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Comparison of scales and otoliths for aging wild rainbow trout from East Tennessee streams

Kimberly L. Cooper

To the Graduate Council:

I am submitting herewith a thesis written by Kimberly L. Cooper entitled "Comparison of scales and otoliths for aging wild rainbow trout from East Tennessee streams." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

Richard Strange, Major Professor

We have read this thesis and recommend its acceptance:

L. Larry Wilson, Jim Habera

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Vice Provost and Dean of Graduate Studies

COMPARISON OF SCALES AND OTOLITHS FOR AGING WILD RAINBOW TROUT FROM EAST TENNESSEE STREAMS

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Kimberly L. Cooper

December 2003

DEDICATION

This thesis is dedicated to my loving parents

Harold R. Cooper

and

Alice V. Cooper

Who have given me invaluable educational opportunities.

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The preparation of this thesis was a task I could not have achieved on my own and I wish to recognize those individuals who have assisted me. I would like to thank my advisor, Dr. Richard Strange, for his encouragement, guidance, and objective criticism. His flexibility and positive encouragement helped me when things seemed hopeless. Jim Habera of Tennessee Wildlife Resource Agency (TWRA) helped me design and implement the experiment and provided invaluable information and suggestions. I also want to give my sincere thanks to Dr. Larry Wilson for his guidance and assistance as a committee member.

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ABSTRACT

Age estimation is essential to properly managing the wild rainbow trout *Oncorhynchus mykiss* populations in east Tennessee. The age structure of a population can be used to quantify growth, longevity, and total mortality, as well as to assess environmental or management impacts. Scales have traditionally been used to age rainbow trout, but estimates using these structures may be inaccurate. As an alternative to scales, otoliths are increasingly being used to determine age estimates in fish populations. Otolith ages have been obtained and verified for wild brown trout *Salmo trutta* in East Tennessee but not for rainbow trout. To address this need, two readers aged scale and otolith samples from 621 wild rainbow trout from 12 East Tennessee streams. Scales identified fish up to age-3, whereas otoliths documented fish up to age-8. Reader agreement (precision) was much higher with otoliths (95%) than with scales (79%). Agreement between the two structures was only 69%. Scale accuracy also declined from 93% for age-1 fish to 50% for age-3 fish, while otoliths were 100% accurate when compared with known-age fish collected. Despite the greater accuracy and precision of otoliths as compared with scales, growth and mortality rates derived from the two structures did not differ substantially, primarily because fish older than age-3 were relatively uncommon (3.2%). Therefore, no changes in the basic management strategies applicable to wild rainbow trout populations in East Tennessee are currently necessary.

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CHAPTER I

INTRODUCTION

Rainbow trout *Oncorhynchus mykiss* are among the most important sport fishes in East Tennessee, due to their beautiful coloration, aggressive fighting behavior, and excellent taste. The importance of this species requires accurate and reliable estimates of growth, longevity, and annual mortality rates for proper management of wild populations. Thus, calculation of these indices requires reliable fish-aging techniques. At present, reliable age, growth, and mortality information may not exist for Tennessee rainbow trout because of potentially inaccurate aging methods (Habera et al. 1999).

In the past, the scale method of age determination was generally accepted as the routine and accurate method for aging all fish in a population (Beamish and McFarlane 1987). The first verified demonstration of the use of scales in aging fish was for carp, *Cyprinus carpio*, in 1898 (Carlander 1986). Scales were the preferred aging structure because they were relatively easy to collect, prepare, and read, and because scales can be obtained without sacrificing the fish (Everhart and Youngs 1981, Beamish and McFarlane 1987). Although the scale method was used for so long that it became common practice, its accuracy remained questionable as it had seldom been successfully validated (Casselman 1983; Beamish and McFarlane 1983; 1987). Investigators also did not consider the possibility that fish could live for many years with little or no growth. In such cases, incorrect aging of older fish will inadvertently lead to misrepresentation of growth, longevity, and potentially, improper management decisions.

To understand the problems associated with the scale method of age determination, it is necessary to understand the development and function of the scale (Beamish and McFarlane 1987). Scales of teleosts fishes develop as bony plates embedded in pockets of fibrous connective tissue in the skin. The scale is formed from two layers of bone-forming cells (osteoblasts). The upper (outer) layer of the scale is characterized by a series of ridges called circuli and the lower (inner) layer forms a smooth surface (Beamish and McFarlane 1987). Typically, fish growth occurs in a relatively short time during the summer months. Scales reflect this pattern of fish growth, resulting in periods during which little or no growth occurs. The resumption of active scale formation by osteoblasts produces an annual ring called an annulus around the periphery of the scale. The length of time with reduced or no scale growth is generally longer than the period of growth (Beamish and McFarlane 1987). Therefore, if the period of reduced or no growth becomes 12 months long and continues for many years there will be little or no scale growth, leading investigators to believe the fish is not getting older. Thus, the nature of scale growth should indicate to investigators that scale ages might become inaccurate at the point in the life history of a species when growth becomes asymptotic and annuli are no longer being formed. If incorrect ages are assigned to fish as a result of the use of the scale method, then there is an accumulation of ages at the point where the method breaks down. This results in a serious overestimate of production (Beamish and McFarlane 1987).

Goeman et al. (1984) found that the scale method tended to overestimate the age of freshwater drum *Aplodinotus grunniens* through age 9 and underestimate the age of older fish. Underestimation of age for older fish using scales has been reported by others

(Power 1978; Harrison and Hadley 1979) and discussed in detail by Carlander (1974). However, overestimation of age using scales from young fish has not been a prevalent conclusion in previous investigations (Goeman et al. 1984). The average variability of scale age among young fish (<age 8) was generally in error by one year or less in the Goeman et al. (1984) study. Age underestimation error for older fish was found to be of greater magnitude, with an average variability of three years. Inconsistencies associated with scale ages were exemplified by one fish, age 18, which was assigned four different ages ranging from 8-12 using scales. Overall, scales were only 61% reliable for aging in this experiment (Goeman et al. 1984).

