**Special Publication No. 99-4**

# SCALE AGING MANUAL FOR COASTAL CUTTHROAT TROUT FROM SOUTHEAST ALASKA

**by**

**Randolph P. Ericksen**

**December 1999**

**Alaska Department of Fish and Game** **Division of Sport Fish**

## Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used in Division of Sport Fish Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications without definition. All others must be defined in the text at first mention, as well as in the titles or footnotes of tables and in figures or figure captions.

**Weights and measures (metric)**

| | |
|---|---|
| centimeter | cm |
| deciliter | dL |
| gram | g |
| hectare | ha |
| kilogram | kg |
| kilometer | km |
| liter | L |
| meter | m |
| metric ton | mt |
| milliliter | ml |
| millimeter | mm |

**Weights and measures (English)**

| | |
|---|---|
| cubic feet per second | $ft^3/s$ |
| foot | ft |
| gallon | gal |
| inch | in |
| mile | mi |
| ounce | oz |
| pound | lb |
| quart | qt |
| yard | yd |
| Spell out acre and ton. | |

**Time and temperature**

| | |
|---|---|
| day | d |
| degrees Celsius | °C |
| degrees Fahrenheit | °F |
| hour (spell out for 24-hour clock) | h |
| minute | min |
| second | s |
| Spell out year, month, and week. | |

**Physics and chemistry**

| | |
|---|---|
| all atomic symbols | |
| alternating current | AC |
| ampere | A |
| calorie | cal |
| direct current | DC |
| hertz | Hz |
| horsepower | hp |
| hydrogen ion activity | pH |
| parts per million | ppm |
| parts per thousand | ppt, ‰ |
| volts | V |
| watts | W |

**General**

| | |
|---|---|
| All commonly accepted abbreviations. | e.g., Mr., Mrs., a.m., p.m., etc. |
| All commonly accepted professional titles. | e.g., Dr., Ph.D., R.N., etc. |
| and | & |
| at | @ |
| Compass directions: | |
| east | E |
| north | N |
| south | S |
| west | W |
| Copyright | © |
| Corporate suffixes: | |
| Company | Co. |
| Corporation | Corp. |
| Incorporated | Inc. |
| Limited | Ltd. |
| et alii (and other people) | et al. |
| et cetera (and so forth) | etc. |
| exempli gratia (for example) | e.g., |
| id est (that is) | i.e., |
| latitude or longitude | lat. or long. |
| monetary symbols (U.S.) | $, ¢ |
| months (tables and figures): first three letters | Jan,...,Dec |
| number (before a number) | # (e.g., #10) |
| pounds (after a number) | # (e.g., 10#) |
| registered trademark | ® |
| trademark | ™ |
| United States (adjective) | U.S. |
| United States of America (noun) | USA |
| U.S. state and District of Columbia abbreviations | use two-letter abbreviations (e.g., AK, DC) |

**Mathematics, statistics, fisheries**

| | |
|---|---|
| alternate hypothesis | $H_A$ |
| base of natural logarithm | e |
| catch per unit effort | CPUE |
| coefficient of variation | CV |
| common test statistics | F, t, $\chi^2$, etc. |
| confidence interval | C.I. |
| correlation coefficient | R (multiple) |
| correlation coefficient | r (simple) |
| covariance | cov |
| degree (angular or temperature) | ° |
| degrees of freedom | df |
| divided by | ÷ or / (in equations) |
| equals | = |
| expected value | E |
| fork length | FL |
| greater than | > |
| greater than or equal to | ≥ |
| harvest per unit effort | HPUE |
| less than | < |
| less than or equal to | ≤ |
| logarithm (natural) | ln |
| logarithm (base 10) | log |
| logarithm (specify base) | $log_2$, etc. |
| mideye-to-fork | MEF |
| minute (angular) | ' |
| multiplied by | x |
| not significant | NS |
| null hypothesis | $H_O$ |
| percent | % |
| probability | P |
| probability of a type I error (rejection of the null hypothesis when true) | α |
| probability of a type II error (acceptance of the null hypothesis when false) | β |
| second (angular) | " |
| standard deviation | SD |
| standard error | SE |
| standard length | SL |
| total length | TL |
| variance | Var |

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# ABSTRACT

Scale aging techniques designed to improve the accuracy and precision of ages estimated for coastal cutthroat trout *Oncorhynchus clarki clarki* in Southeast Alaska are presented in this manual. Scales should be collected near the lateral line from the region of the caudal peduncle because this is where scales are first formed. Scales should be cleaned, mounted on glass slides, and viewed with high magnification and resolution (e.g. using a compound stereomicroscope at 100× or 200×) due to the low number of circuli between annuli. In Alaska, cutthroat trout often do not form a recognizable annulus during the first year of life. Scales that are missing the first annulus typically have a larger number of circuli before the first apparent annulus than is normally observed. The average number of circuli associated with a given annulus generally increases up to about age 3 or 4 and then decreases as the fish ages. Under high magnification the annuli on scales from older fish may appear to be separated by only a few "wavy" circuli deposited during periods of high growth. Each sample should be independently aged three times to estimate reader variability. All fish above a certain age should be pooled into one age class due to difficulties in obtaining accurate age estimates from older fish. Aging error models should be used to correct for reader error whenever possible.

Key words: age estimation, aging error model, coastal cutthroat trout, *Oncorhynchus clarki clarki*, scales, Turner Lake, Florence Lake, Auke Creek, Southeast Alaska

# INTRODUCTION

This manual presents methods to improve the accuracy and precision of ages estimated from scales sampled from coastal cutthroat trout *Oncorhynchus clarki clarki* in Southeast Alaska. Accurate and precise ages are necessary for unbiased estimation of age composition, growth rates, mortality rates, and sustained yield.

In Southeast Alaska, cutthroat trout have been aged using either scales (Baade 1957, Jones and Harding 1991, Frenette and Bryant 1993) or otoliths (Armstrong 1971, Jones 1978, Ericksen and Marshall 1991). Otoliths from cutthroat trout generally provide older (and perhaps more accurate) age estimates than scales (Hubert et al. 1987, Downs 1995, de Leeuw *Unpublished*). However, large numbers of scale samples can be collected and prepared without killing or severely harming fish. In addition, aging error models can now be applied to correct for reader error (Richards et al. 1992, Ericksen 1997). Therefore scales are the preferred structure for aging cutthroat trout when non-lethal methods are necessary or desired.

Estimating the age of fish using scales has been complicated by many factors, such as a high incidence of regenerated scales, a missing first annulus, and ineffective viewing equipment. Also, estimated ages based on "reading" scale patterns have been found to be biased low in some cases (Downs 1995, Ericksen 1997). The methodology described in this manual was developed during several years of graduate study on the subject (Ericksen 1997). Techniques were validated through comparison of scales and otoliths from the same fish, examination of scales from known age (hatchery) fish, and from scales collected from the same fish over known time periods (tag-recapture studies).

## Pertinent Cutthroat Trout Life History

The coastal cutthroat trout is the only subspecies of cutthroat trout found in Alaska. This sub-species is distributed within 150 km of the Pacific Coast from Eel River, California, to Gore Point on the Kenai Peninsula, Alaska (Behnke 1988).

Anyone wishing to accurately estimate the age of cutthroat trout using scales should have a basic understanding of their life history. The growth of the scale is closely related to the growth of the fish. Because fish growth can vary greatly depending on food availability (due to seasonal and habitat changes), spawning activities, migration activities, senescence (older fish tend to grow slower than younger fish), or other factors, these events can leave a mark on the scale record. Thus, knowledge of these events is useful for deciphering patterns on the scale.

Coastal cutthroat trout can be classified into three basic life history forms (Trotter 1989). There are two migratory forms: anadromous (sea-run) and potamodromous (both river- and lake-dwelling), in addition to a nonmigratory (stream-resident) form. Because most cutthroat trout in Alaska are either anadromous or lake-dwelling forms, this manual is focused toward aging those forms. In Alaska, adult cutthroat trout spawn in spring when the water temperature reaches 5-6°C, which generally occurs in April or May. Eggs deposited in the gravel hatch in 6 to 7 weeks, and emerge as fry 1 to 2 weeks later (Trotter 1989). Juvenile cutthroat trout typically reside about 3 years in their natal streams before migrating to the sea, lake, or large river for the first time (Trotter 1989).

After cutthroat trout migrate from their natal stream, the life history of anadromous and lake-dwelling forms differ considerably. Lake-dwelling cutthroat trout typically remain in the lake until returning to the natal stream to spawn. In contrast, the life history of anadromous cutthroat trout is much more complex. The peak of anadromous smolt migration in Alaska is in late May or early June (Armstrong 1971). After spending the summer feeding, most cutthroat trout return to freshwater lakes to spend the winter. Anadromous trout may migrate freely between salt and freshwater throughout the season.

Growth patterns are similar between anadromous and lake-dwelling forms. Growth is typically slow for the first few years, accelerates for one season at about age 3 or 4, then gradually declines as the fish ages (Narver 1975, Tomasson 1978, Ericksen 1997).

### SCALE FORMATION AND DEVELOPMENT

Like other salmonids, cutthroat trout have cycloid scales that begin with the formation of the scale center or focus and move outward. Fine ridges called circuli are laid down in a circular pattern around the focus as growth proceeds. Cutthroat trout have circuli that frequently pass entirely around the scale margin as growth is added. Circuli are relatively widely spaced and sometimes wavy in appearance during warmer seasons when growth is rapid, and closely spaced during winter, when growth slows or discontinues. This slowing down of growth is generally evident on the scale beginning around mid-October, and is usually completed by mid to late June. The outer edge of a series of closely spaced circuli is considered the end of growth for that year and is referred to as the annulus (Lux 1971). The age of a fish is estimated by counting the number of annuli. However, one important exception to this is discussed below.

In Southeast Alaska, cutthroat trout often do not form a recognizable annulus during the first year of life (Ericksen 1997). Fry typically emerge from the gravel in late July at about 25 mm in length. Scales first develop near the lateral line along the caudal peduncle when they reach about 35–40 mm in length (Neave 1936, Cooper 1970, Giger 1972, Ericksen 1997). Thus, young of year cutthroat trout frequently do not develop scales until late August or September. As a result, their scales have very few circuli by the end of the first growing season. Scales that form 3 or less circuli during the first growing season frequently do not have a recognizable annulus that first year (Laakso and Cope 1956).

Cutthroat trout produce fewer circuli annually than most salmonids. Thus, identification of individual annuli can be difficult. In general, the number of circuli between annuli increases up to age 3 or 4 and then decreases as the fish ages.

## METHODS

The scales used as examples in this report came from three lakes in Southeast Alaska (Figure 1). Turner and Florence Lakes are typical of two extremes of habitat for lake-dwelling cutthroat trout, and Auke Lake provides overwintering habitat for anadromous cutthroat trout. Alaska Department of Fish and Game (ADF&G) Division of Sport Fish personnel have routinely collected scale samples from Turner and Florence lakes while conducting mark-recapture experiments. Uniquely marked cutthroat trout were repeatedly sampled for scales on an annual basis over increments of 2–8 years. Thus, age increments (time between capture events) for individual fish were known. Both ADF&G and the National Marine Fisheries Service jointly sampled scales from wild and known-age hatchery sea-run cutthroat trout emigrating through the Auke Creek weir during 1995 and 1996.

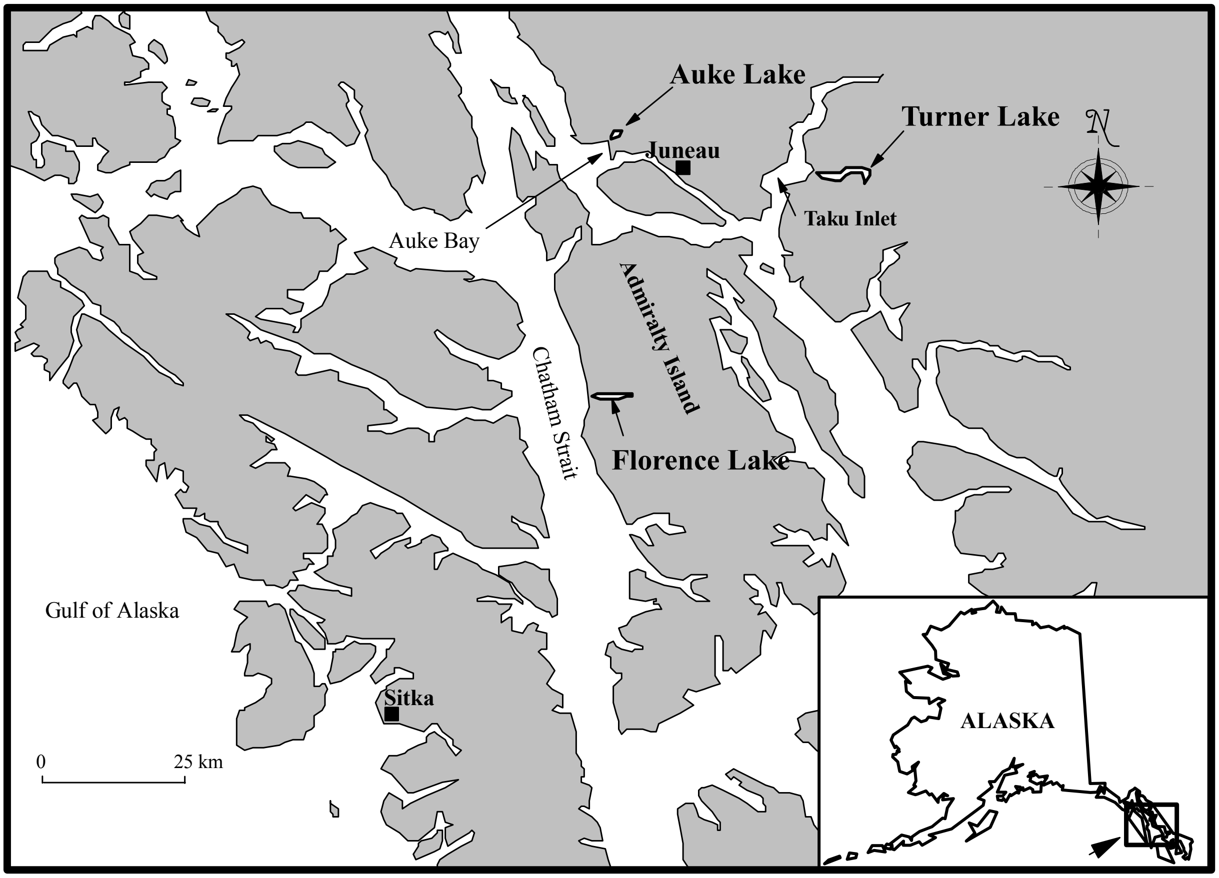


**Figure 1.–Location of Turner, Florence, and Auke lakes in Southeast Alaska.**

Scale images for this manual were collected with a WILD MPS 46/52 photoautomat 35-mm camera mounted on a Leica Lab S compound microscope using either 40× (standard), 100× (high), or 200× (very high) magnification. Images on black and white negatives were then digitized with a Nikon LS-1000 35 mm film scanner. Finally, digitized images were enhanced with image editing software for use in this report.

# AGING TECHNIQUE

Estimating the age of cutthroat trout from scales can be a very subjective process. In the past, aging techniques have varied between agencies, between individuals within agencies, and within individuals over time (Jones et al. 1992). Consistent methods for collecting, preparing, viewing, and aging scales are necessary to provide useful age data.

