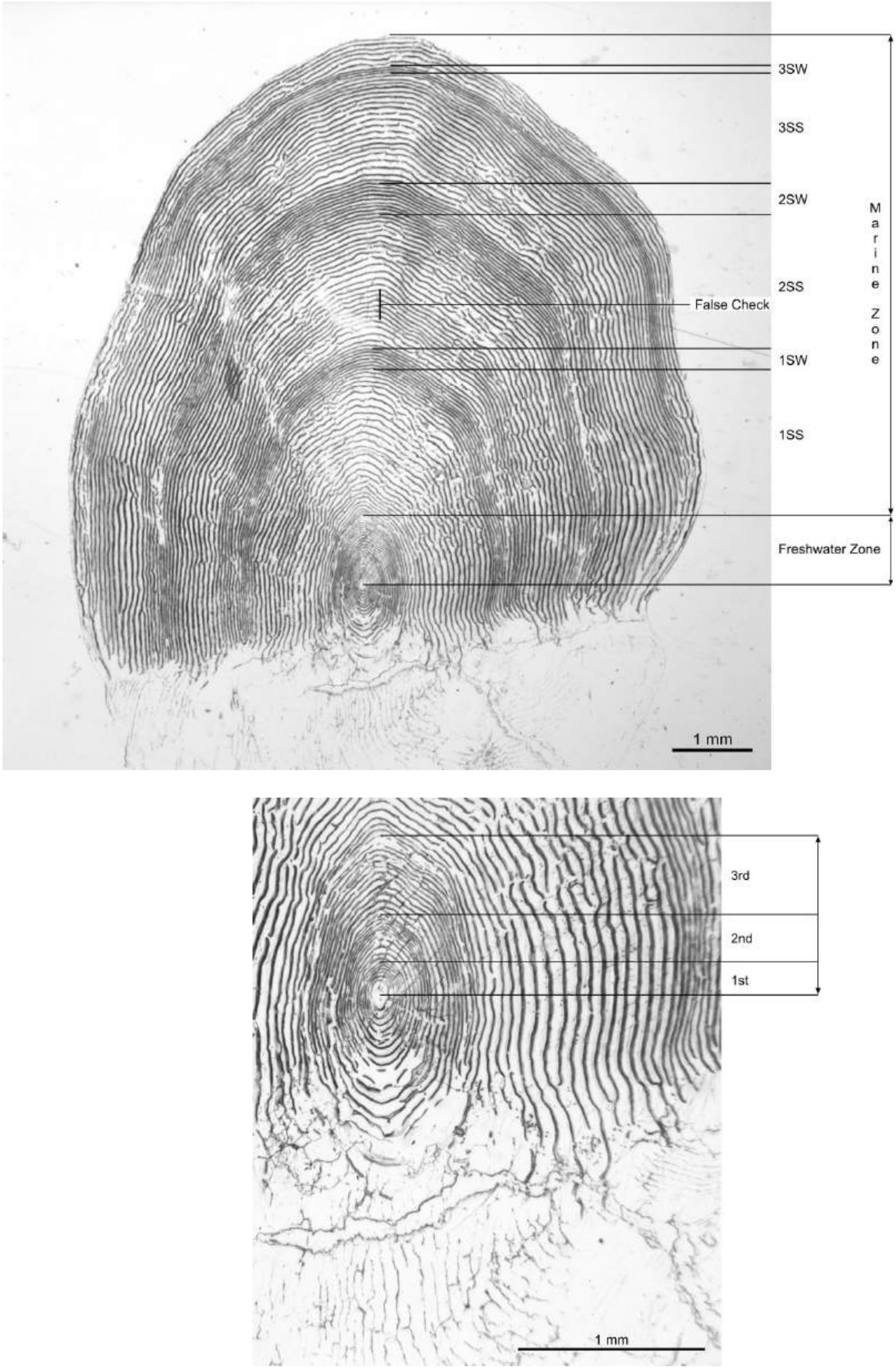
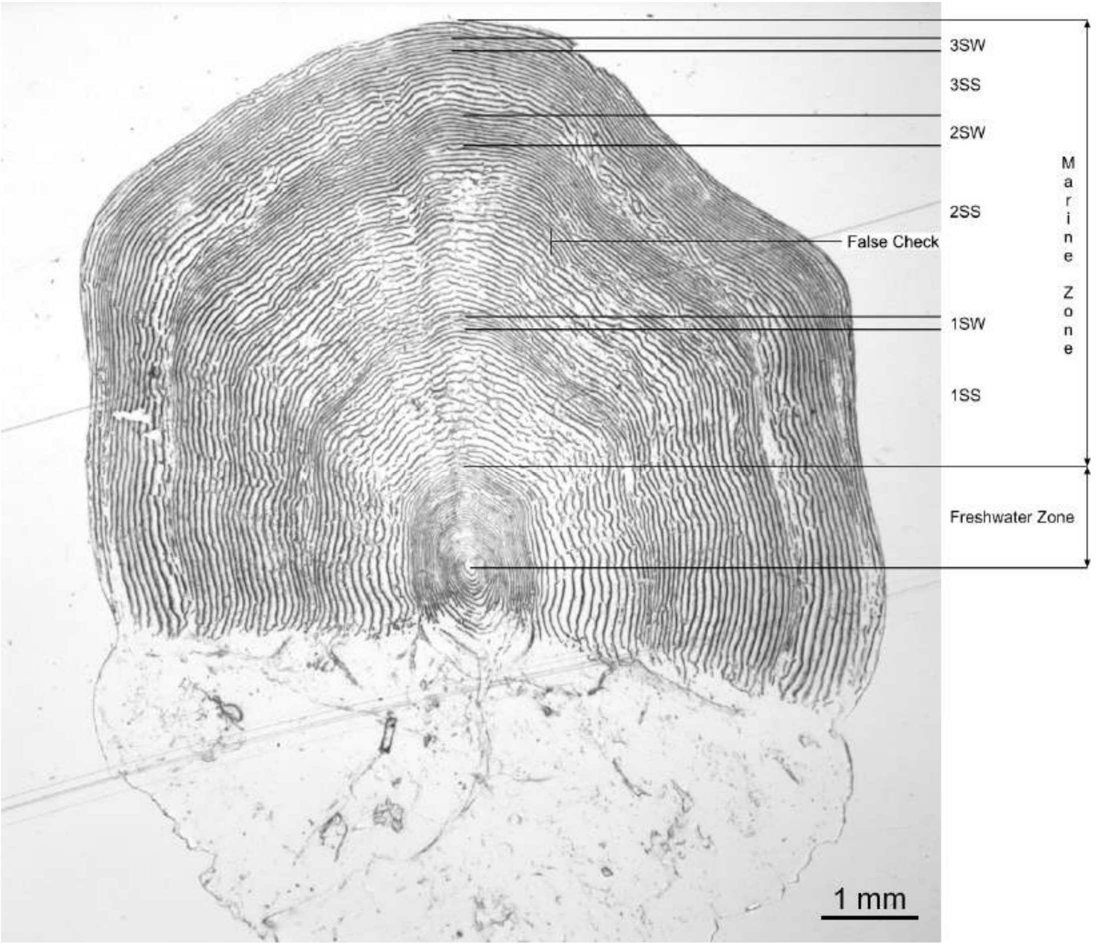


Figure 100. River Teno/Tana mainstream. 3.3SW.



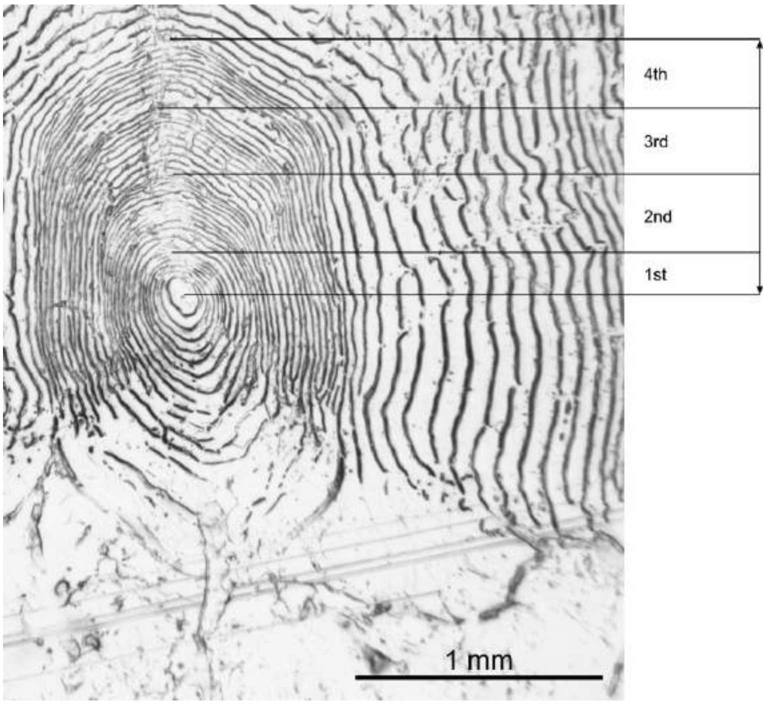
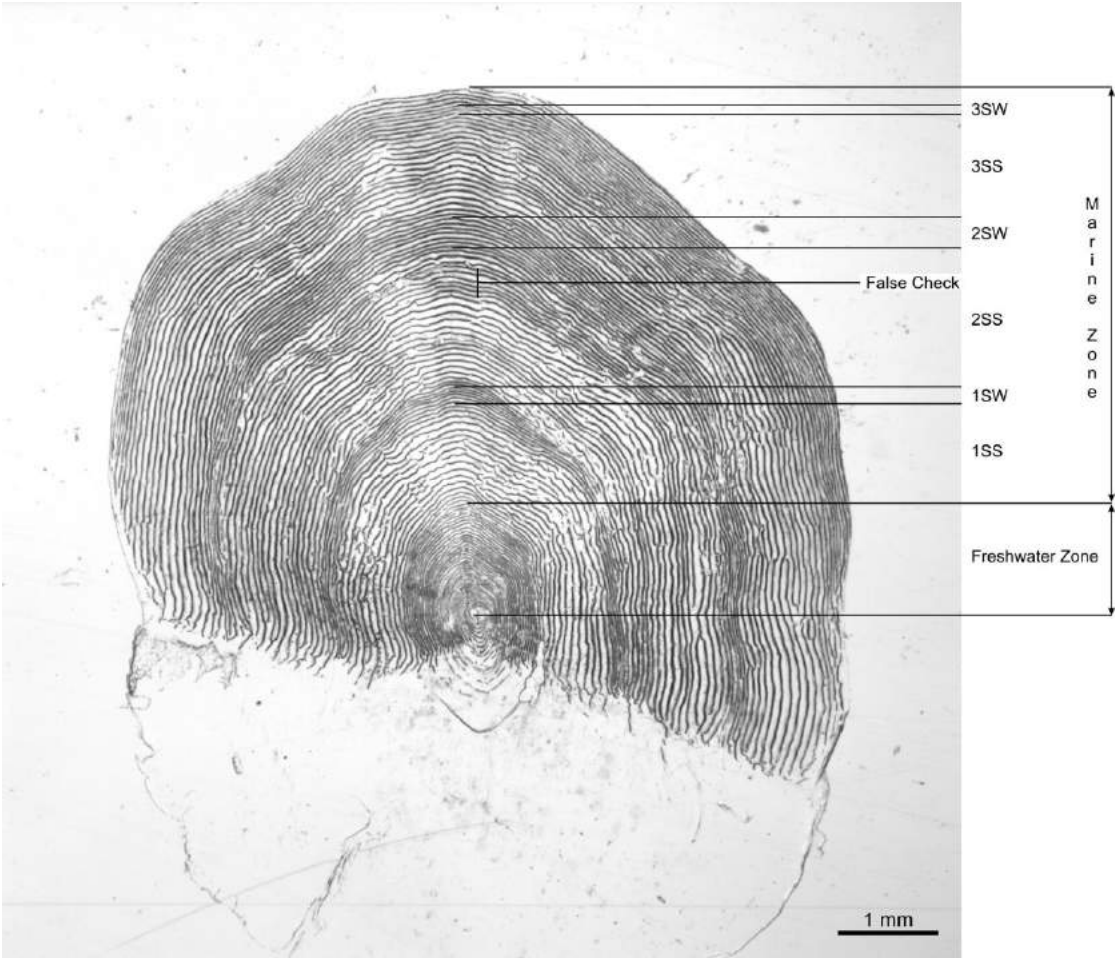


Figure 101. River Teno/Tana mainstem. 4.3SW.



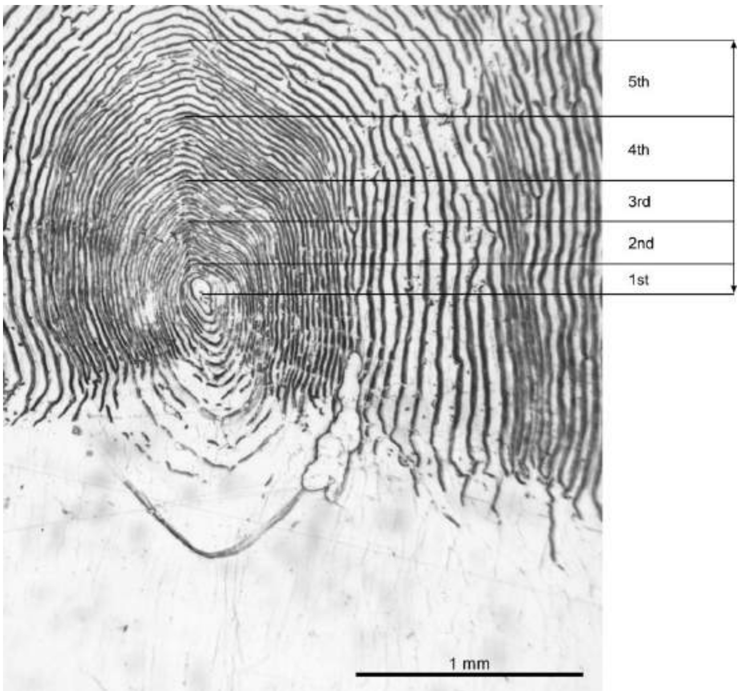


Figure 102. River Teno/Tana mainstrem. 5.3SW.

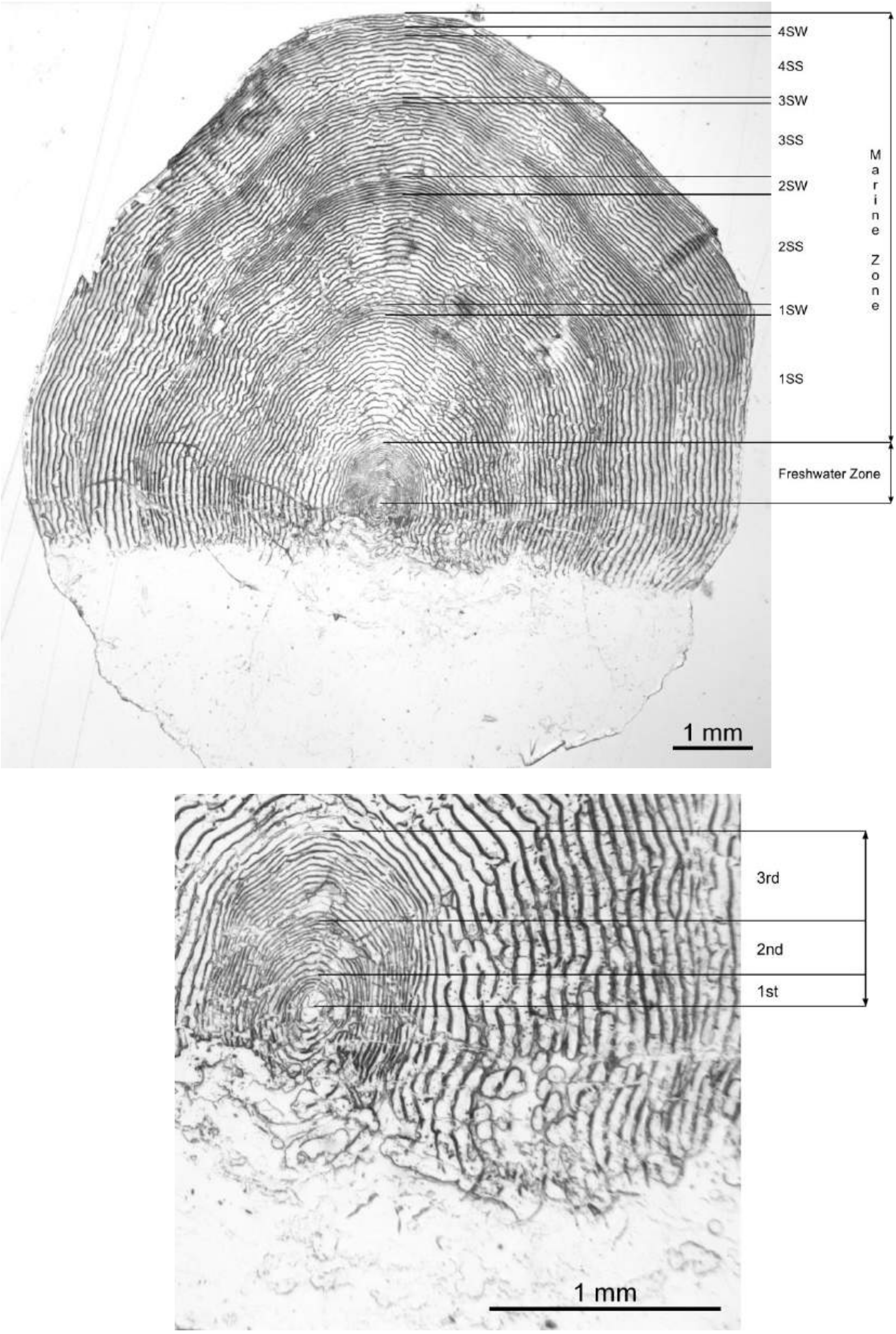
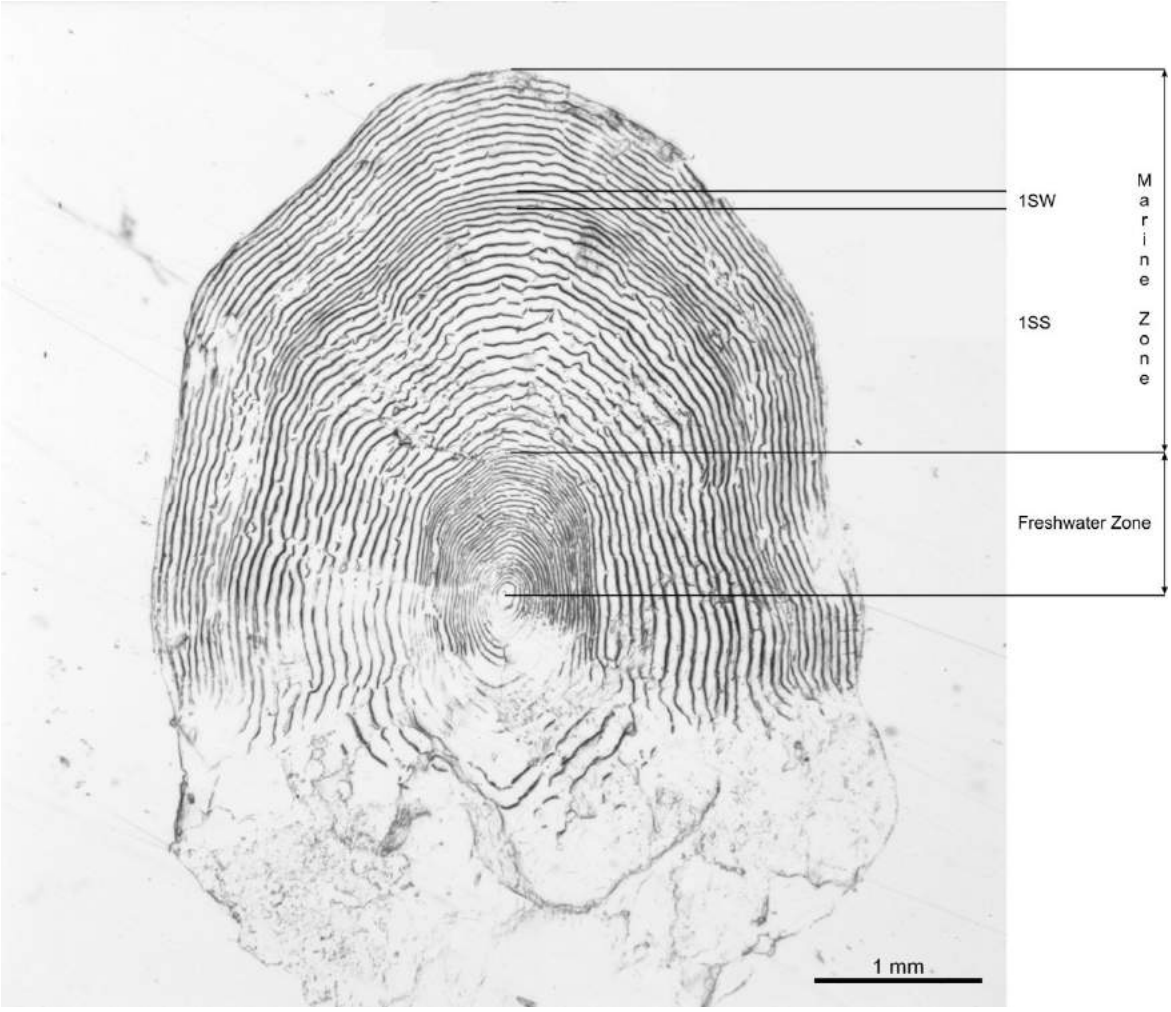


Figure 103. River Teno/Tana mainstem. 3.4SW.



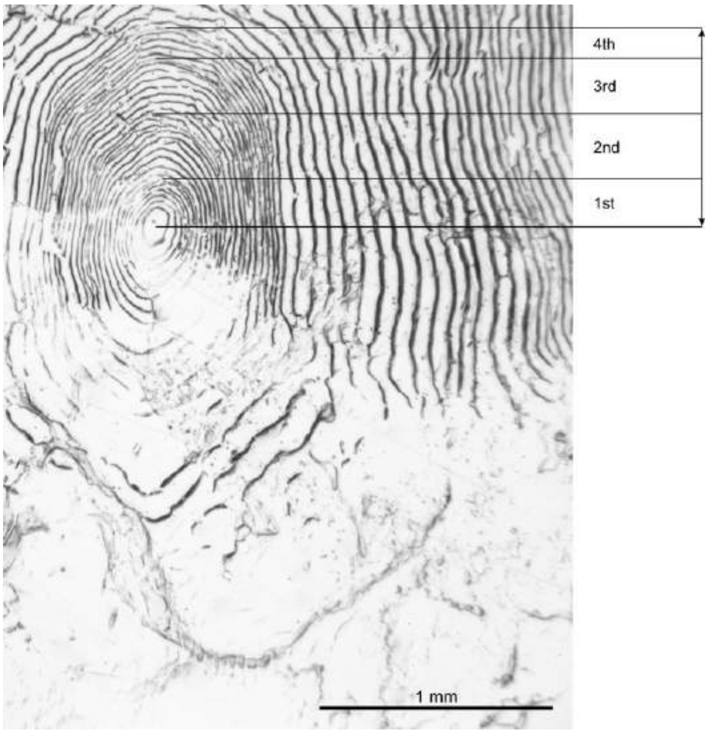
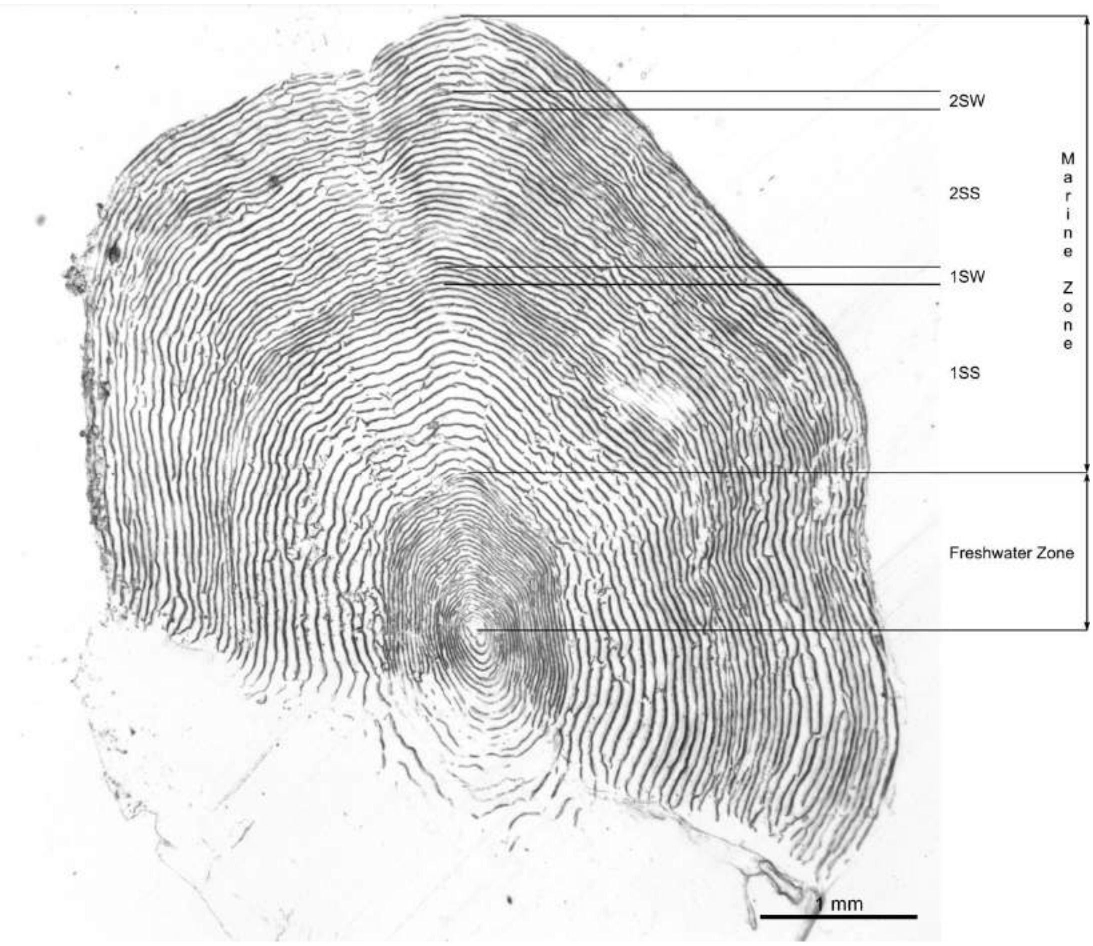


Figure 104. River Sandfjordelva (Gamvik).4.1SW.

Figure 105. River Sandfjordelva (Gamvik). 4.2SW



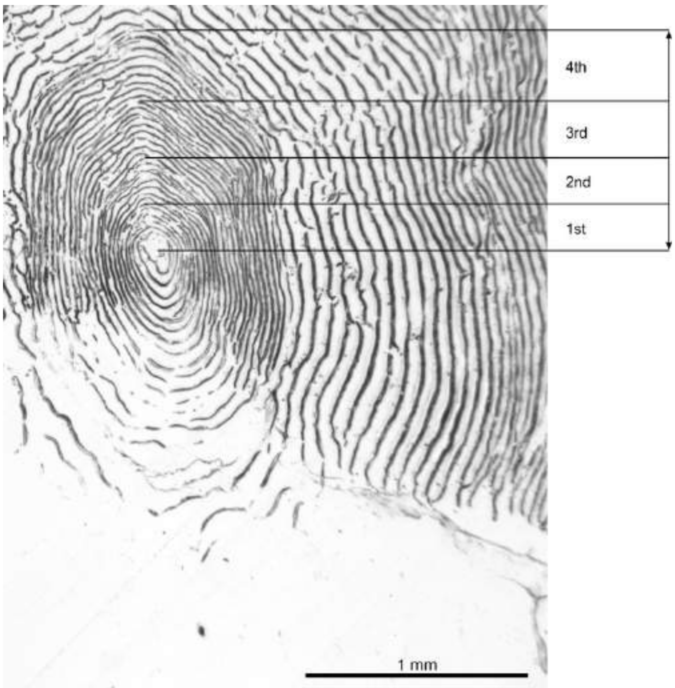


Figure 105. River Sandfjordelva (Gamvik). 4.2SW

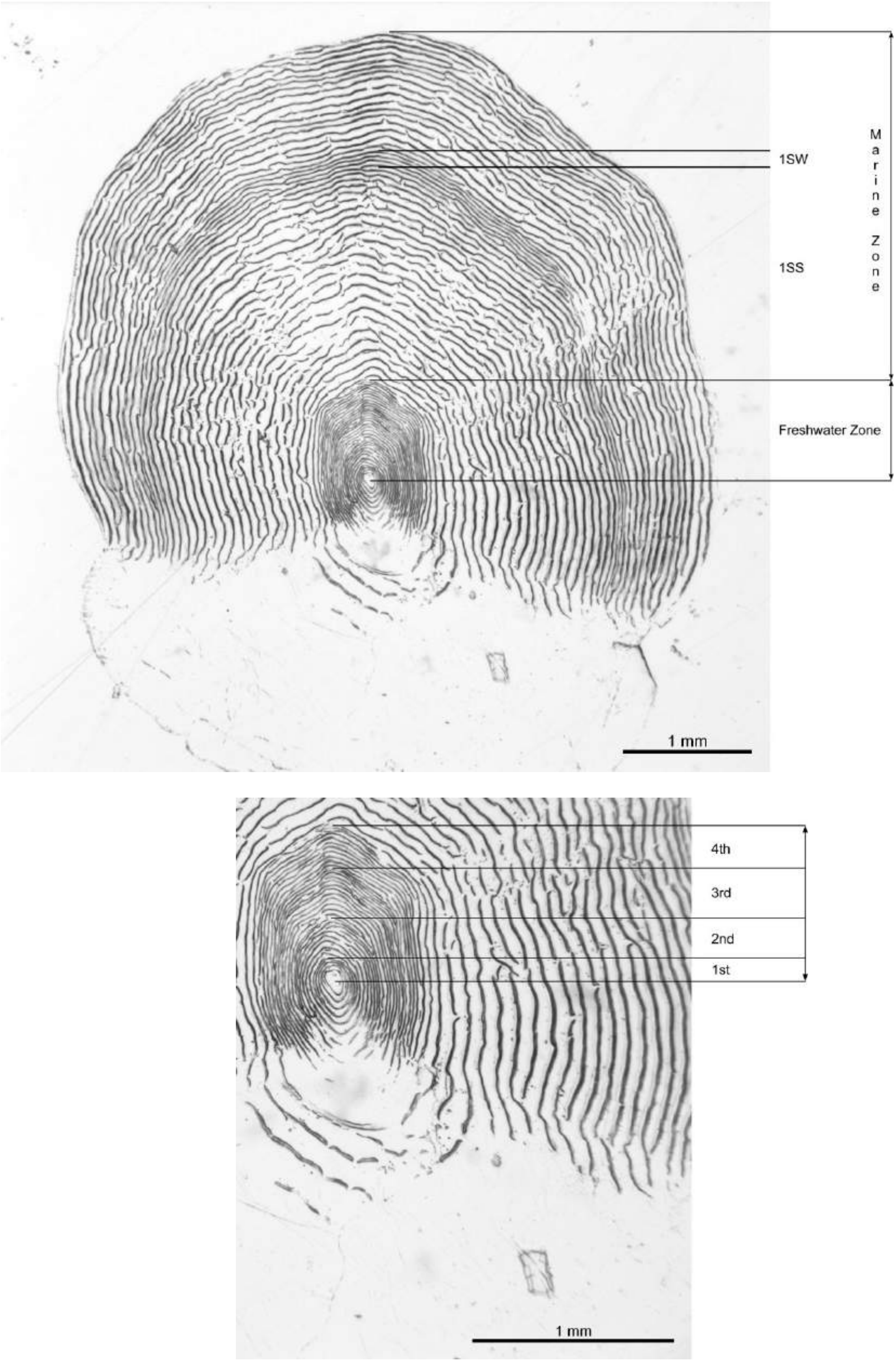


Figure 106. River Børselva. 4.1SW.