Scales also present other age-determination problems. For example, different scales from the same fish may yield different age estimates (Joeris 1965), and scale-derived ages for fish over 2-3 years old can vary as much as five years (Robillard and Marsden 1996; Habera et al. 2001). This reiterates that scale aging results in a consistent under-aging of fish, thereby causing inflation of growth and production estimates and underestimation of mortality rates (Powers 1983; Beamish and McFarlane 1987). These estimates are required to determine commercial and sport-harvest targets and prevent over fishing of naturally reproducing populations. Therefore, validation of an aging technique is essential to ensure the accuracy of age related data.

The otolith aging method has proven to be a more valid and reliable means for aging fish than scales (Beamish and McFarlane 1987, Robillard and Marsden 1996). Otoliths are bony structures found in the inner ear of the cranial cavity of a fish (Beckman and Wilson 1995). Rainbow trout contain three pairs of otoliths known as the, lapilli, sagittae, and asteriscuses (Table 1, Figure 1) (Secor et al. 1992). All of these

Table 1. Description of the three pairs of otoliths. (Secor et al. 1992)

Otolith	Description
Lapillus Lapilli (pl.)	Occupies utricular vestibule of pars superior lateral and dorsal to the sagitta.
Sagitta Sagittae (pl.)	Occupies saccular vestibule of pars inferior; largest otolith in rainbow trout.
Asteriscus Asteriscuses (pl.)	Occupies lagenar vestibule of pars inferior, caudal to the sagitta.

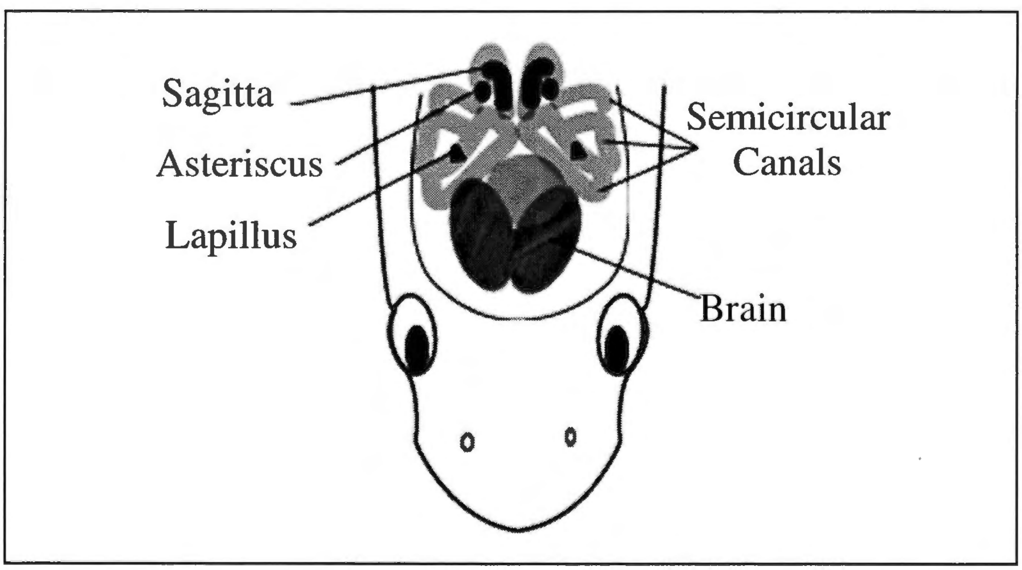

Figure 1. Dorsal view of the vestibular apparatus.(adapted from Secor et al. 1991)

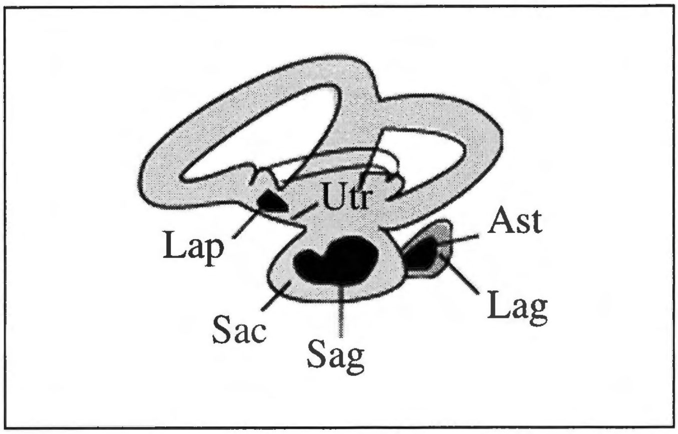

Figure 2. Otoliths within the labyrinth systems.
Ast = asteriscus; Lag = lagenar vestibule;
Lap = lapillus; Sac = saccular vestibular;
Sag = sagitta; Utr = utricular vestibule
(adapted from Secor et al. 1991)

differ in location, function, size, shape, and microstructure. The three pairs of otoliths reside in the fish's vestibular apparatus, which is bilaterally symmetrical (Beckman and Wilson 1995; Secor et al. 1992). The vestibular apparatus is divided into dorsal sacs (pars superior) and ventral sacs (pars inferior). The lapilli are located most anteriorly in the pars superior. The sagittae and asteriscuses are typically located close to the pars inferior and are medial and ventral to the lapilli. The individual sacs (vestibules), which contain the three pairs of otoliths, are termed the utriculus, sacculus, and lagenus for the lapillus, sagitta, and asteriscus, respectively (Figure 2).

The largest and most readily used otoliths for aging are the sagittae. In adults, the sagittae are found within the auditory capsule, which is comprised of five otic bones:

sphenotic, pterotic, prootic, epiotic, and opisthotic (Harrington 1955; Mujib 1967; Cailliet et al. 1986; Secor et al. 1992). Rainbow trout sagittae are found loosely confined within the prootic bulla of the cranial cavity. As with many fish, the sagittae in rainbow trout are the preferred otoliths for aging, not only because of their large and conspicuous size, but also for the easy "up through the gills" dissection method that can be used to obtain them.