## SCALE COLLECTION, PREPARATION, AND VIEWING

Scales should always be collected near the lateral line from the region of the caudal peduncle on cutthroat trout (Figure 2). These scales provide the best information on the early life stage of the fish because this is where scales are first formed. For consistency, I recommend collecting scales above the lateral line on the left side of the fish. When fish that have been previously sampled are recaptured (as in a mark-recapture experiment), scales can be collected from the right side of the fish, or below the lateral line to minimize the probability of collecting regenerated scales.

The number of scales collected from each fish will depend on the length and life history form of the fish. I recommend collecting 14 to 19 scales from lake-dwelling, and 17 to 27 from anadromous cutthroat trout ranging from 200 to 300 mm FL, to obtain at least three readable scales. These numbers should be increased for larger fish. Large numbers of scales are needed because early scale development can vary widely even within individual fish (Figure 3), and because the proportion of regenerated scales on coastal cutthroat trout is very high (Wyatt 1959, Cooper 1970, Moring et al. 1981, Tsao 1980, Fuss 1982, Ericksen 1997). The proportion of regenerated scales increases with the length of fish and is higher for sea-run fish than lake-dwelling fish (Ericksen 1997).

Cutthroat trout scales should be carefully prepared for viewing so that high resolution is obtained at high magnification. Cutthroat trout grow slower and therefore tend to have fewer circuli between annuli than other salmonids. As a result, much information is stored within a small area, which makes their scales more difficult to age. Scales should always be cleaned and separated to remove mucus and avoid overlapping. Mount scales immediately on a glass slide after the fish is sampled. Once dried, the scales should be secured with another slide, or a glass cover slip. Acetate slides should not be used to store scales, as they are easily scratched, which reduces viewing properties. I recommend viewing scales with transmitted light under a scientific grade compound stereomicroscope at magnifications of 40× to 200×. A polarizing filter is useful to reduce glare and enhance contrast. I have found that a 72× microfiche reader, commonly used for aging Pacific salmon scales, does not provide sufficient magnification or resolution to discern individual annuli in older cutthroat trout.

## ESTIMATING AGE

For consistency, all data are collected along an imaginary reference line drawn along the longest axis of the scale from the scale focus to the anterior edge of the scale (Figure 4). This convention is necessary because the number of circuli can vary greatly depending on the axis. In addition, consistent estimates of annual growth can be made using back-calculation techniques if a common reference line is used.

### Scale Selection

All scales in a sample should be examined closely before selecting one to age. An ideal scale will be clean, have a small focus, and be large relative to other scales in the sample. Regenerated scales should not be selected because they lack complete age and growth information. These scales are formed when a scale is lost and a replacement (regenerated) scale grows rapidly to reach the approximate size of the original scale. These scales do not form circuli until they reach the size of the replacement scale, and are readily identified because the scale center is clear, pebbly, or irregularly formed (Figure 5).

### Identification of Annuli

Learning to age cutthroat trout scales is an exercise in pattern recognition. Recognizing the seasonal patterns on the scale is just as important as learning criteria used to define an annulus. Start by viewing the entire scale if possible. Patterns are often evident along the scale at about $45^{o}$ off either side of the reference line (Figure 4). The scale is often reabsorbed along the dorsal and ventral edges of the scale when the annulus is formed. Several circulus segments may appear to join along or near the $45^{o}$ axis of the scale. The criteria used to identify annuli include:

- Relative spacing of the circuli. Circuli are spaced further apart during the summer months when growth is rapid and closer together as growth slows in late fall.
- "Cutting over" or "crossing over" of the annulus across previously deposited circuli. On some scales, the outer circuli laid down during periods of slow growth tend to flare outward or end abruptly on the side of the scale. When rapid growth begins again, the new circuli is complete.
- Circulus segments may be thicker or wavy during active growth, and thinner and straighter during periods of slow growth.
- Summer growth may appear as clear or broken spaces on the posterior portion of the scale. In contrast, annuli may be discernible as a continuous line along the posterior portion of the scale.

The average number of circuli associated with a given annulus generally increases up to about age 3 or 4, then decreases as the fish ages (Figure 6).

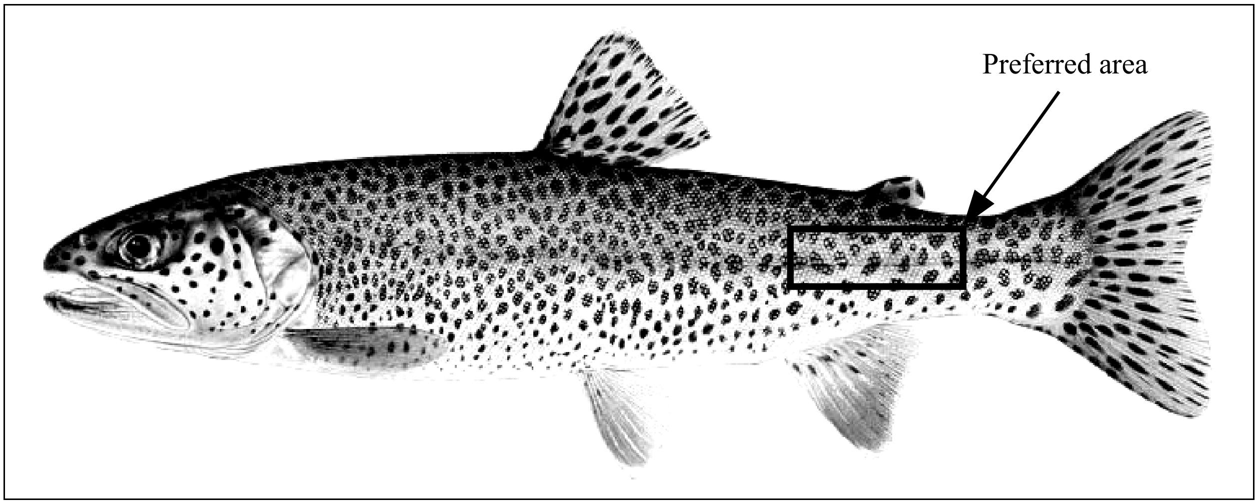


**Figure 2.–The preferred area for collecting scales from coastal cutthroat trout.** Scales first develop above and below the lateral line near the caudal peduncle.

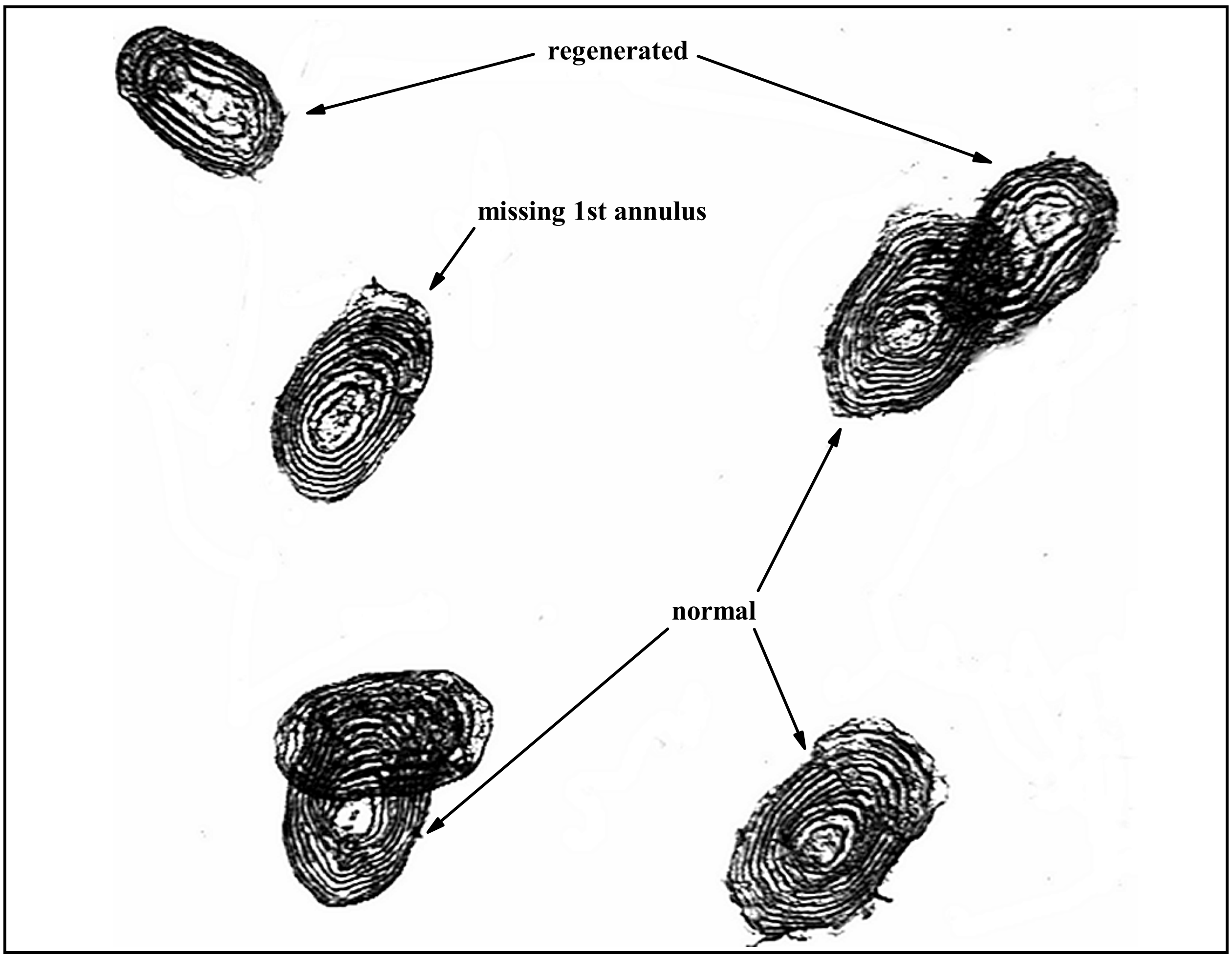


**Figure 3.–Scales collected from an age 2 cutthroat trout showing the variation in scale development within an individual fish.** This sample includes scales that are normal, regenerated, and missing the first year annulus.

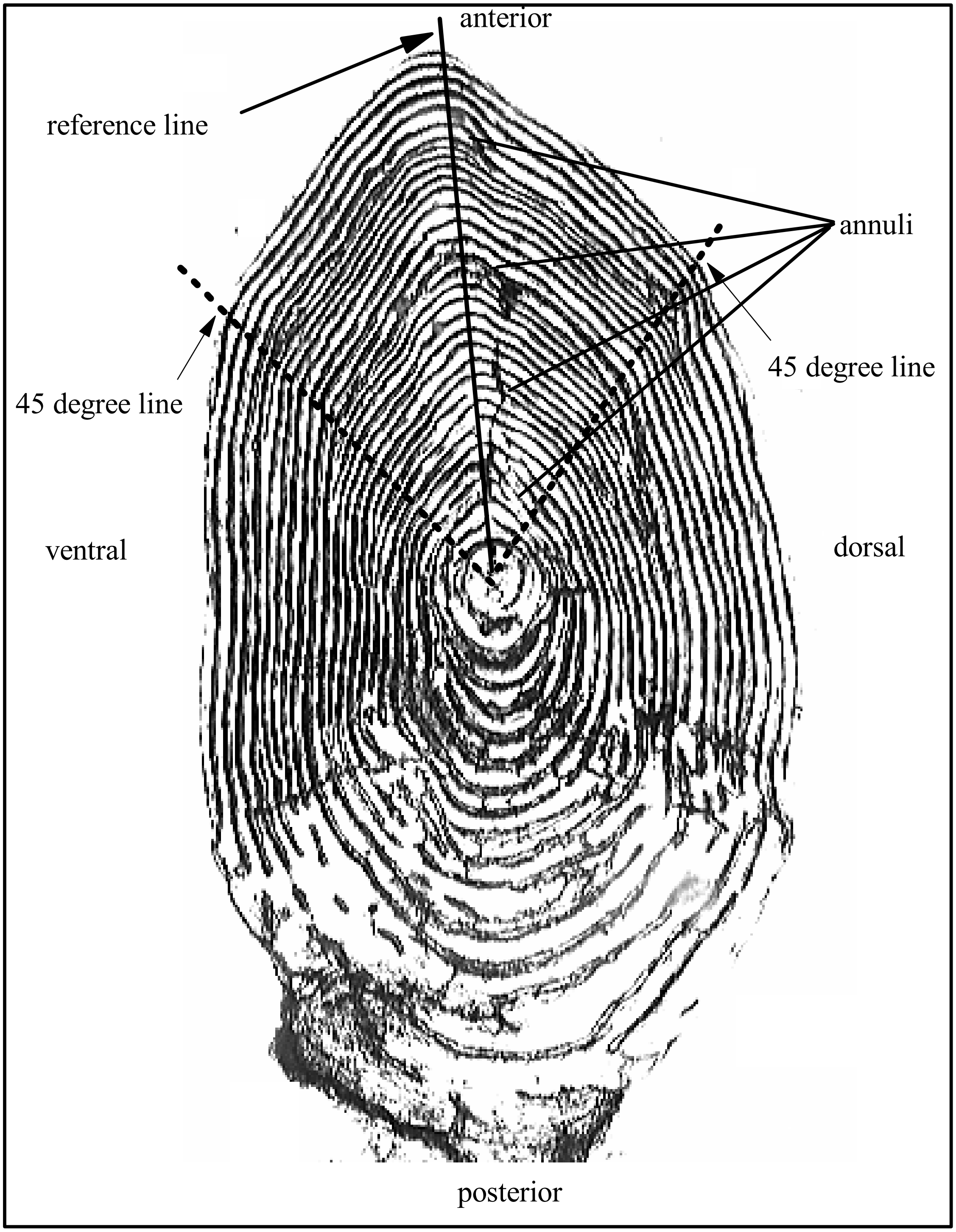


**Figure 4.–View of a typical cutthroat trout scale sampled in August.** Circuli are the concentric lines around the focus (center) of the scale. Circuli are closely spaced during the winter months defining the annulus. Data are collected along the reference line drawn along the longest axis, from the scale focus to the anterior edge of the scale.