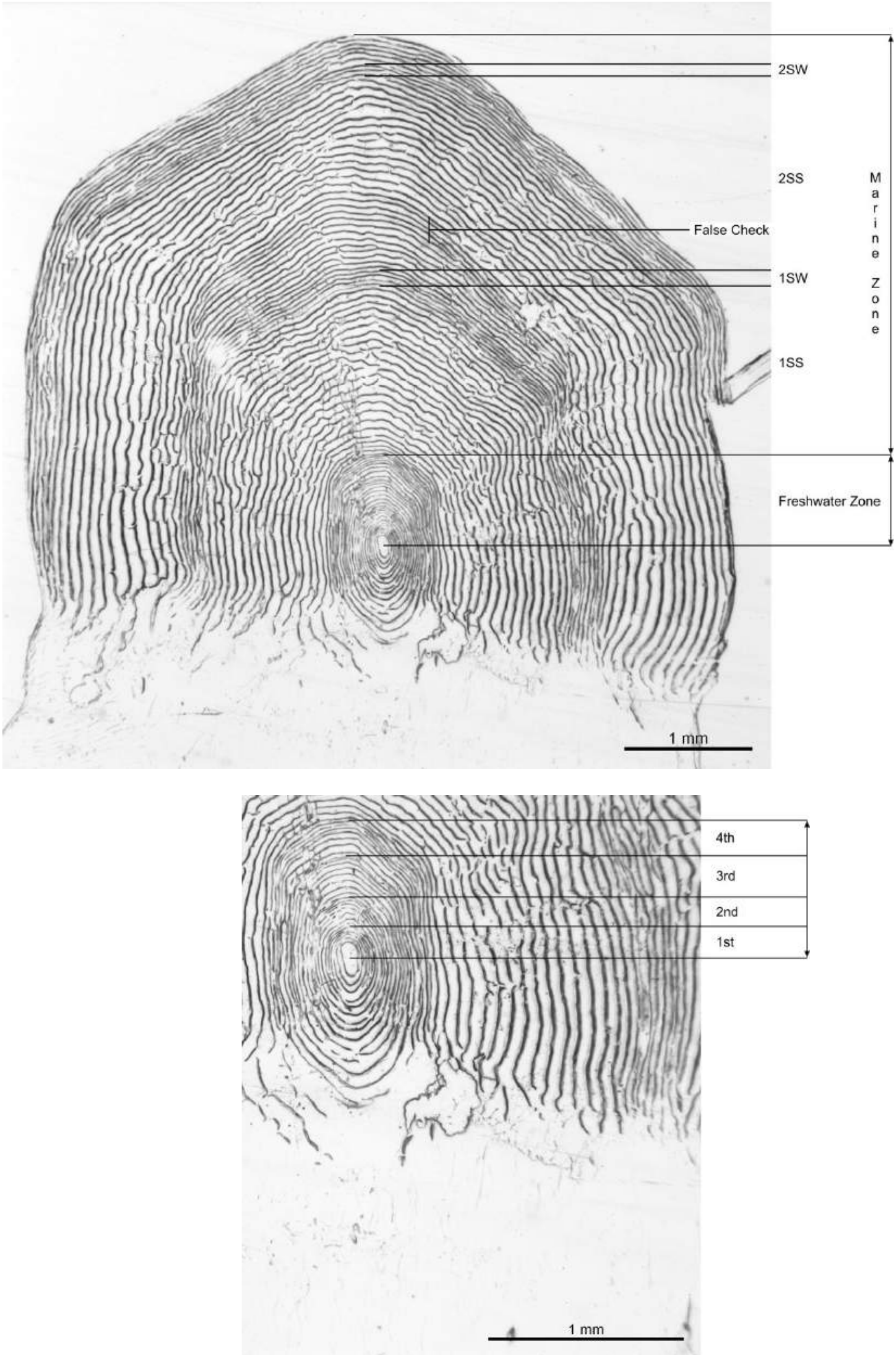
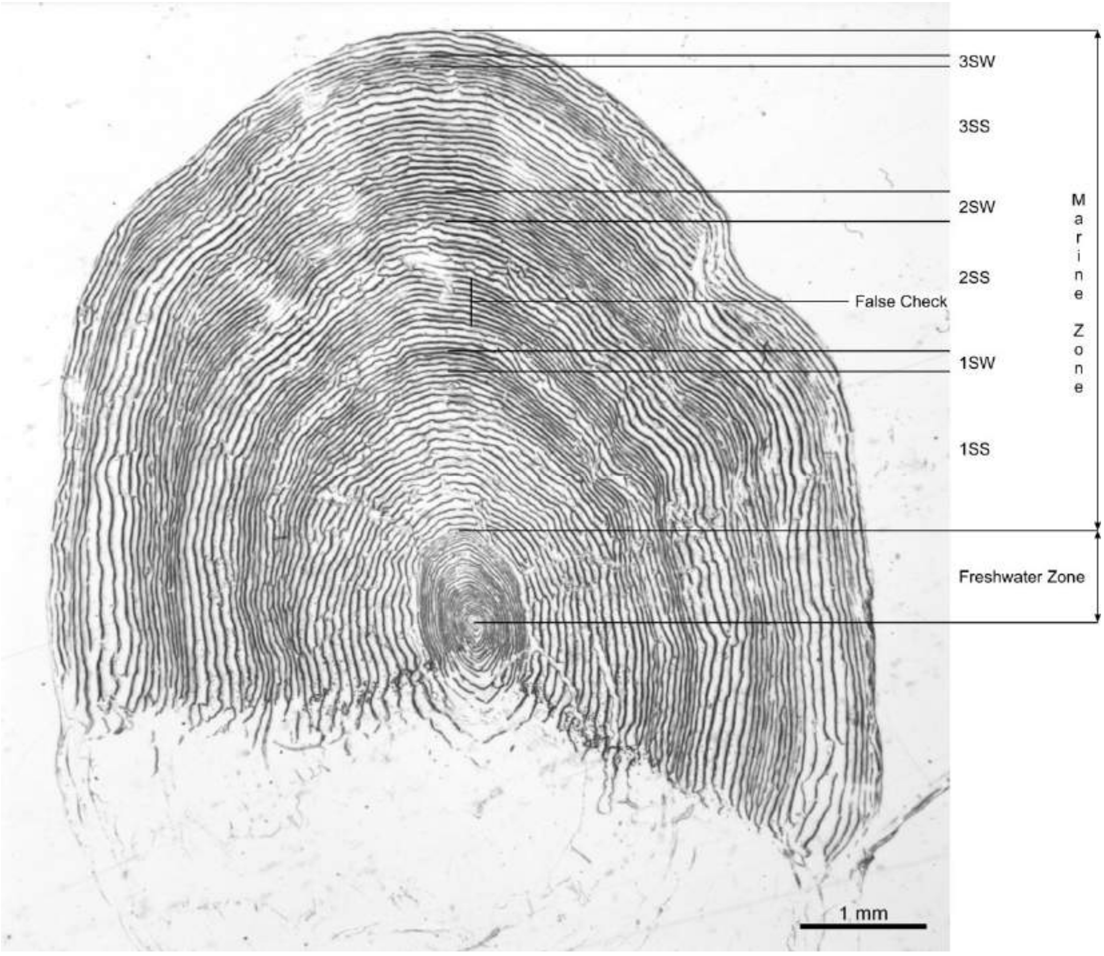


Figure 107. River Børselva. 4.2SW.



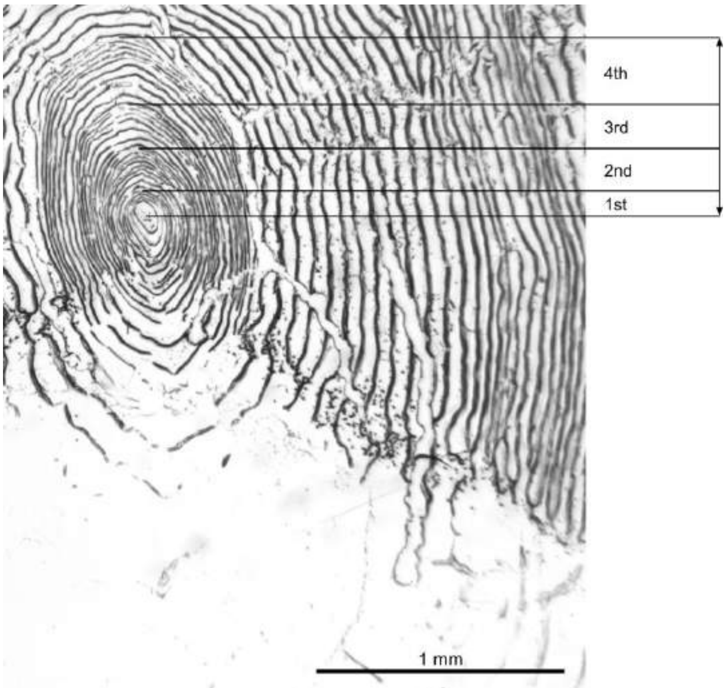
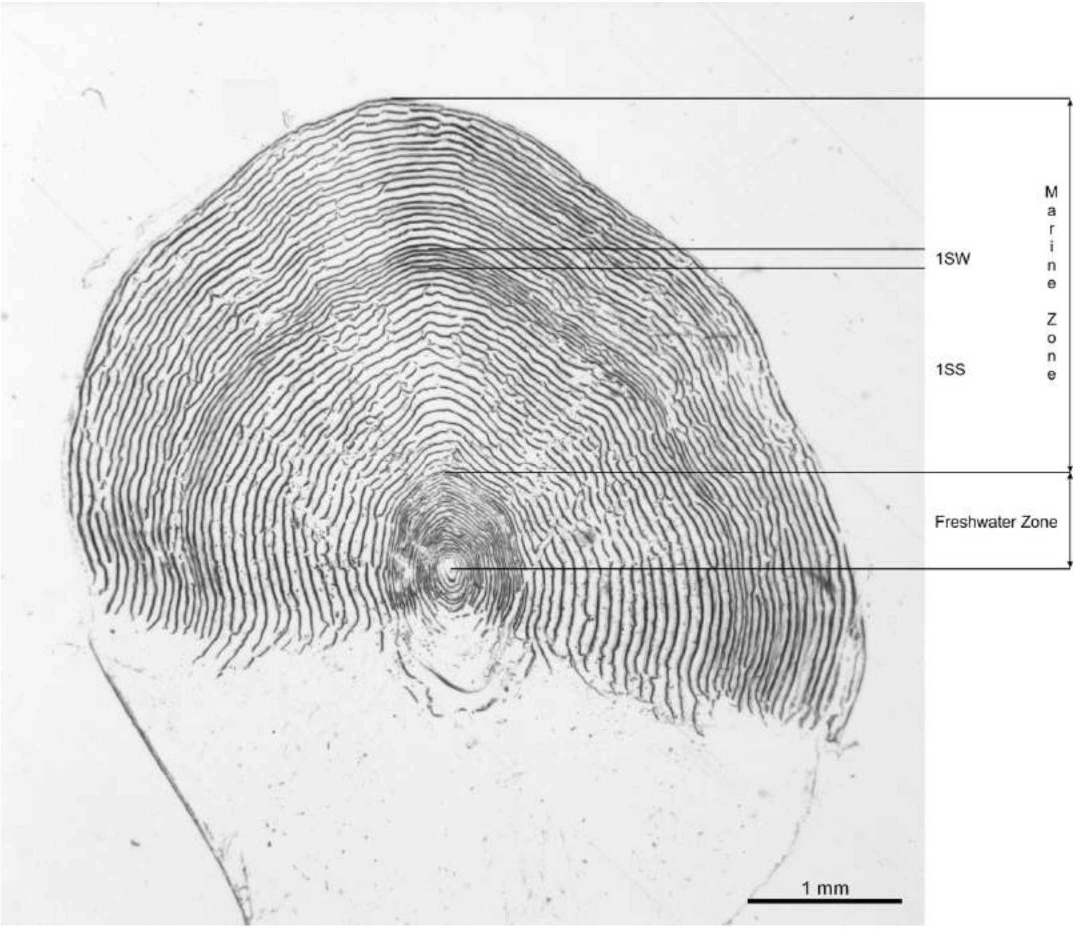


Figure 108. River Børselva. 4.3SW.



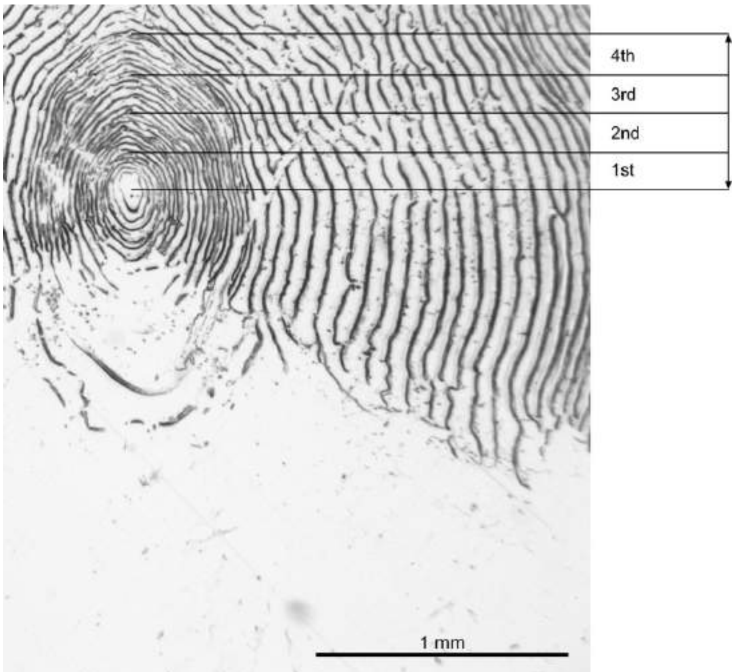
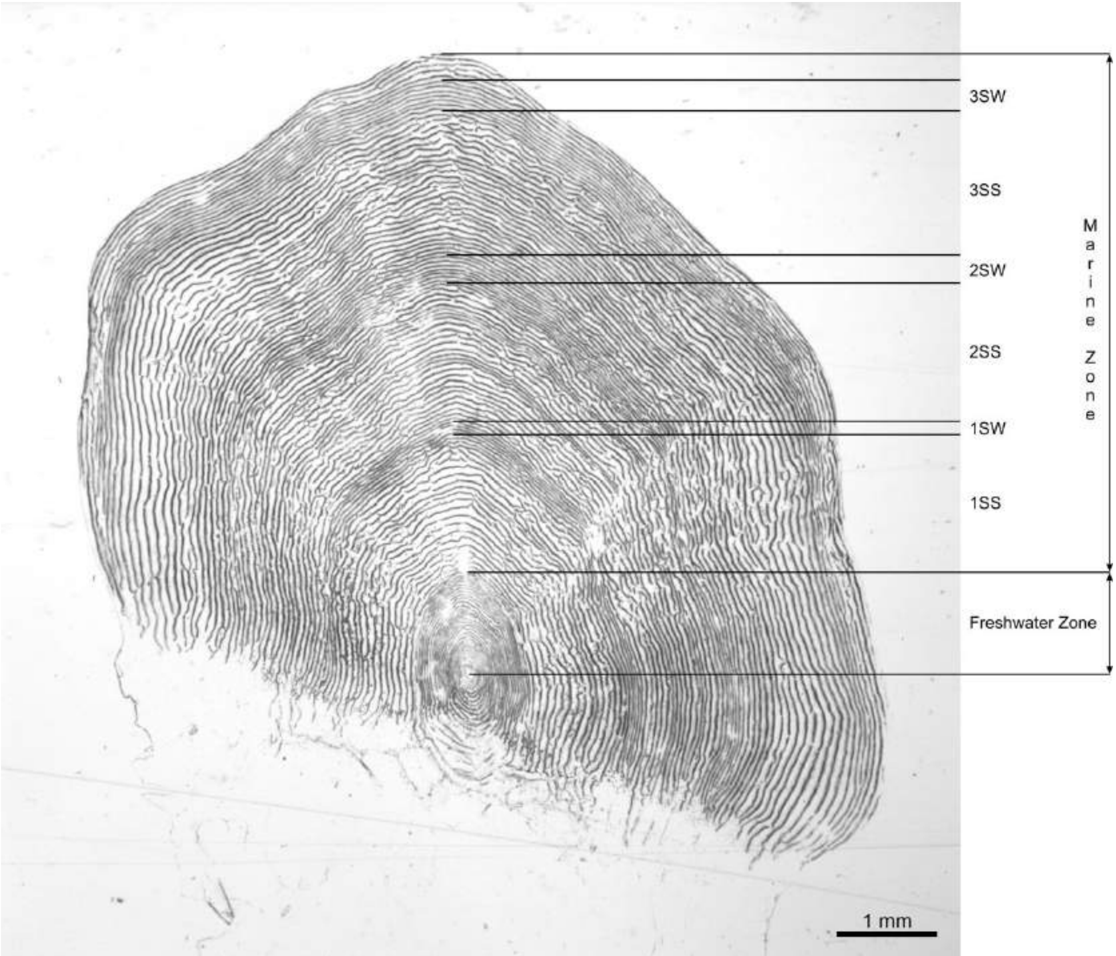


Figure 109. River Lakselva (Porsanger). 4.1SW.



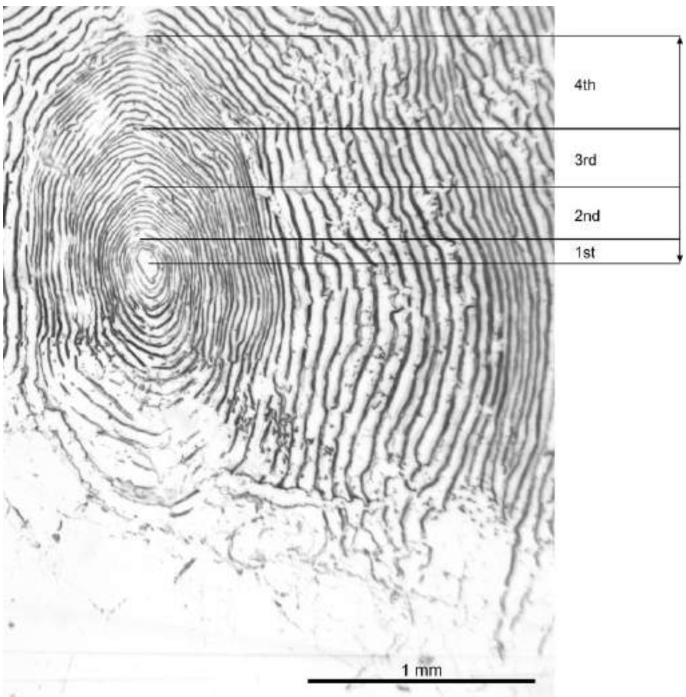


Figure 110. River Lakselva (Porsanger). 4.3SW.

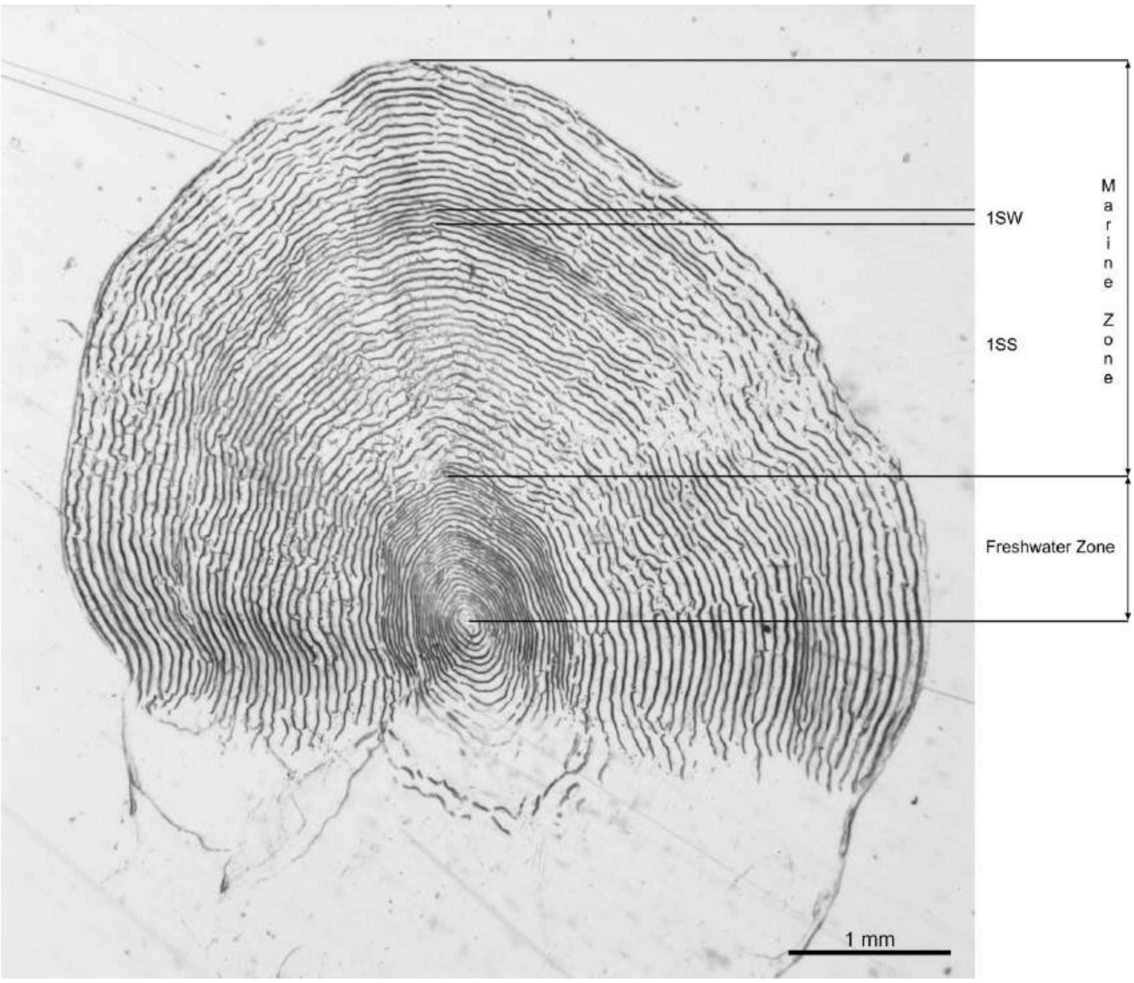


Figure 111. River Alta. 4.1SW.

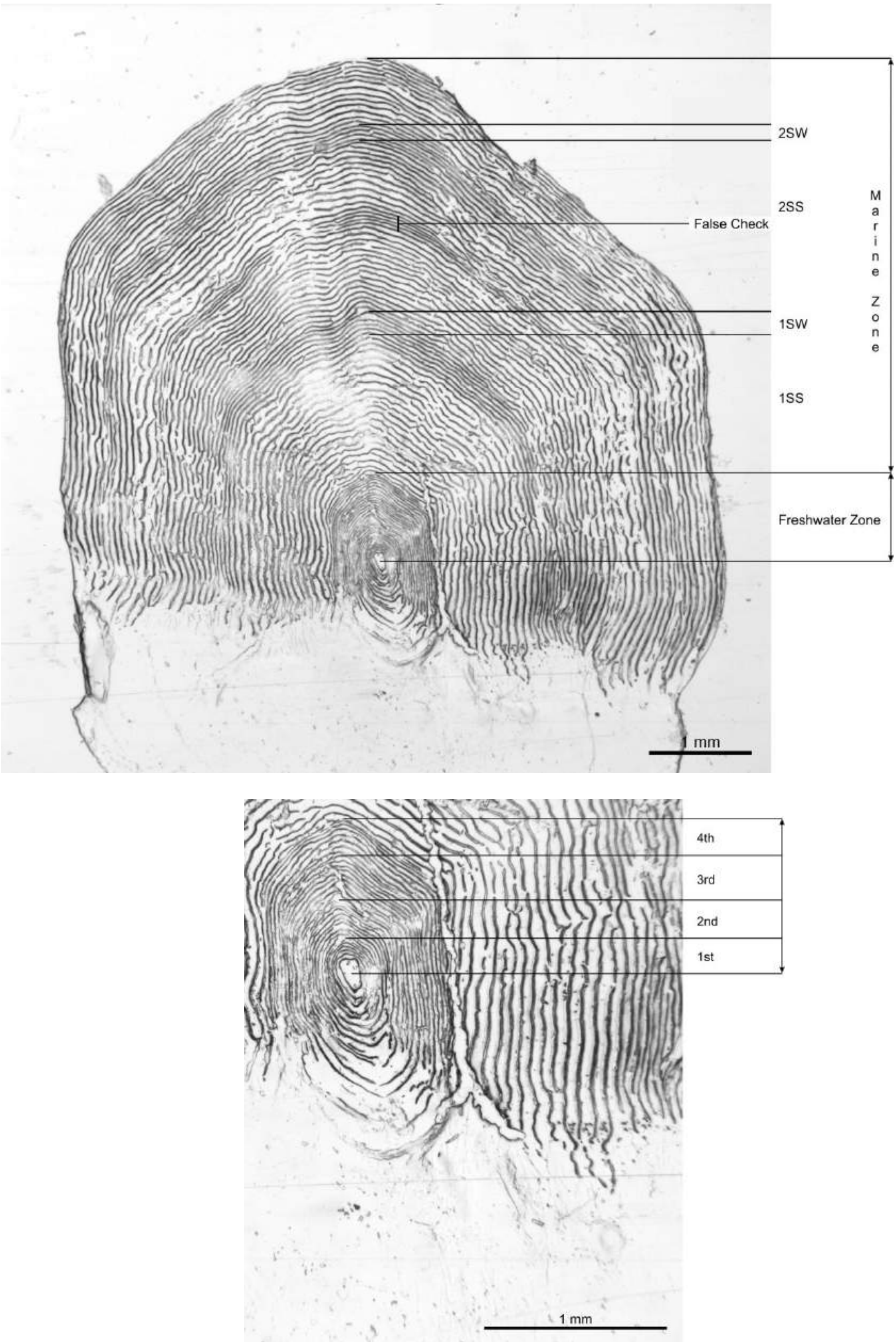


Figure 112. River Alta. 4.2SW.

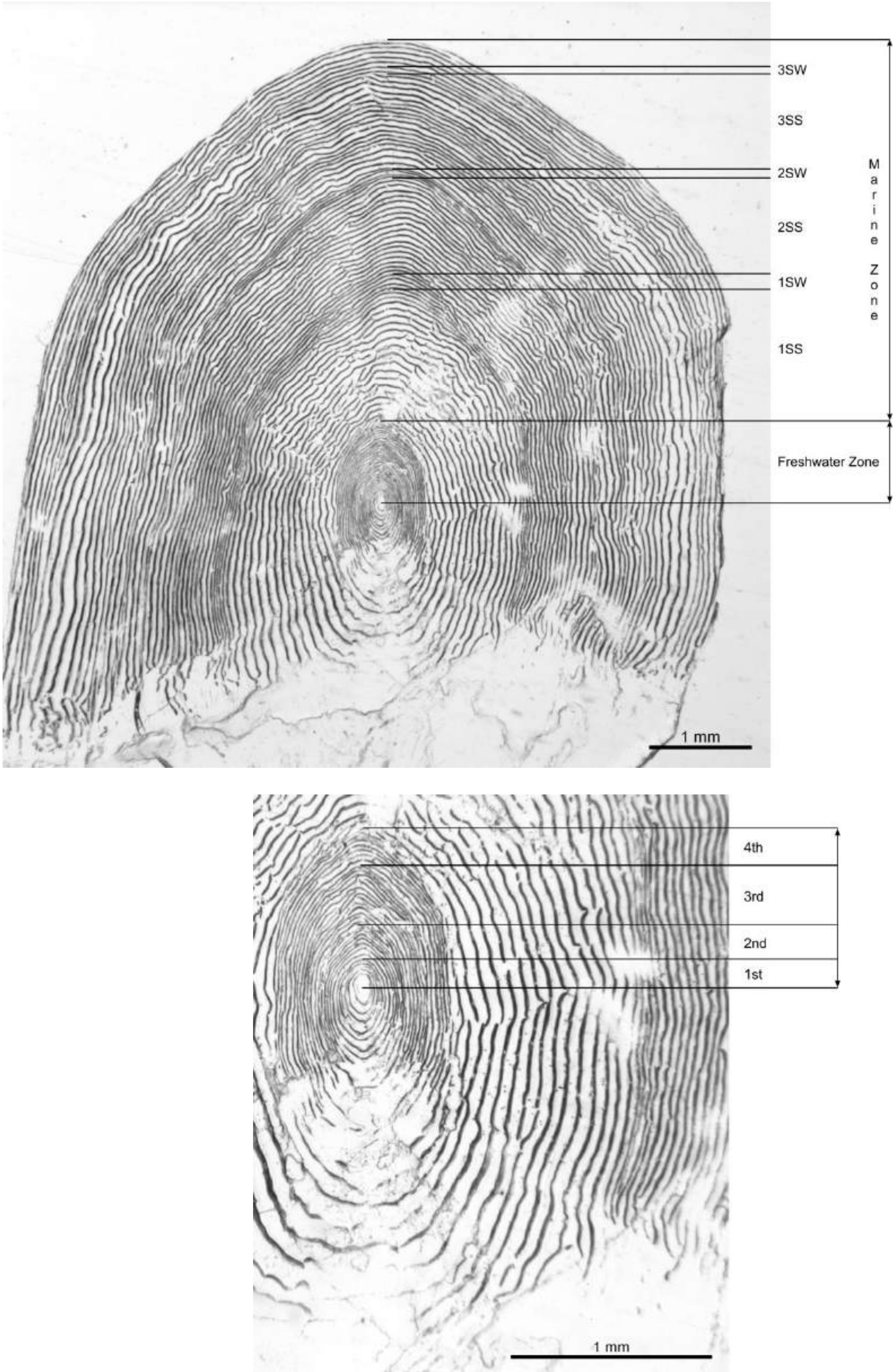
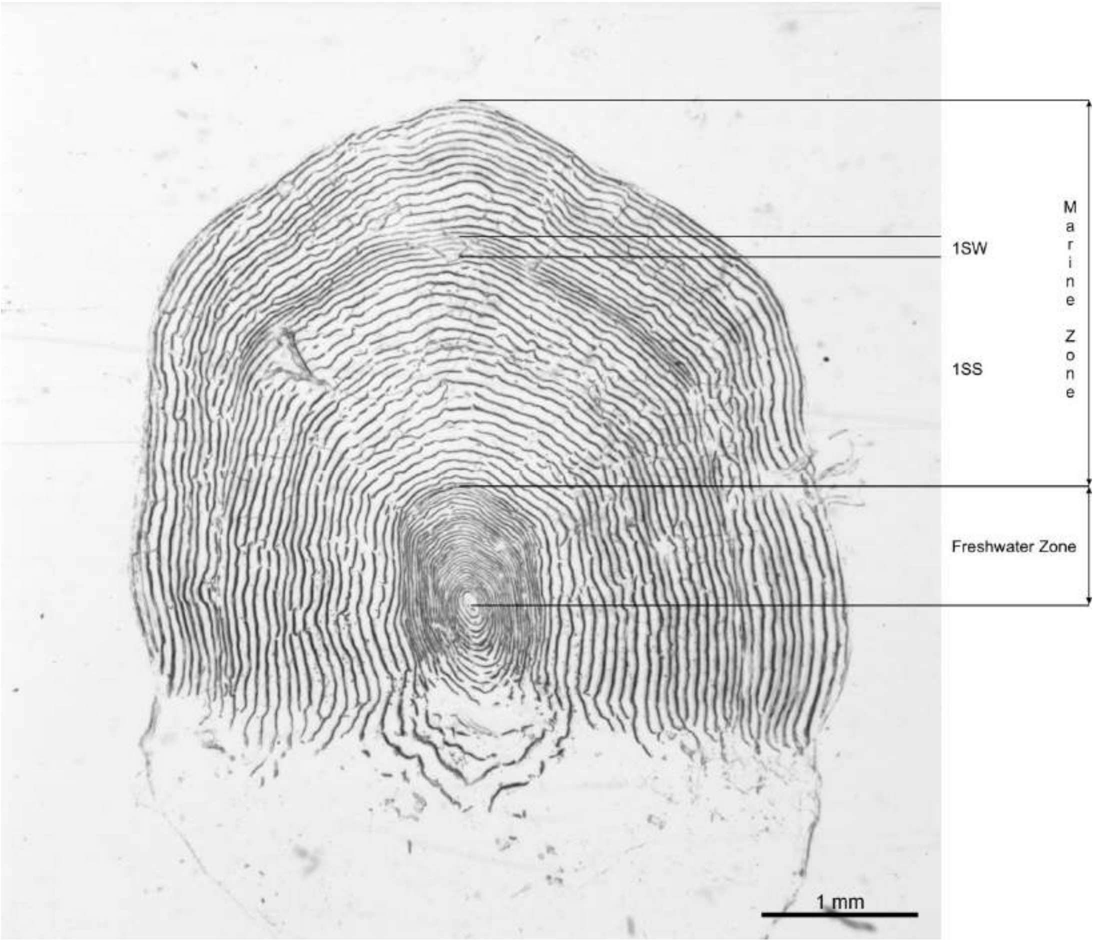


Figure 113. River Alta. 4.3SW.