The sagittae function in fish as sound receptors and for equilibrium maintenance. They are composed of calcium carbonate and protein, and are formed by the process of biomineralization (Beckman and Wilson 1995). There are a number of conditions that must be met to enable biological precipitation of carbonate to occur (Jamieson et al. 1987). First, the organism must partition an area within its body where precipitation can be isolated and controlled. The otoliths of a fish are completely isolated from the environment, allowing the fluid of the inner ear (endolymph) to form the needed precipitate (Jamieson et al. 1987). However, composition of the fluid does not allow for the spontaneous precipitation of carbonate. Therefore, the organism must also lay down an organic template to provide nucleation sites to facilitate precipitation. Selective precipitation can then occur at particular sites on the matrix controlling the final form of the mineralized tissue (Jamieson et al. 1987).

Thin sections examined by Jamieson et al. (1987) revealed that the otolith has a detailed microstructure consisting of bands of opaque and translucent material. The central portion of the otolith is known as the core or primordium. This represents the earliest phase of calcification (Golani and Ben-Tuvia 1985). There are three main phases of post-primordial growth that can be recognized. During the first phase, there is fast growth rate and discontinuities are rare. Growth is nearly isometric in all directions. The growth rate declines during the second phase where the width of the increments becomes smaller and interruptions in deposition become more frequent. There is further reduction in the growth rate during the third phase, and discontinuities and nonconformities become more evident (Jamieson et al. 1987).

Obvious bands (annuli) form in the otoliths during the growth of the fish (Jamieson et al. 1987). These opaque and translucent bands were thought to correlate with fast and slow growth periods. It was generally considered that opaque zones corresponded with summer growth and translucent zones formed during winter (Jamieson et al. 1987). Beckman and Wilson (1995) corroborated this by compiling the results of numerous otolith studies that determined the time of opaque zone information. The results of their work showed that the majority of fish were forming opaque zones during the spring and summer months. Beckman and Wilson (1995) also showed that the translucent zones are dominated by organic material while the opaque zones are dominated by carbonate. Otolith ages can be validated by using fish of known age, with length frequency distributions, or by using chemical markers such as oxytetracycline (Robillard and Marsden 1996). While patterns of incremental formation are generally consistent between calcified tissues, otoliths have now been recognized as the most reliable method for age determination (Jamieson et al. 1987).

Once it was realized by investigators that the otolith method of aging was more accurate than the scale method, it was found that many species were considerably older than previously thought (Beamish and McFarlane 1987). For example, lake whitefish *Coregonus clupeaformis* and lake trout *Salvelinus namaycush* were reported to exceed 60 and 50 years old, respectively (Power 1978), and brown trout *Salmo trutta* over 30 years old have been identified (Svalastog 1991). One of the most astonishing examples that has changed our understanding of maximum ages occurred with several groundfish species, such as *Sebastes aleutianus,* off the west coast of Canada (Chilton and Beamish 1982), where commercially important species are now believed to be much older. Nine percent of the species have estimated maximum ages of less than 20 years, while 48% range from 21 to 49 years and the remainder have estimated ages from 50 to greater than 100 years (Beamish and McFarlane 1987). There are several additional studies of salmonids and other species cited by Beamish and McFarlane (1987) clearly indicating that the scale method underestimates the age of older fish (Table 2).

Some of the oldest estimated ages to date have been obtained from examinations of otolith sections (Table 3). It has been found that unlike scales, otoliths continue to grow as the fish ages (Beamish and McFarlane 1987). However, otolith growth becomes allometric because deposition occurs predominantly on the inner surface. Otoliths from older fish are obviously much thicker than from younger fish, and when examined in cross section, the thickened area contains a prominent pattern of growth zones (Beamish and McFarlane 1987). These growth zones are interpreted to form annually, which indicates that the fish is quite old. For some species, the validity of these older ages has been proven and this proof provides circumstantial evidence that interpretations for other species may be correct.

The otolith method for aging fish has clearly given investigators a better understanding of age-related population characteristics. This information is important to natural resource management agencies for developing appropriate management strategies

Table 2. Examples of aging error using the scale method. (Beamish and McFarlane1987)

Species	Reference	Comment
Salvelinus namaycush	Simard and Magnin 1972	Scale growth slows down at maturity while otoliths continue to grow in relation to length.
Salvelinus fontinalis	Dutil and Power 1977	Scale age was generally less than otolith age and could underestimate ages by 40%.
Coregonus albula	Aass 1972	Scale ages are mostly lower than otolith ages with disagreements at all age levels and differences as great as 7 years.
Prosopium cylindraceum	Jessop 1972	Scales underestimated the age of oldest fish.
Coregonus clupeaformis	Power 1978	Otolith cross-section ages up to 35 years older than previously recorded maximum age.
Coregonus clupeaformis	Barnes and Power 1984	Scale ages underestimate otolith ages of western Labrador lake whitefish. Discrepancies occur from age 4 or 5 and can be considerable.
Thymallus arcticus	Sikstrom 1983	Ages determined from scales may underestimate the true age and should be used cautiously unless validated.
Rutilus rutilus	Hansen 1978	Scale ages underestimate older ages and are less suitable than opercular bones for age determination.

Table 2. (continued)

Species	Reference	Comment
Catostomus commersoni	Beamish 1973	Scale ages are unreliable beyond the age of maturity.
Micropterus salmoides	Maraldo and MacCrimmon 1979	Scales are likely to underestimate true ages of older fish.
Stizostedion vitreum vitreum	Belanger and Hogler 1982	Otoltih or pectoral fin-ray aging methods should be used as an occasional check for scale ages.
Aplodinotus grunniens	Goeman et al. 1984	Oldest fish underestimated by scale method, scales only 61% reliable species.
Ophidon elongates	Beamish and Chilton 1977	Scale ages unreliable for fish shortly after the age of maturity. Scale ages can only be half of true age.