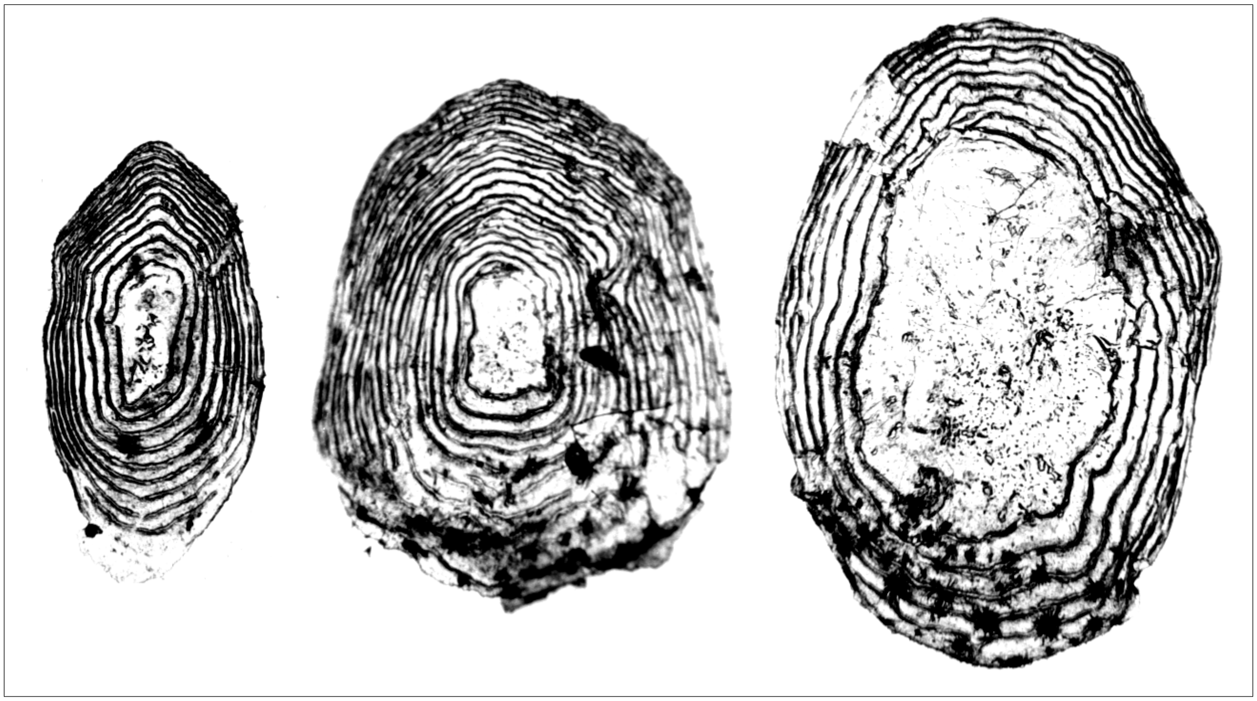

**Figure 5.–Regenerated scales are readily identified by a scale center that is clear, pebbly, or irregularly formed. These scales should not be used because they lack complete age and growth information.**

## First Year Annulus

It is essential to identify scales that are missing the first year annulus. In some populations, 40% of the cutthroat trout may not have a recognizable first year annulus (Ericksen 1997). Failure to account for this will significantly bias age estimates. Scales that are missing the first annulus typically have more circuli before the first apparent annulus than are normally observed (Figure 7). Normal scales will have fewer circuli before the first annulus than between the first and second annuli, because scales are formed late in the season during the first year of life. Downs (1995) developed a useful algorithm to identify missing first year annuli for westslope cutthroat trout *Oncorhynchus clarki lewisi*:

> **If the number of circuli from the first annulus to the second is less than or equal to the number of circuli plus 1 up to the first annulus, add 1 year. If there is no second annulus, and the number of circuli to the first annulus is greater than 6, add 1 year.**

I recommend using this algorithm to determine whether a scale is missing the first year annulus. For example, in the first situation, if you counted seven circuli between the first and second annulus, and six circuli up to the first apparent annulus, you would assume it was missing an annulus and add 1 year (i.e., since $7 \leq 6+1$).

## Identification of Annuli in Older Fish

As cutthroat trout get older, growth slows and fewer circuli are laid down during the growing season (Figure 8). This makes identification of annuli in older fish more difficult. In some cases, 2 or 3 circuli separate individual annuli and these may only be discernible at the anterior margin of the scale and not along the sides. It is essential to view the anterior margin of the scale under high magnification to identify individual annuli (Figure 8). Under high magnification the annuli may appear to be separated by “wavy” circuli. I recommend grouping all fish above a certain age into one age class (e.g., age 7+). In most cases there are very few fish above a certain age. Pooling fish above this age will reduce aging bias.


**Figure 6.–Progressive development of cutthroat trout scales from age 1 to age 6.** These scales were all collected between June 4 and June 29.

## Checks or False Annuli

A slowing of growth may occur during the growing season due to stress from an injury or spawning, and may result in a check (false annulus) (Figure 9). If these are mistakenly identified as annuli, age determinations will be greater than the true age. Checks are difficult to identify but usually display one or more of the following characteristics:

- A ring with closely spaced rows that are discontinuous around the edge of the scale.
- A ring with fewer rows of circuli than are present in obvious annuli.
- Circuli of the wrong type during the winter (circuli close together should be narrow rather than broad, relative to other circuli).

## Estimation of Total Age

The reader estimates the age of a cutthroat trout by counting the number of annuli on the scale, plus any correction for a missing first year annulus.

In addition, the reader should be aware of what time of year the fish was sampled. For example, if the fish was sampled in early spring before the onset of rapid summer growth, there should not be any circuli past the last annulus (plus growth). If there is plus growth, then an annulus should be assumed at the anterior edge of the scale and one year should be added to the estimated age.

## AGED EXAMPLES

I have provided images of scales from cutthroat trout that were tagged and later recaptured in Appendices A, B, and C, to aid in training readers. Images of scales from known age hatchery fish are also provided in Appendix C. However, because these fish were reared in a hatchery environment for the first season, their growth was accelerated, and the algorithm to determine whether they are missing a first year annulus does not apply.

The images in the appendices can be used as an aid to training readers. First, potential readers should review the images to learn the features discussed above and to estimate total age. The reader should then use the attached overlay to compare their estimates with those that I have provided. My estimate is provided to help guide readers (note the ages provided in Appendices A and B are estimates, not known values).

## RECOMMENDATIONS

One of the most important concepts to understand is that ages are estimated, not determined, from scales. The best we can do using current technology is to obtain unbiased estimates of the age of a fish, or age composition of a population. To do this, I recommend three independent replications of each reading as a standard for aging cutthroat trout scales. Replicate readings are necessary to estimate and correct for reader

**Figure 7.–Comparison between a normal scale (left) and a scale missing the first year annulus (right).** These scales were sampled from two age 2 cutthroat trout in early June.

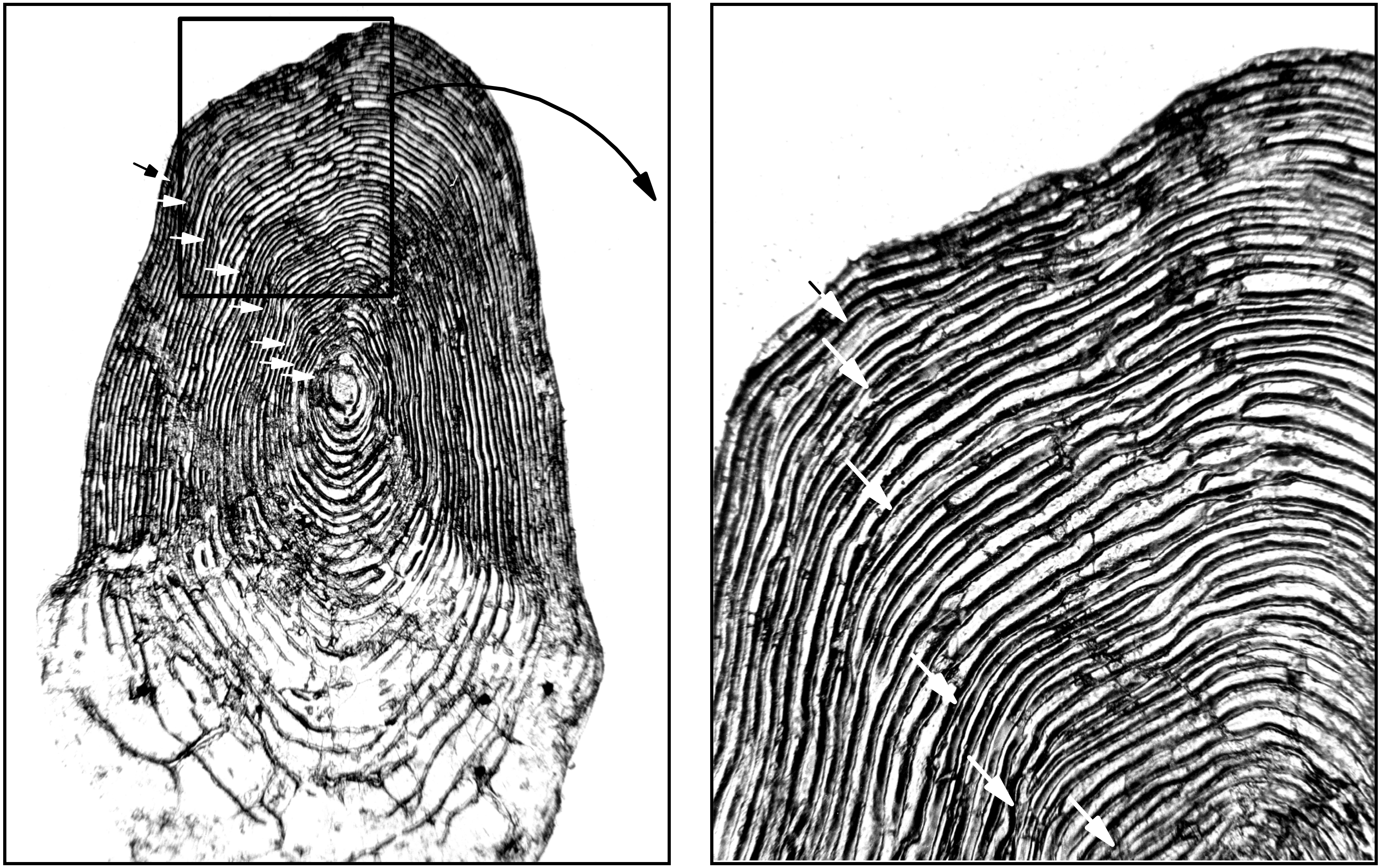

Figure 8.–A scale from a cutthroat trout sampled on September 2 estimated to be age 8 under normal (40×) magnification (left) and high (100×) magnification (right). Note the distinctive "wavy" circuli under high magnification.

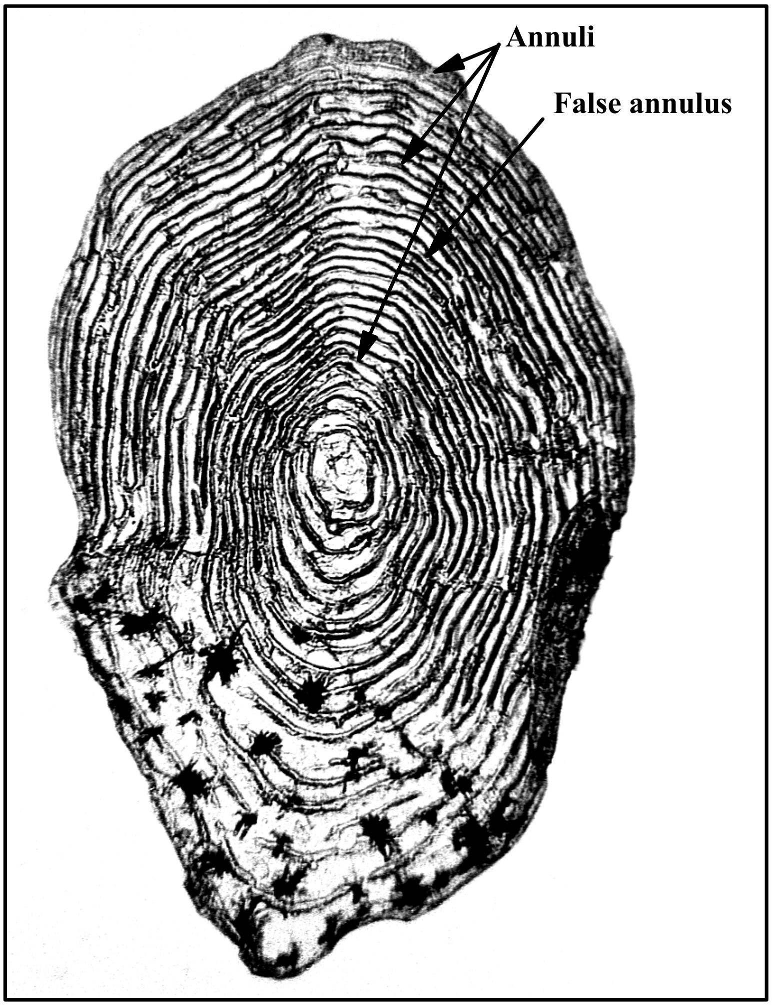


**Figure 9.–An example of a cutthroat trout scale with a false annulus.** This scale was collected from an age 3 hatchery fish (1993 brood) in late April 1996. The fish developed the false annulus (check) on its scale when it was released into Auke Lake in June 1994.

variation (Richards et al. 1992, Ericksen 1997). The reader should be provided with only the sample number, collection date, and location of the sample. Fish length should not be provided to the reader as this can bias age estimates.

Scale readers need frequent, standardized training in scale aging techniques. When scale-aging criteria are unused over a period of time, readers tend to forget and/or alter them (Jones et al. 1992, Ericksen 1997). Frequent training, and interest in the task, is necessary to ensure that readers maintain consistent and accurate aging techniques over time. Agencies should develop a reference set of 25 to 30 scale samples for cutthroat trout populations from as many locations as possible. Ideally, there would be a reference set for each population from which age information is needed. Alternatively, reference sets could be classified into several categories based on scale type (e.g., potamodromous—difficult to age; anadromous—easy to age). These reference sets need to include scales from a range of ages and paired scales from tagged fish recaptured one or more years later.

Each set can be used to train new readers to age scales sampled from that population (or scale category). Readers should review each reference set periodically to maintain consistency in their aging techniques.

Whenever possible, use aging error models (Ericksen 1997) to estimate and correct for reader variation and bias. To develop an aging error model, construct a calibration set of 250 to 300 scale samples for a given location/ classification type. The calibration set will be used to estimate the aging error and bias for a given reader and location/classification type. Ideally, about 50% of the samples should consist of scale samples from tagged fish that were later recaptured. The hiatus between recapture events should span as many years as possible. The calibration samples should be randomly ordered in individually numbered envelopes marked only with the month and day of sample collection, and location/classification type.

Development of aging error models requires a commitment to sample a population for several (preferably at least 4) years, since paired scale samples from tag/recaptured fish are needed to estimate reader accuracy. I recommend that all captured cutthroat trout be tagged and sampled for scales at least during the first 2 years. After the second year, all recaptured fish need to be scale sampled to obtain paired scale samples for several (preferably at least 3) known age increments (years between capture events).

# ACKNOWLEDGMENTS

Doug Jones, Roger Harding, and Kurt Kondzela provided logistical support and shared with me their accumulated knowledge of cutthroat trout biology. Kris Munk with the Coded Wire Tag and Otolith Processing Lab allowed us to use the lab facilities to photograph cutthroat trout scales. Zelda Swain and Carole Coyle collected and digitized the bulk of the images used in this manual. Bob Marshall and Paul Suchanek provided critical review of this report. Alma Seward prepared the final copy of this report for publication.