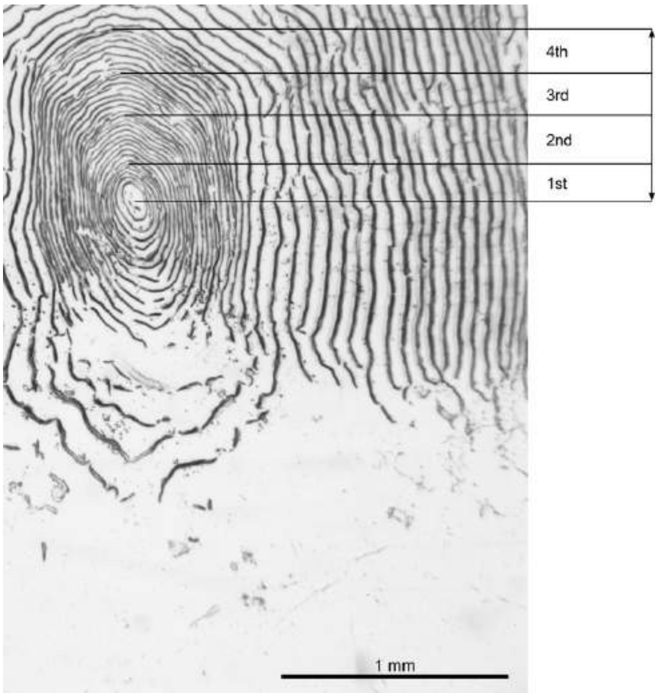


Figure 114. River Reisaelva. 4.1SW.

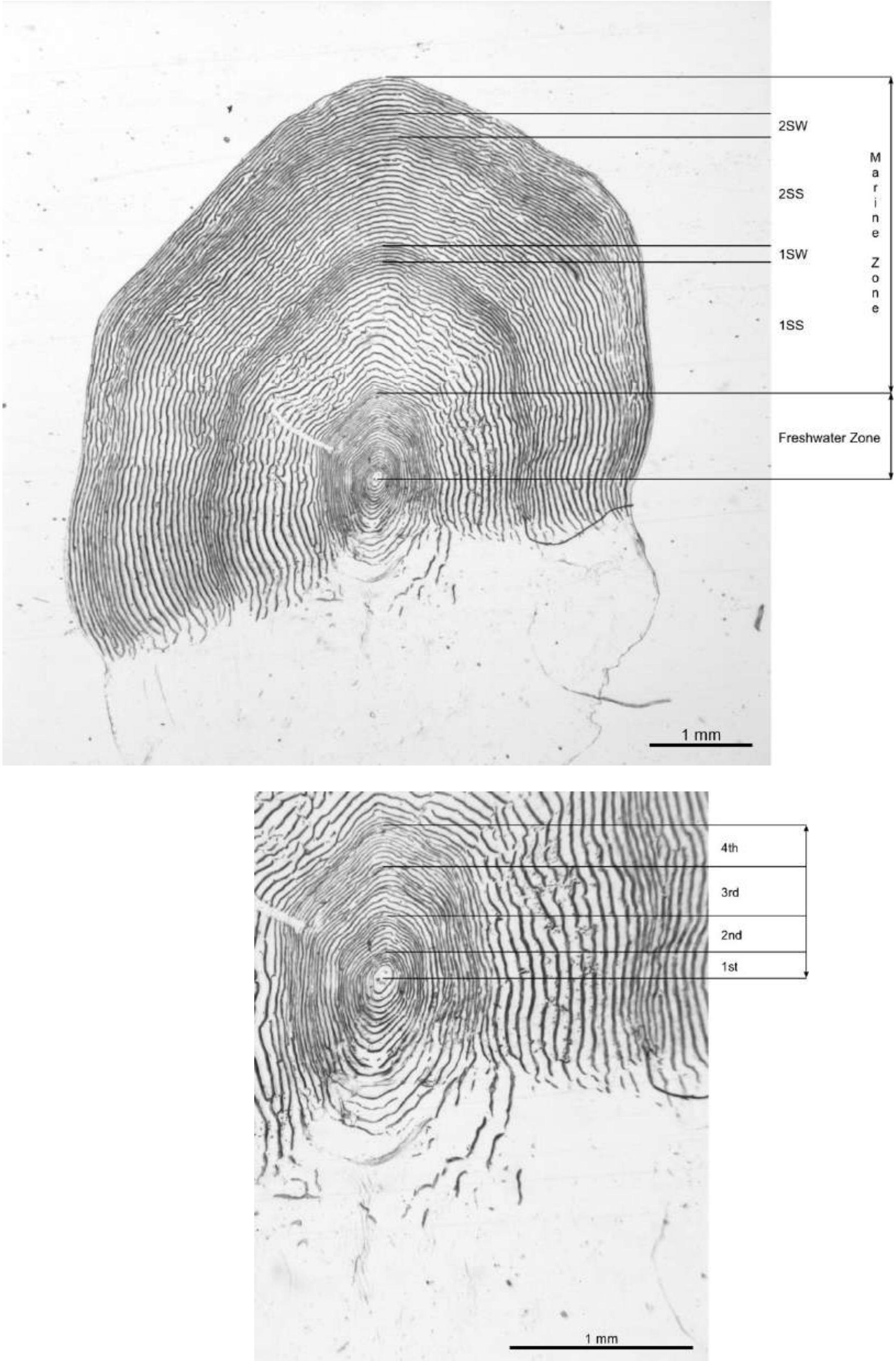


Figure 115. River Reisaelva. 4.2SW.

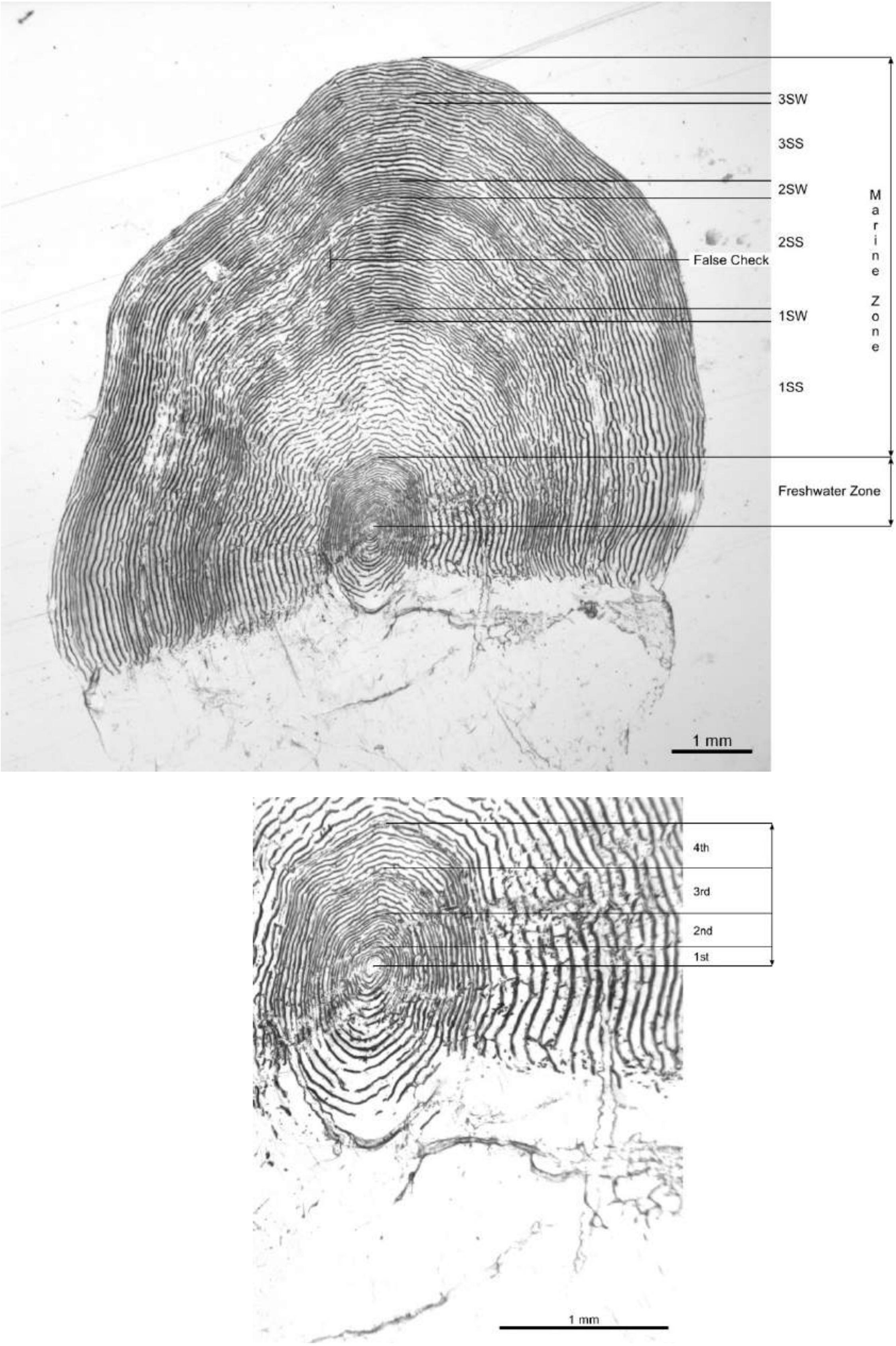
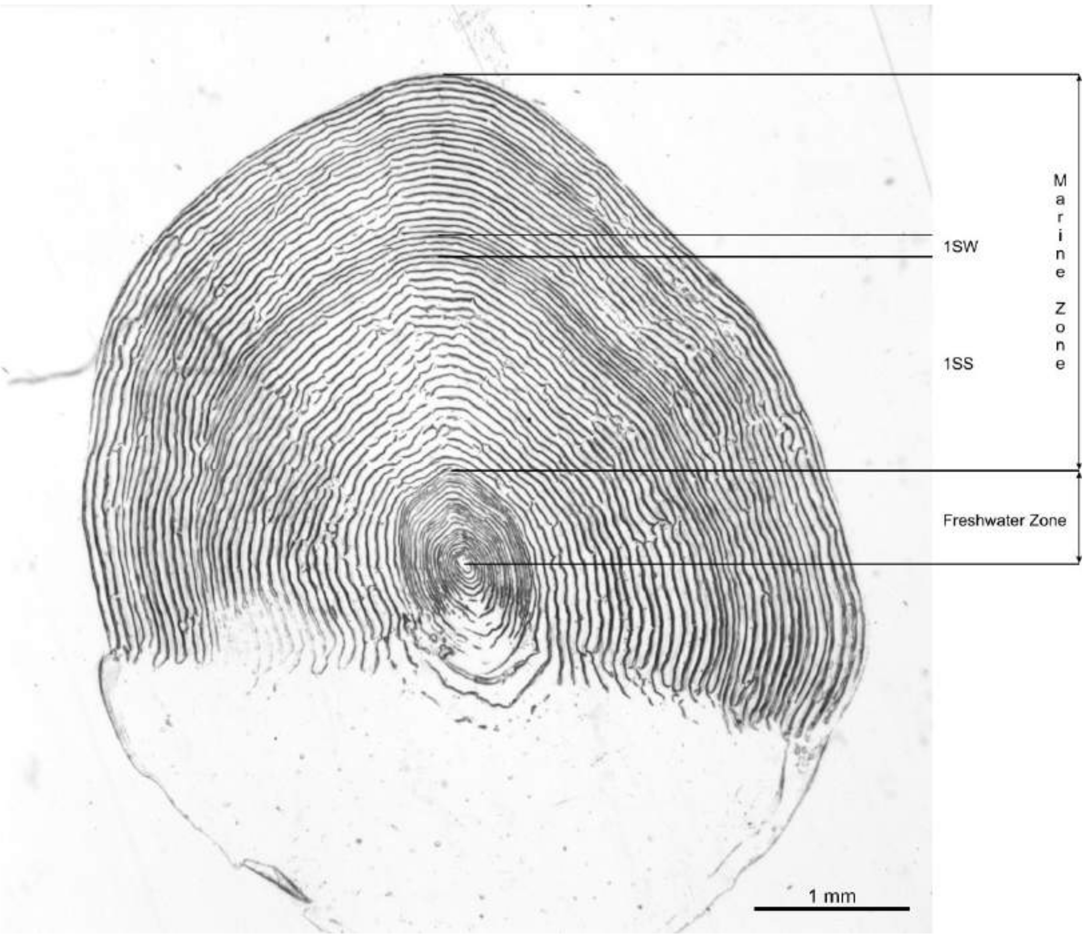


Figure 116. River Reisaelva. 4.3SW.



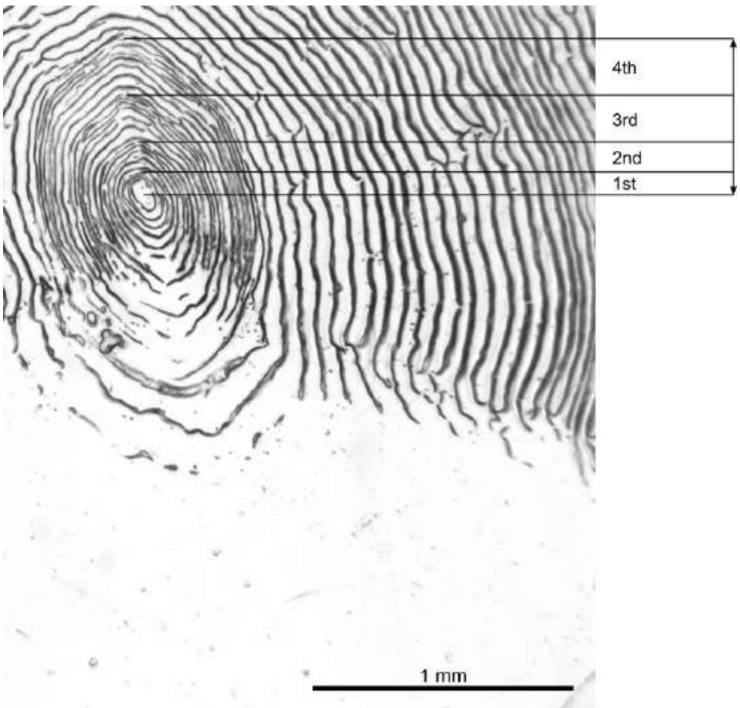
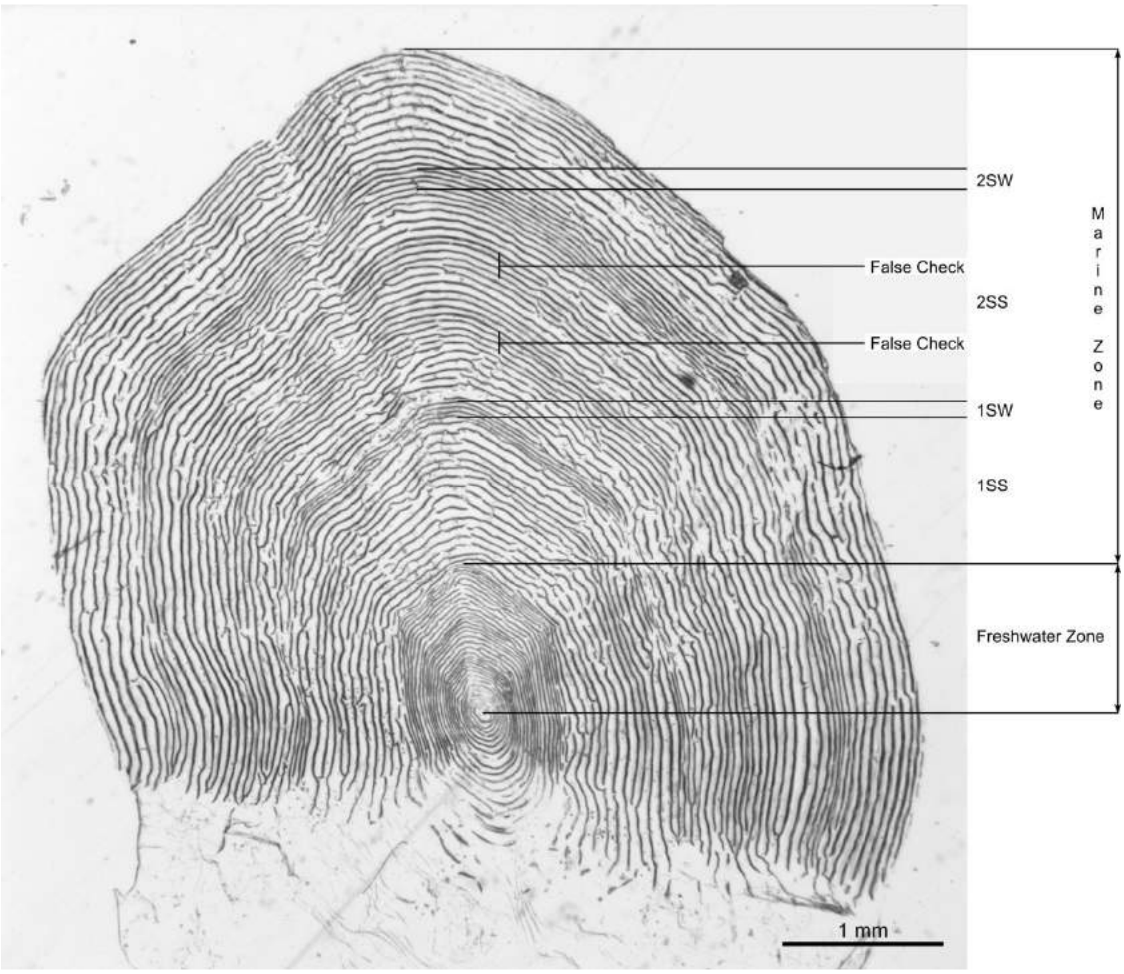


Figure 117. River Målselva. 4.1SW.



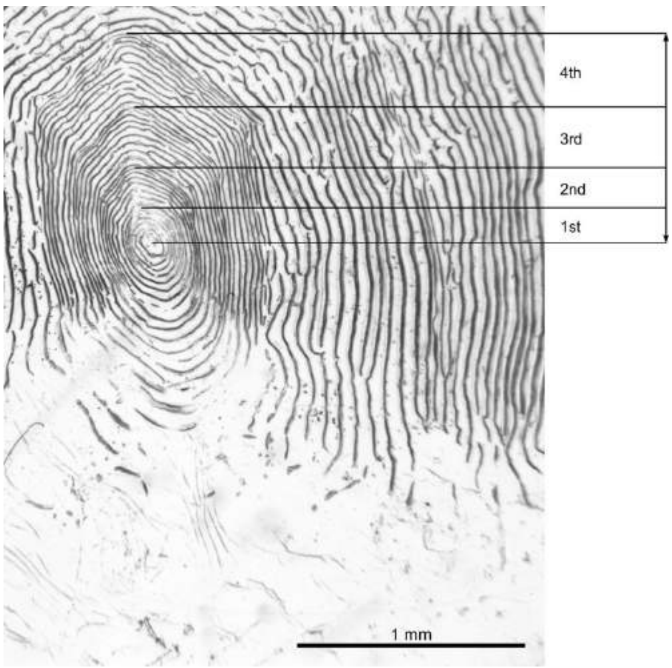
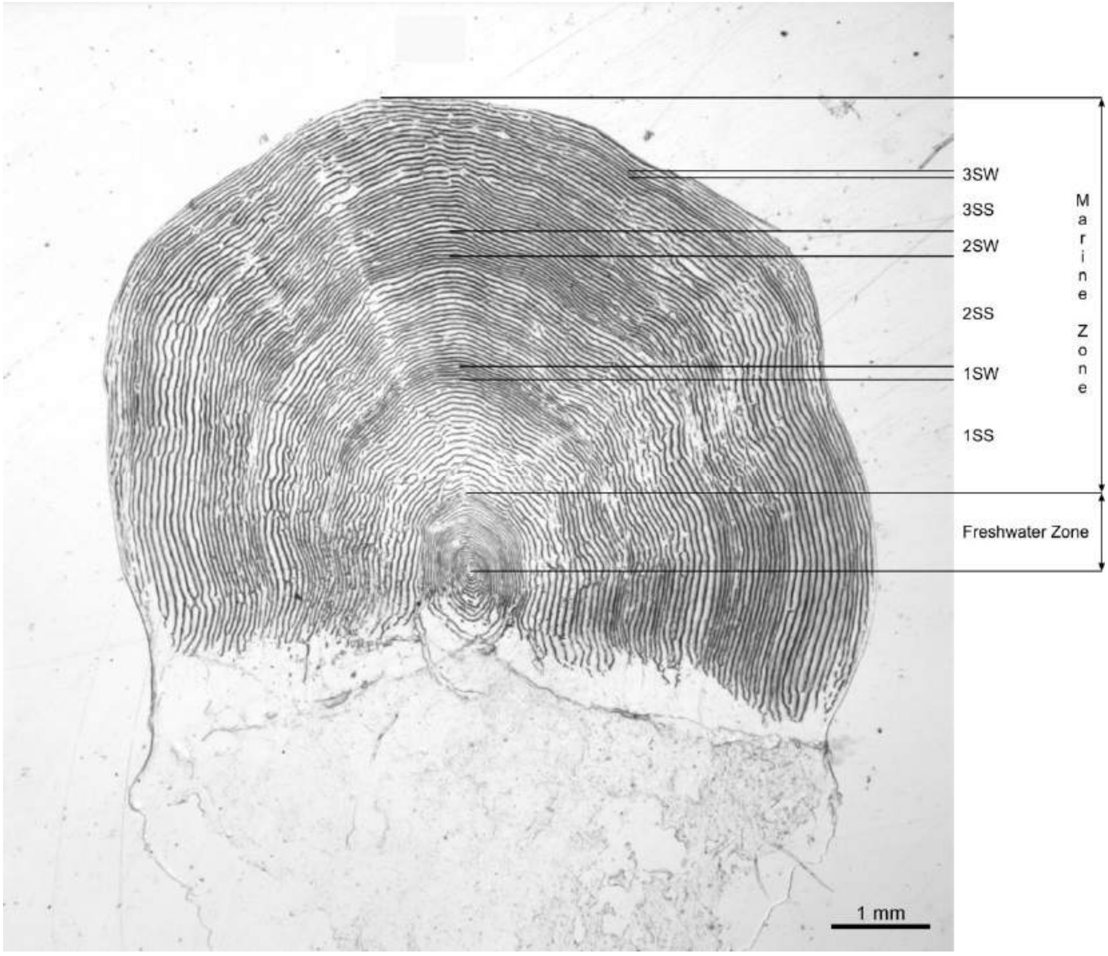


Figure 118. River Målselva. 4.2SW.



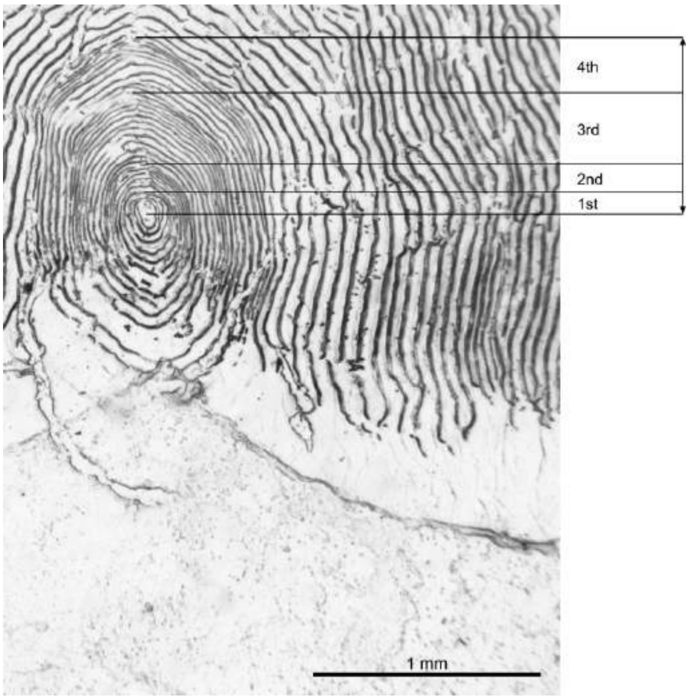


Figure 119. River Målselva. 4.3SW.

10. Kelts

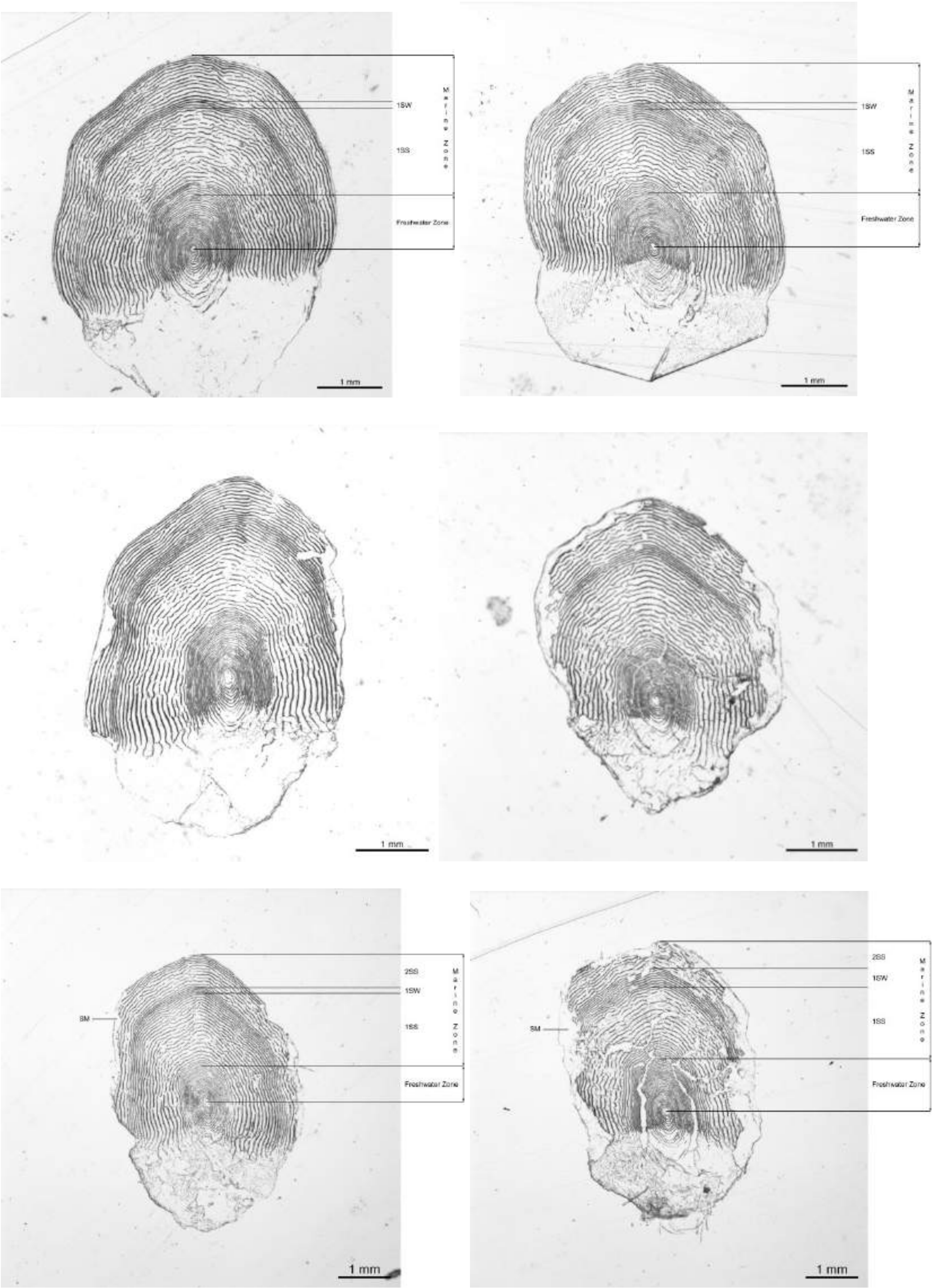


Figure 120. Life history of 1SW salmon from the River Pulmankijoki (River Teno/Tana tributary). Scales on the left are for females and on the right for males. Scales above are from maiden 1SW salmon caught in July; scales in the middle are from the post spawners in October one month after the spawning; scales below are from kelts (sea-age of 1S) on the way from the River Pulmankijoki to the sea. Scale erosion is much larger for males than for females.

11. Previous spawners

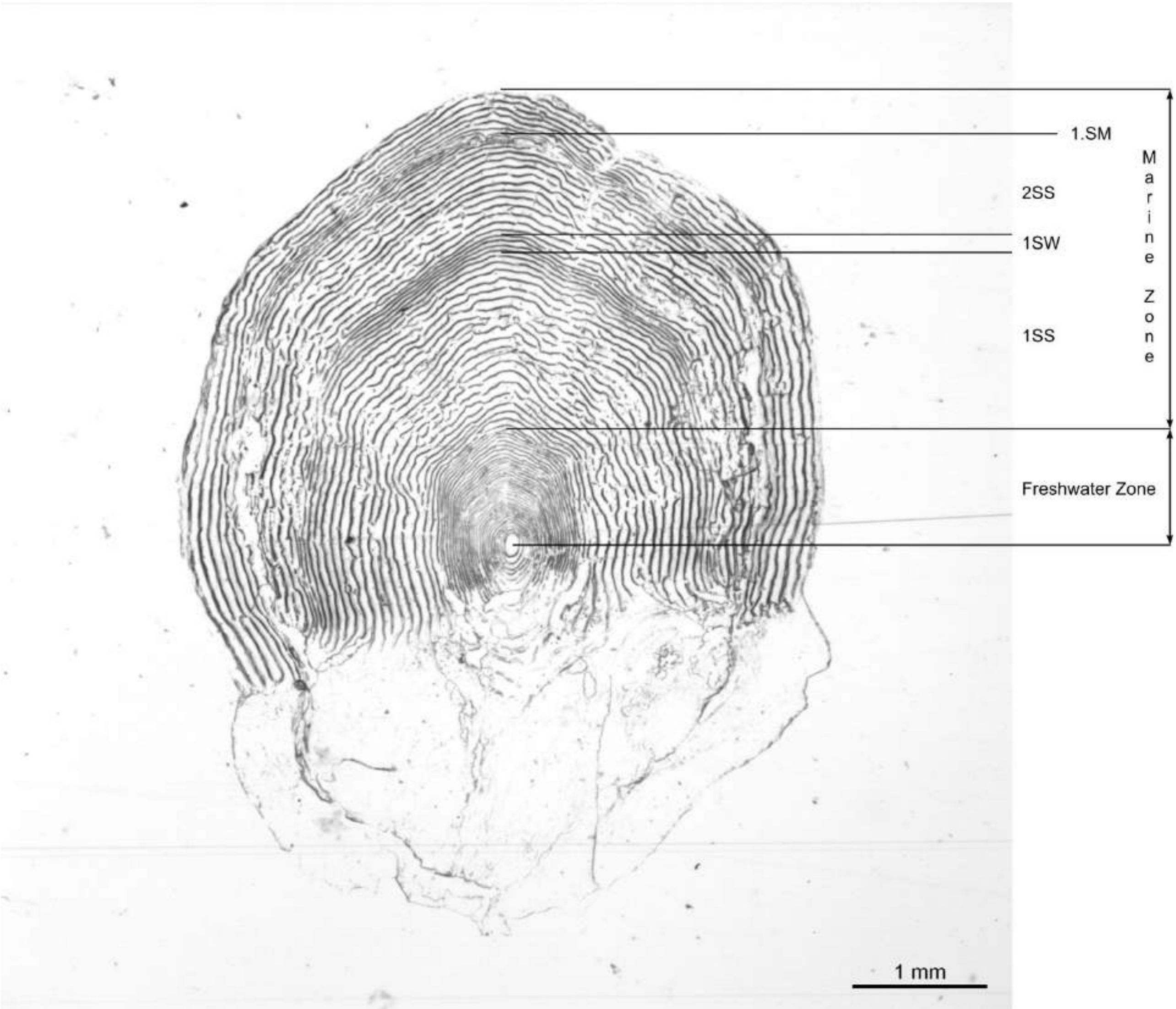


Figure 121. Previous spawner male salmon, sea-age of 1S+, was caught 24.06.2009 at sea in Varangerfjord in Norway. This fish descended the river as kelt in the year when it was caught at sea and it has started to recondition for the next maturity.