Table 3. Maximum ages for some commercially important groundfish species off the west coast of Canada. (Chilton and Beamish 1982; Beamish and McFarlane 1987)

Family and common name	Scientific name	Maximum age (years)
Anoplopomatidae		
Sablefish	*Anoplopoma fimbria*	70
Pleuronectidae		
Dover sole	*Microstomus pacificus*	45
Scorpaenidae		
Rougheye rockfish	*Sebastes aleutianus*	140
Pacific ocean perch	*Sebastes alutus*	90
Shortraker rockfish	*Sebastes borealis*	120
Silvergray rockfish	*Sebastes brevispinis*	80
Darkblotched rockfish	*Sebastes crameri*	47
Widow rockfish	*Sebastes entomelas*	58
Yellowtail rockfish	*Sebastes flavidus*	64
Bocaccio	*Sebastes paucispinis*	36
Canary rockfish	*Sebastes pinniger*	75
Redstripe rockfish	*Sebastes proriger*	41
Yellowmouth rockfish	*Sebestes reedi*	71
Harlequin rockfish	*Sebastes varigatus*	43
Sharpchin rockfish	*Sebastes zaxentrus*	45
Squalidae		
Spiny dogfish	*Squalus acanthias*	80

for a variety of sport fisheries. For example, the Tennessee Wildlife Resource Agency (TWRA) recently conducted a study comparing scale and otolith for wild brown trout, *Salmo trutta*. Results indicated that otoliths were much more reliable than scales after age 4 and that discrepancies of up to five years between scales and otoliths from the same fish occurred (Strange and Habera 1998; Habera et al. 1999).

The results of the brown trout study indicated that a similar study of wild rainbow trout was needed to better understand the age, growth, and mortality characteristics of this species. The specific objectives were as follows:

1. Determine otolith ages of wild rainbow trout from 12 different populations throughout eastern Tennessee.
2. Determine scale ages for the same rainbow trout and compare with corresponding otolith ages.
3. Validate scales and otoliths by evaluating samples from known-age fish
4. Determine growth and annual mortality rates (catch curves) for each rainbow trout population.

CHAPTER II

METHODS

2.1 Study Site

Rainbow trout samples (n = 658) were obtained between October 1998 and October 2002 from 12 streams across East Tennessee (Figure 3). Additional samples (n = 43) of known-aged fish, marked by adipose fin clips, were collected from five of the 12 study streams for validation purposes. Streams were selected to represent potential geographic and productivity variability (Habera et al. 1999).

Physical and chemical data for the 12 study streams are provided in Appendix A1. Overall, the sample areas averaged 238 m in length and had a mean width of 9.3 m. Temperature (°C), pH, total alkalinity (mg/L $CaCO_3$), and conductivity (µS/cm) were measured at each sampling location. Temperature ranged from 15.4 to 21.8°C, pH ranged from 6.4 to 7.8, alkalinity ranged from 10-75mg/L $CaCO_3$, and conductivity ranged from 14µS/cm to 170µS/cm. Steam flow, measured with a Marsh-McBirney model 2000 electromagnetic flow meter, ranged from 1.5-61.8 ft^3/s.

2.2 Sampling Procedures

Backpack electroshockers were used to collect all samples of *O. mykiss*. One shocker was used on smaller streams (<5 m mean width), two shockers were used when the mean width of the stream varied from 5-12 m, and three shockers were used when

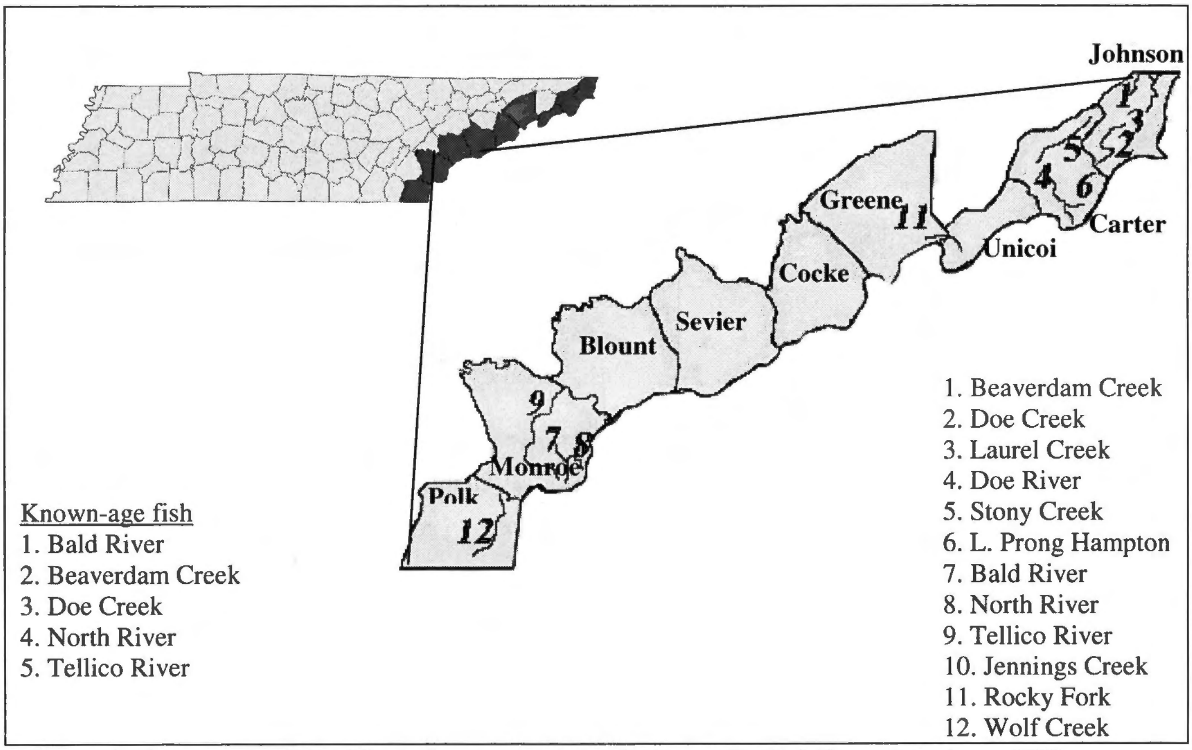

Figure 3. Location of the12 study stream populations of wild *O. mykiss* (n = 658).

mean stream width ranged from 12-18 m. The backpack electroshockers were operated at 300 to 500 VAC depending upon the conductivity of the stream.