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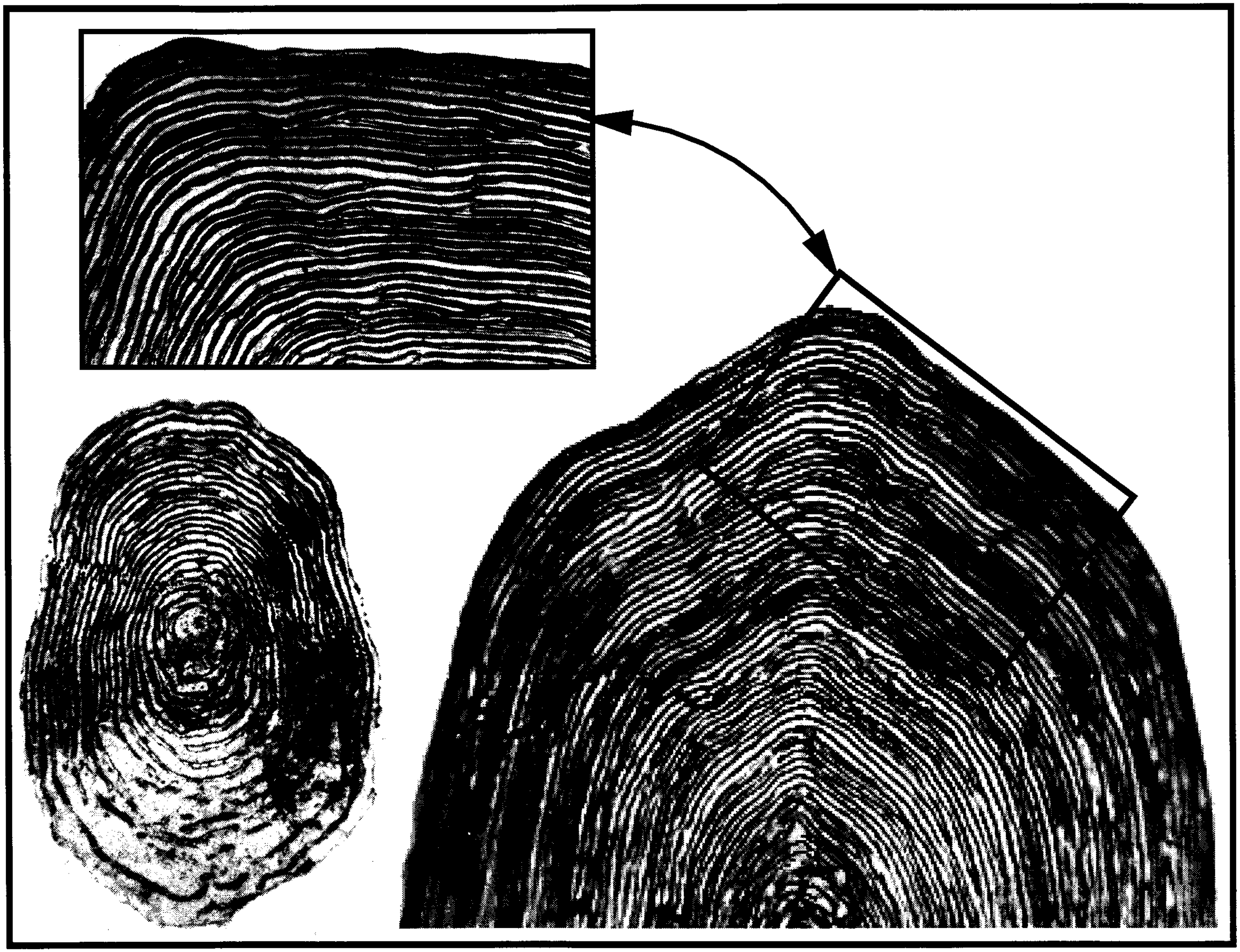
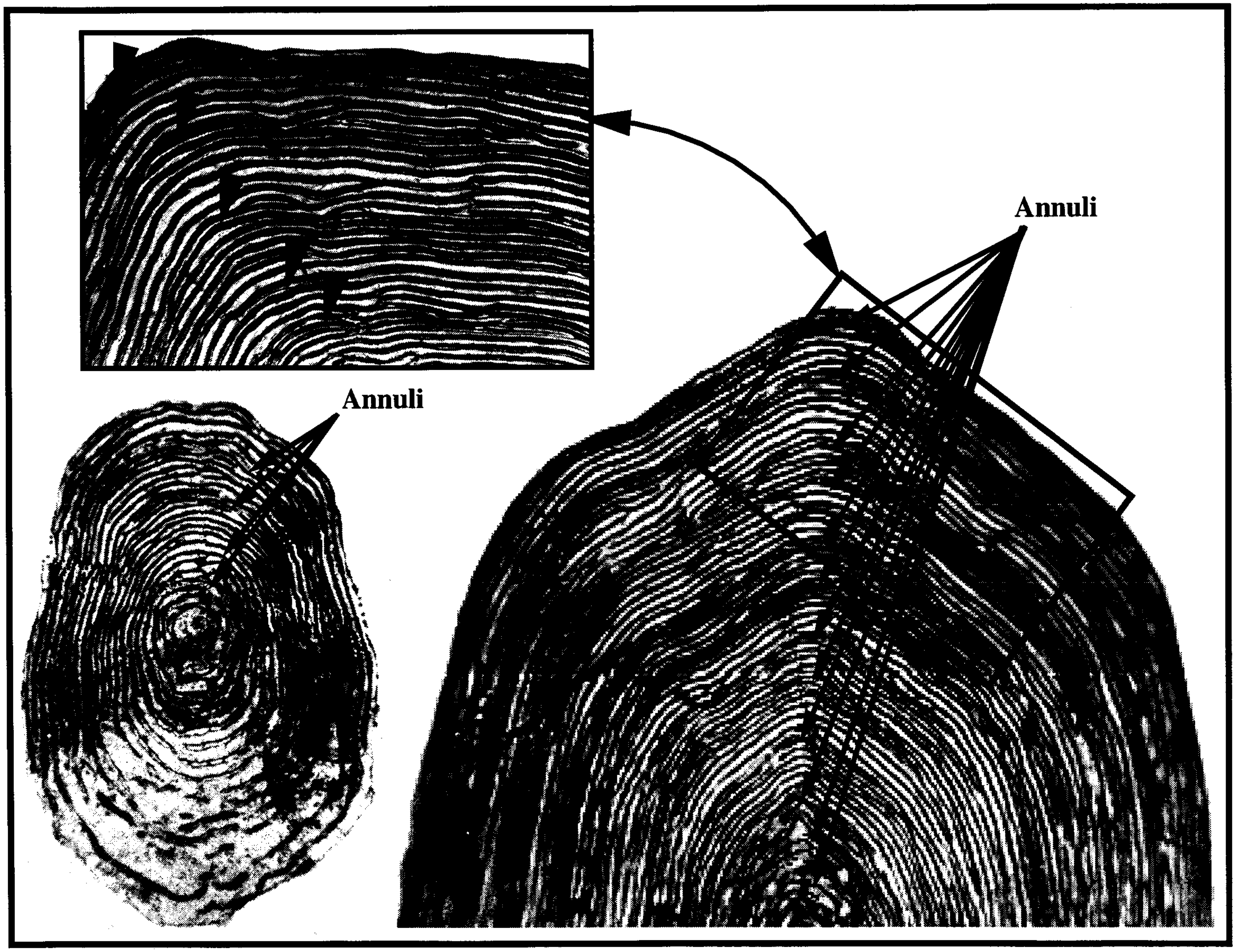
# APPENDIX A

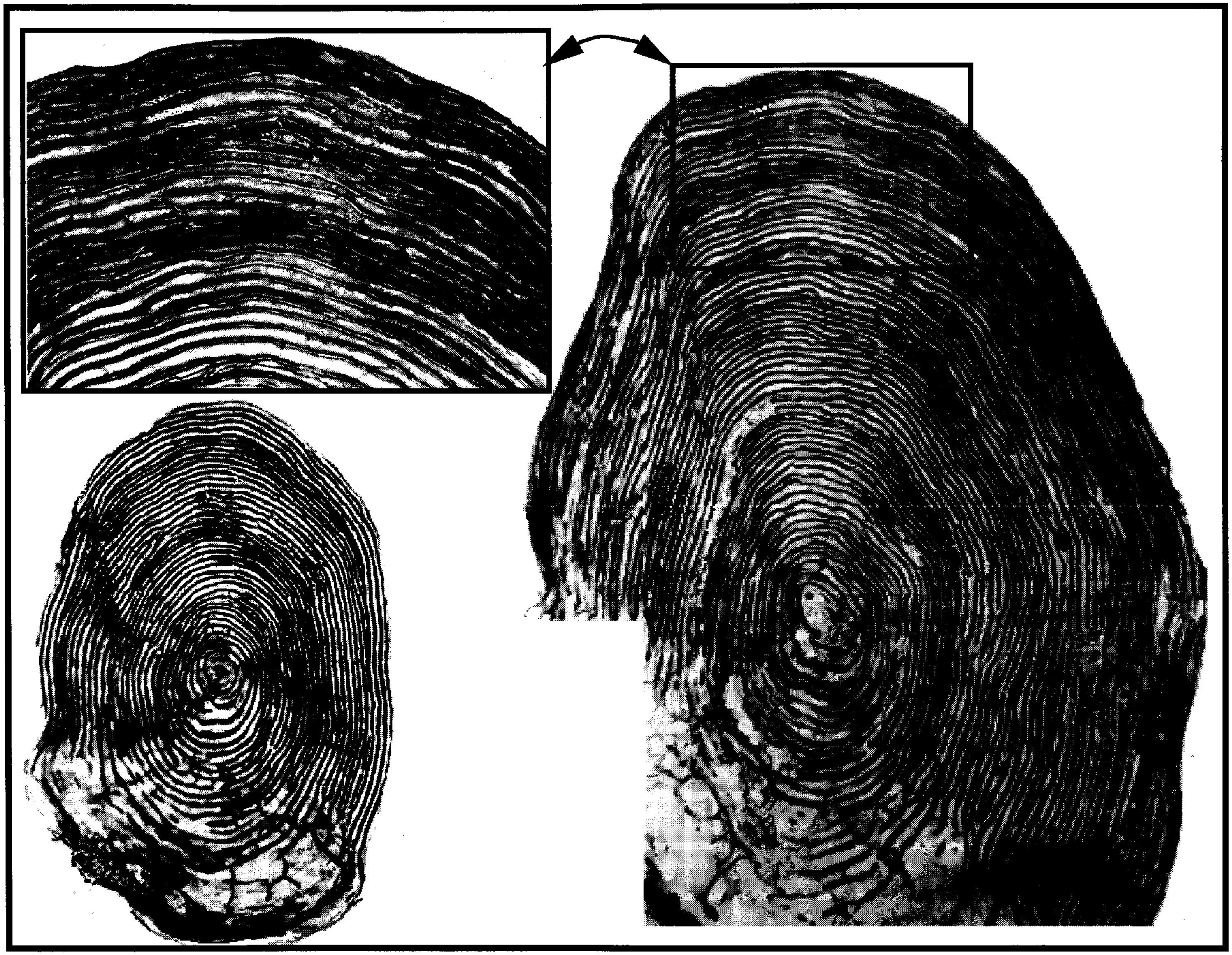
# TURNER LAKE SCALES: LAKE-DWELLING, EASY TO AGE



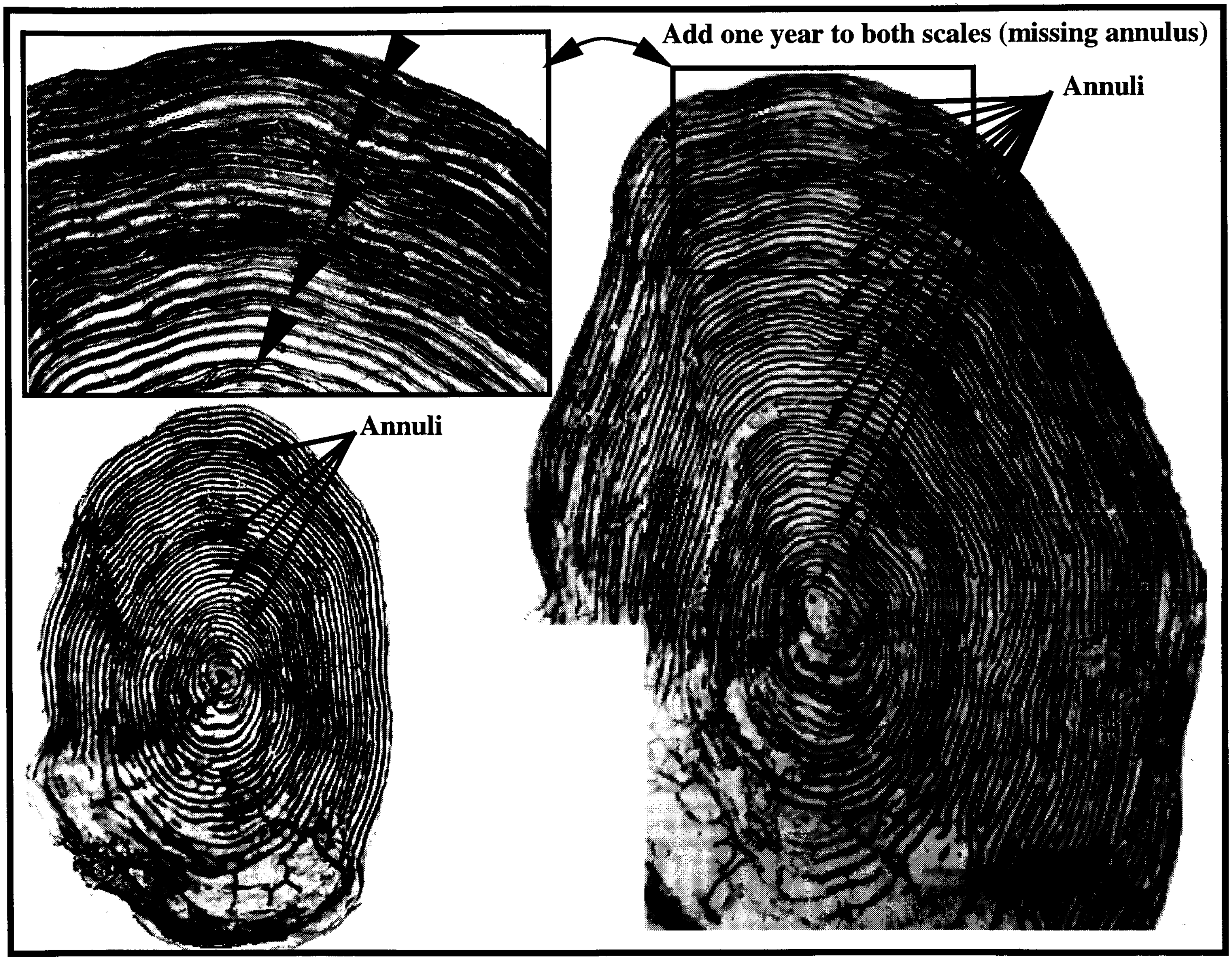
**Appendix A1.–Scales from cutthroat trout when it was tagged (181 mm) at Turner Lake on July 21, 1989 (left), and recaptured (505 mm) on August 13, 1997 (right).**