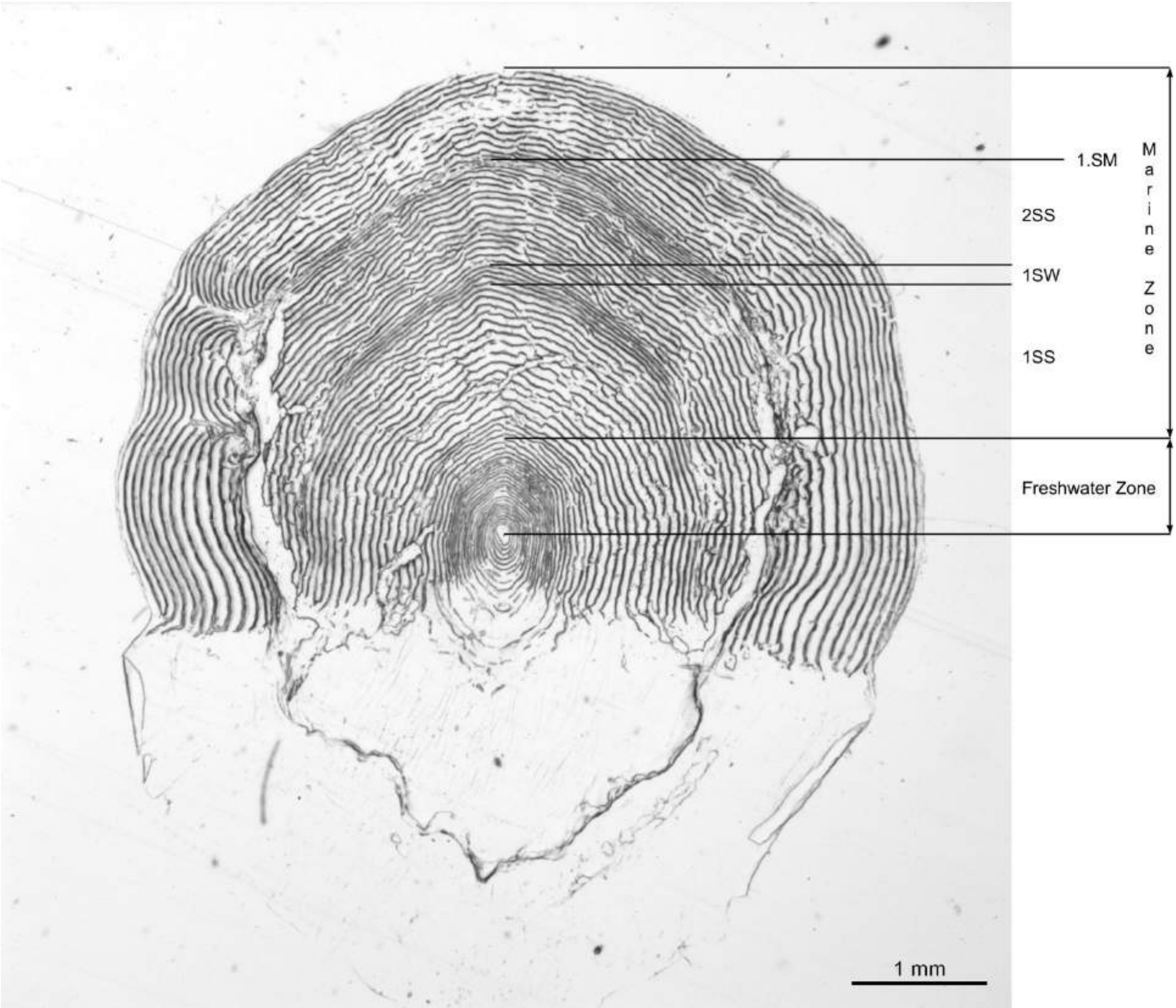


Figure 122. Previous spawner male salmon, sea-age of 1S+, was caught 07.11.2009 at sea in Varangerfjord in Norway. This fish descended the river as kelt in the year when it was caught at sea and it has started to recondition for the next maturity. The wide summer band in the edge of the scale after the spawning mark (1.SM) indicates the reconditioned growth.

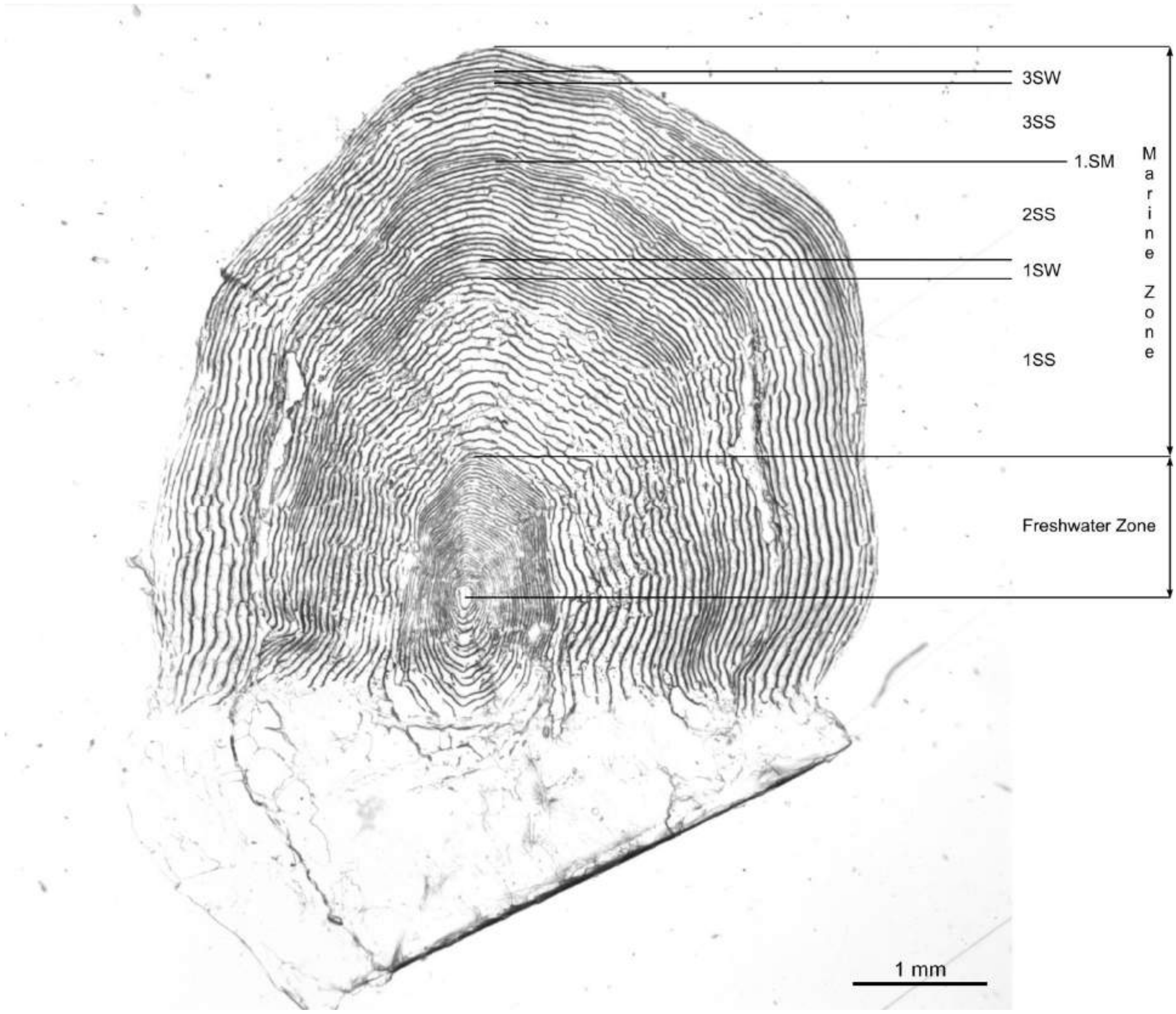


Figure 123. Previous spawner salmon, sea-age of 1S1+, was caught 17.05.2011 at sea in Finnmark. Fish was from the River Levajohka stock (tributary of the River Teno/Tana).

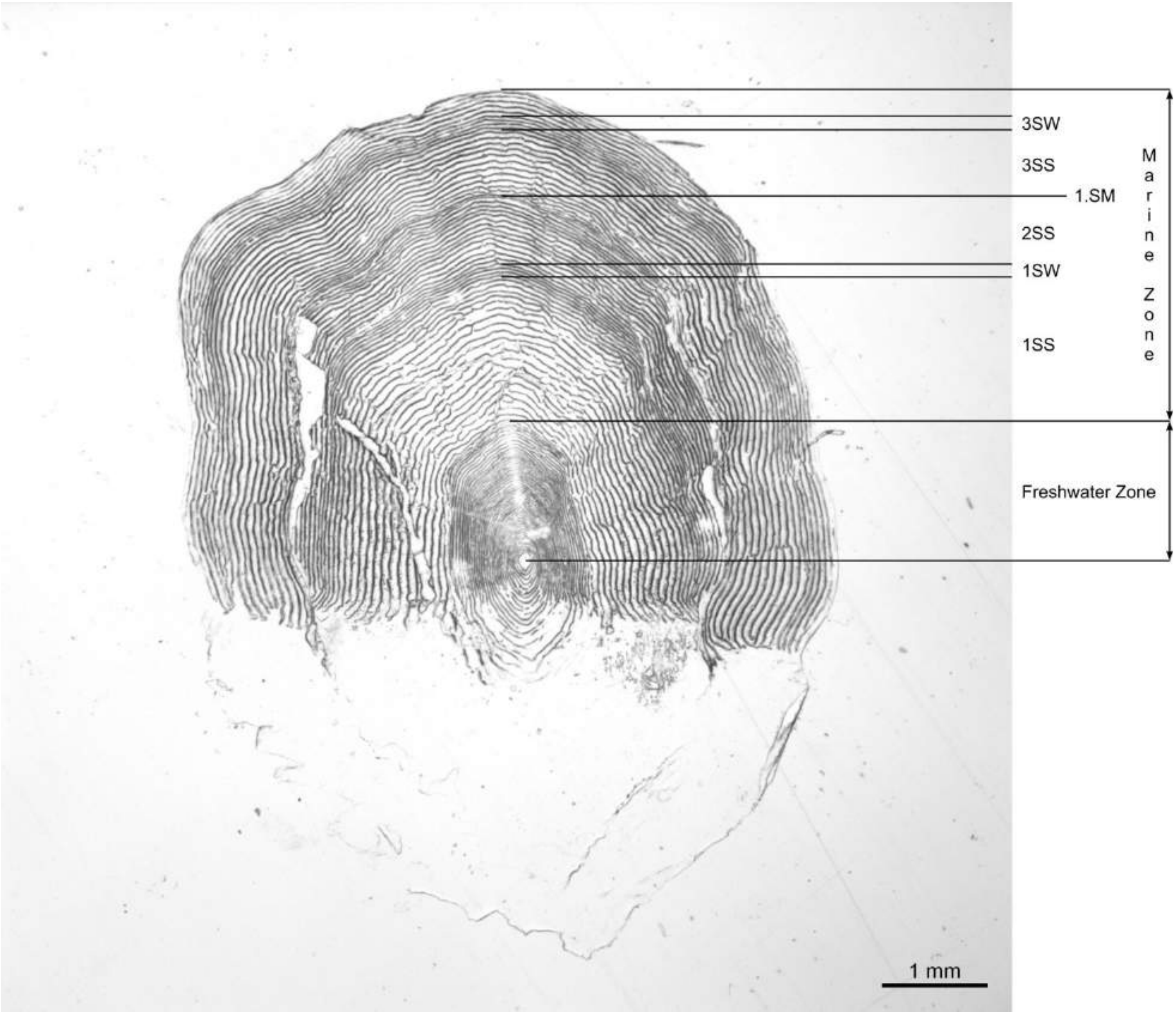


Figure 124. Previous spawner salmon, sea-age of 1S1+, was caught 24.05.2012 at sea in Finnmark. Fish was from the River Sandfjordelva stock in Finnmark.

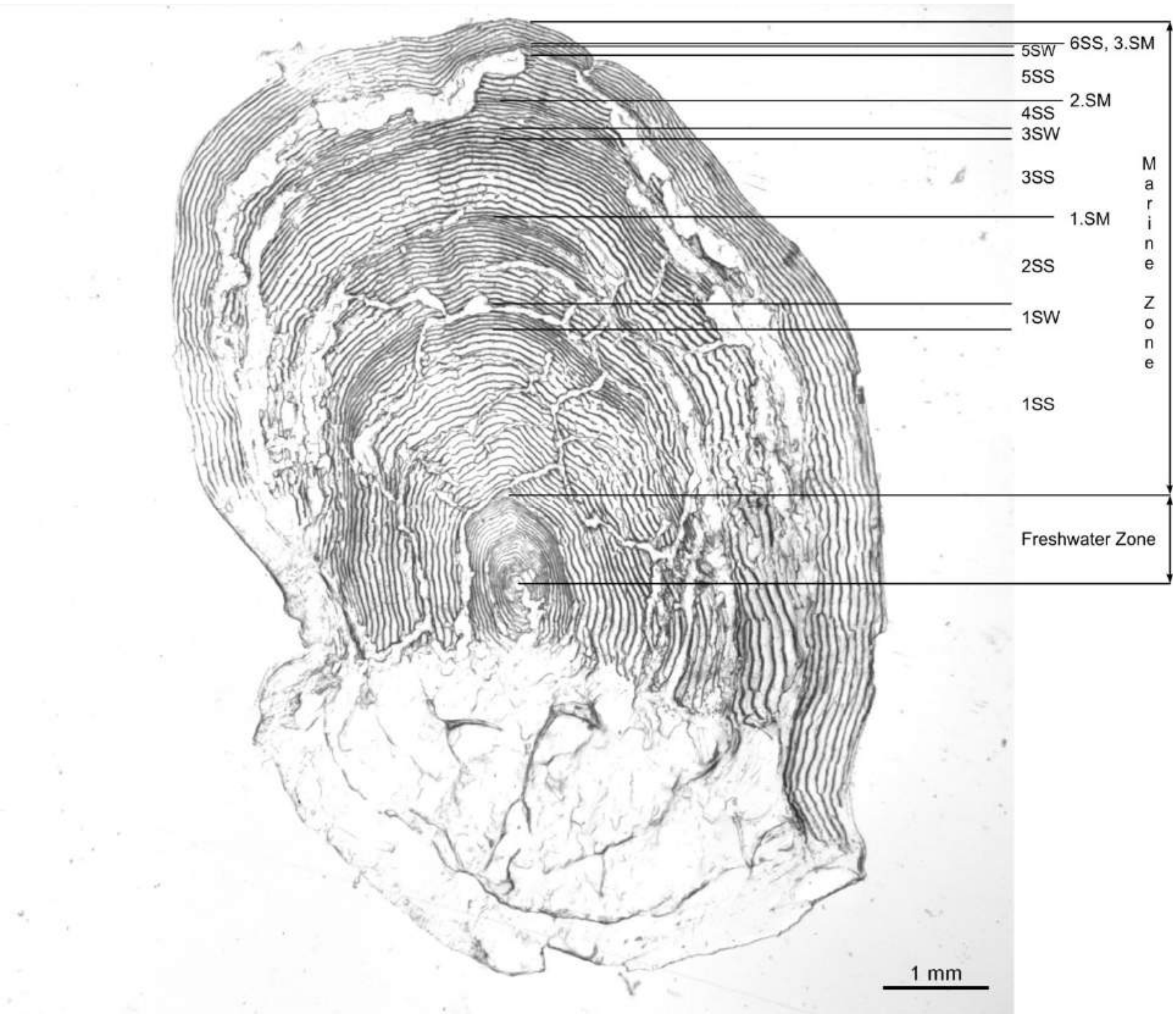


Figure 125. Previous spawner female salmon, sea-age of 1S1S1S1, was caught 25.05.2012 at sea in Finnmark. Fish was from the River Titovka stock in Russia. This fish was on the way to spawn for the fourth time in the beginning of its eight sea year. After the third spawning (3SM) salmon has spent one full year for reconditioning at sea and it was returning to the river in its eigth sea year.

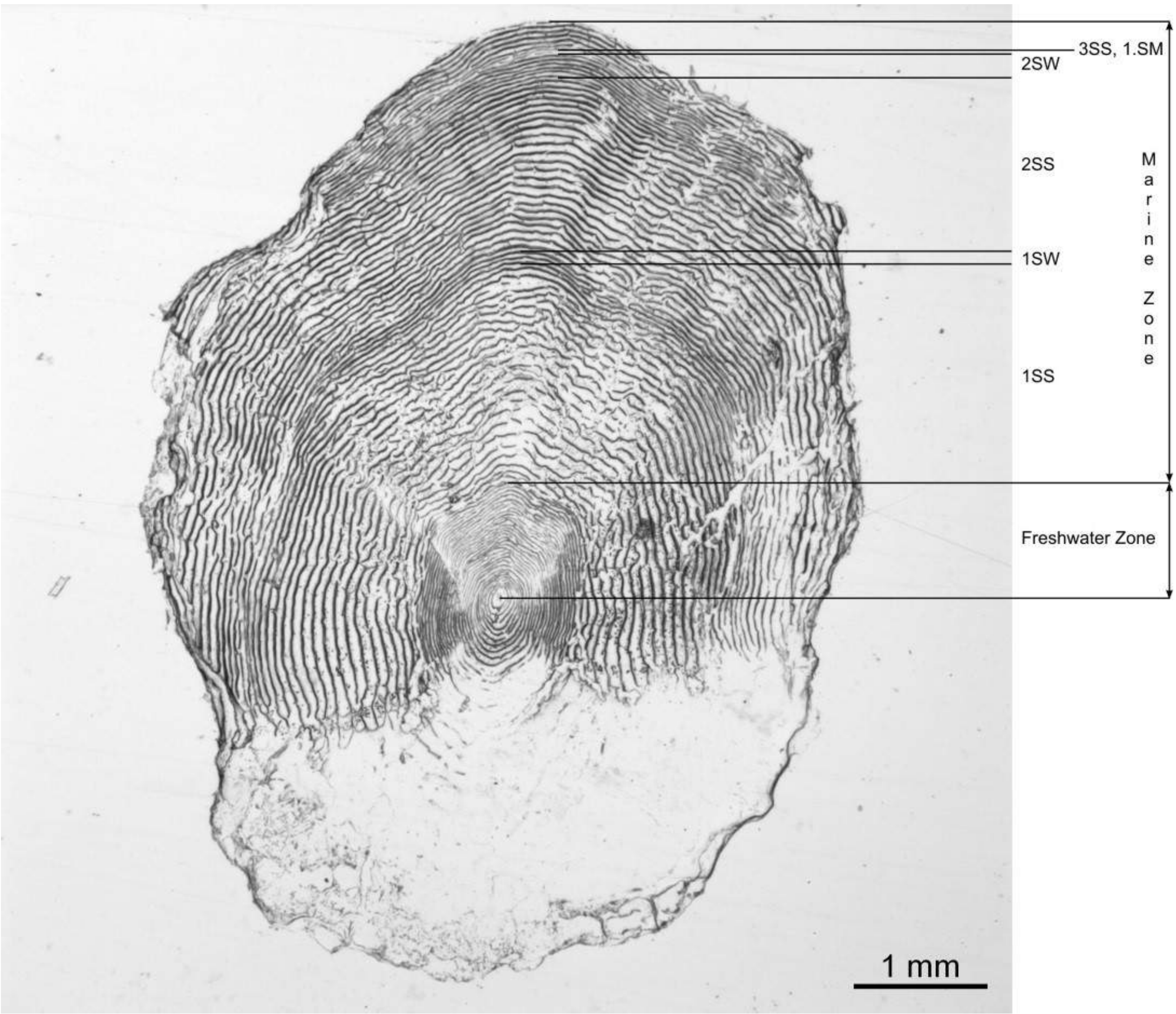


Figure 126. Previous spawner female salmon (70cm, 2200g), sea age of 2S+ (smolt age of 4 years). Fish was caught on 8.8.1978 in the River Teno/Tana. This previous spawner is most probably consecutive spawner. It has migrated as kelt to Tanafjord for short reconditioning period and then it has returned into the River Teno during the same summer.

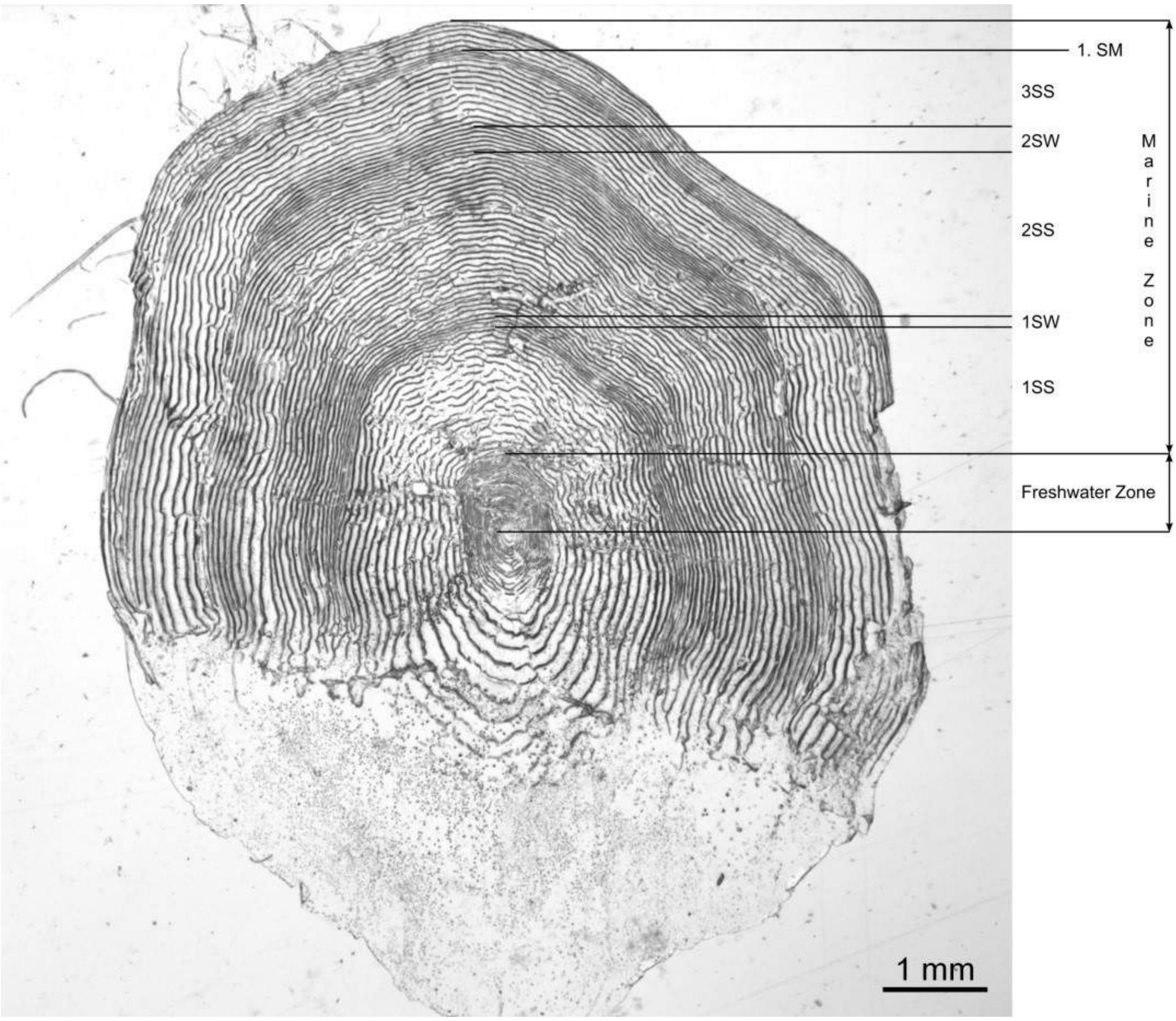


Figure 127. Previous spawner male salmon (96cm, 9300g), sea age of 2S+ (smolt age of 4 years). Fish was caught on 2.8.1978 in the River Teno/Tana. This previous spawner is most probably consecutive spawner. It is also possible that this male salmon ascended into the River Teno very late in the previous autumn, and it did not succeed to spawn although there is erosion marks in the scale. Then in the following spring it migrated to Tanafjord and after a short feeding period it returned back into the River Teno.

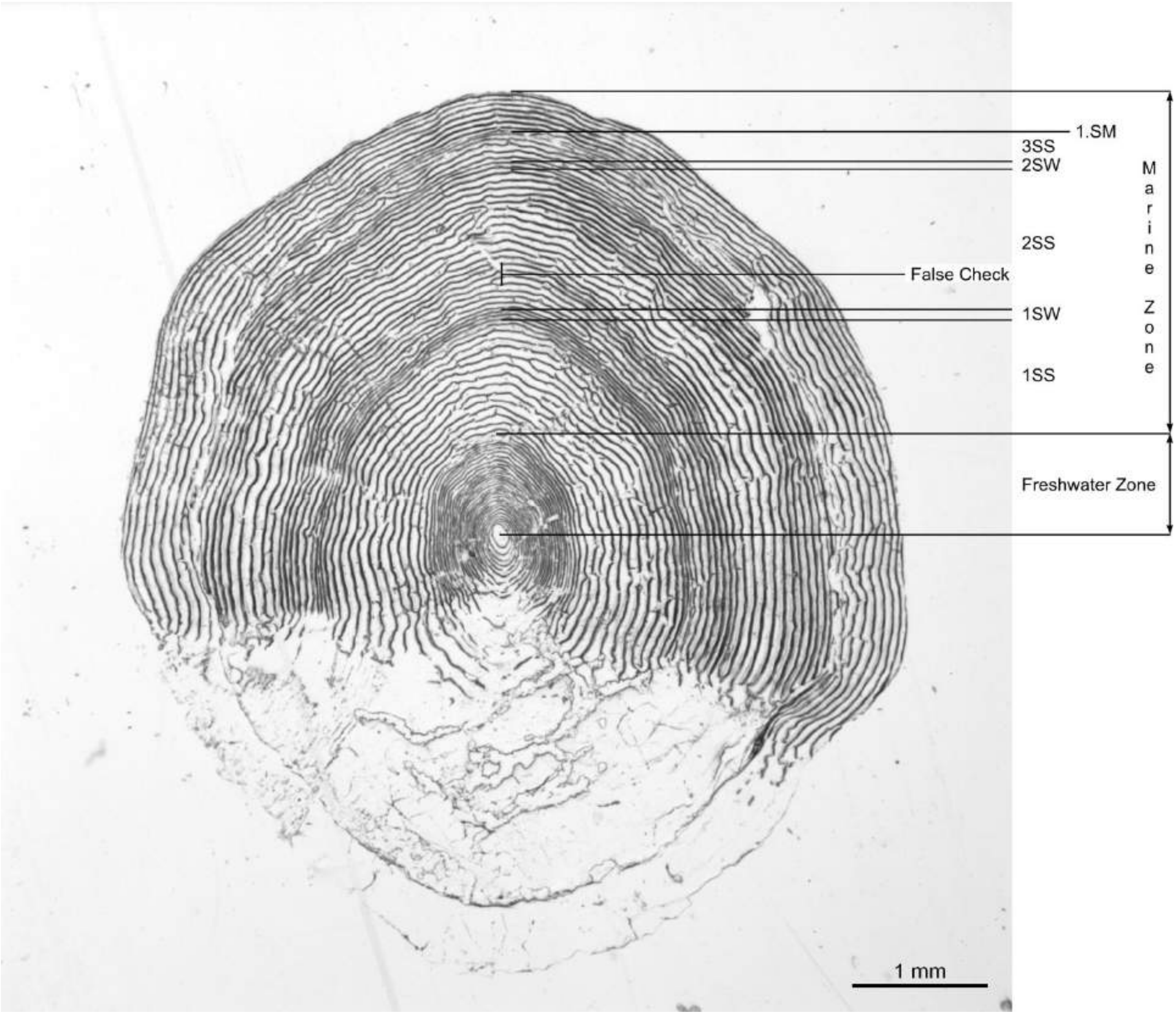


Figure 128. Previous spawner female salmon, sea-age of 2S+, was caught 19.06.2012 at sea in Finnmark. Fish was post spawner. Fish was from the River Teno/Tana mainstream stock.

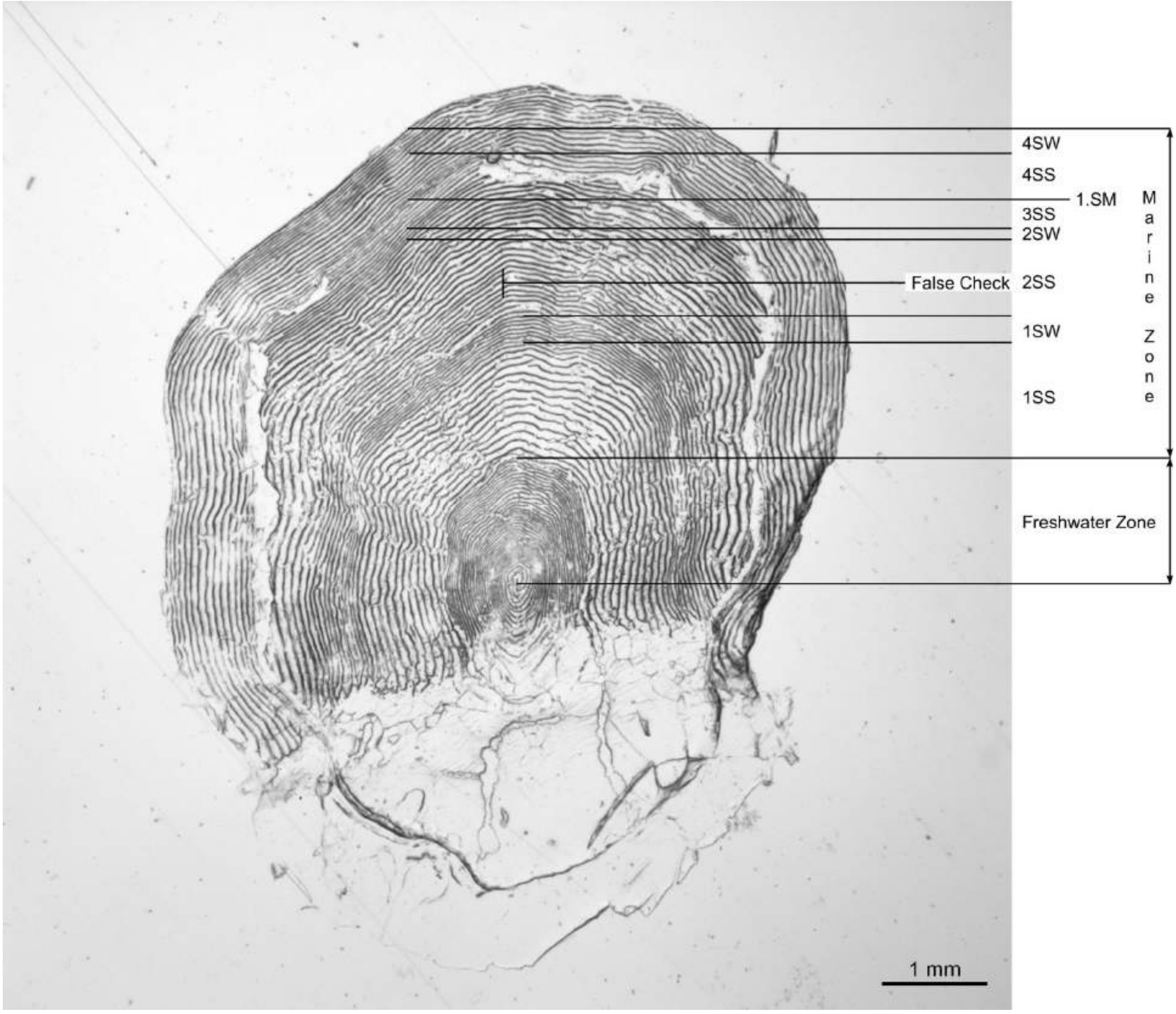


Figure 129. Previous spawner female salmon, sea-age of 2S1, was caught 15.05.2012 at sea in Finnmark. Fish was from the River Karasjohka stock (tributary of the River Teno/Tana).