All adult *O. mykiss* captured within the sample area in each stream were retained to permit mortality estimation. Because young of the year (YOY) were not useful for mortality estimation, only 10 were kept from each location. These fish were typically easy to identify by their small size (<10 cm). Captured fish were held on ice in the field. Within 10 hours of collection and prior to the removal of scale and otolith samples, all fish were measured to the nearest millimeter total length (TL), with the body flattened and the jaw closed (Newman 2002), and weighed to the nearest gram total weight (TW).

2.3 Scale Preparation and Age Determination

Scales were removed with a scalpel by scraping the area between the dorsal fin and the lateral line on the right side of each fish. Scales were stored in a labeled envelope or a 7.0-mL plastic vial for a minimum of one week at room temperature (22.2°C) to permit drying. The scales were then separated using a dissecting probe and forceps and placed between a microscope slide (25×75×1 mm) and a cover slip. Scale samples were examined in a microfiche reader at 32X magnification. Two independent readers examined the scales and recorded the number of annular growth rings on a data sheet. Scales were read without referencing to previous samples and without any knowledge of the length or weight of the fish. If the two readings coincided, then the number of annuli was recorded as the age (Radebe et al. 2002). If the readers did not agree, the sample was jointly reevaluated until a consensus was reached. Scale samples were discarded if they were unreadable or if the readers could not reach agreement about the number of annuli (Hining et al. 2000). Scale samples were not available for the Left Prong Hampton Creek population.

To determine the age of a fish, the number of marks interpreted as annuli on the scale were counted (Robillard and Marsden 1996). Criteria for identifying annuli on scales included the crowding of circuli, the cutting over of the annulus across previously deposited circuli, and the changes in circuli thickness (Jearld 1983). Each annulus represented one year of growth.

2.4 Otolith Preparation and Age Determination

The "up through the gills method" (Secor et al. 1992) was used to obtain otoliths from *O. mykiss* samples. Secor et al. (1992) used this procedure for extracting sagittae from both juvenile and young adult flatfishes. The procedure involved making a scapel incision on each side of the gill isthmus (Figure 4b). A V-shaped cut was then made under the gular, connecting the two initial incisions (Figure 4c). The head was then bent back, away from the gills and the rest of the body, allowing better access to the prootic bullae of the fish. In larger fish (TL > 50 mm), it was often necessary to cut away the gill arches and strip away epidermal, connective, and muscular tissue from the inferior portions of the neurocranium to expose the prootic bullae. For smaller specimens, the exposed bulla portion of the prootic was visible without removing gill arches and excess tissue. Light pressure was then applied perpendicular to the prootic bullae with a scalpel to create a clean cut with little disturbance to the brain cavity. Entrance to the brain cavity was gained by bending the fish backwards at approximately a 45° angle, with little pressure, along the cut in the prootic bullae. This produced an opening to the auditory bullae of the fish's brain cavity where the sagittae were located. Each pair of sagittae was removed with forceps from the auditory bullae with extreme care, due to their small size (0.5-4.0 mm) and fragile structure (Radebe et al. 2002). A dissecting microscope (40X magnification) was sometimes used when extracting otoliths from YOY. Otoliths were cleaned of attached tissue and fluids with a paper wipe, and stored at room temperature (22.2°C) in small, labeled vials prior to processing (Brothers 1987).

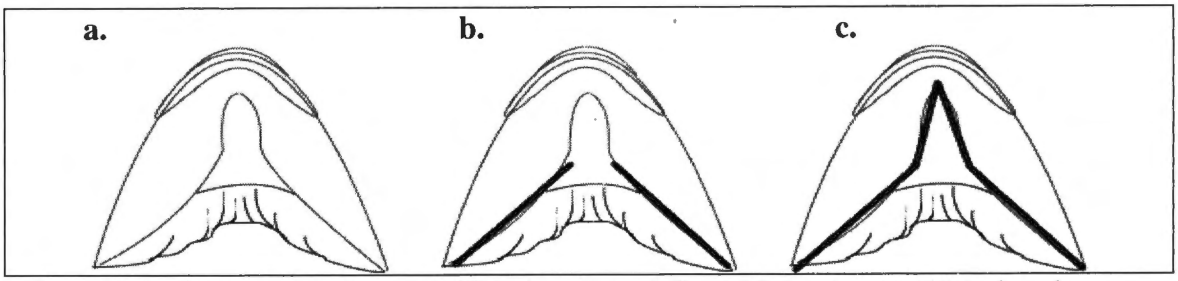

Figure 4. Incisions made in ventral head region of *O. mykiss.* (a) ventral head region before incisions (b) incisions made through the gill isthmus (c) V-shape incision made under the gular connecting the two incisions at the gill isthmus.

The right sagitta of each fish was embedded sulcus side up in a silicone mold with clear epoxy resin and hardener (Beamish 1979; Radebe et al. 2002). The epoxy prevented the fragmentation of thin sections and helped facilitate handling and mounting of the cut sections (Beamish 1979). The mold containing the otolith was clamped into a low-speed Struers Minitom saw (Newman 2002) and a thin transverse section (0.5 mm) was cut through the core of the otolith from the dorsal apex to the ventral apex (Figure 5). The saw employed diamond-impregnated, water-cooled grinding disks to produce the sections. Cut sections of otoliths were mounted sulcus side up on labeled glass slides using heated Crystalbond chips (Hining et al. 2000; Radebe et al. 2002). The otolith was then hand polished with 600 or 800-grit silicon carbide wet/dry sandpaper (emery paper) to clarify the annuli (Hining et al. 2000).