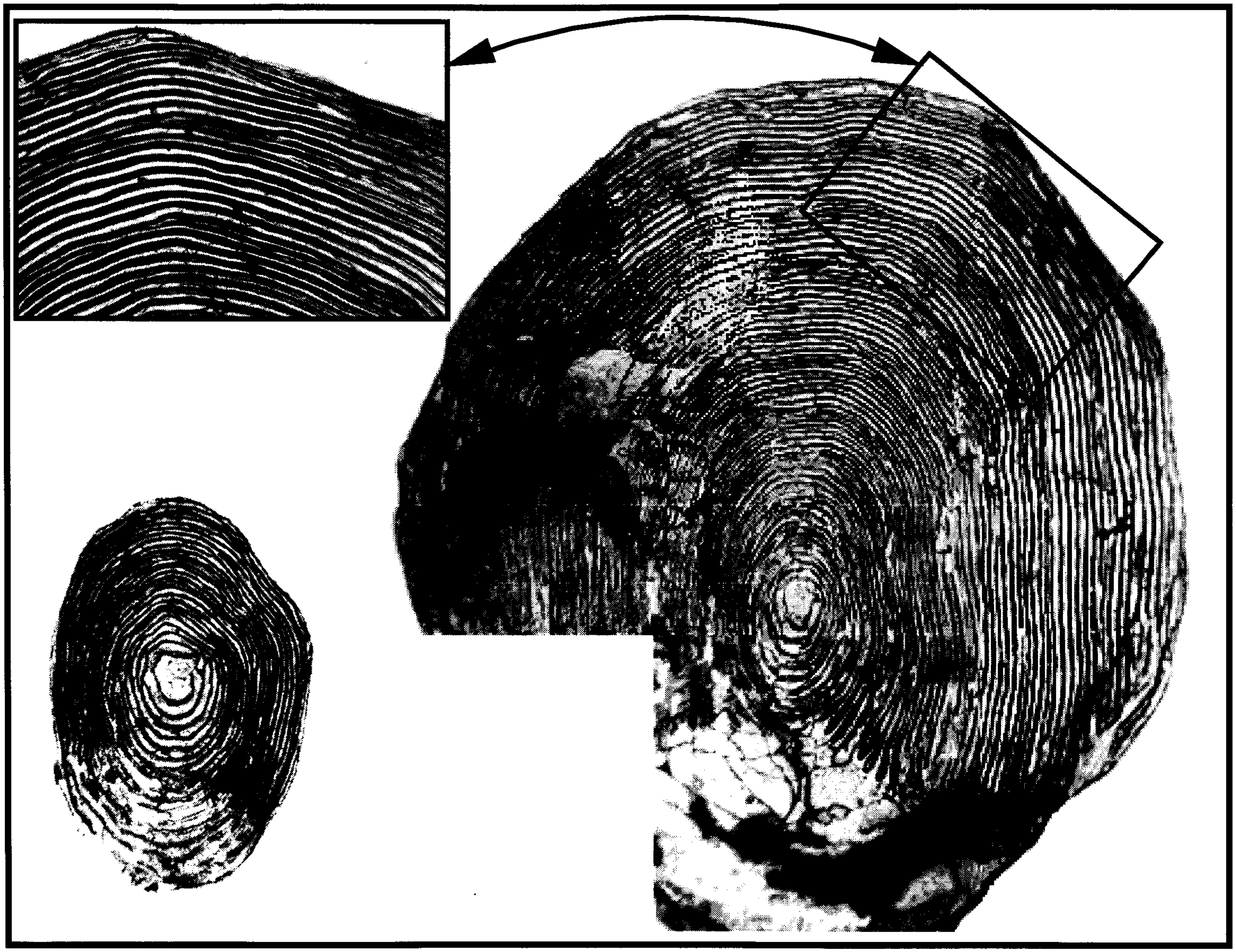

**Appendix A1 with overlay.**



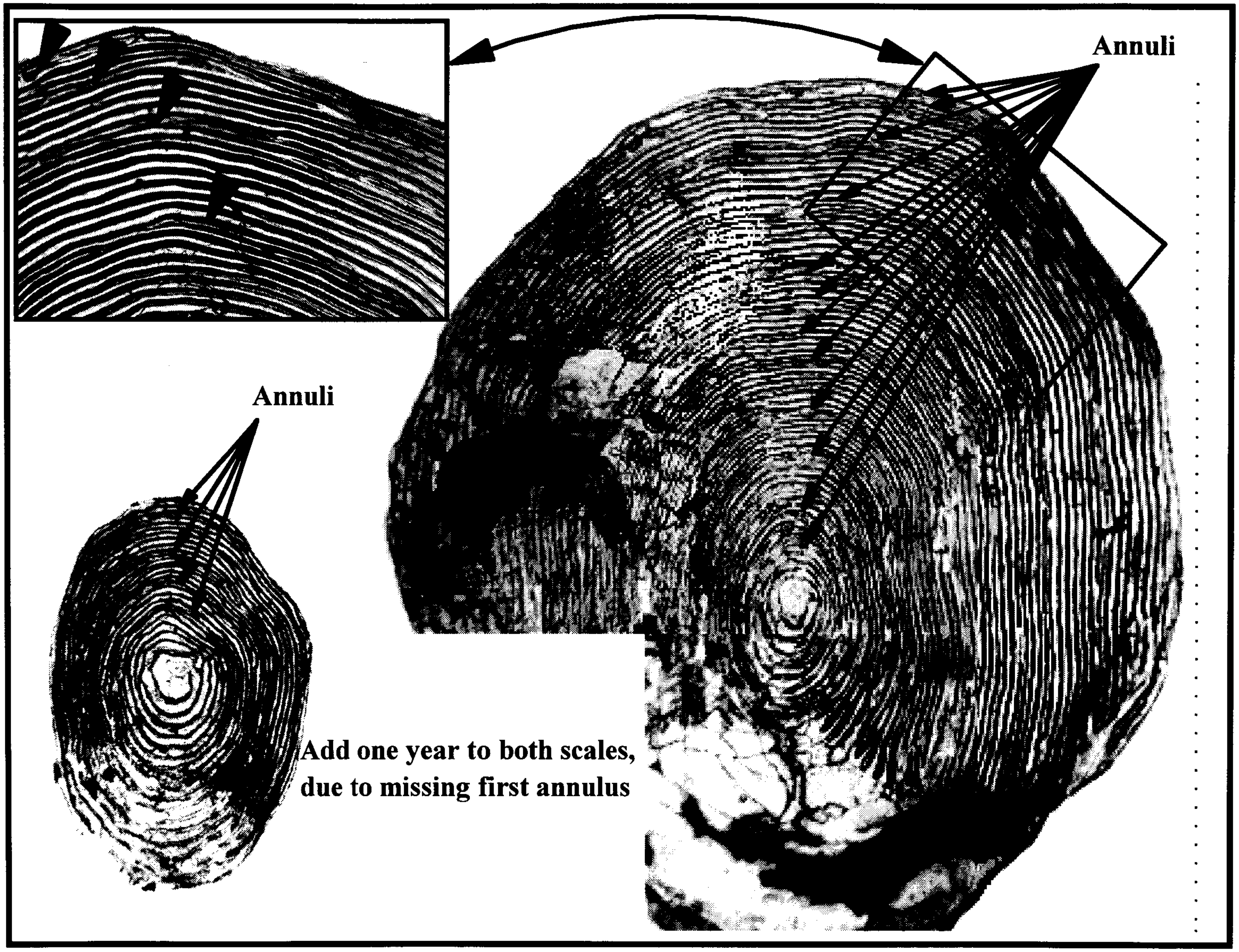
**Appendix A2.–Scales from cutthroat trout when it was tagged (252 mm) at Turner Lake on July 19, 1990 (left), and recaptured (430 mm) on July 29, 1997 (right).**




**Appendix A2 with overlay.**



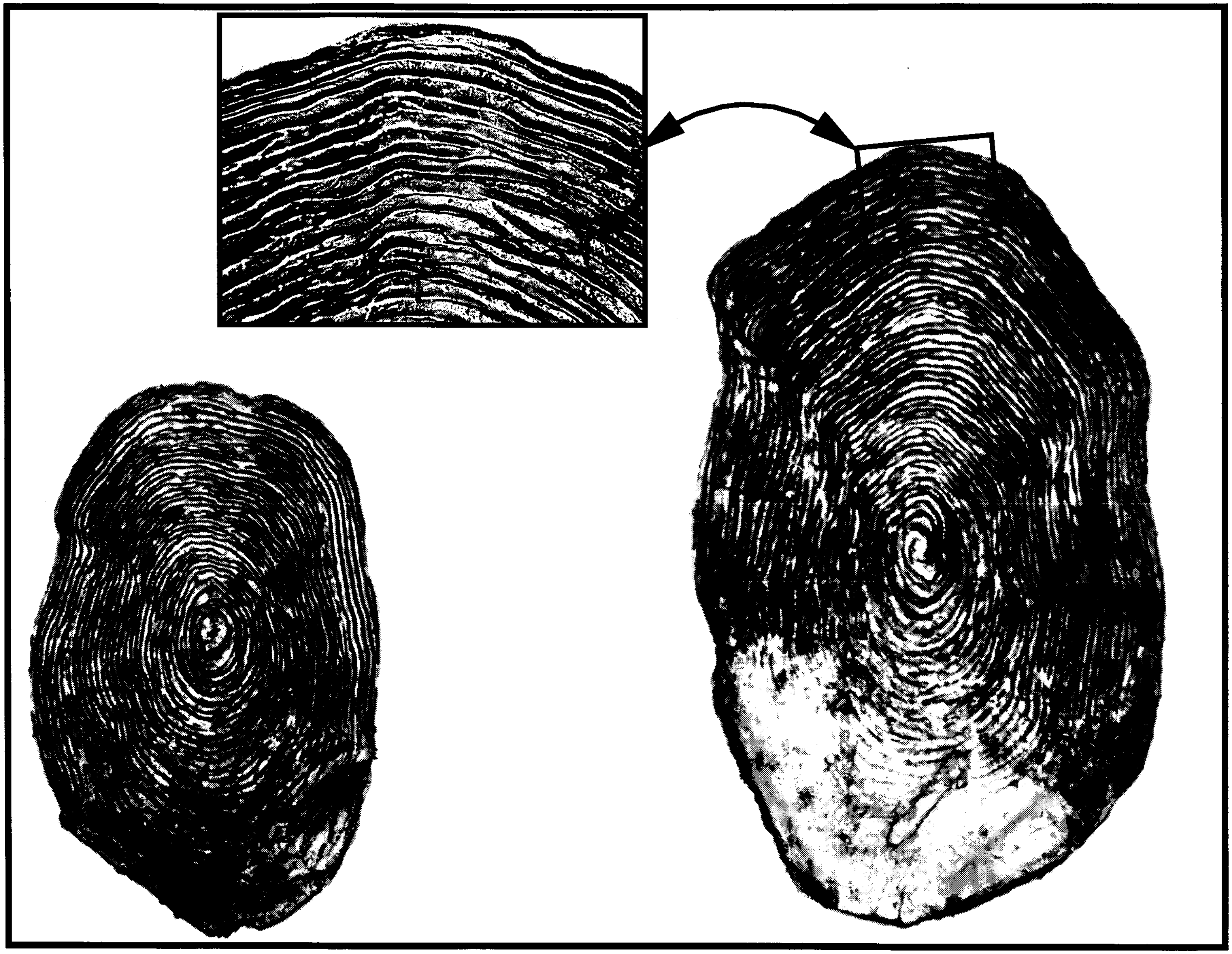
**Appendix A3.–Scales from cutthroat trout when it was tagged (255 mm) at Turner Lake on July 24, 1989 (left), and recaptured (575 mm) on August 11, 1997 (right).**