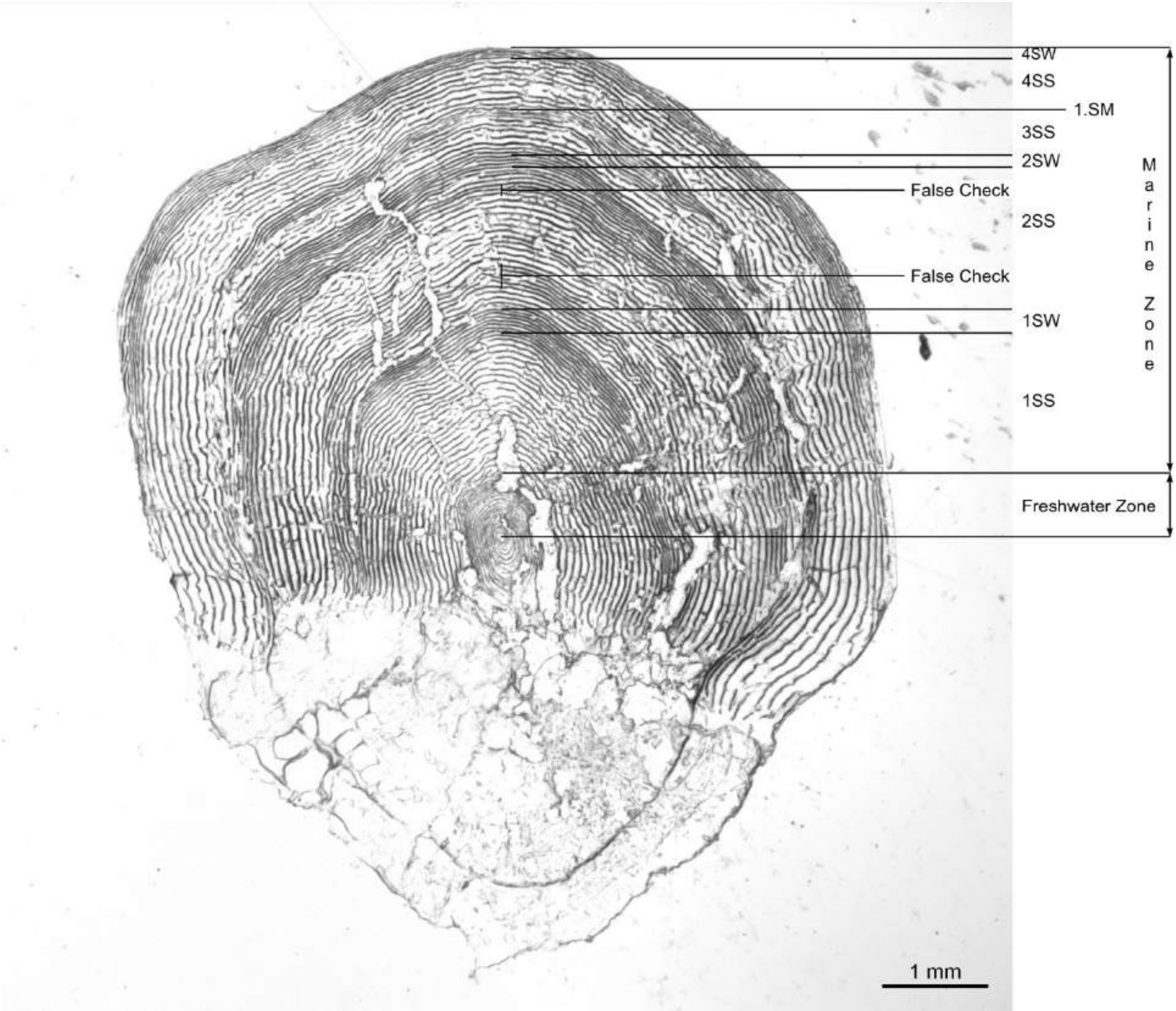


Figure 130. Previous spawner male salmon, sea-age of 2S1, was caught 07.07.2011 at sea. Fish was from the River Åndervassdraget stock in Norway.

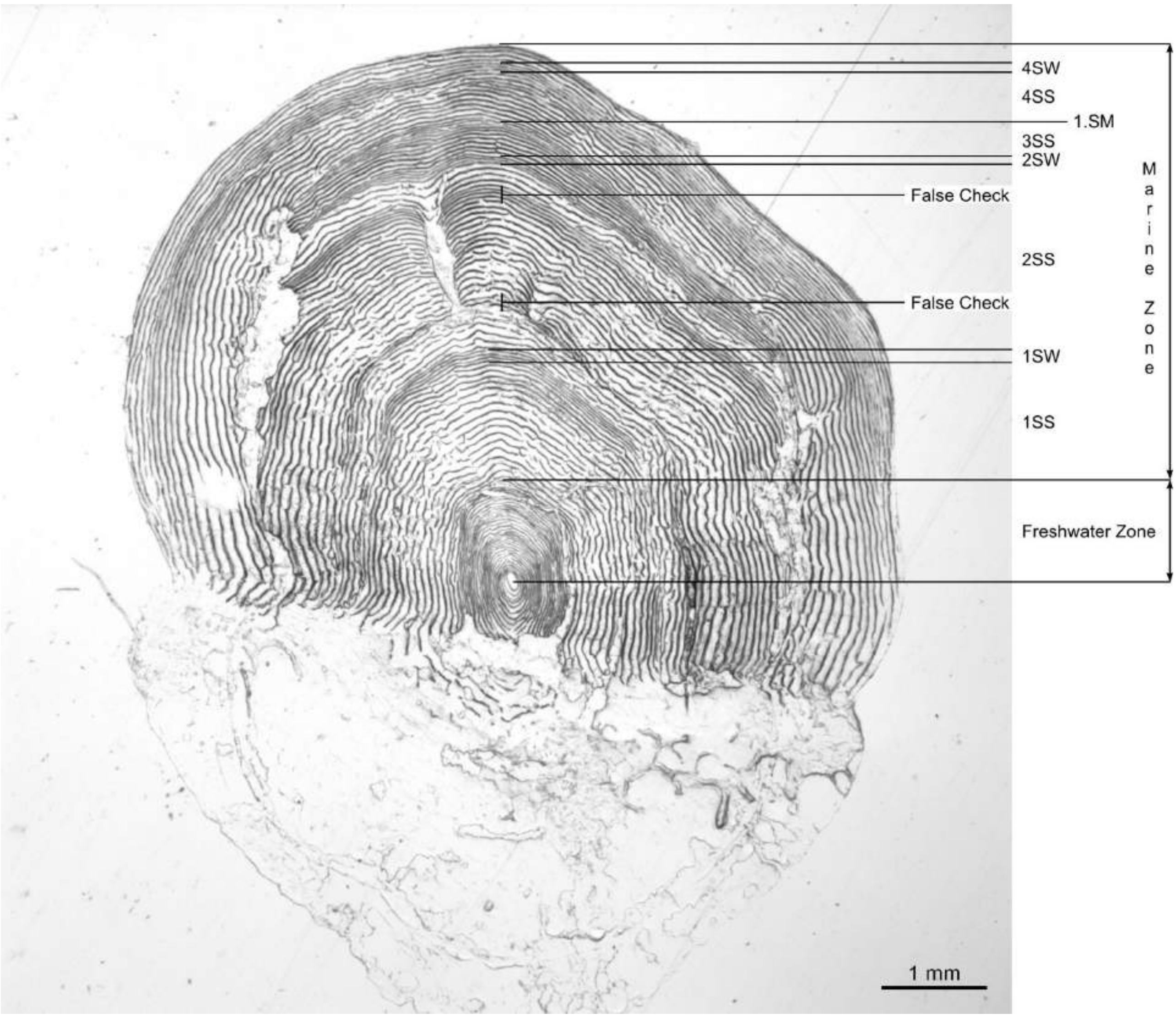


Figure 131. Previous spawner female salmon, sea-age of 2S1+, was caught 21.6.2011 at sea. Fish was from the River Pyave stock in Russia.

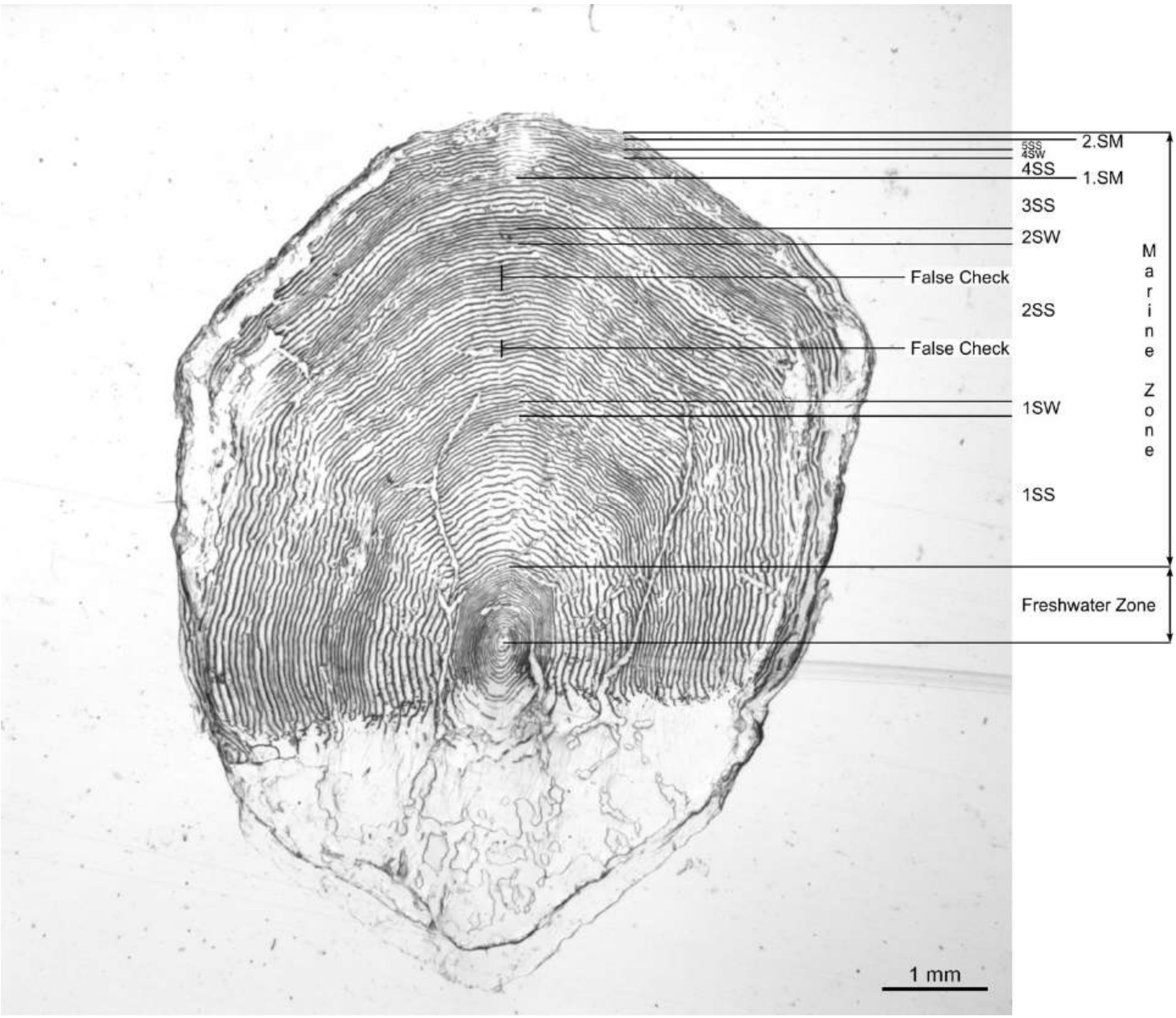


Figure 132. Previous spawner female salmon, sea-age of 2S1S+, was caught 10.8.2012 at sea in Finnmark.

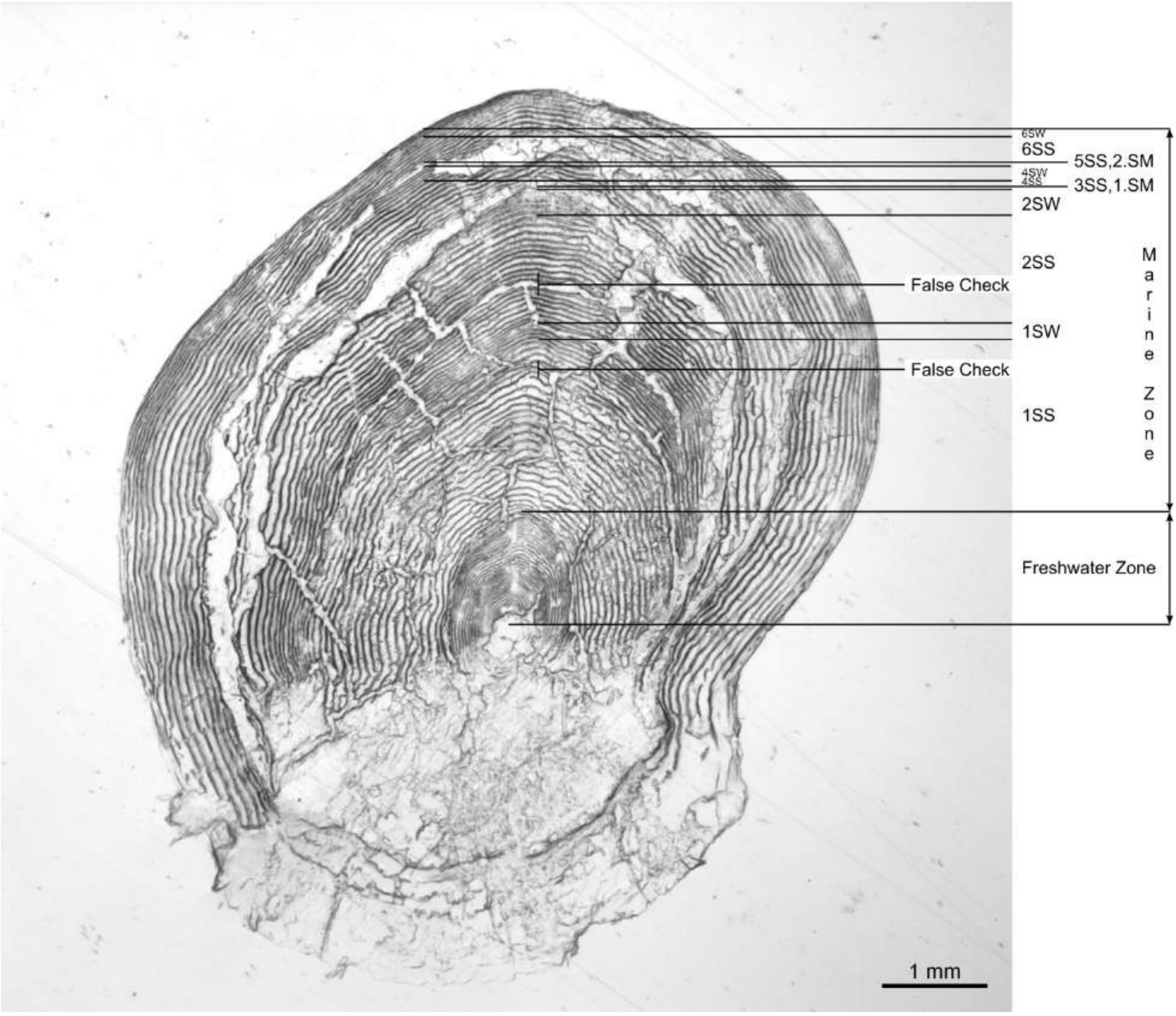


Figure 133. Previous spawner female salmon, sea-age of 2S1S1, was caught 27.05.2011 at sea in Finnmark.

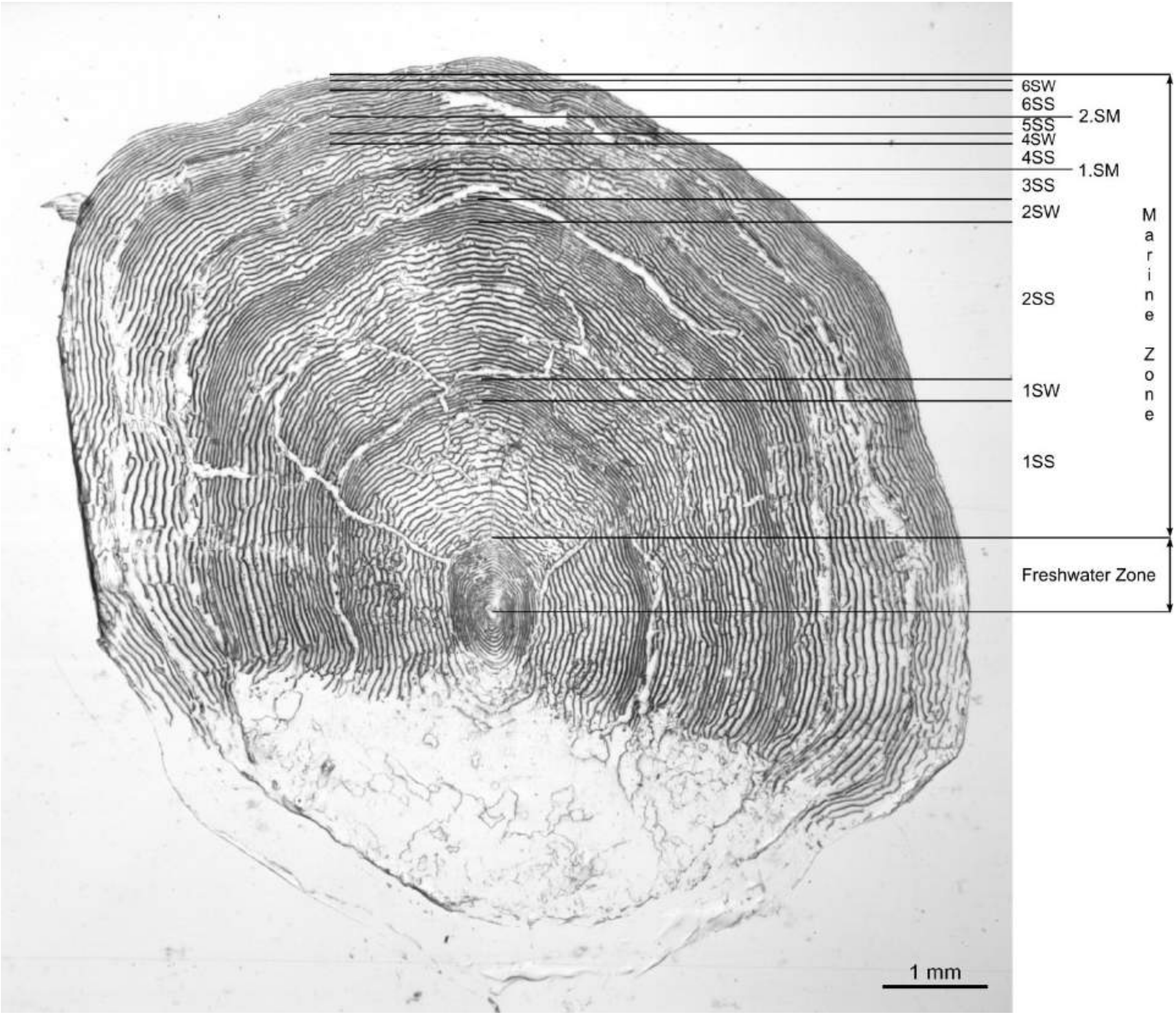


Figure 134. Previous spawner female salmon, sea-age of 2S1S1+, was caught 15.06.2011 at sea in Troms. Fish was from the River Målselva stock in Troms/Norway.

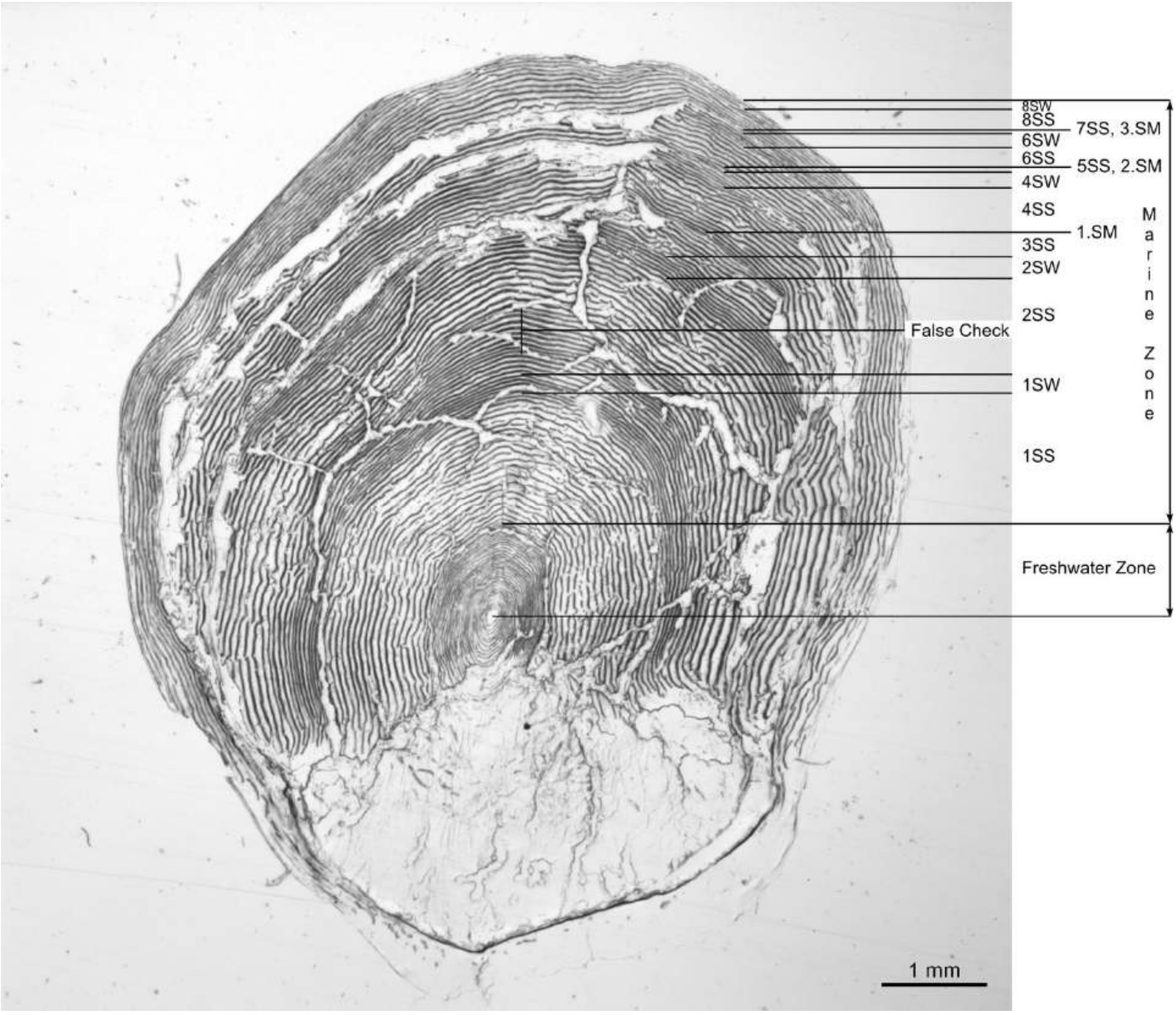


Figure 135. Previous spawner female salmon, sea-age of 2S1S1S1, was caught 11.06.2012 at sea in Finnmark. After the third spawning (3SM) salmon has spent one full year for reconditioning at sea and it was returning to the river in its ninth sea year.

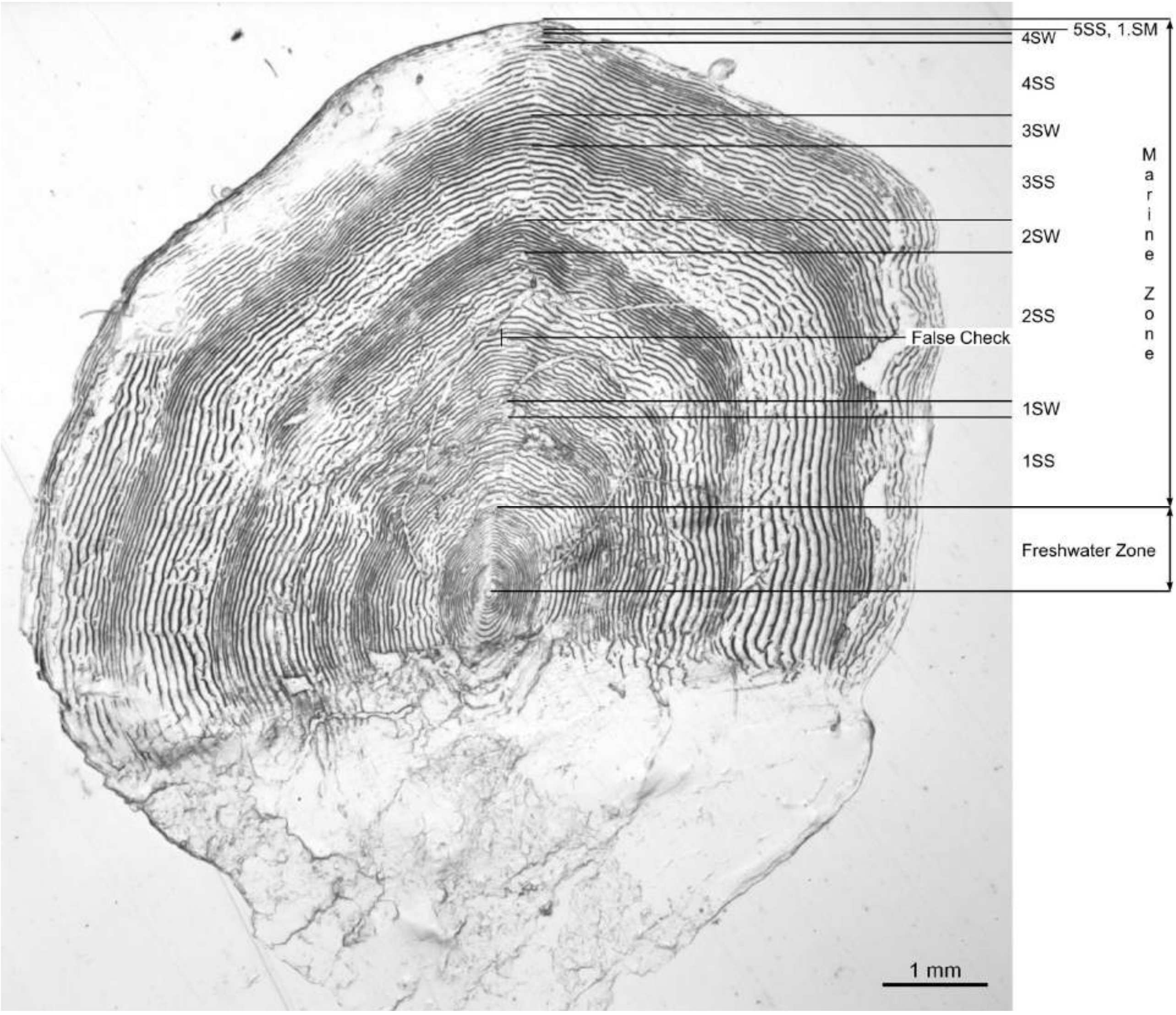


Figure 136. Previous spawner female salmon, sea-age of 4S1, was caught 06.07.2011 at sea in Finnmark. Fish was from the River Alta stock in Finnmark/Norway. After the first spawning (1SM) salmon has spent one full year for reconditioning at sea and it was returning to the river in its seventh sea year.

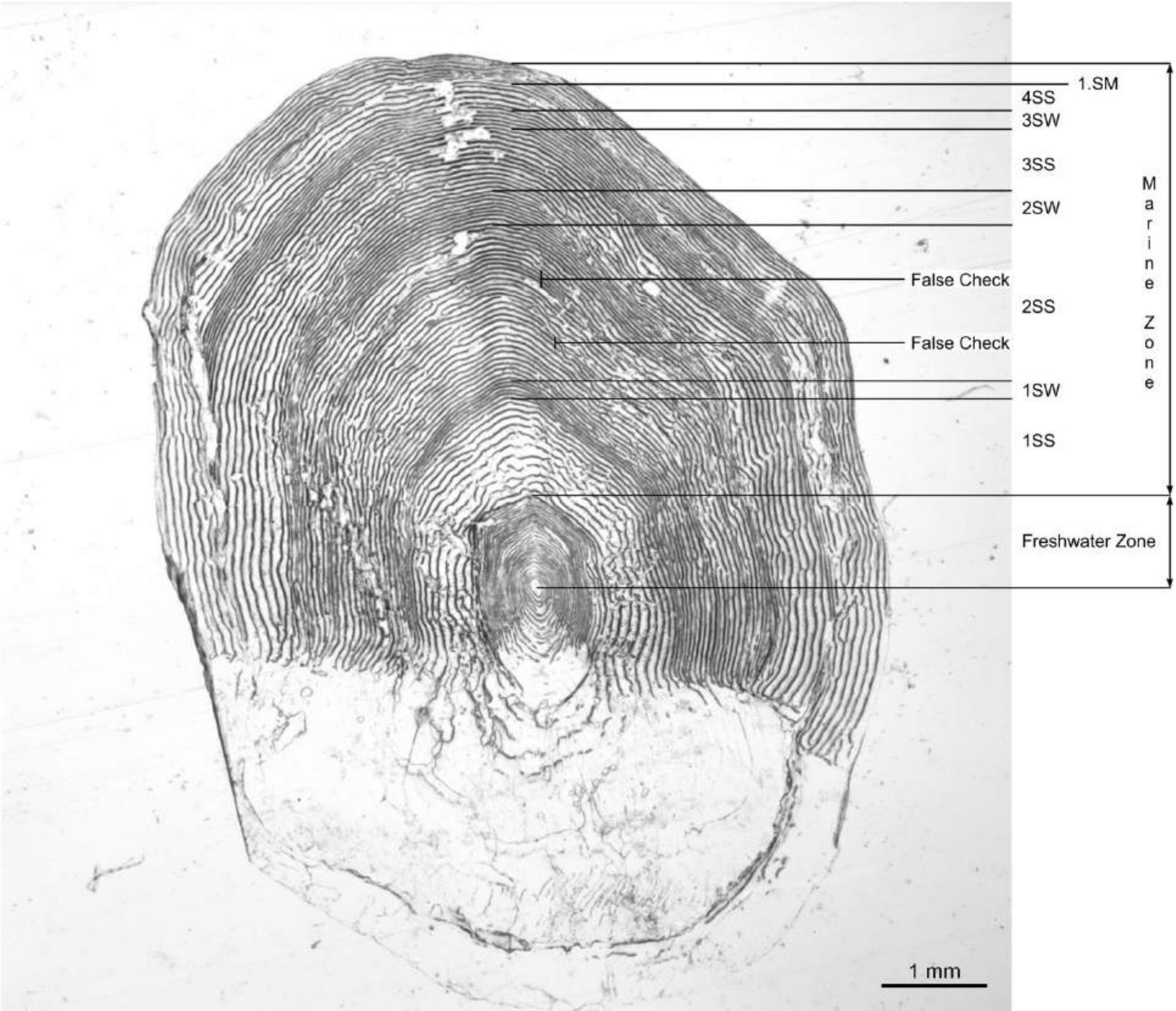


Figure 137. Previous spawner male salmon, sea-age of 4S1, was caught 26.06.2012 at sea in Finnmark. Fish was from the River Neiden stock in Finnmark/Norway. After the first spawning (1SM) salmon has spent one full year for reconditioning at sea and it was returning to the river in its seventh sea year.

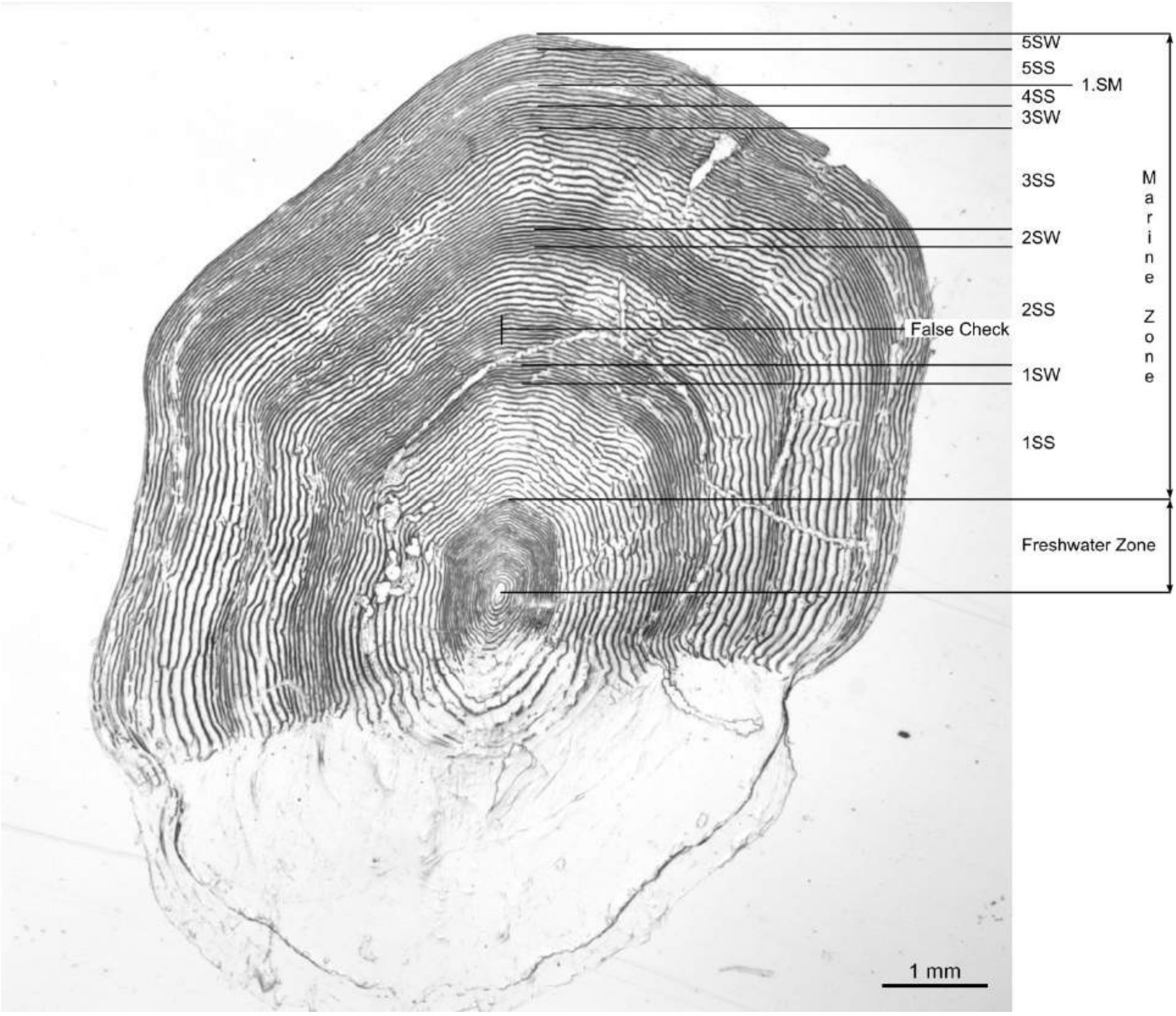


Figure 138. Previous spawner female salmon, sea-age of 3S1, was caught 18.07.2012 at sea in Troms. Fish was from the River Reisa stock in Troms/Norway. After the first spawning (1SM) salmon has spent one full year for reconditioning at sea and it was returning to the river in its sixth sea year.