Otoliths were examined for distinguishing opaque and translucent zones under transmitted light (100X magnification). Opaque and translucent zones corresponded to the slow and fast growth periods exhibited by the fish (Beamish 1979). The opaque zone (annulus) was determined as the portion of the otolith formed during slow growth and the

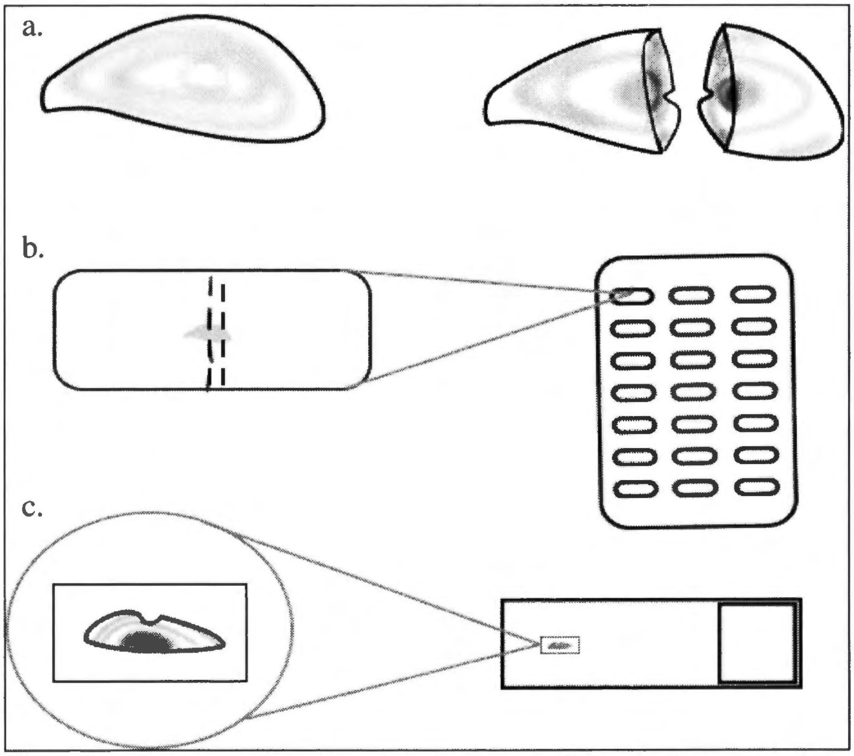

Figure 5. Procedure for preparing sagitta otoliths in *O. mykiss*. (a) whole otolith (b) whole otolith placed in silicone mold of epoxy resin and hardener (c) transverse cross section of otolith mounted on a slide with heated crystal bond.

translucent zone was determined as the portion formed during active growth (Beckman and Wilson 1995; Hining et al. 2000).

Two independent readers counted the number of annuli exhibited on each otolith. The otoliths were read without reference to other otoliths and without any knowledge of the length or weight of the fish. Immersion oil was sometimes used to better clarify annuli on many otolith samples. Some otoliths had to be removed from the slide, flipped, remounted, and polished again on the other side for better results. Unreadable otoliths were discarded and otoliths with annuli counts that differed between readers were reconciled (Hining et al. 2000).

2.5 Age Validation

All age-0 rainbow trout captured during TWRA's annual monitoring efforts in five study streams (Figure 3) were marked with adipose fin clips in 1997 or 1998 (Doe Creek) (Habera et al. 1999). Scale and otolith samples from 43 of these marked fish, recaptured during subsequent monitoring efforts (at age 1 to age 3), were used to validate the accuracy of both structures. Age determinations for the known-age fish were made in the same fashion as previously described. Scales and otoliths were read independently without prior knowledge of weight or length. Agreed upon ages for both scales and otoliths were compared to the corresponding known age for each fish.

2.6 Catch Curve Mortality Estimation

Total mortality for a fish population is comprised of natural mortality and angling mortality (Ricker 1975; Everhart and Youngs 1981). At the time of the study, harvest rates could not be determined for long-term monitoring streams due to the absence of creel data. Without creel data, it was not feasible to calculate total mortality rates directly, but it was possible to estimate total mortality indirectly by estimating survival (Strange and Habera et al. 1998). Survival rates can be estimated by plotting simple catch curves of the natural logarithms of the numbers of fish captured by age (Ricker 1975; Van Den Avyle 1993). Given the predictive equation for population size:

$$N_t = N_o e^{-Zt}$$

where N_t = number alive at time t,
N_o = number alive initially (time t_o),
Z = instantaneous total mortality rate, and
t = time elapsed since t_o.

Survival (S) is e^{-Z} if t = 1 year and the annual mortality rate (A) is 1-S or 1-e^{-Z} (Van Den Avyle 1993), where *e* is a constant value of 2.302585093 and Z is the slope of the descending line portion of the catch curve. The equation for the catch curve line is estimated by regressing $\log_e(N_t)$ and *t* (Ricker 1975). Constant recruitment and survival over time and equal survival among ages are assumed and age groups with less than three fish and YOY fish were excluded to limit extreme variation (Van Den Avyle 1993; Strange and Habera 1997).

2.7 Statistical Analyses

Statistical analyzes were performed using the statistical software SAS (2002). A Randomized Complete Block Design (RCB) was used to test for differences in growth among populations. The RCB test used otolith age as the block effect and site (stream population) as the treatment effects. A nonparametric Kolmogorov-Smirnov test (Sokal and Rohlf 1981) was run to compare cumulative age frequencies for scale and otolith ages. This test is based on the unsigned differences between the relative cumulative frequency distributions of the two samples (i.e., scale and otolith age). Observed and expected values are compared to determine if the maximum difference between the two cumulative frequency distributions is significant (Sokal and Rohlf 1981). Mean lengths obtained from scales and otoliths were compared using t-tests. T-test evaluates differences among paired observations in populations (Burt and Barber 1996). All statistical tests and comparisons were assessed at the $\alpha = 0.05$ significance level.