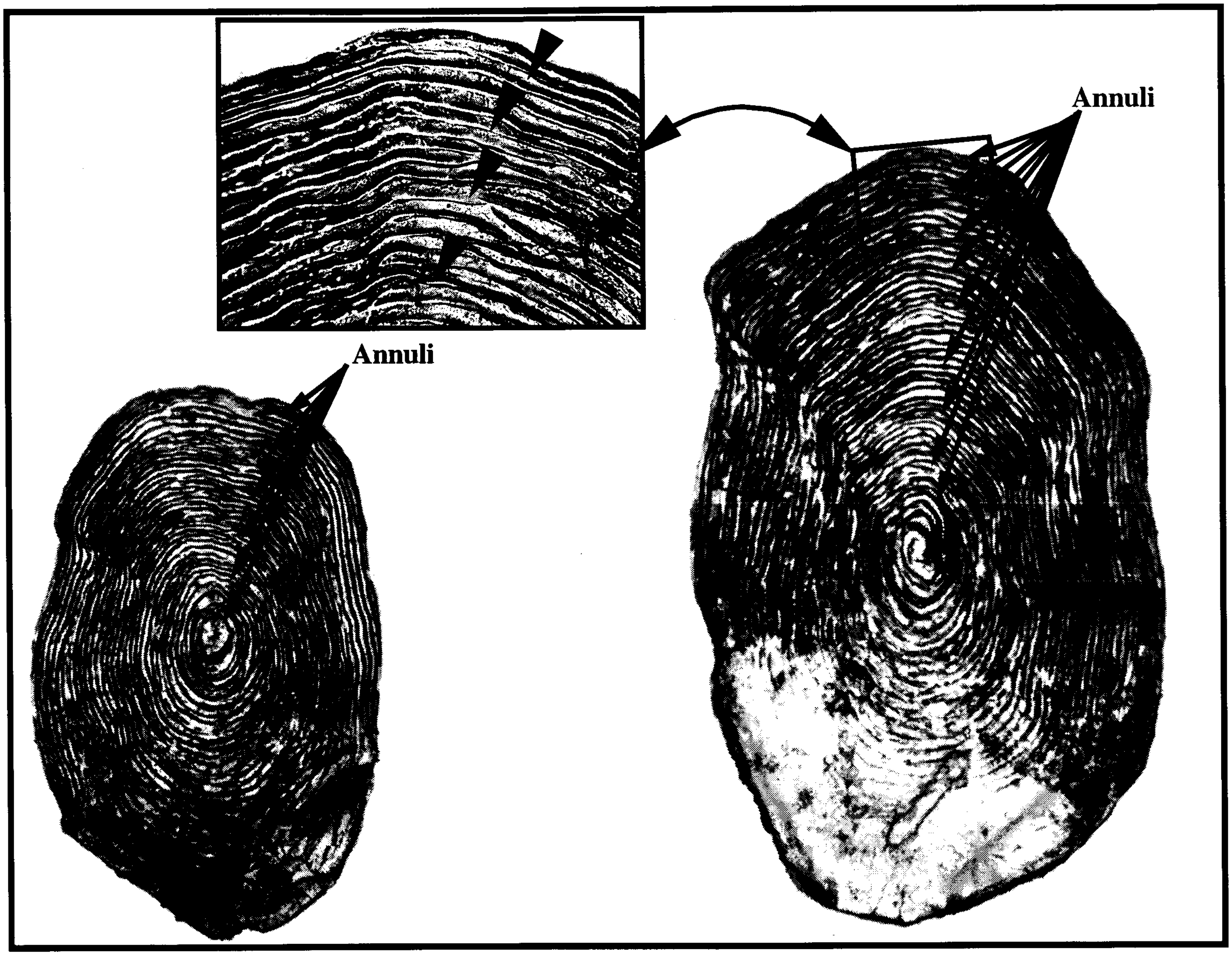

**Appendix A3 with overlay.**

# APPENDIX B

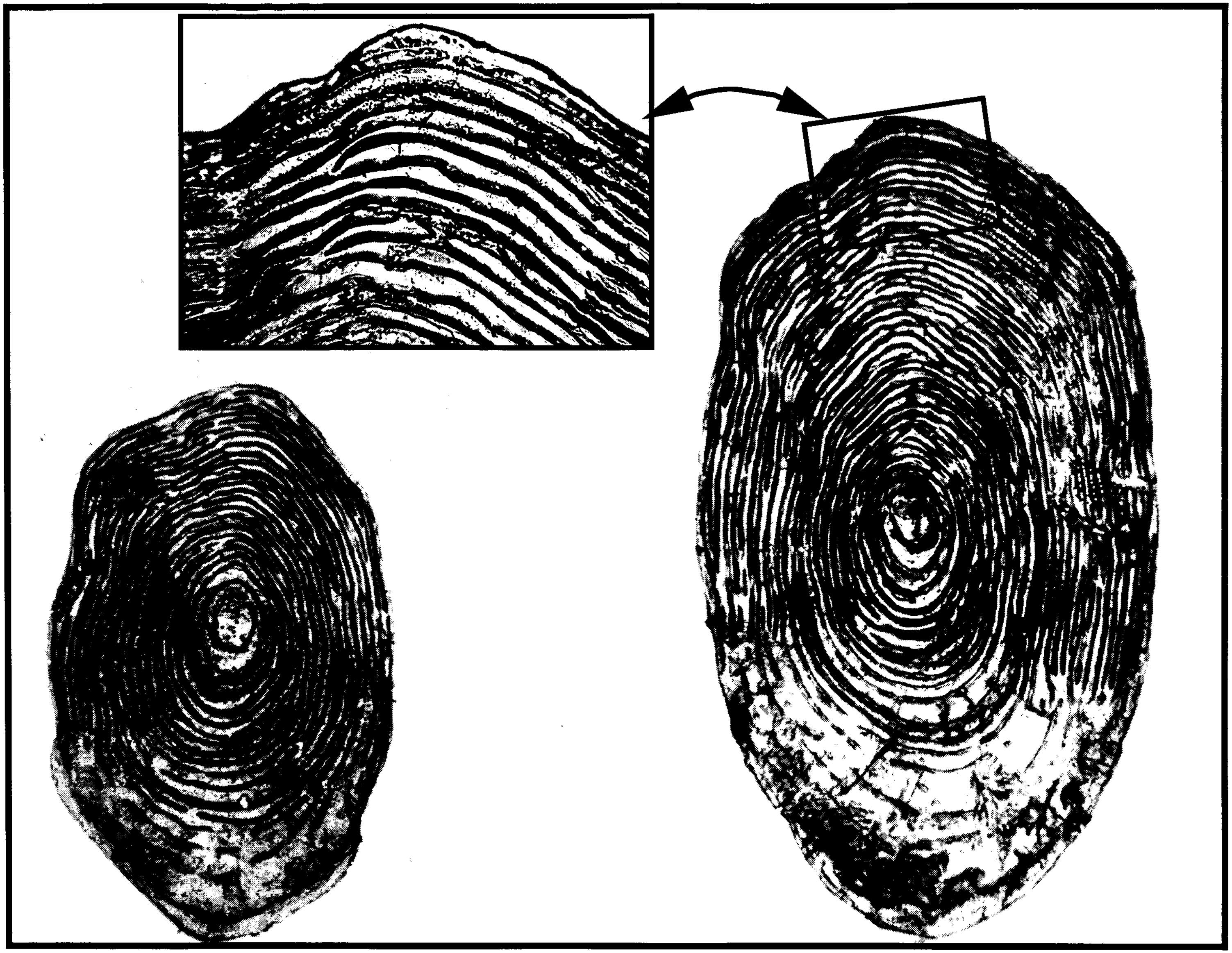
# FLORENCE LAKE SCALES:
# LAKE-DWELLING, DIFFICULT TO AGE



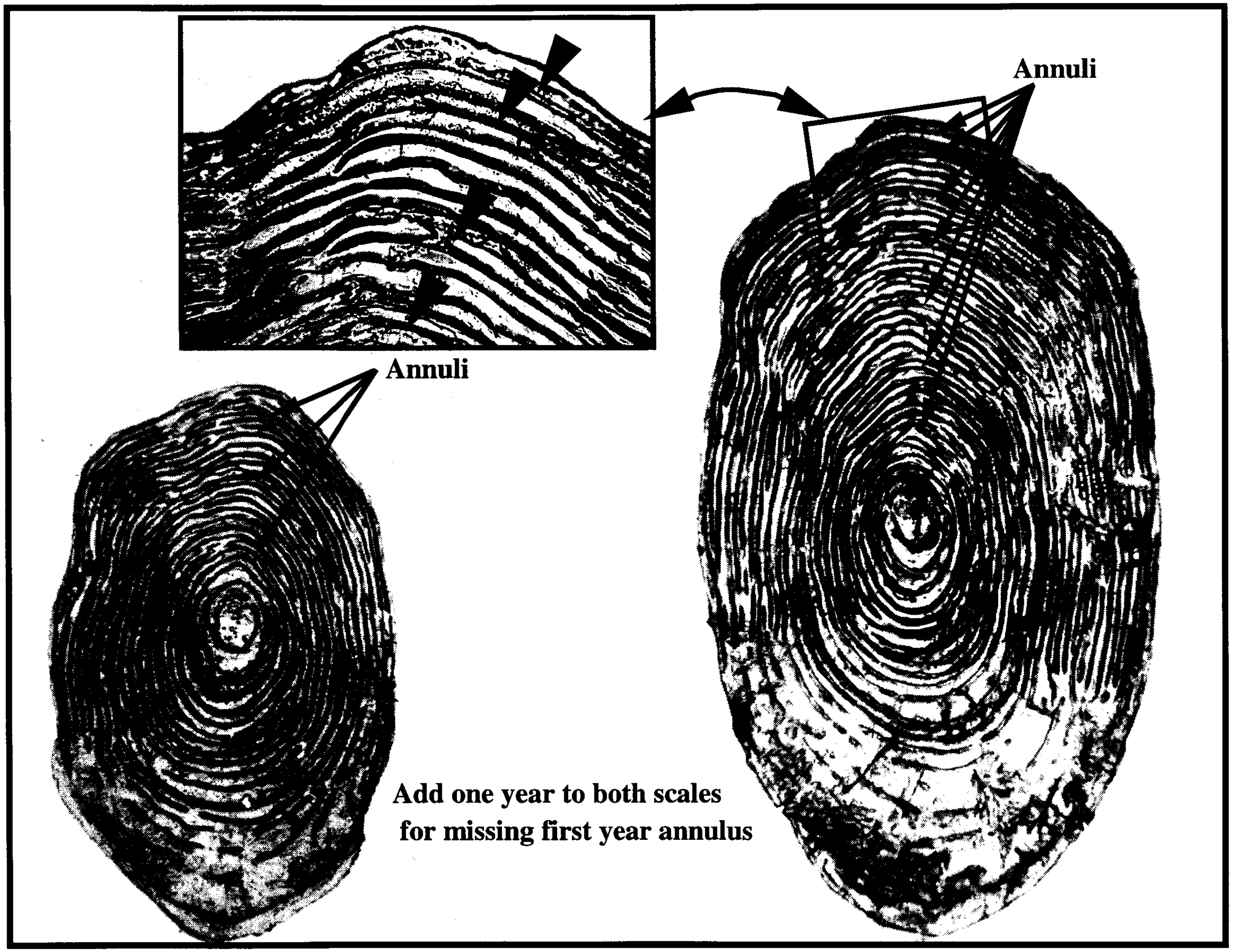
**Appendix B1.–Scales from cutthroat trout when it was tagged (237 mm) at Florence Lake on August 7, 1990 (left), and recaptured (303 mm) on May 27, 1994 (right).**



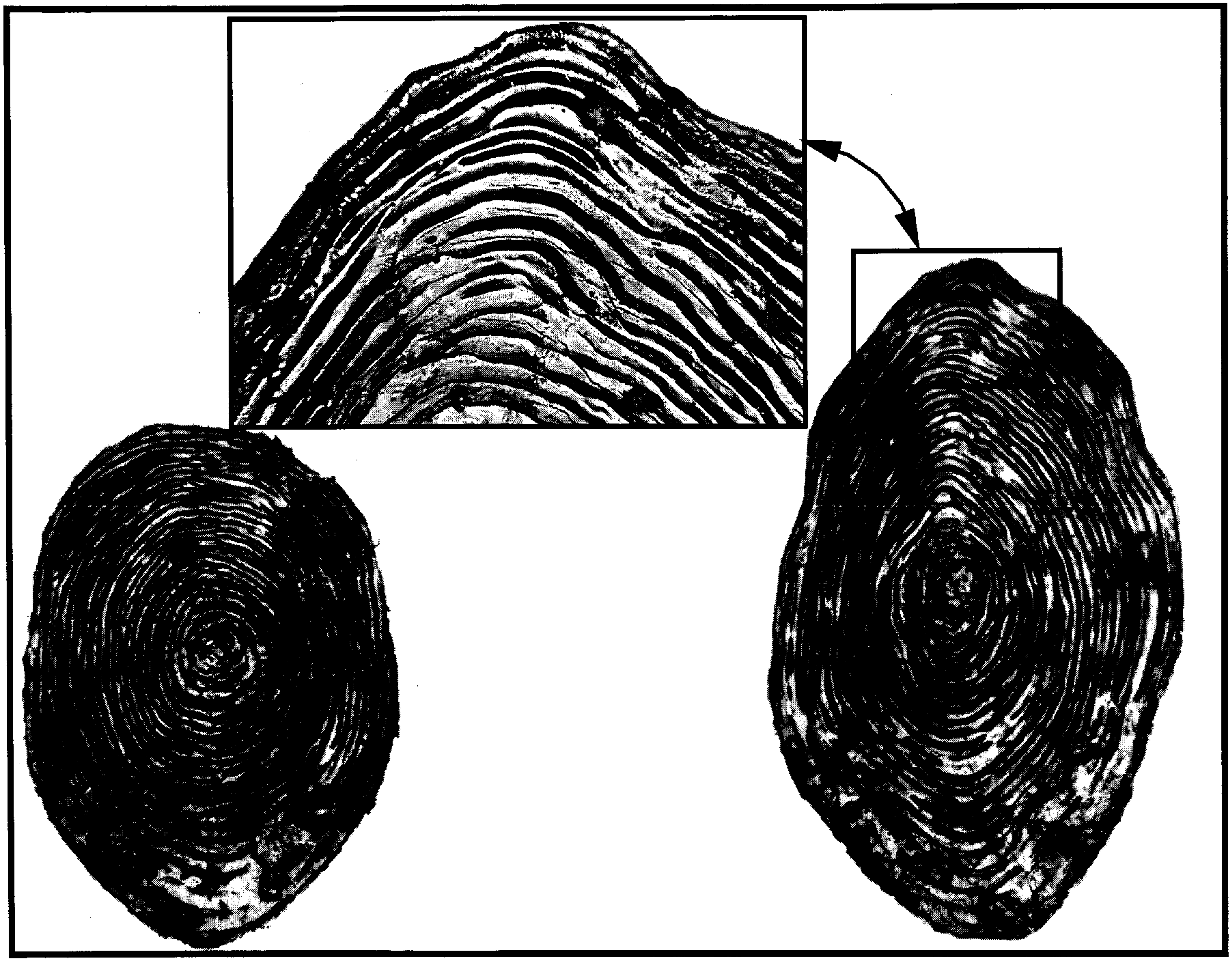

**Appendix B1 with overlay.**



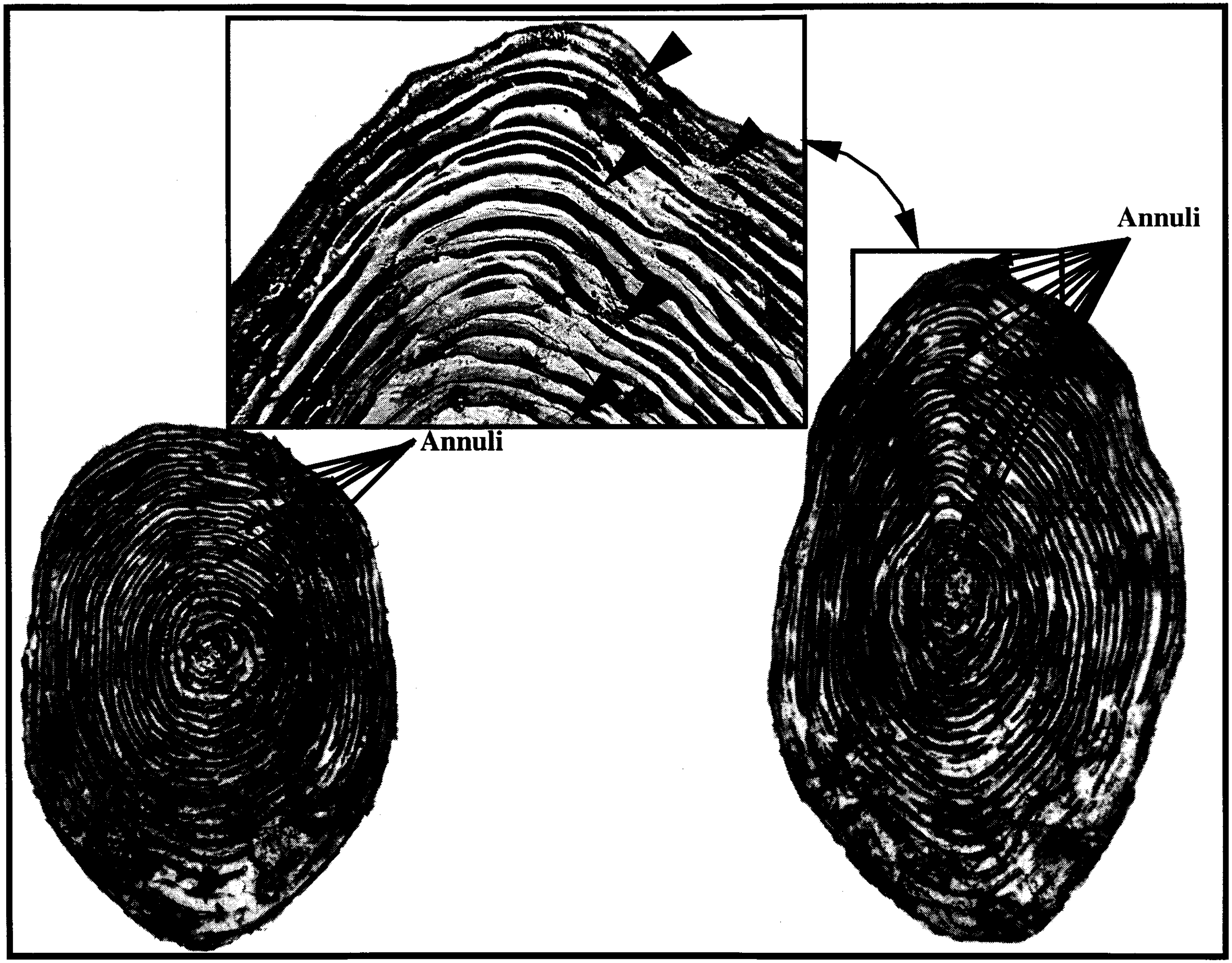
**Appendix B2.–Scales from cutthroat trout when it was tagged (197 mm) at Florence Lake on August 18, 1988 (left), and recaptured (259 mm) on June 8, 1992 (right).**




**Appendix B2 with overlay.**



**Appendix B3.–Scales from cutthroat trout when it was tagged (189 mm) at Florence Lake on August 26, 1989 (left), and recaptured (227 mm) on April 14, 1994 (right).**