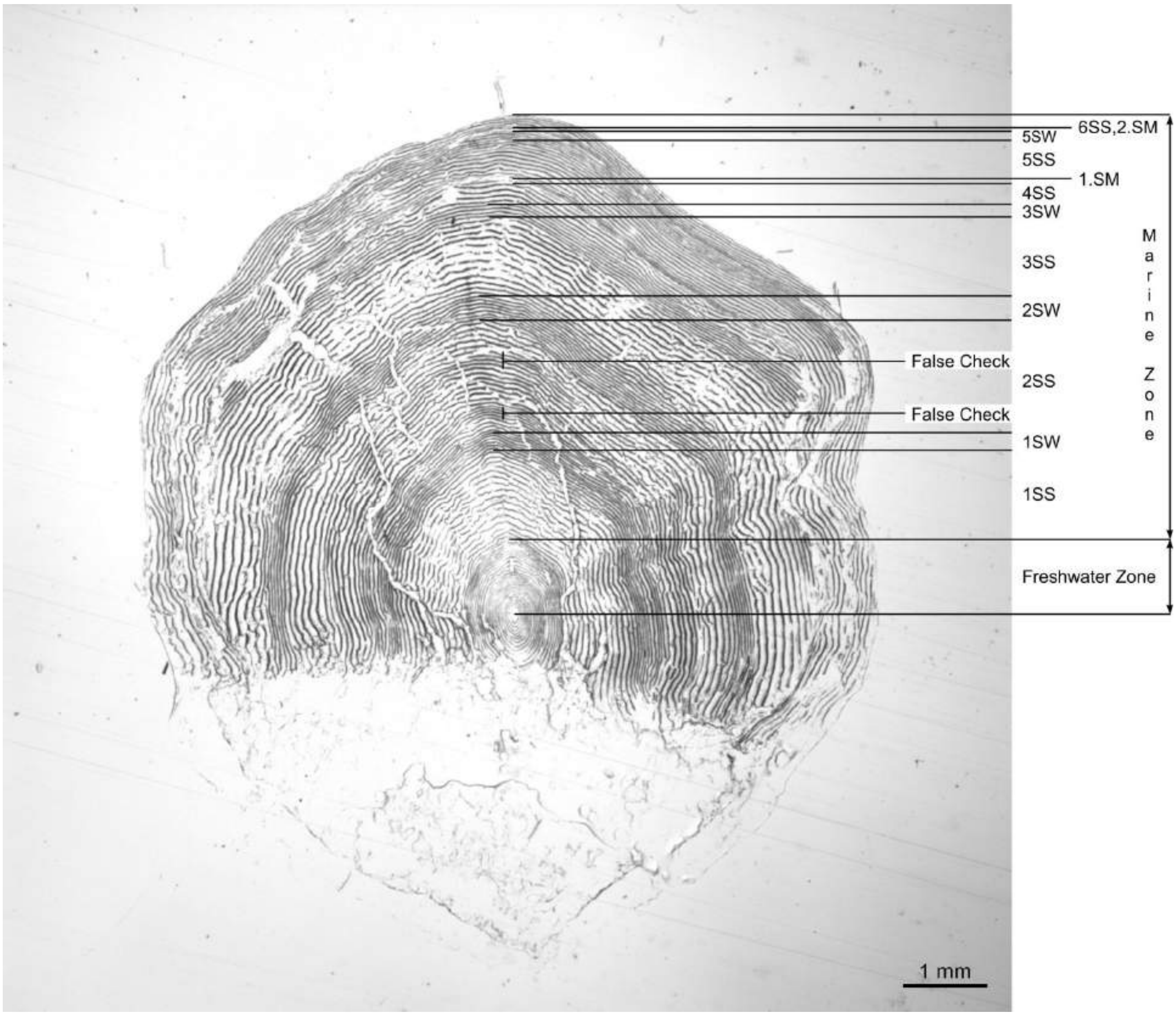


Figure 139. Previous spawner female salmon, sea-age of 3S1S1, was caught 14.06.2012 at sea in Troms. Fish was from the River Reisa stock in Troms/Norway. After the second spawning (2SM) salmon has spent one full year for reconditioning at sea and it was returning to the river in its eight sea year.

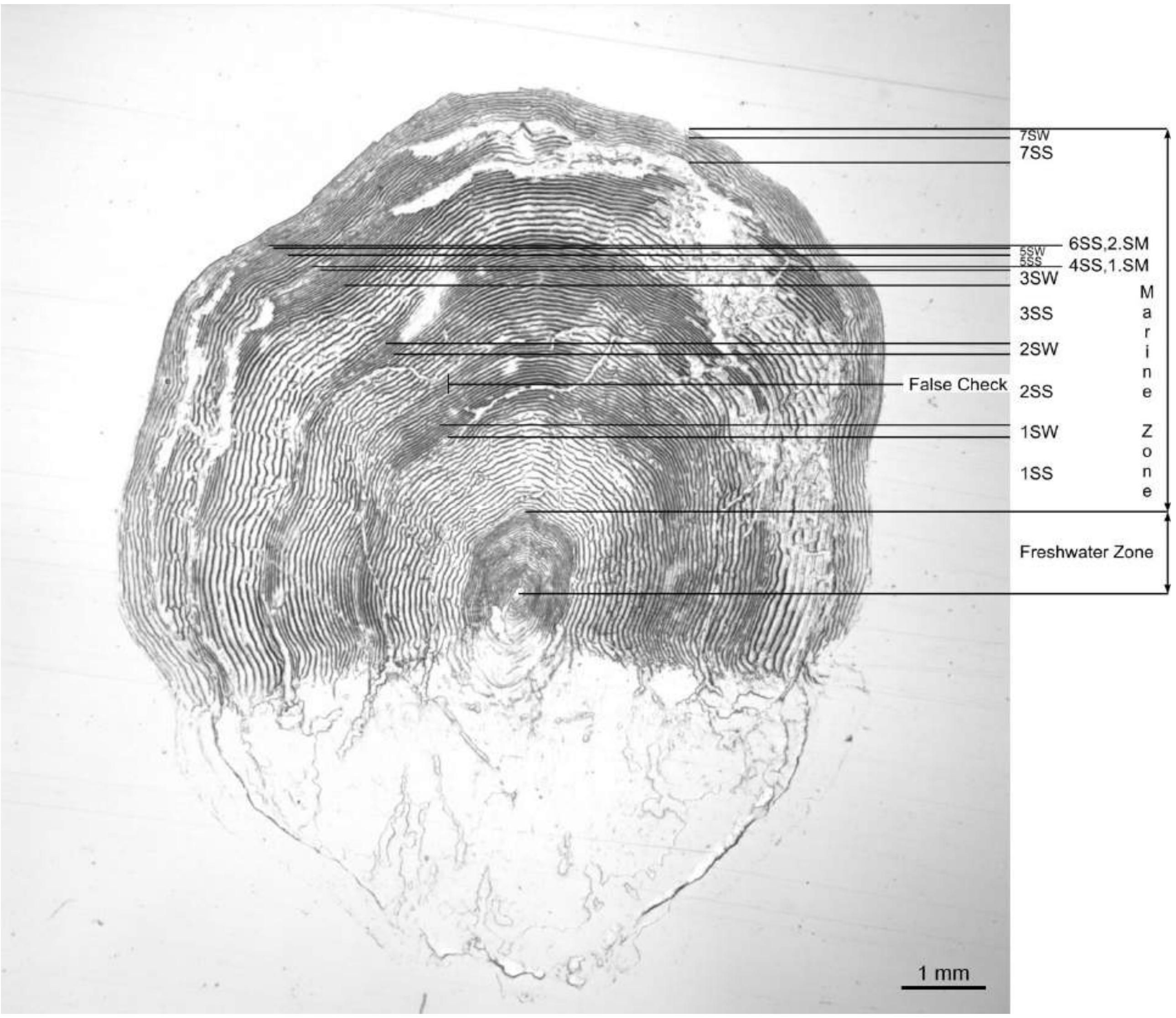


Figure 140. Previous spawner female salmon, sea-age of 3S1S1, was caught 12.06.2012 at sea in Finnmark. Fish was from the River Teno/Tana mainstream stock in Finnmark. After the second spawning (2SM) salmon has spent one full year for reconditioning at sea and it was returning to the river in its eight sea year.

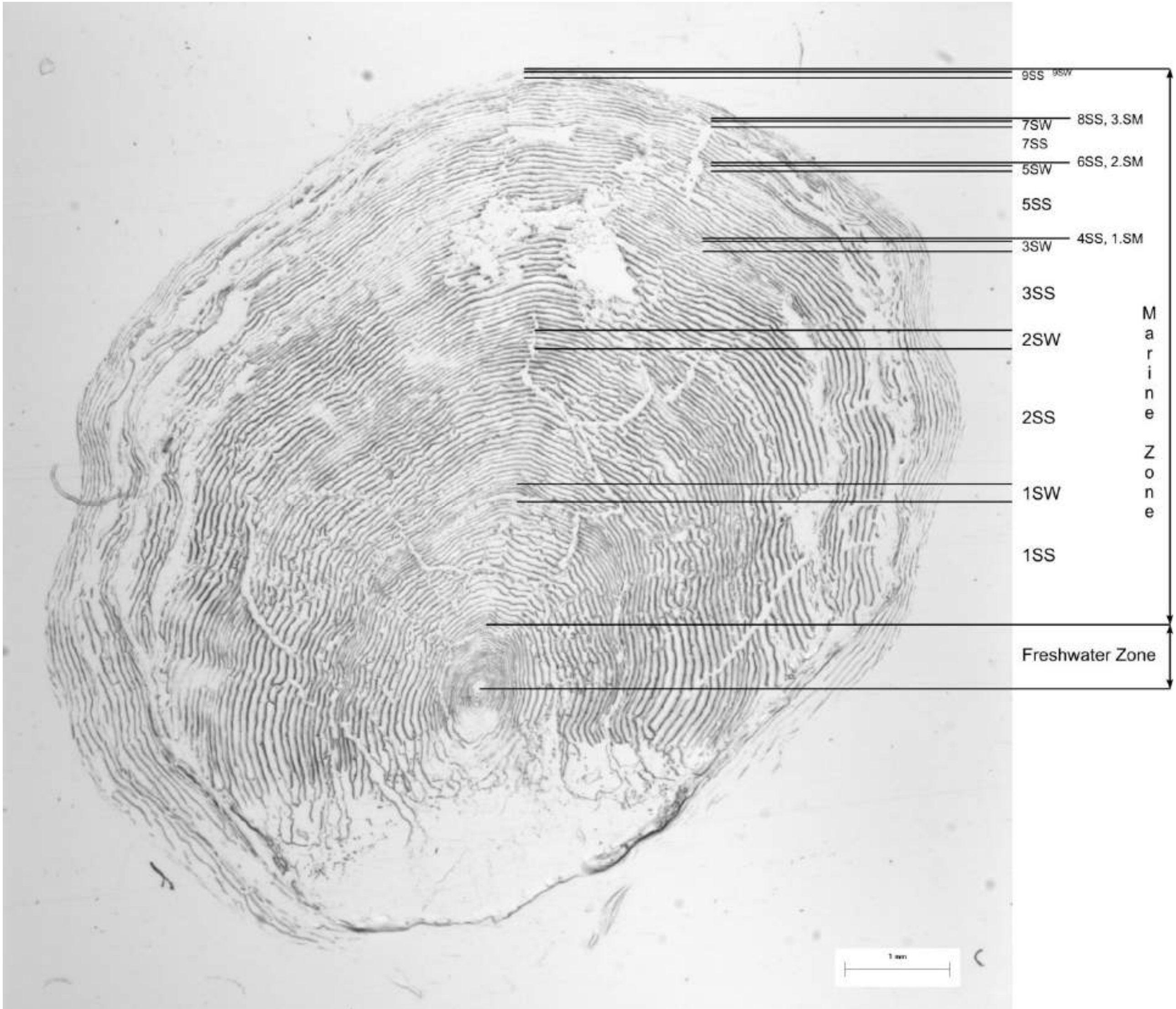


Figure 141. Previous spawner female salmon, sea-age of 3S1S1S1, was caught 19.06.2007 at sea. After the third spawning (3SM) salmon has spent one full year for reconditioning at sea and it was returning to the river in its tenth sea year.

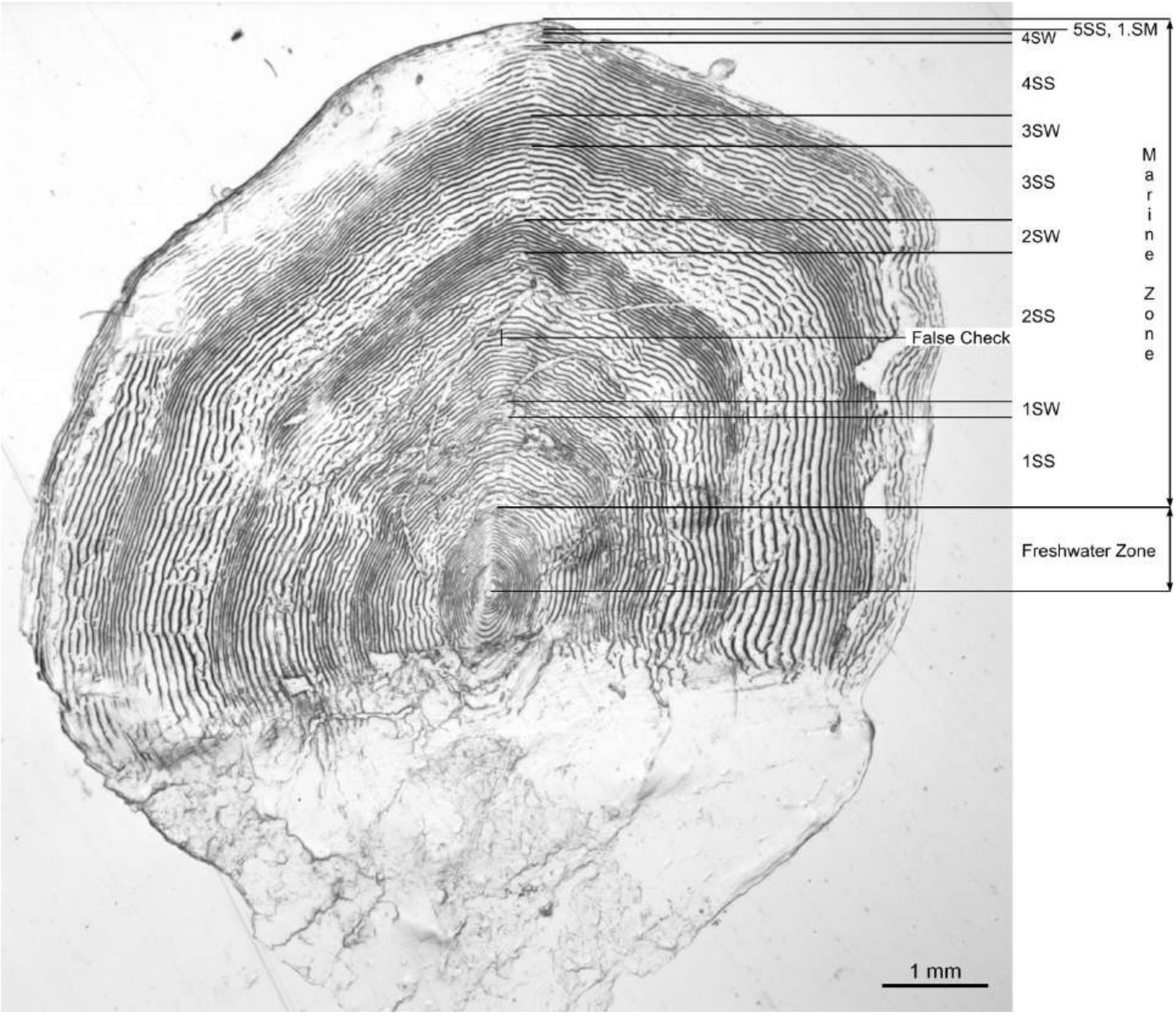


Figure 142. Previous spawner female salmon, sea-age of 4S1, was caught 06.07.2011 at sea. After the first spawning (1SM) salmon has spent one full year for reconditioning at sea and it was returning to the river in its seventh sea year.

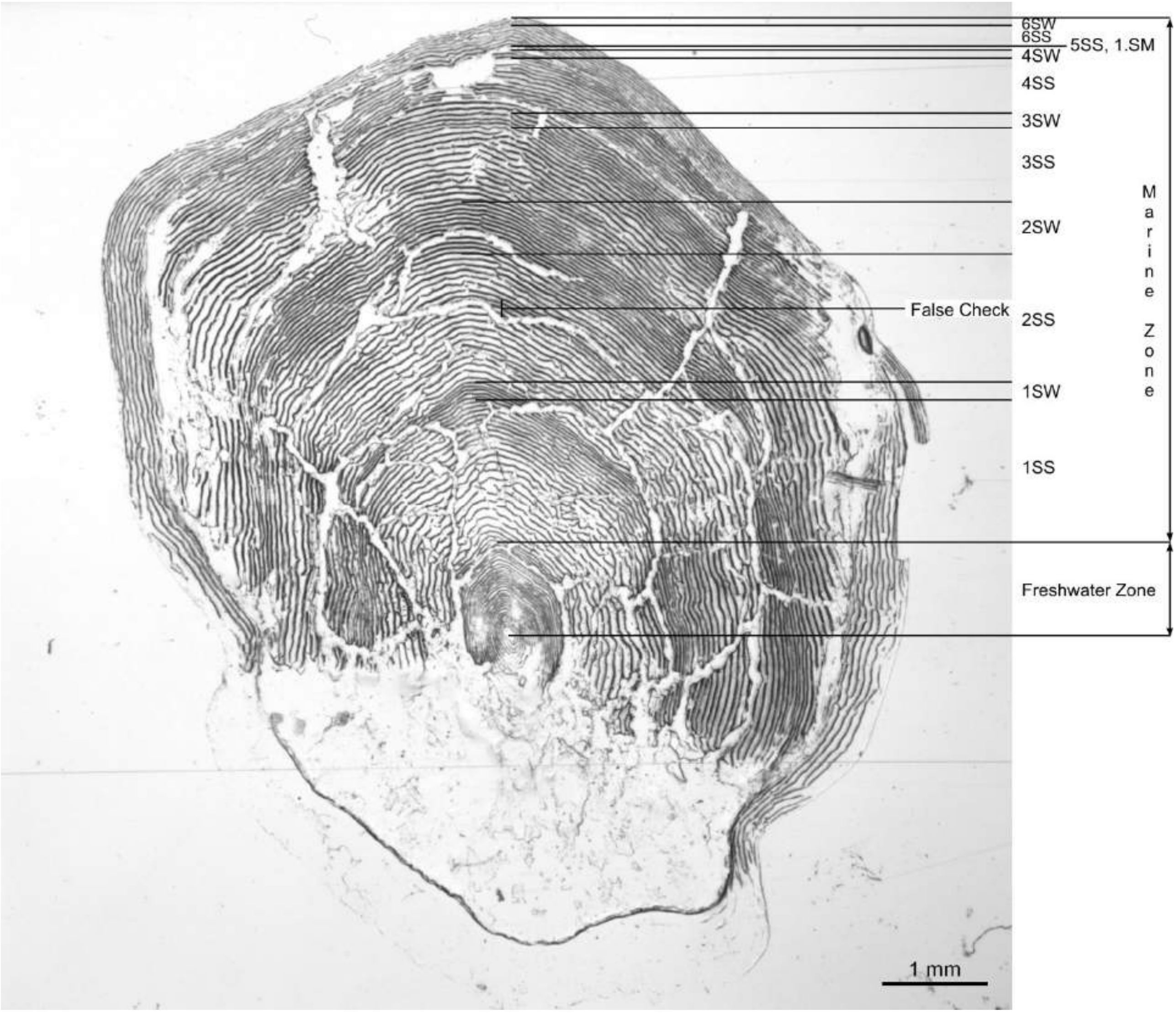


Figure 143. Previous spawner female salmon, sea-age of 4S1, was caught 16.5.2012 at sea in Finnmark. Fish was from the River Karasjohka (tributary to the River Teno/Tana) stock in Finnmark/Norway. After the spawning (1SM) salmon has spent one full year for reconditioning at sea and it was returning to the river in its eight sea year. There might be first spawning after the third sea year (3SW) but the eroded area is not clear.

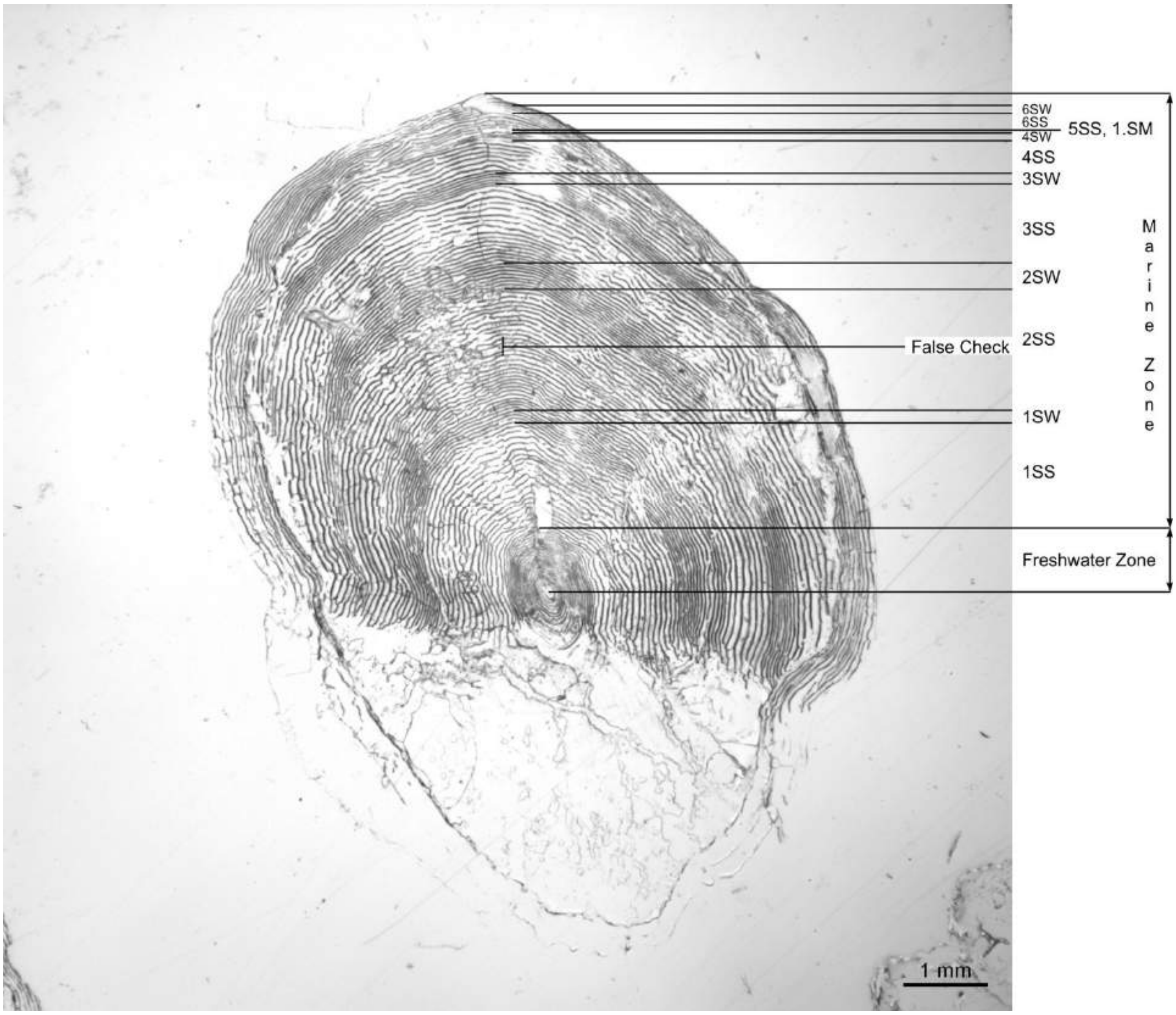


Figure 144. Previous spawner male salmon, sea-age of 4S1, was caught 21.6.2011 at sea in Troms. Fish was from the River Reisaelva stock. After the spawning (1SM) salmon has spent one full year for reconditioning at sea and it was returning to the river in its eight sea year.

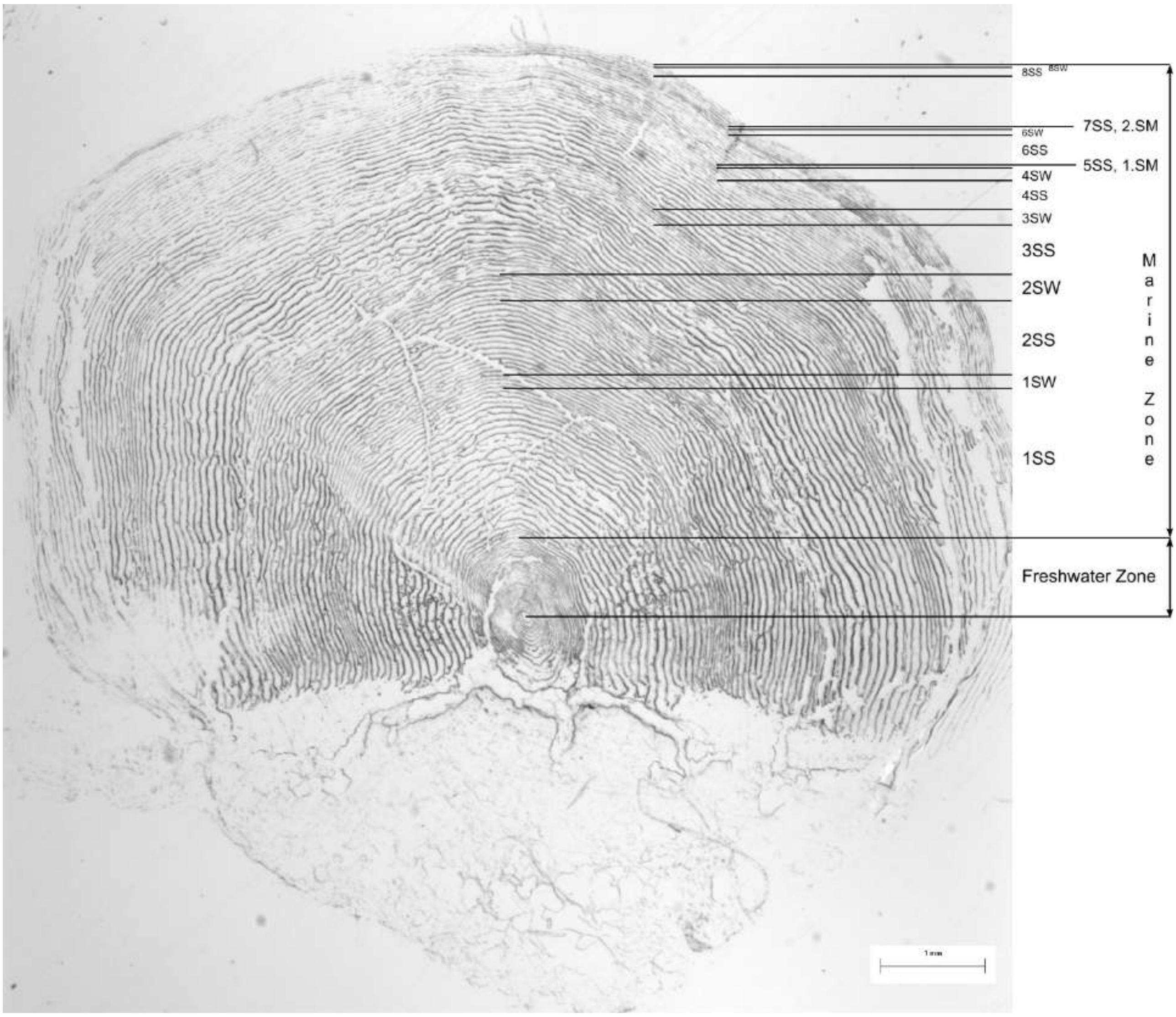


Figure 145. Previous spawner female salmon, sea-age of 4S1S1 and smolt age of 4 years. The weight was 21.5 kg. Fish was caught in the River Teno/Tana (Sirma) on 6.8.2008. First spawning took place after the fourth sea year during the fifth sea-year. After the second spawning (2SM) salmon has spent one full year for reconditioning at sea and it was returning to the river in its nineth sea year. The total age of this female previous spawner was 12+ years.