CHAPTER III

RESULTS

A total of 658 *Oncorhynchus mykiss* were collected from 12 East Tennessee streams. Sample size at each location ranged from 33 to 70 fish and averaged 55 fish. The size of the individual fish ranged from 42 to 312 mm (Table 4). Thirty-seven fish (5.6%) were discarded because their otoliths were unreadable or the readers could not agree upon a final age. An additional four fish had readable otoliths, but unreadable scales. These fish were not used for analyses or comparisons involving scales (Appendix B1-B12). Final ages (based on agreed otolith ages) were obtained for 621 fish.

Table 4. Adjusted sample sizes and size ranges for *O. mykiss* for the 12 East Tennessee study streams.

Stream	County	n	Discarded samples	Size range (mm)
Beaverdam Creek	Johnson	41	3	43-242
Doe Creek	Johnson	62	3	86-270
Laurel Creek	Johnson	69	5	42-254
Doe River	Carter	70	8	130-269
Stony Creek	Carter	52	3	74-256
Left Prong Hampton	Carter	48	0	55-312
Bald River	Monroe	57	0	66-207
North River	Monroe	52	2	78-204
Tellico River	Monroe	64	6	63-229
Jennings Creek	Greene	33	2	49-232
Rocky Fork Creek	Unicoi/Greene	68	2	60-251
Wolf Creek	Polk	42	3	102-184
Total		658	37	42-312

3.1 Scale and Otolith Comparability

Ages obtained from scales typically differed from those obtained from otoliths. Scale ages ranged from 0 to 3, whereas fish up to age 8 were identified with otoliths (Figure 6). However, only five populations had fish older than age-3 and only two (Left Prong Hampton Creek and Rocky Fork) had fish over age-5. Only 20 fish older than age were collected representing 3.2% of the entire population for which final ages were determined. Three-fourths of the fish older than age 3 were from Left Prong Hampton Creek (8) and Rocky Fork (7).

Agreement between readers was relatively high for scales from age-0 (93%) and age-1 fish (87%), then decreased to 57% for age-2, and 42% for age-3 fish (Table 5). Mean differences when readers disagreed were 1.3, 1.2, 1.1, and 1.3 years for ages 0-3, respectively. This demonstrated that there was less agreement between the readers as age increased. There was much better agreement between readers with otoliths, especially for

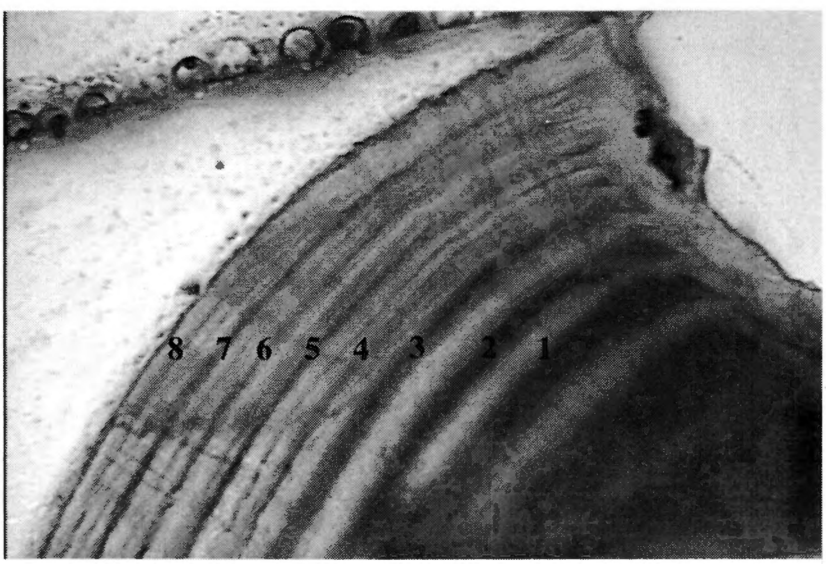

Figure 6. Photograph of an age-8 rainbow trout otolith from Rocky Fork. (100 X magnification)

Table 5. Agreement between two readers for ages derived from scales and otoliths from *O. mykiss* (N = 621), along with agreement between final ages for the two structures.

	Scales			Otoliths			Scales/Otoliths		
Final Age[a]	N	Agreed (%)	Mean difference[b]	N	Agreed (%)	Mean difference[b]	N	Agreed (%)	Mean difference[c]
0	168	156 (93)	1.3	137	127 (93)	1.0	175	139 (79)	1.2
1	253	220 (87)	1.2	289	276 (95)	1.0	275	189 (69)	1.0
2	166	95 (57)	1.1	108	104 (96)	1.0	104	72 (69)	1.0
3	19	8 (42)	1.3	29	29 (100)	0.0	22	7 (32)	-1.3
4				9	9 (100)	0.0	6	0 (0)	-1.8
5				4	4 (100)	0.0	4	0 (0)	-3.0
6				4	4 (100)	0.0	1	0 (0)	-4.0
7									
8				3	3 (100)	0.0	1	0 (0)	-6.0
Total	606	479(79)	1.2	621	606(95)	1.0	588	407(69)	-1.6

[a] Age ultimately agreed upon by the two readers for each scale or otolith. Scale/otolith comparisons involved final ages for each structure.

[b] For cases where there was a difference between readers (absolute values).

[c] For comparisons between structures, otolith age was considered correct, thus scale underestimates resulted in negative values.

older fish. In fact, agreement exceeded 90% for all ages and was 100% for all fish age-3 and older (Table 5). When the readers did disagree, the mean difference was one year for age classes 0-2 and never exceeded two years for any specimen. This demonstrated a high level of precision between readers for otoliths from all age classes.