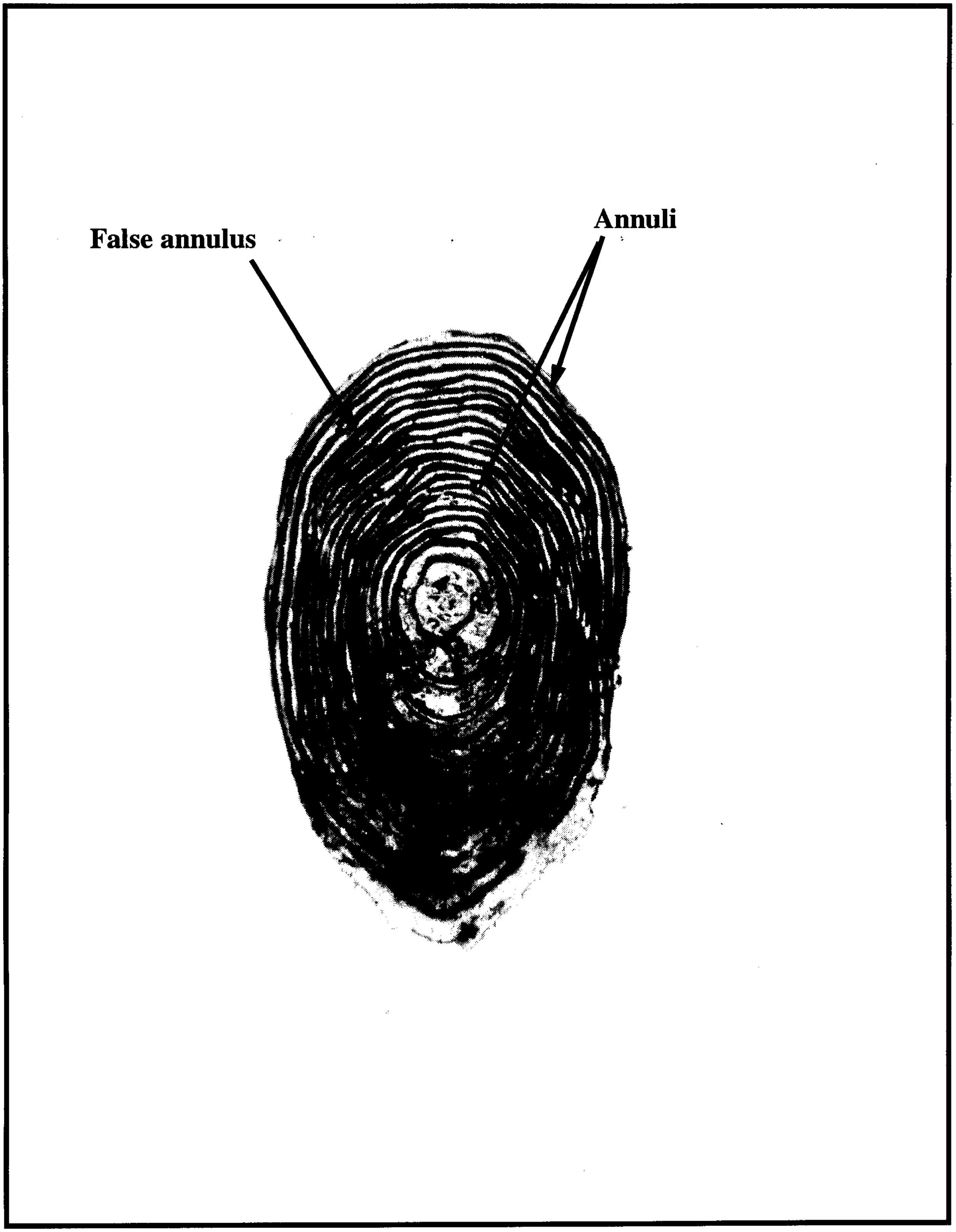



**Appendix B3 with overlay.**

# APPENDIX C

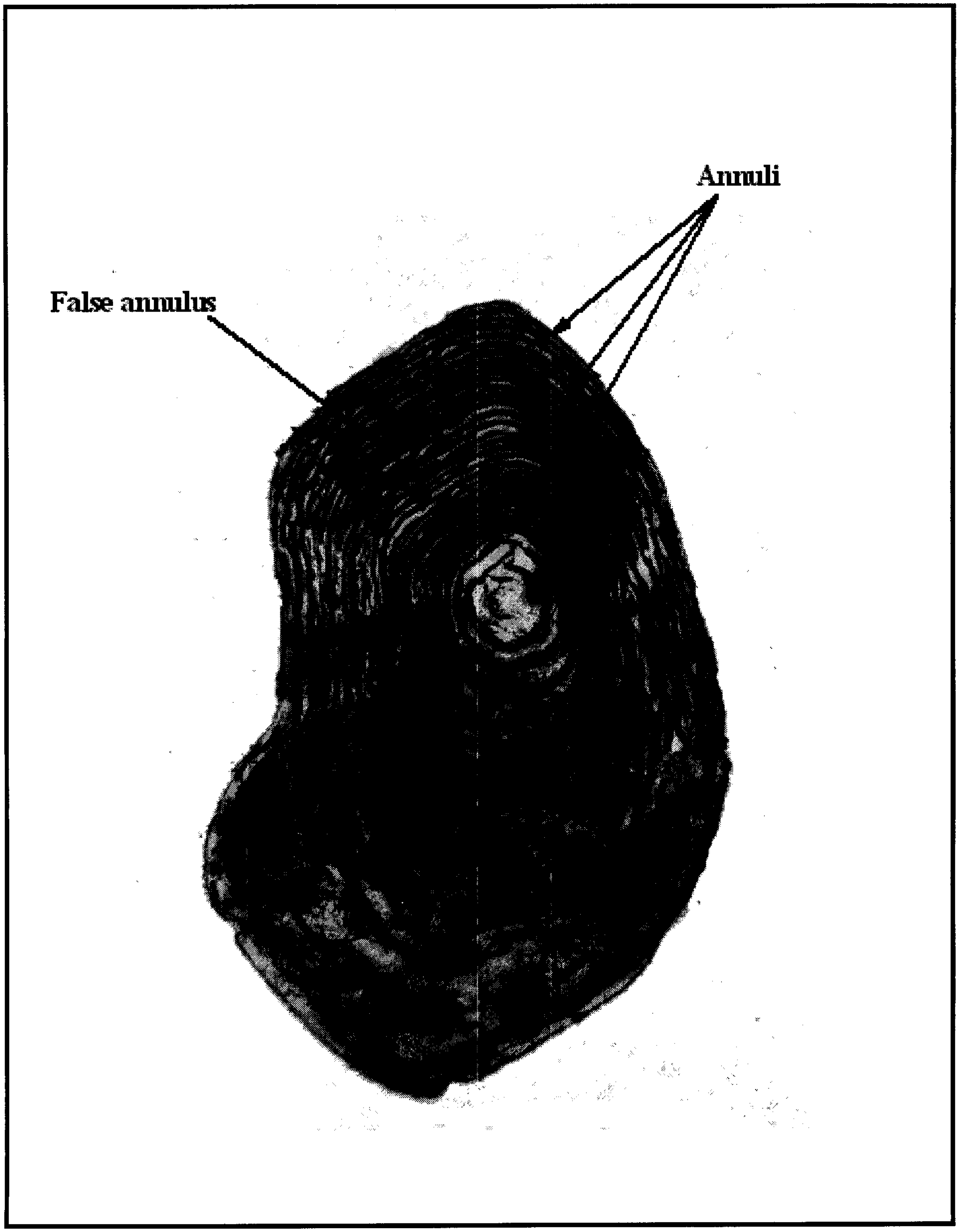
# AUKE CREEK SCALES: ANADROMOUS

**Appendix C1.–A scale from a 135 mm (FL) known age 2 (BY93) hatchery cutthroat trout released into Auke Lake in June 1994, and sampled on May 2, 1995.**

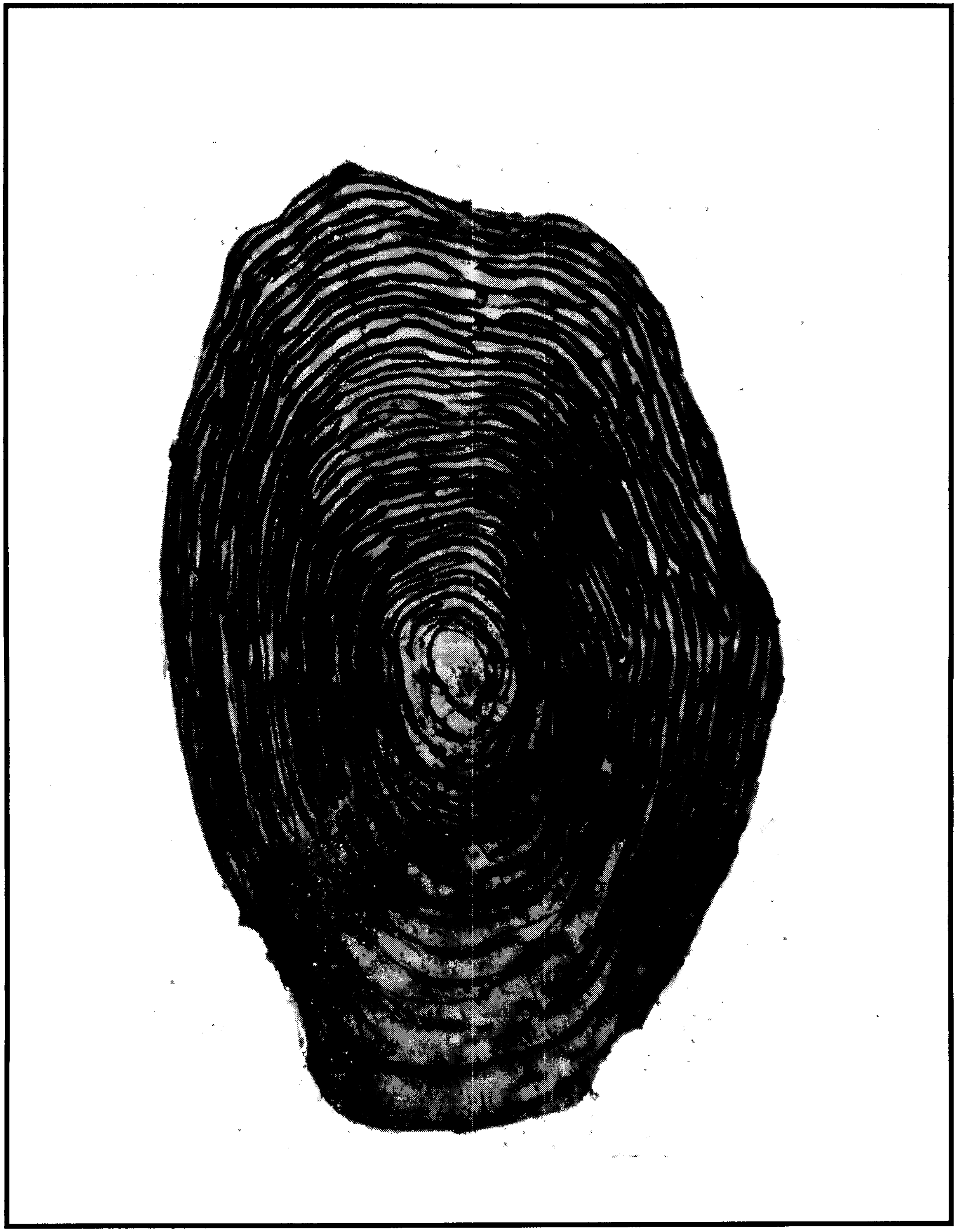



**Appendix C1 with overlay.**

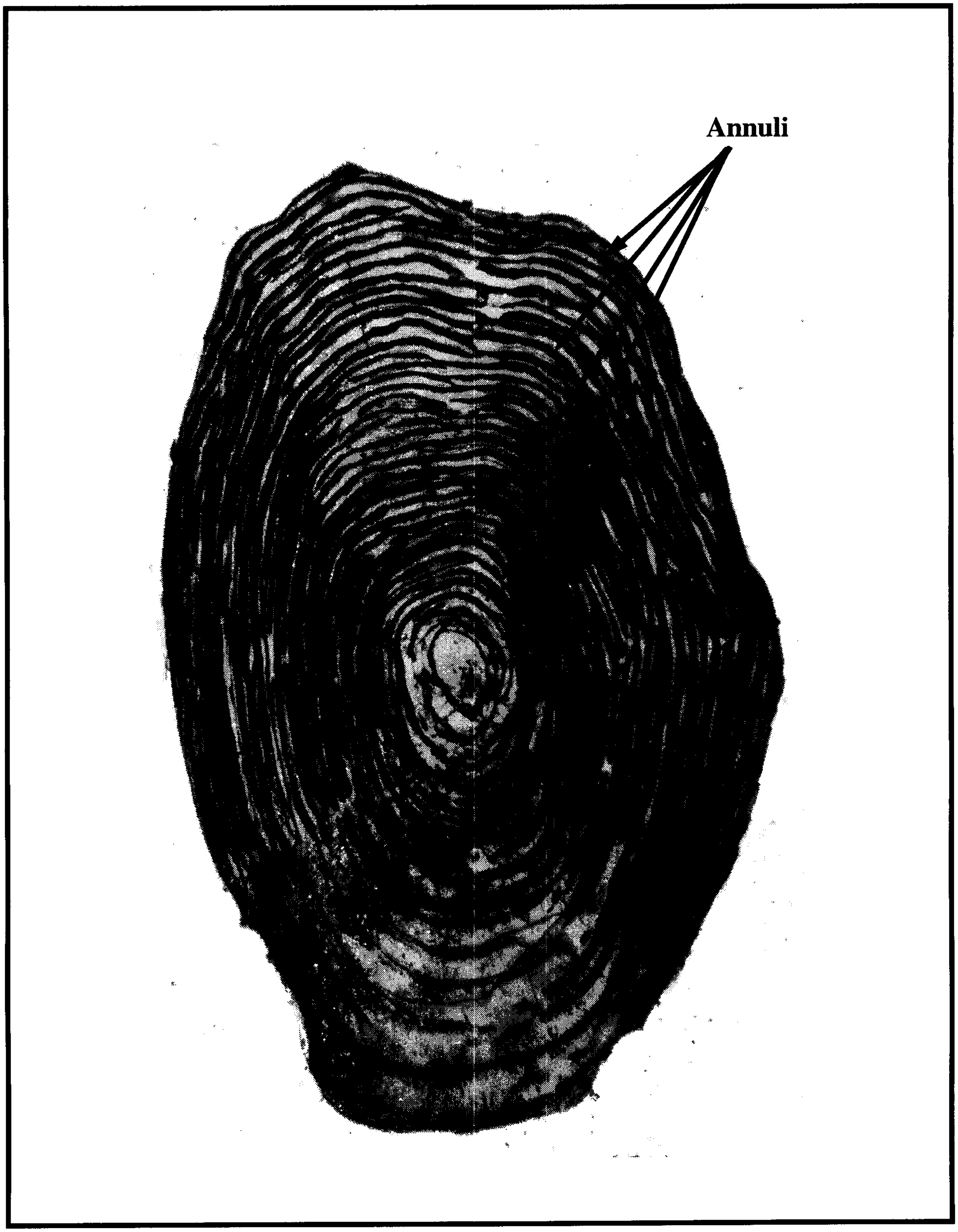
**Appendix C2.–A scale from a 228 mm (FL) known age 3 (BY93) hatchery cutthroat trout released into Auke Lake in June 1994, and sampled on April 24, 1996.**