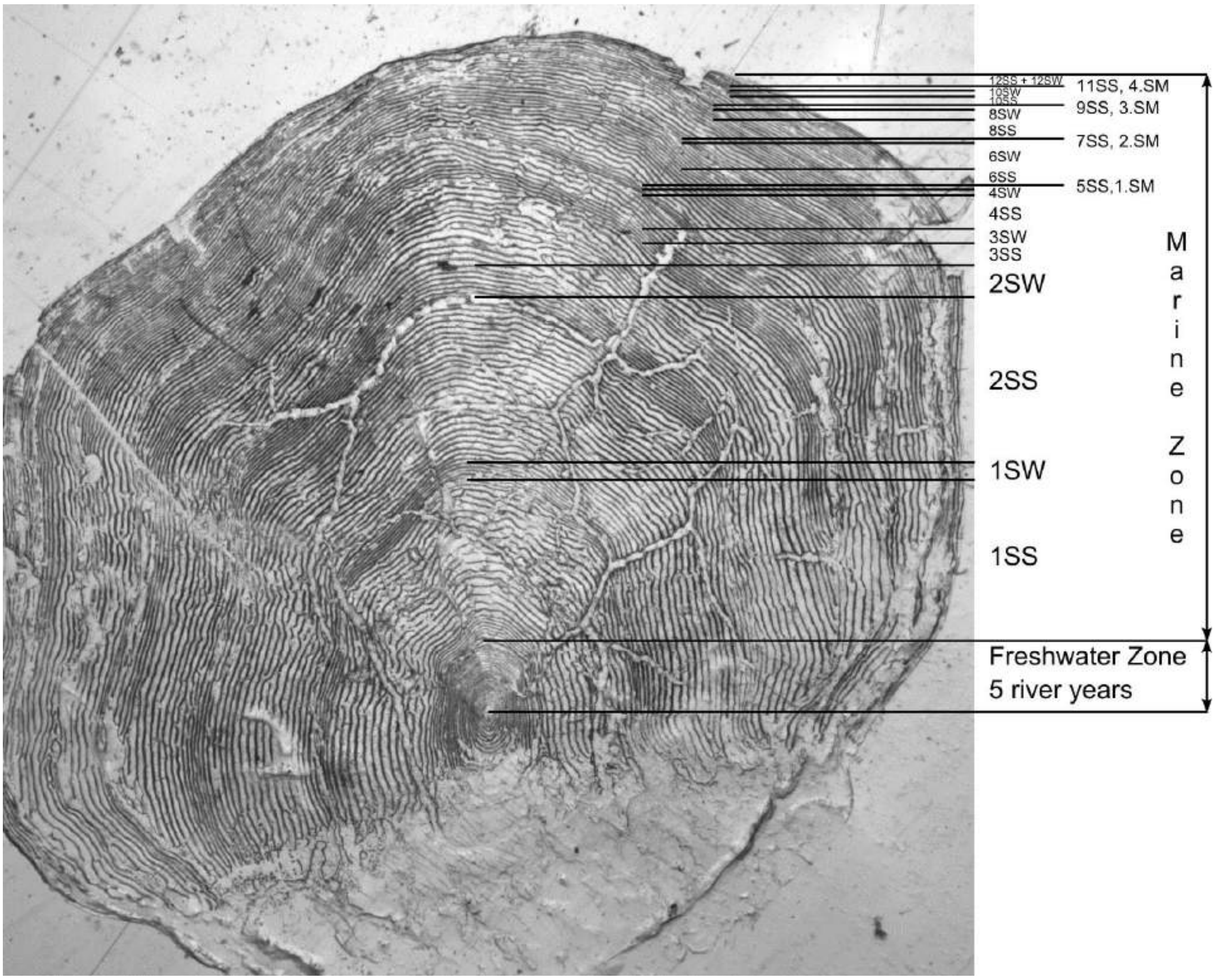
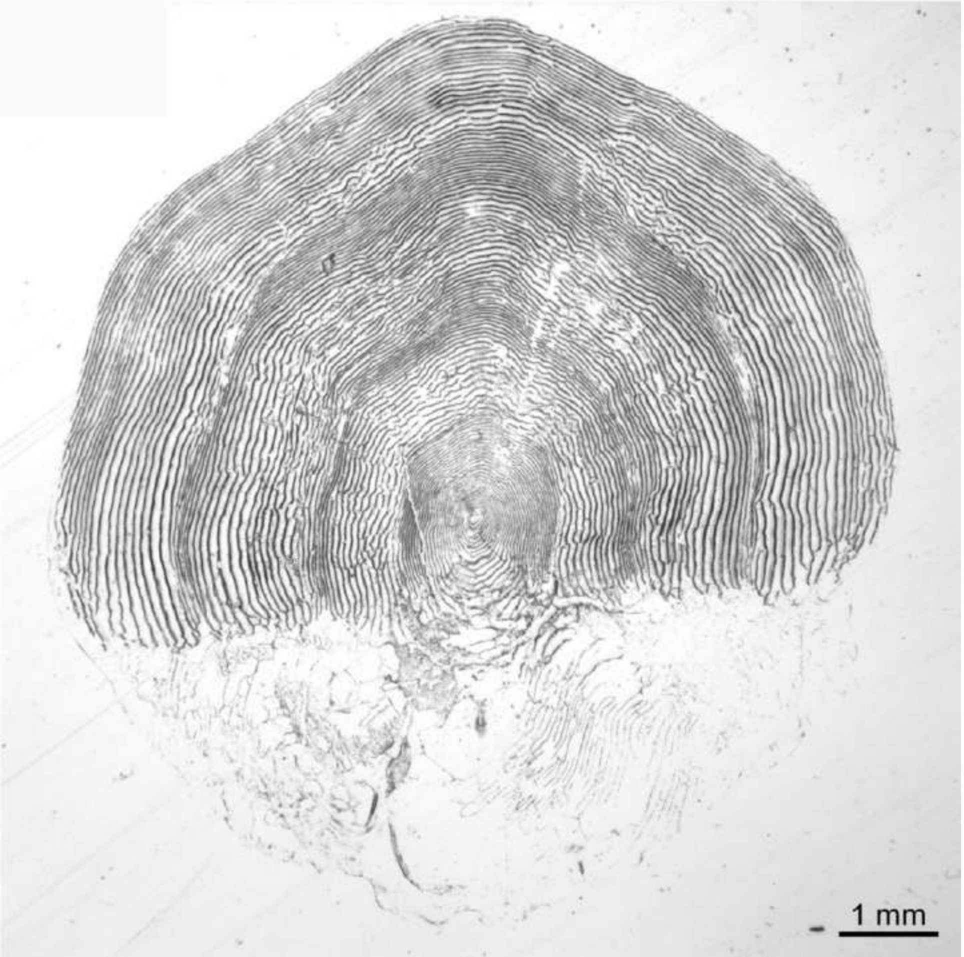


Figure 146. Previous spawner female salmon, river age of five (5) years and sea-age of 4S1S1S1S1, was caught in the River Tana/Finland. This female salmon was on the way to spawn for the fifth time. This fish might be one of the oldest Atlantic salmon caught in the world with the total age of 17 years and sea-age of 12 years.

12. Hatchery released smolt



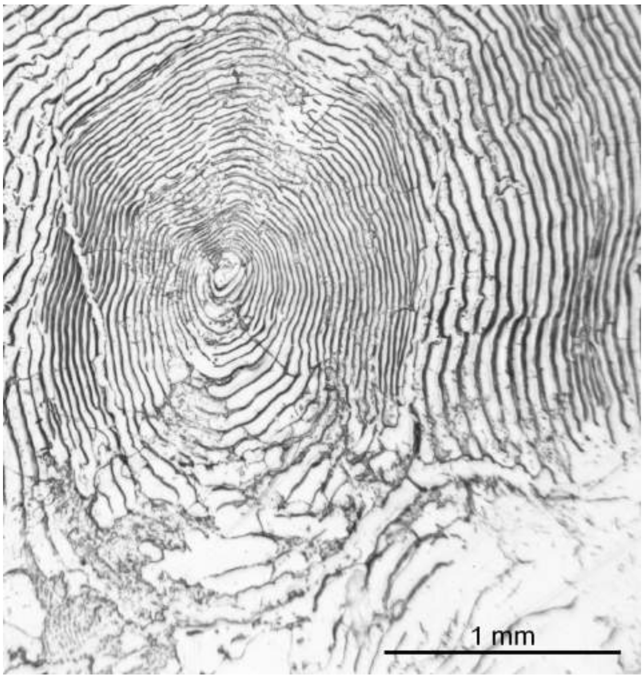


Figure 147. Carlin tagged (Carlin NI 066199) male salmon (95,5cm, 11015g) was caught in North Norway in the year 2008. Released as smolt and the sea growth is like for wild salmon.

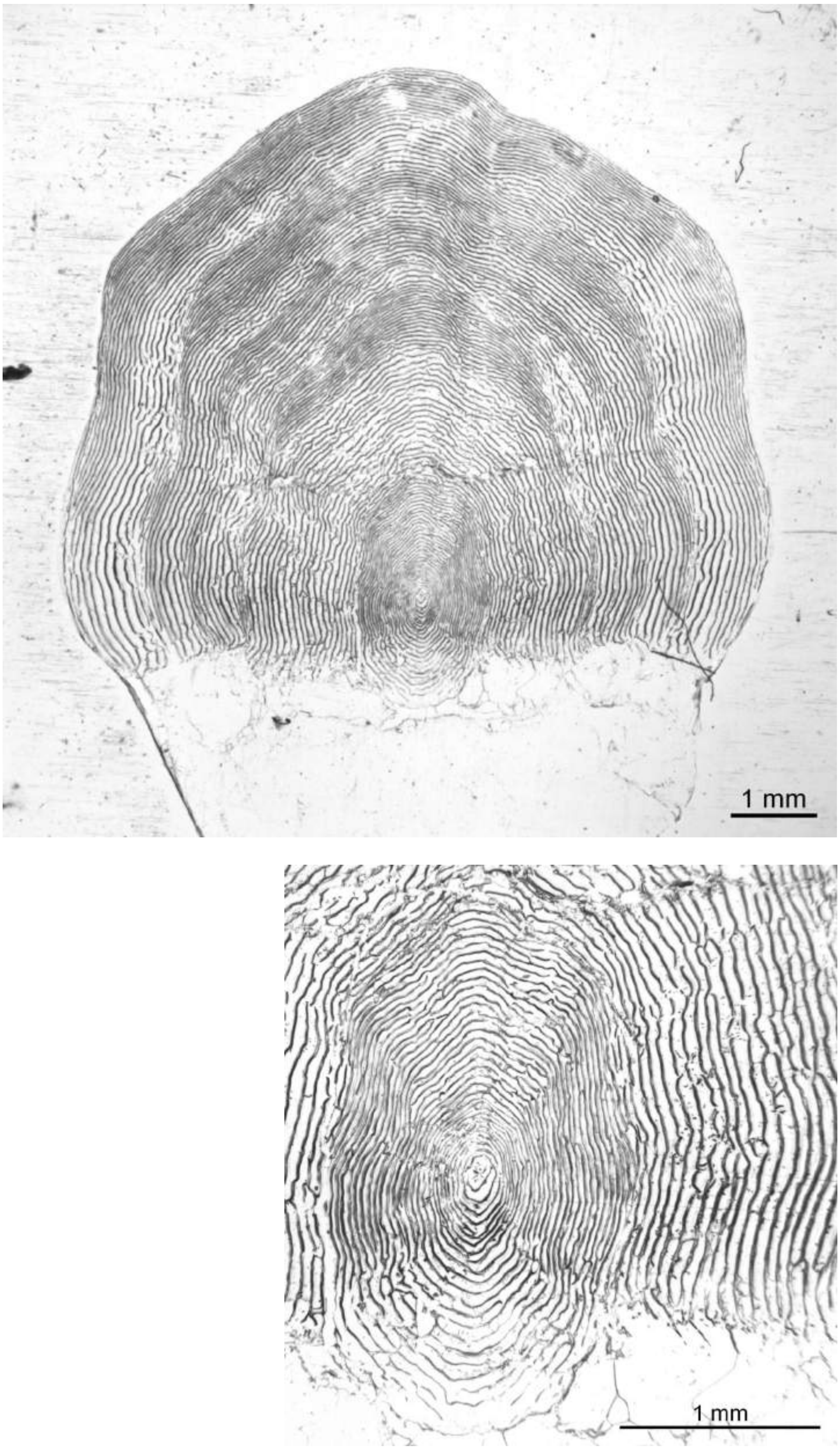


Figure 148. Reared and released smolt was caught as female salmon (106cm, 14540g).

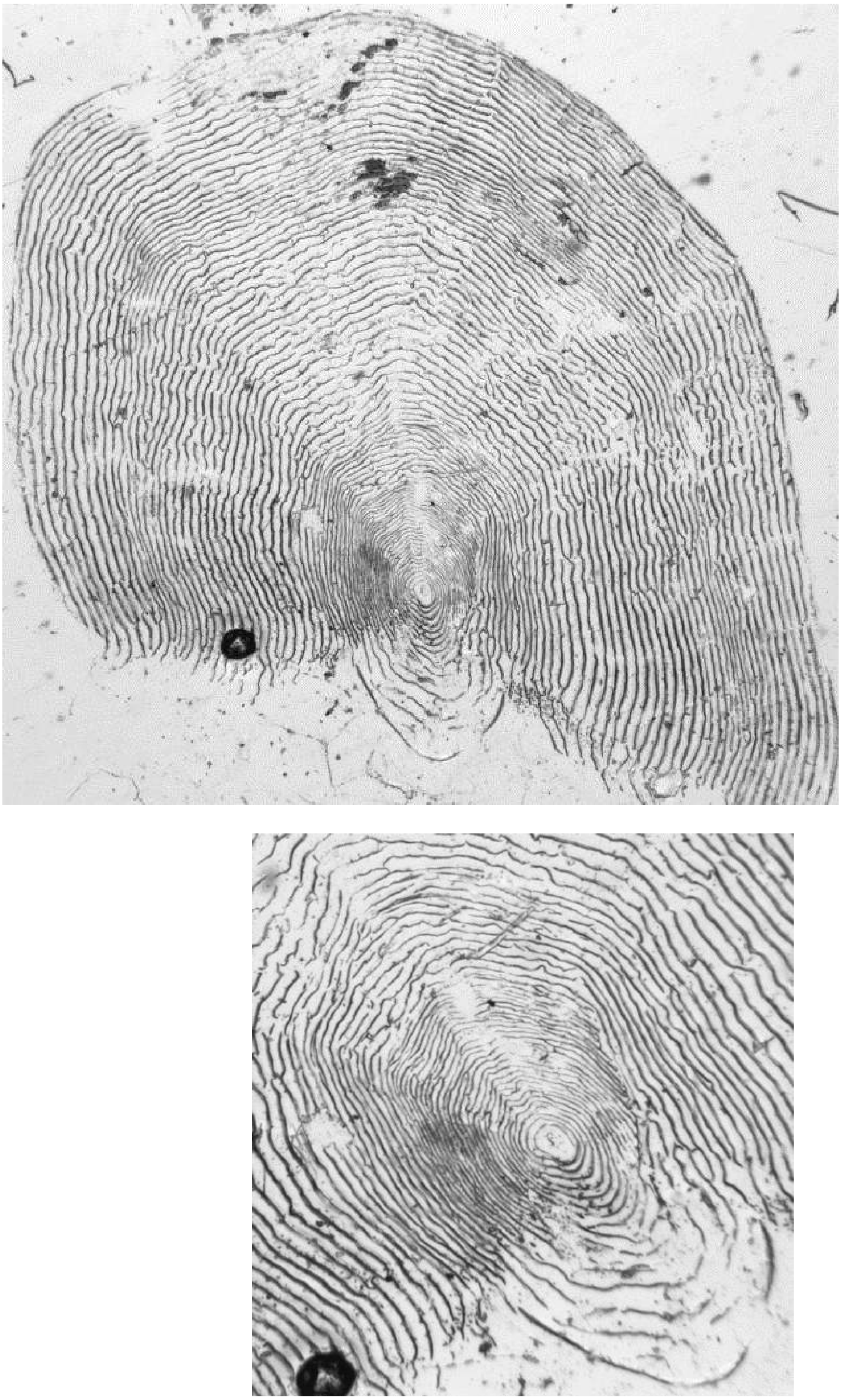


Figure 149. Reared and released smolt or escaped smolt from salmon cage.

13. Escaped salmon

The rapid development of salmon farming also in North Norway (Nordland,Troms and Finnmark) like in North-East Russia (Kola Peninsula) has led to a large number of salmon escaping into the wild. These escaped salmon are then later caught at sea and in the rivers. For the management of salmon stocks it is of great importance to identify escaped salmon in the catches. In hatcheries and salmon farms, fish are managed to obtain good growth which is resulting in growth patterns differing from those of wild fish. This can be detected in the scale patterns (Antere & Ikonen, 1983; Lund & Hansen 1989, Lund *et al*. 1991; Anon. 1991). Escaped salmon have always hatchery origin where juvenile salmon are reared c. 6 months. This artificial rearing can clearly see from the juvenile phase in the scales compared to the juvenile growth of wild salmon (see figures 26, 34, 147,150).

There is a striking difference in scale growth pattern between wild and farmed salmon. The transition zone from freshwater to saltwater on the scales from wild salmon is sharp and easily defined (Figures 54–119); while on ranched and farmed salmon scales, this zone is often large and very diffuse (Figures 150–165).

The main problem is to detect salmon which escape at the smolt stage, and to separate those from ranched (Figure 147) of fish stocked for enhancement purposes (Figure 150).

Photo 4. Escaped salmon caught in River Vestre Jakobselv, year 2009. Photo: Terje Holm

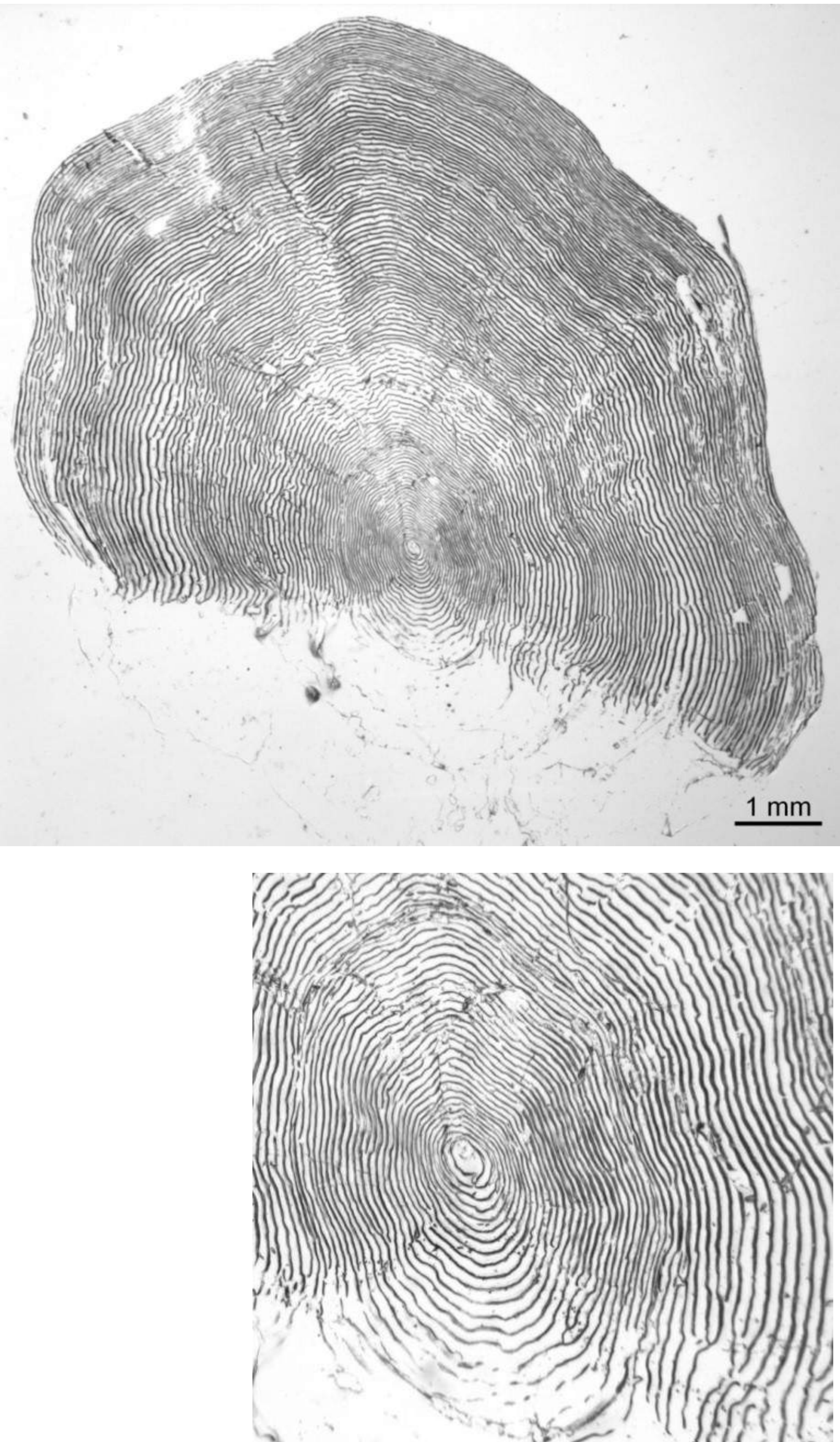


Figure 150. Escaped male salmon (97cm, 11000g) was caught at sea in the year 2008.

Figure 151. Escaped salmon.

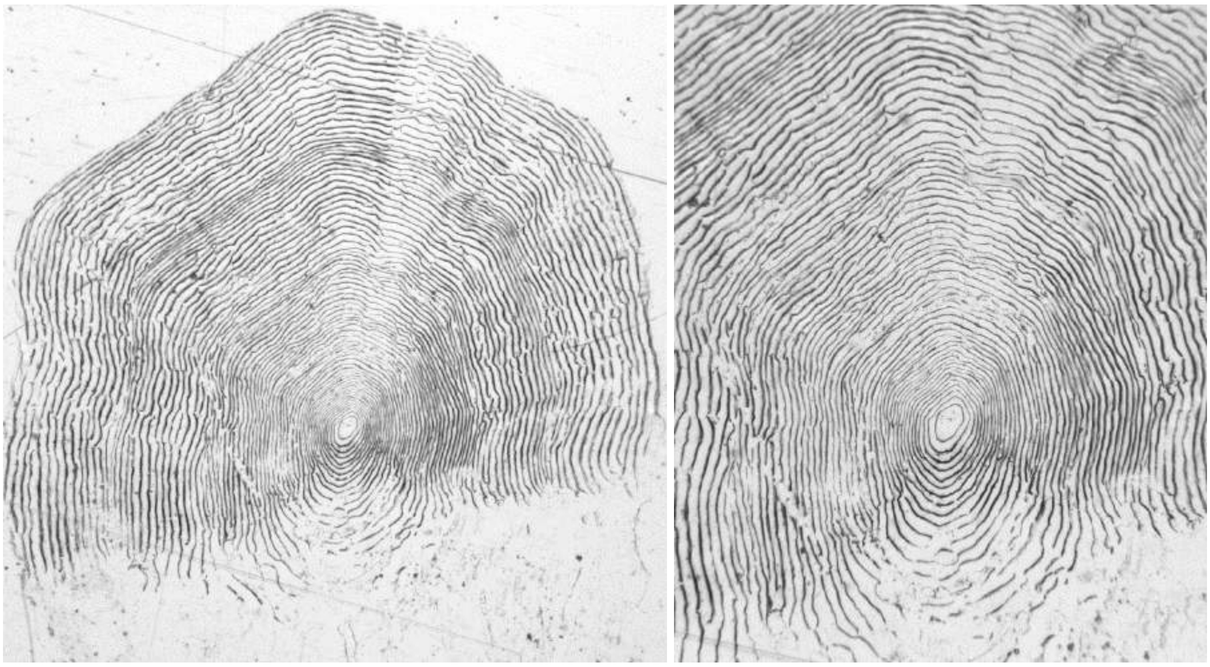


Figure 152. Escaped salmon.

Figure 153. Escaped salmon.

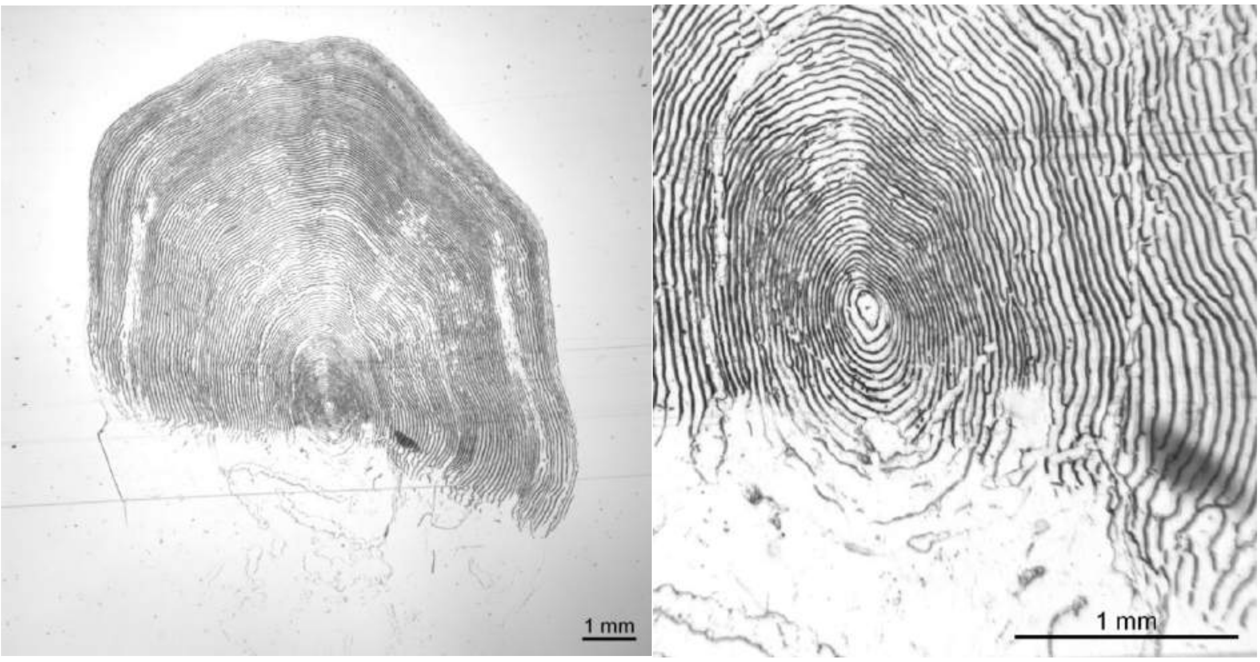


Figure 154. Escaped female salmon (102cm, 11500g) was caught at sea in the year 2008.

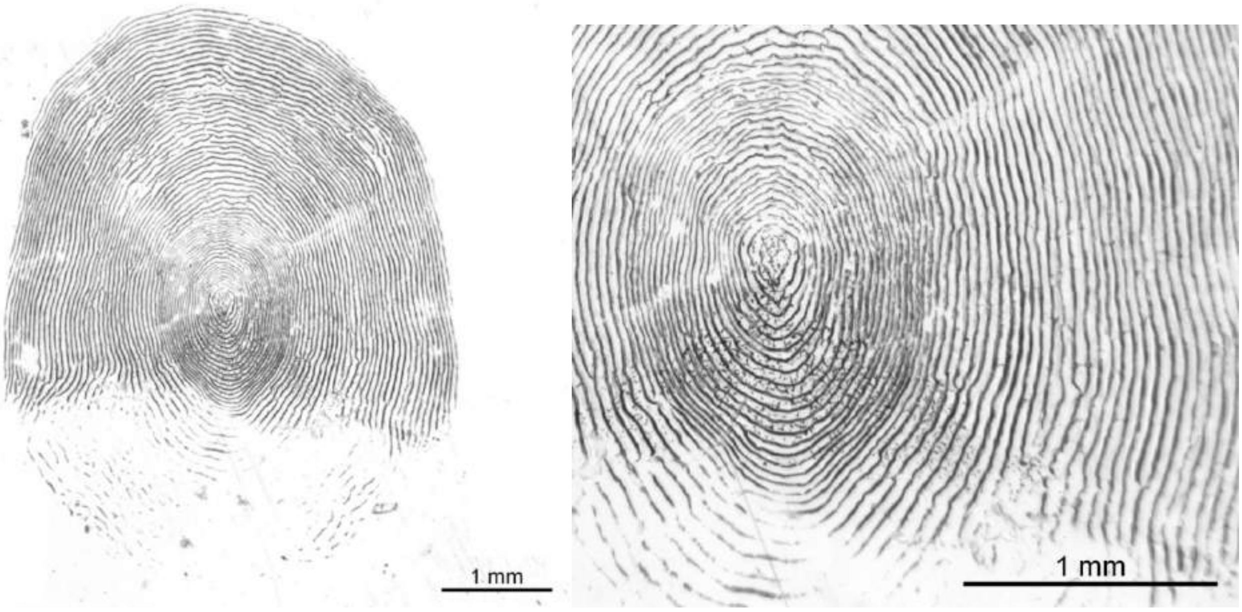


Figure 155. Escaped male salmon (54cm, 2800g) was caught at sea in the year 2009.

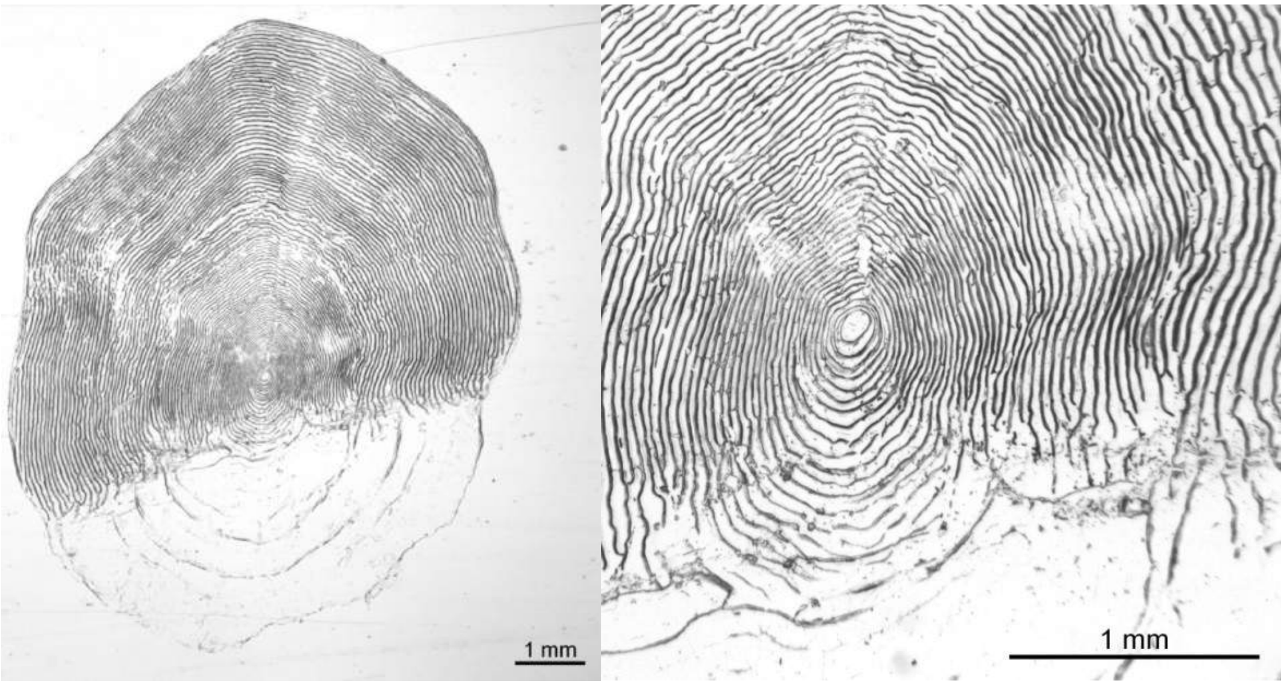


Figure 156. Escaped male salmon was caught at sea on 10.5.2011.

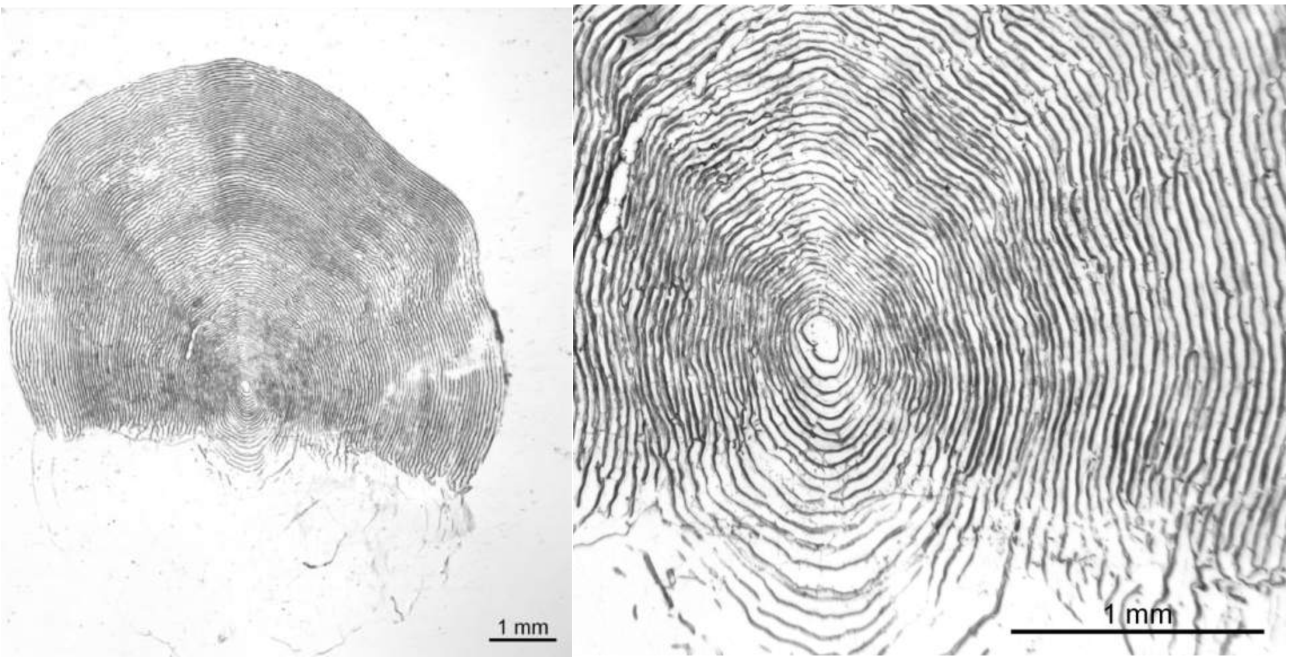


Figure 157. Escaped male salmon (85cm, 7000g) was caught at sea in the year 2009.