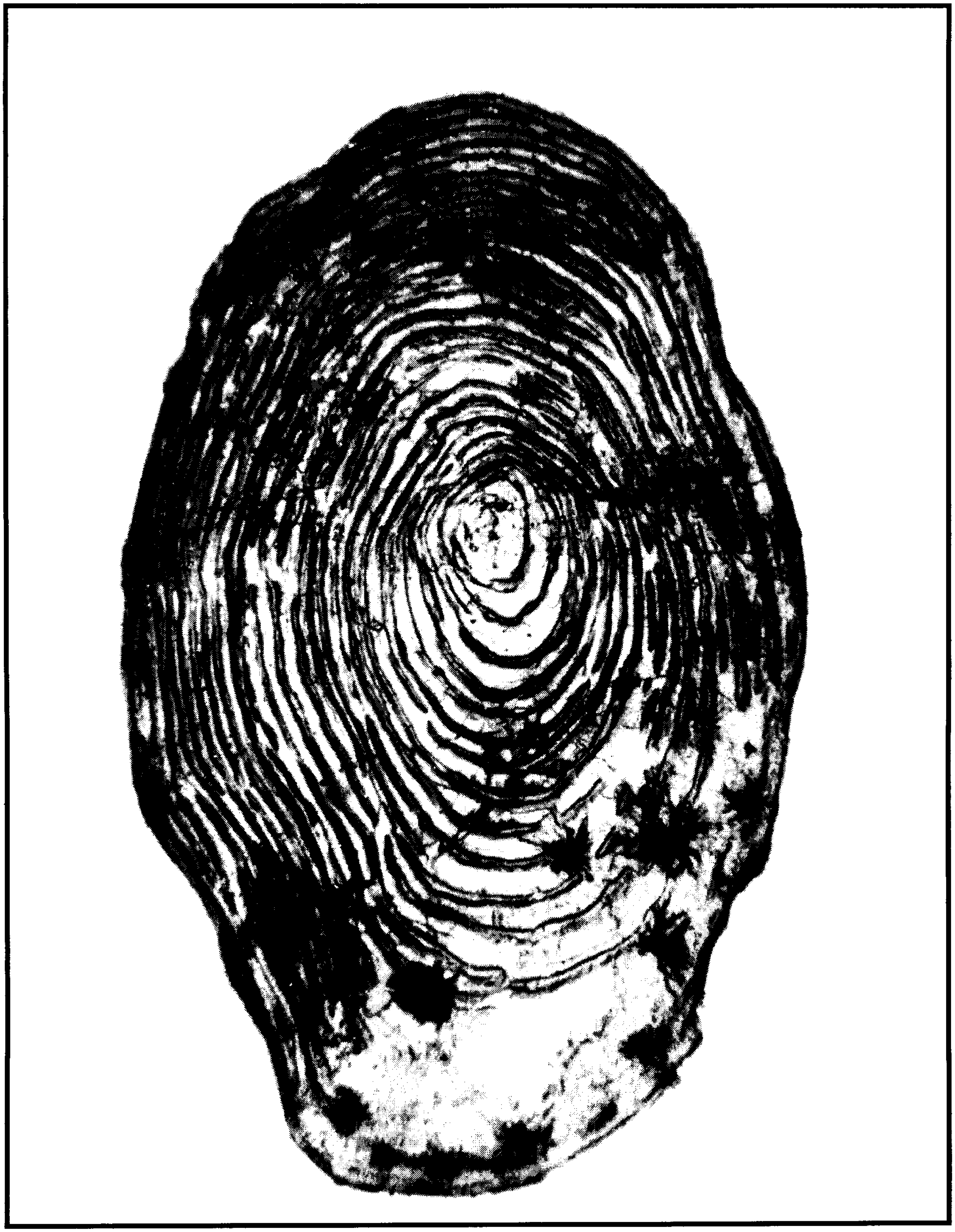

**Appendix C2 with overlay.**



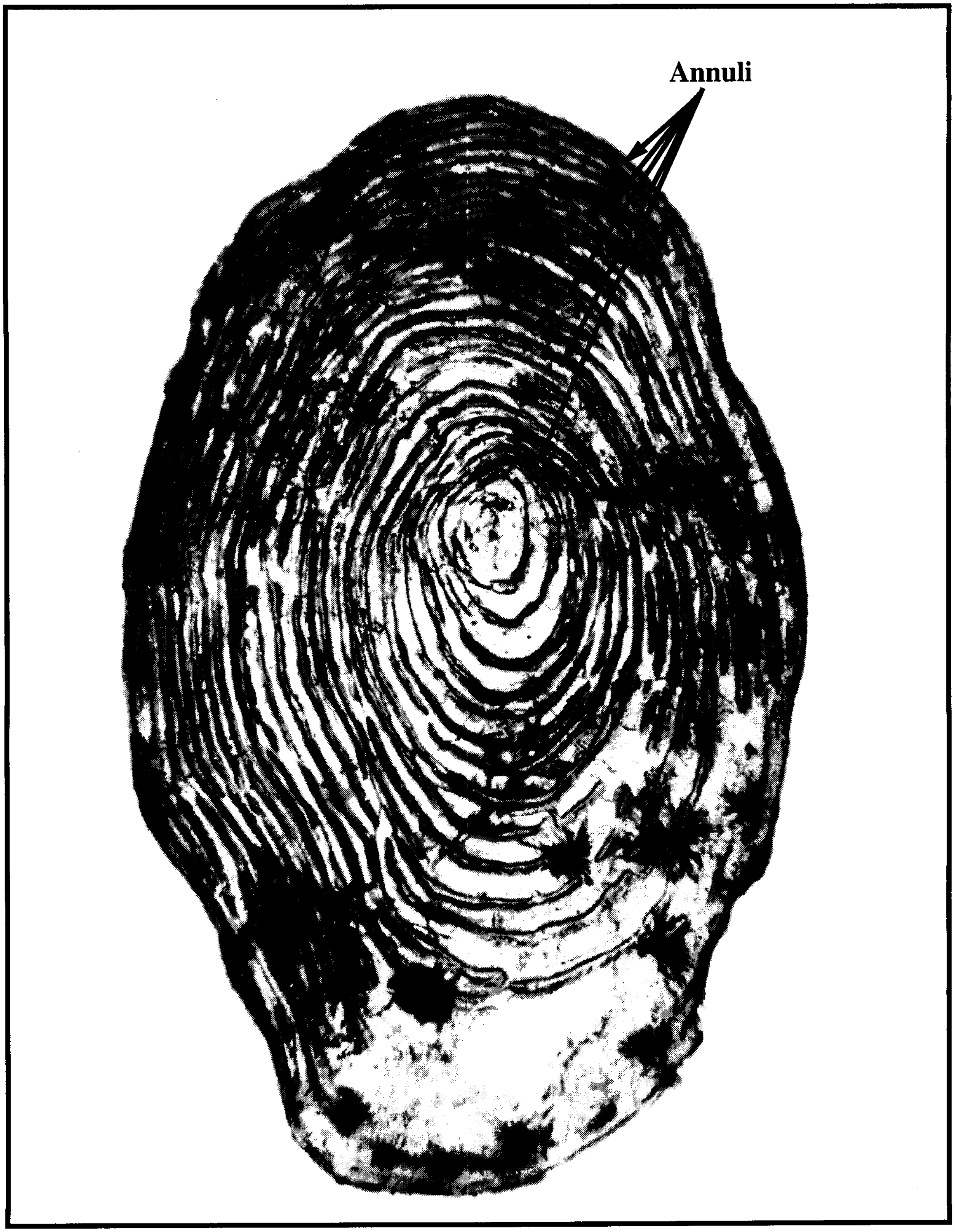
**Appendix C3.–A scale from a 270 mm (FL) known age 4 (BY91) hatchery cutthroat trout released into Auke Lake in November 1991, and sampled when it was recaptured on April 25, 1995.**




**Appendix C3 with overlay.**

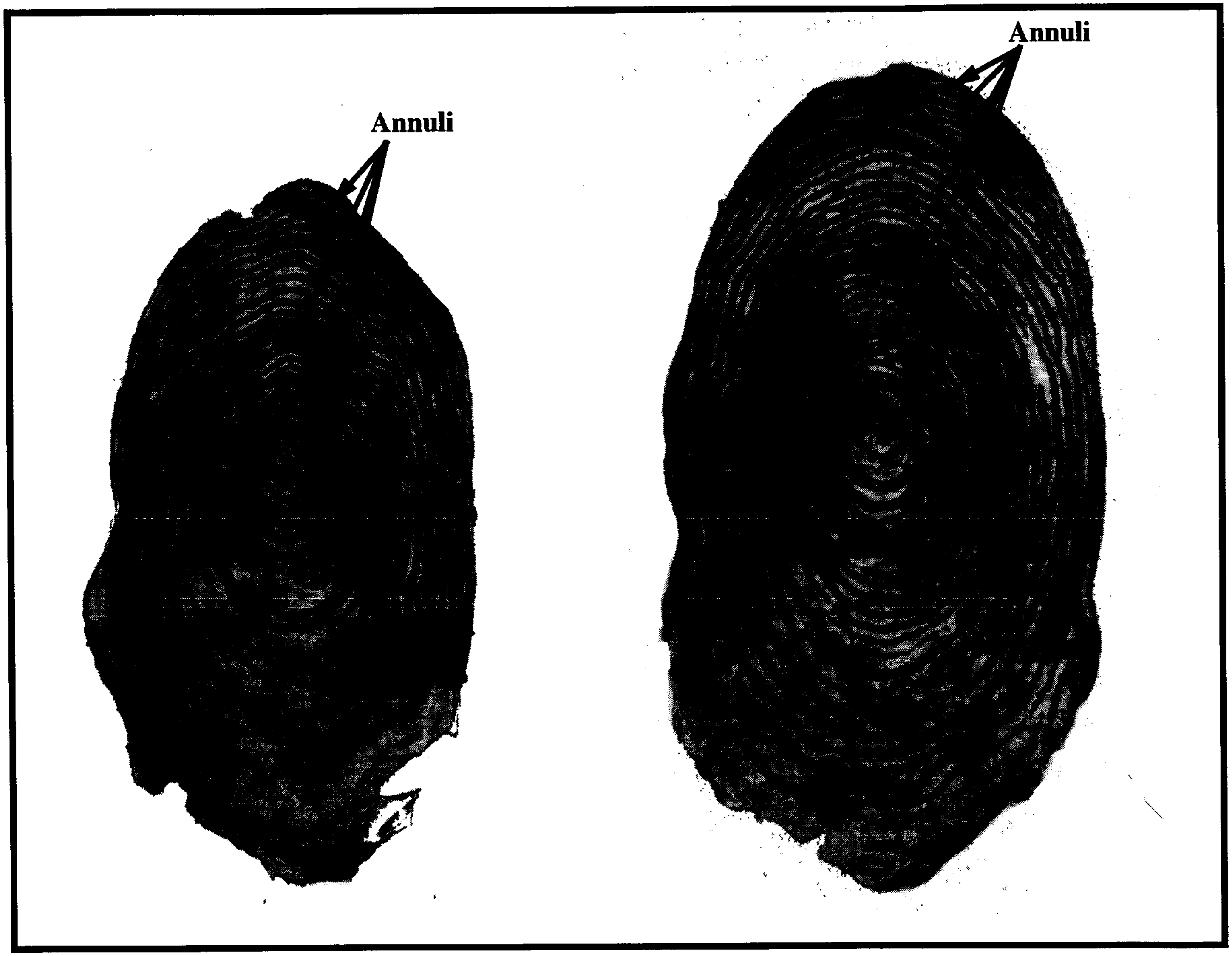


**Appendix C4.–A scale from a 300 mm (FL) known age 5 (BY91) hatchery cutthroat trout released into Auke Lake in November 1991, and sampled on April 18, 1996.**



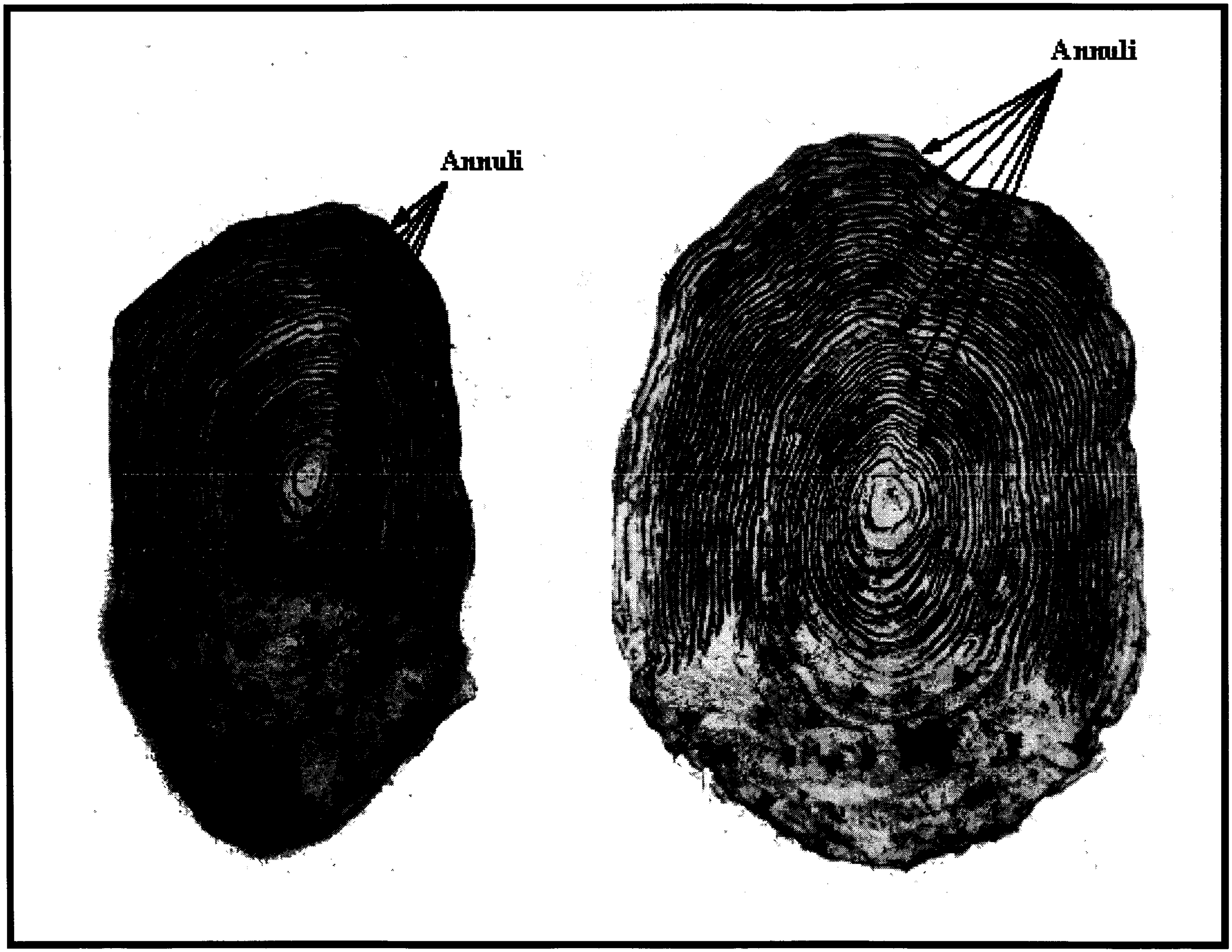

**Appendix C4 with overlay.**

**Appendix C5.–Scales from an anadromous cutthroat trout when it was tagged (218 mm) at Auke Creek as it emigrated from Auke Lake on May 7, 1995 (left), and recaptured (292 mm) at the same location April 25, 1996 (right).**




**Appendix C5 with overlay.**

Appendix C6.–Scales from an anadromous cutthroat trout when it was tagged (270 mm) at Auke Creek as it emigrated from Auke Lake on May 9, 1995 (left), and recaptured (302 mm) at the same location April 30, 1996 (right).




**Appendix C6 with overlay.**