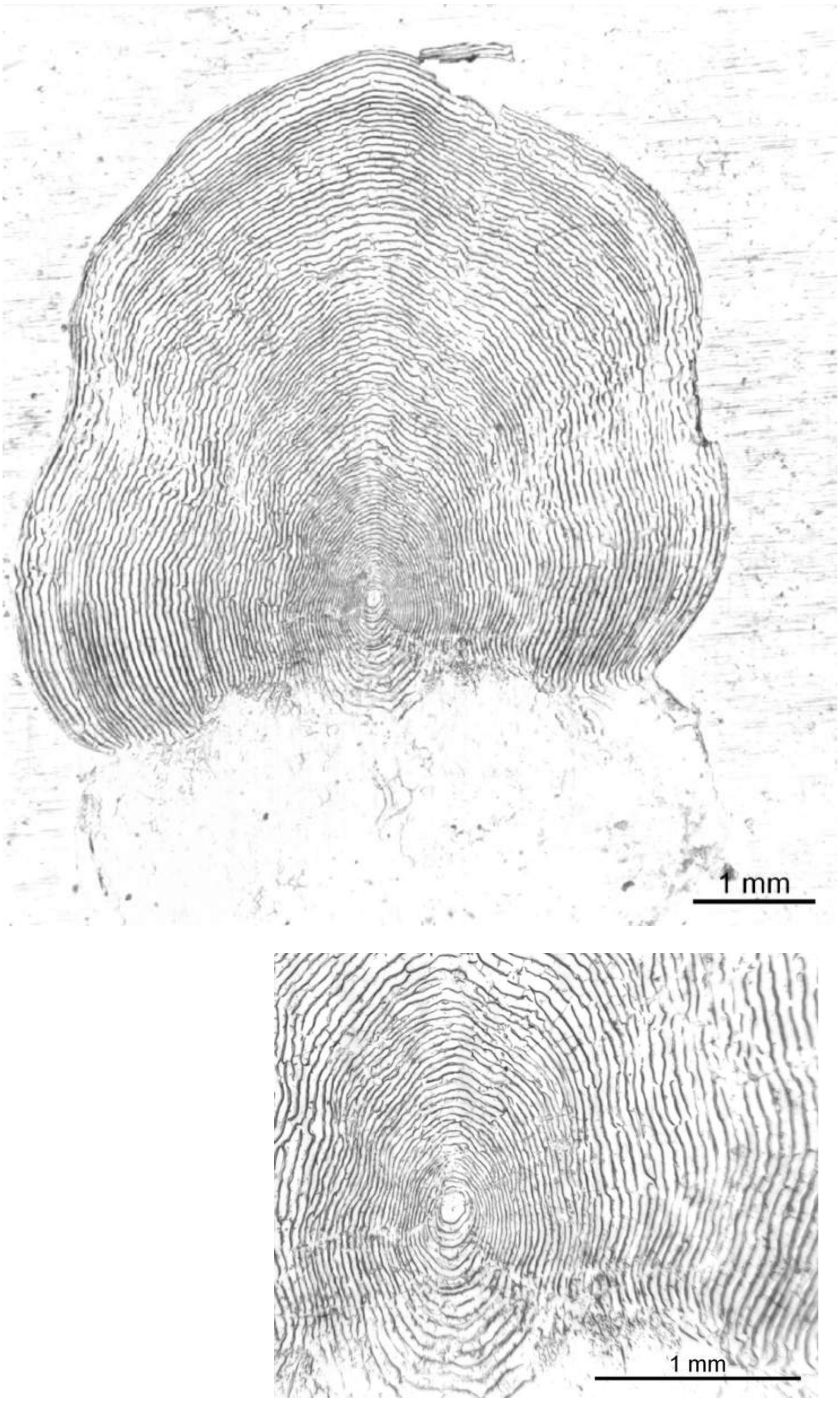


Figure 158. Escaped male salmon (72cm, 3930g).

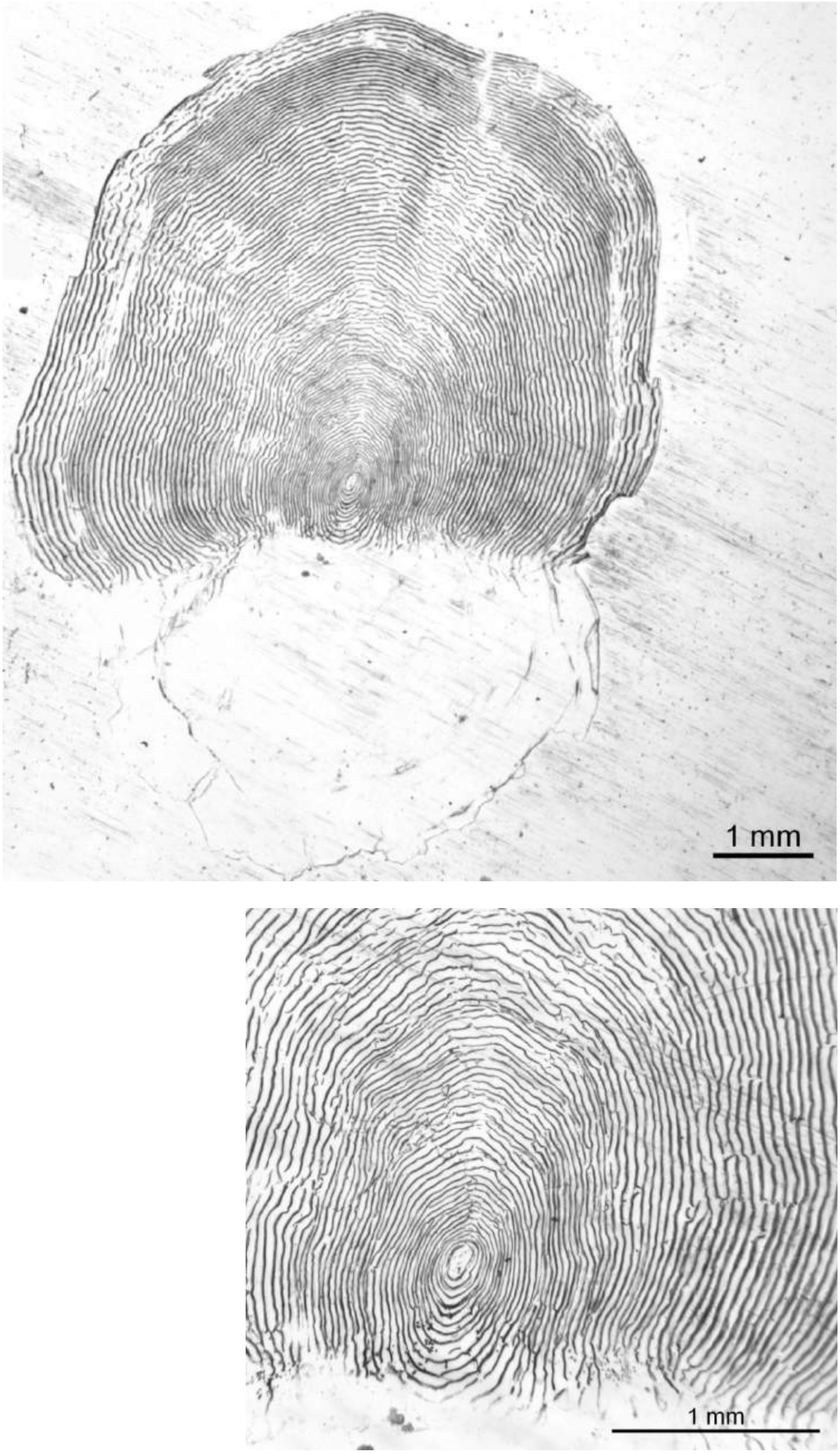


Figure 159. Escaped male salmon (72cm, 3720g).

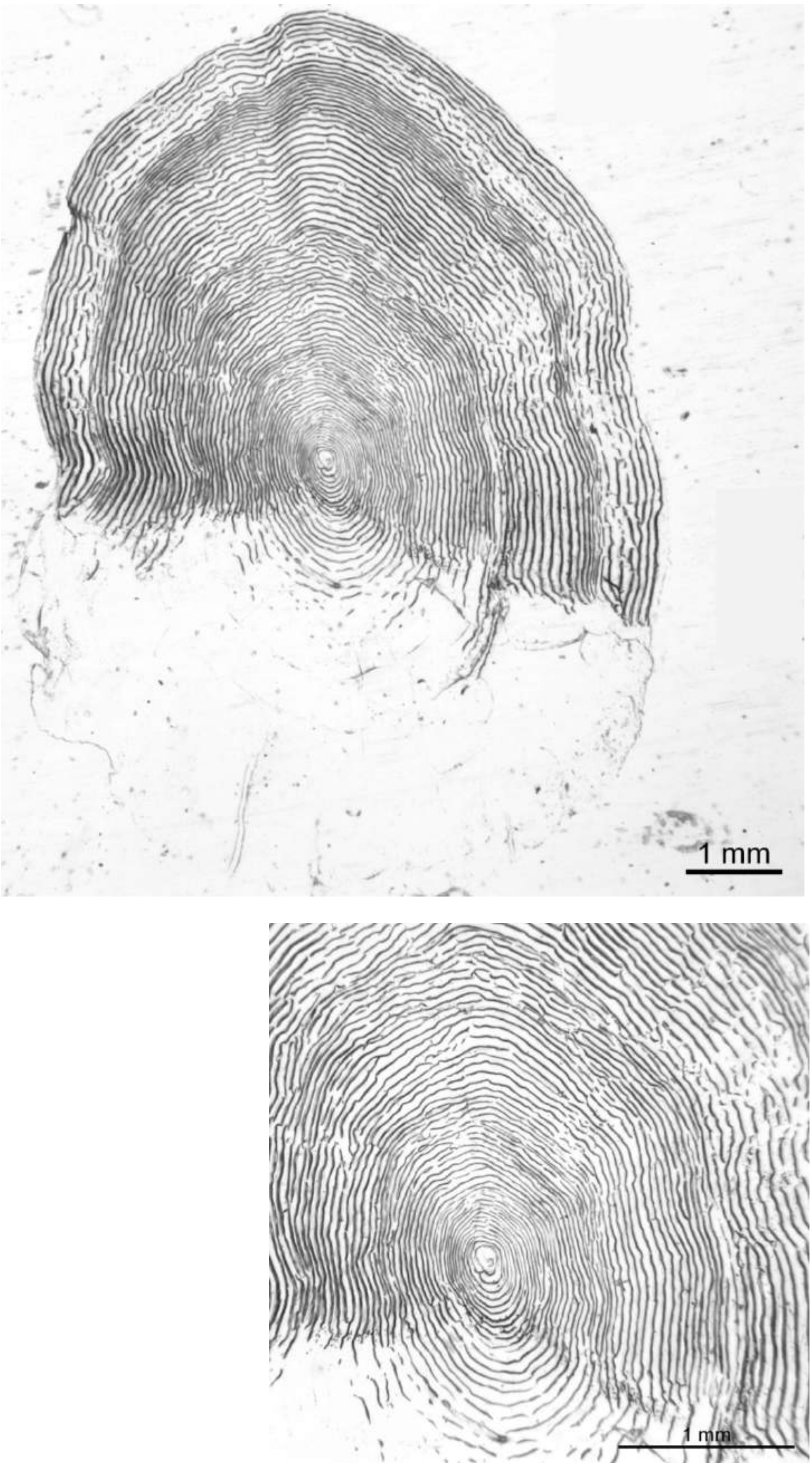


Figure 160. Escaped male salmon (63cm, 2840g).

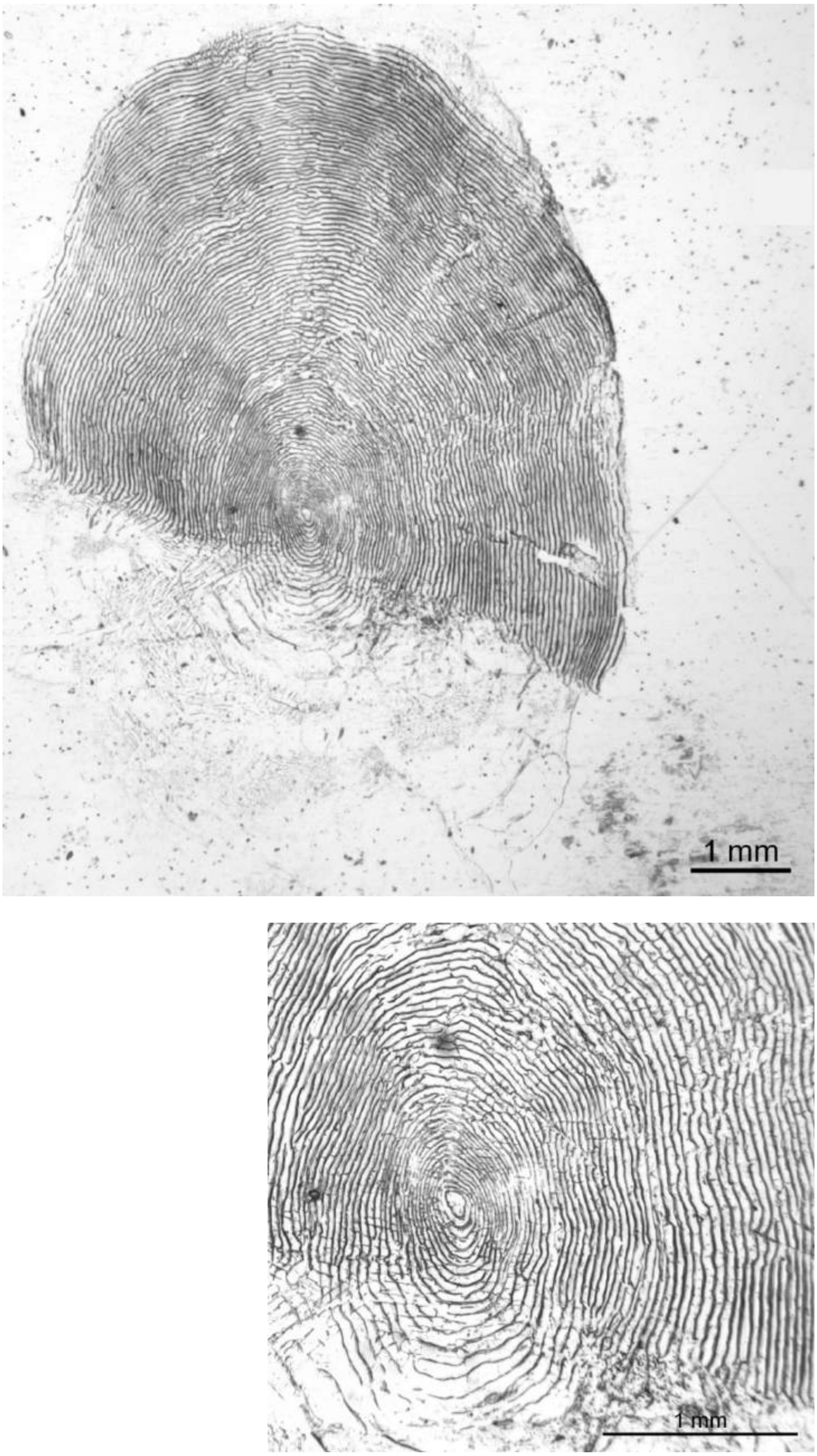


Figure 161. Escaped male salmon (69cm, 2600g).

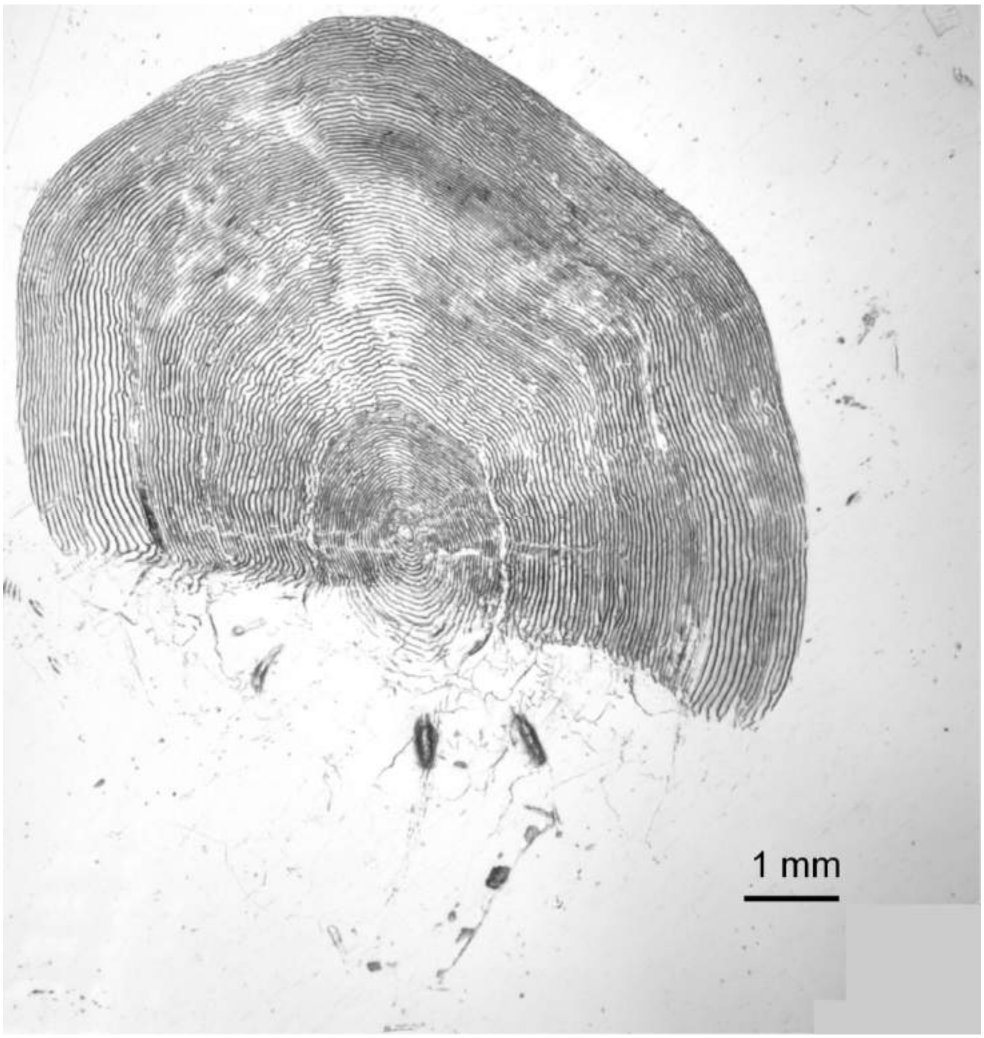
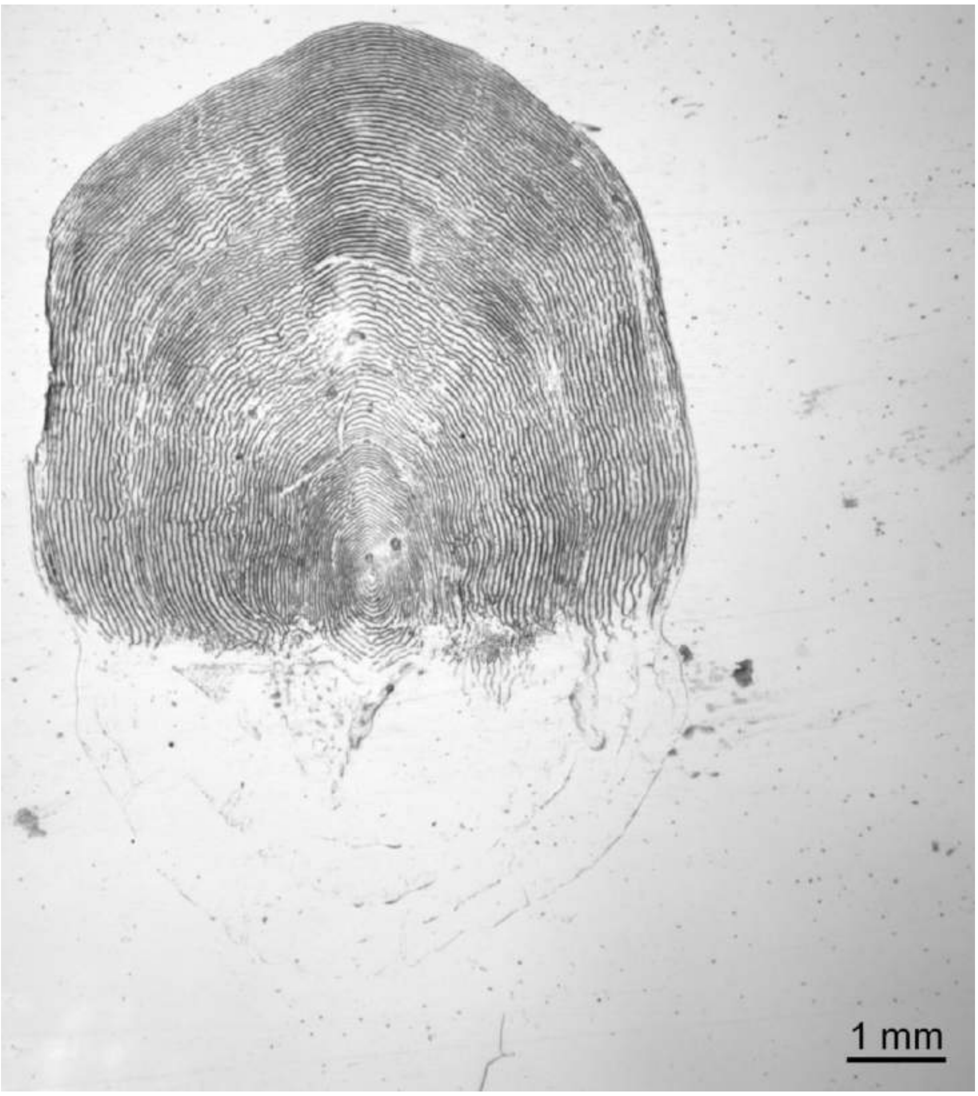


Figure 162. Escaped female salmon (94cm, 9700g).



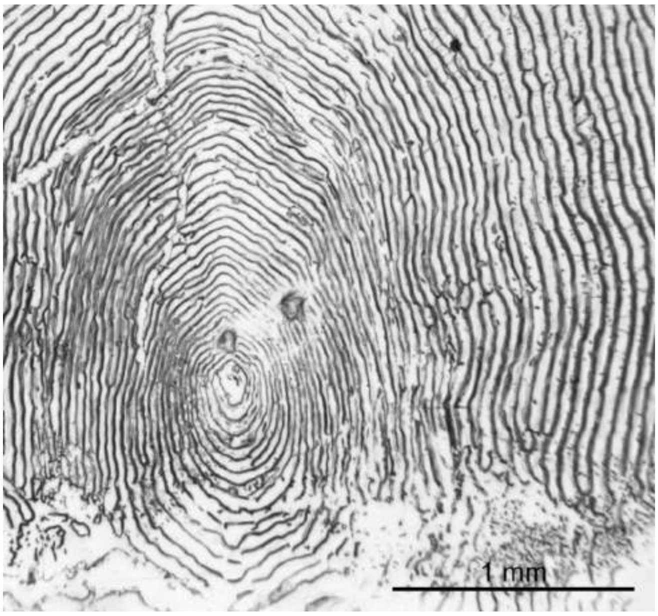
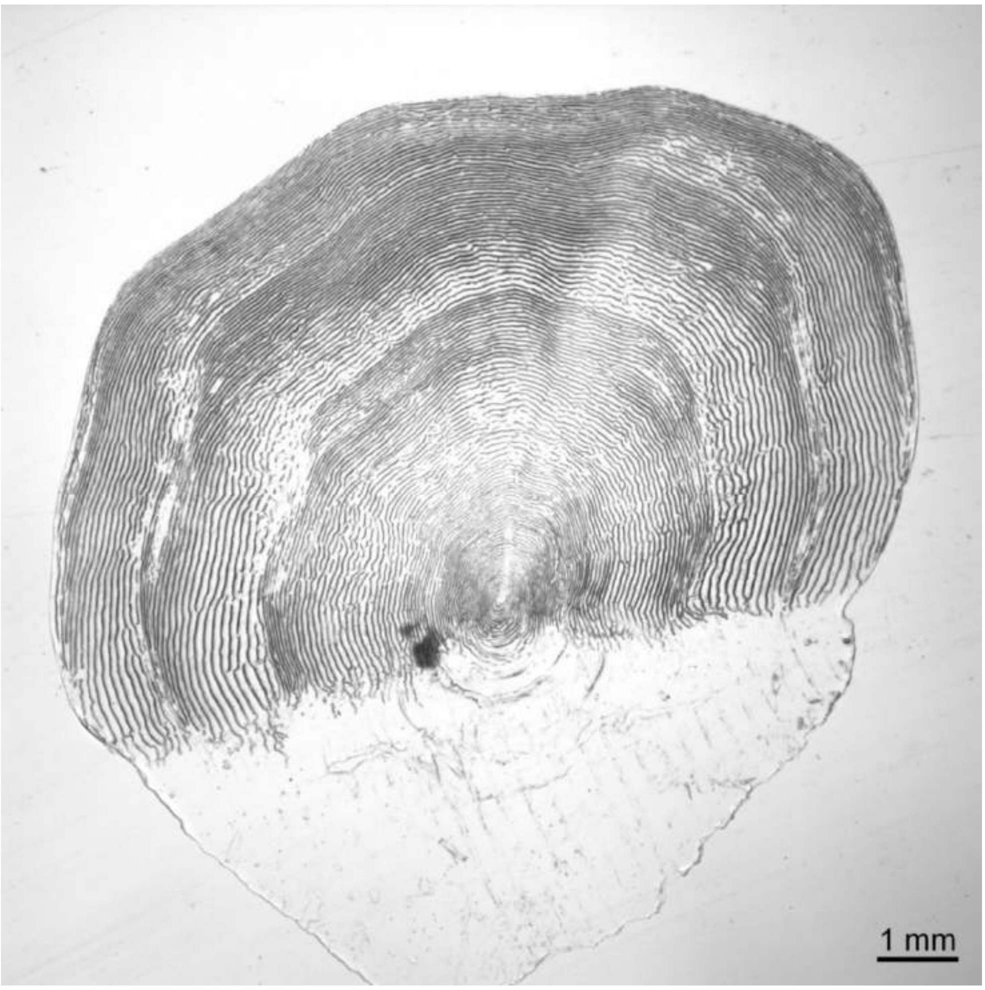


Figure 163. Escaped female salmon (81cm, 4700g).



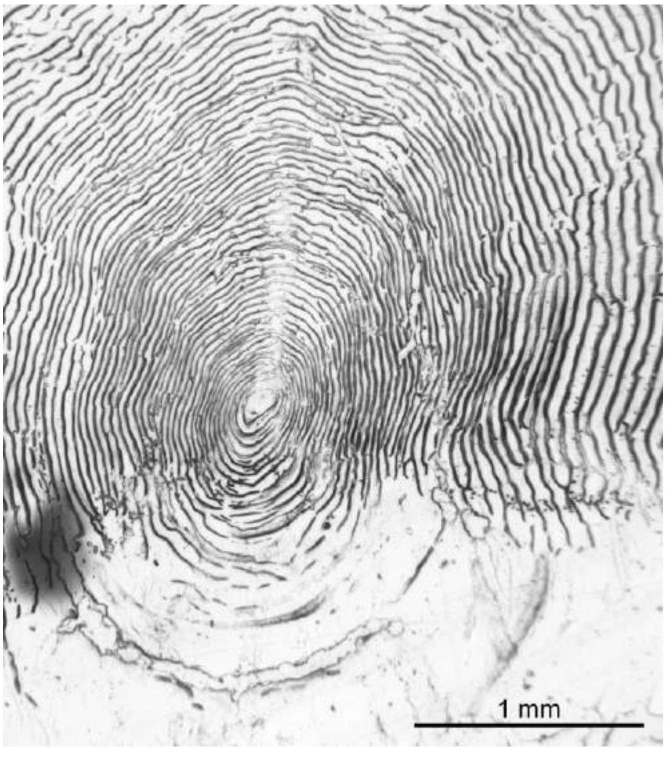
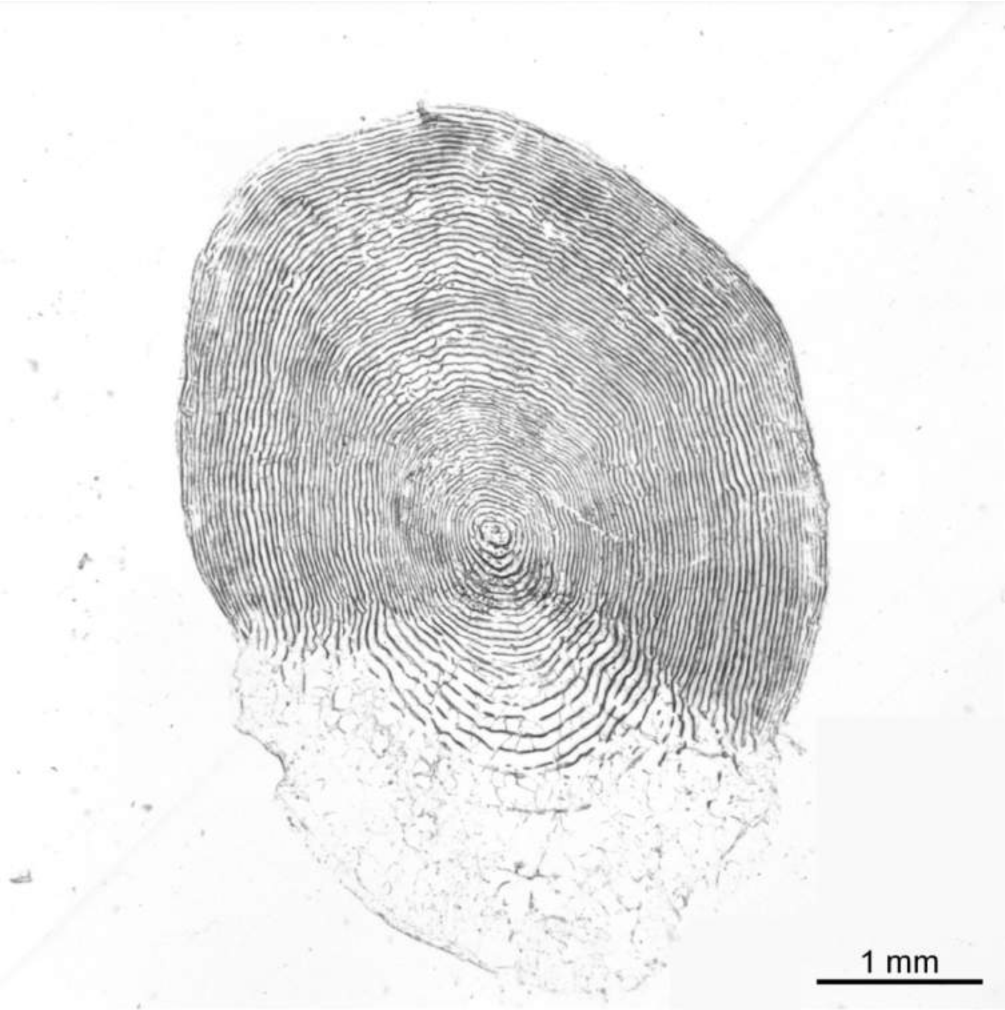


Figure 164. Escaped male salmon (16500g) was caught on 15.8.2011 in Vestre Jakobselva in Finnmark.



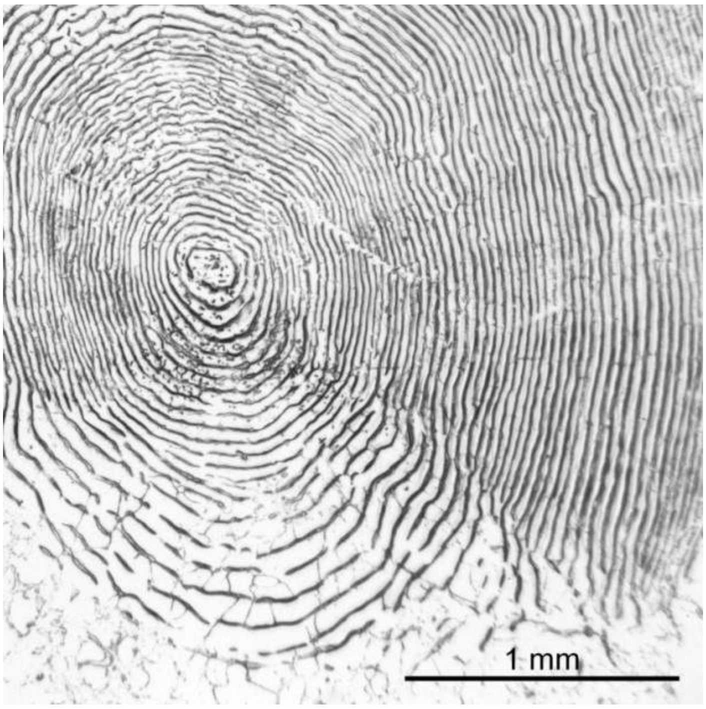


Figure 165. Recently escaped female salmon caught from Porsangerfjord in Finnmark on 25.6.2009.

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