Agreement between scale and otolith ages was relatively low and decreased as age increased. Scale and otolith agreement was less than 80% for all age classes and there was no agreement between the two structures for ages 4-8 (Table 5). The mean difference between scale and otolith ages ranged from 1.0 to 6.0 years and increased with increasing age.

If scale and otolith ages always agreed, a hypothetical slope of 1.00 would exist if the two were graphed (Figure 7). A regression of otolith age and scale age data from this study produced a slope of 0.60, which was significantly different from the hypothetical slope. The calculated slope indicates that scale age begins to substantially underestimate otolith age (true age) beyond age-2 and that scales are extremely inaccurate beyond age-3 (Figure 8).

The Kolmogorov-Smirnov test indicated that there were no significant differences (P= 0.001) between age frequencies for scales and otoliths. This was most likely related to the small number of fish older than age-3 identified with otoliths (even though no fish older than age-3 were identified with scales). The low quantity of age-3 fish and absence of older fish for scales is illustrated in Figure 9.

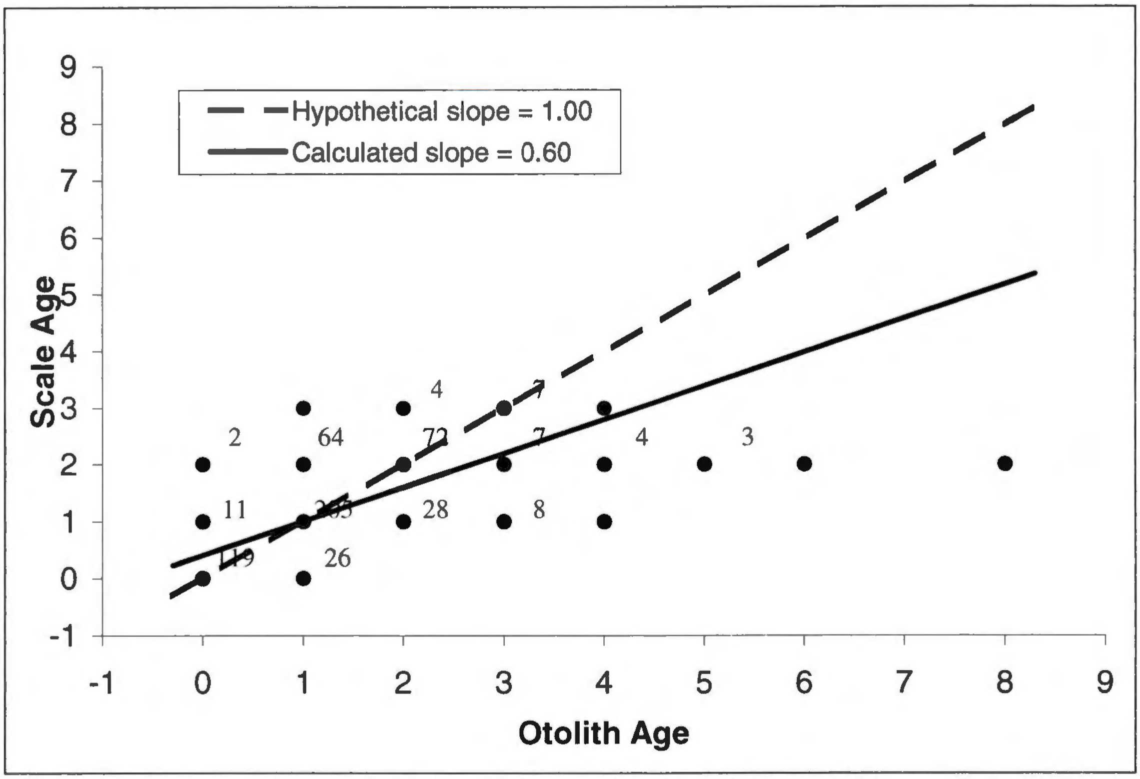

Figure 7. Corresponding scale and otolith ages for *O. mykiss* from 11 populations. Numbers indicate sample size for points representing more than one fish. The calculated slope (0.60) was significantly different from the hypothetical slope 1.00.

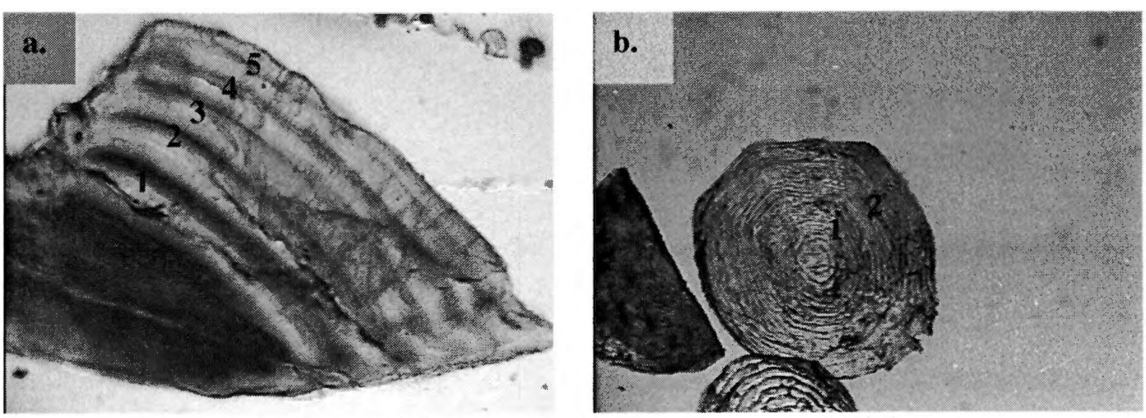

Figure 8. Photograph of an otolith and scale from the same age-5 rainbow trout. (a) otolith with five detectable annuli (100 X magnification) (b) scale with two detectable annuli (40 X magnification)

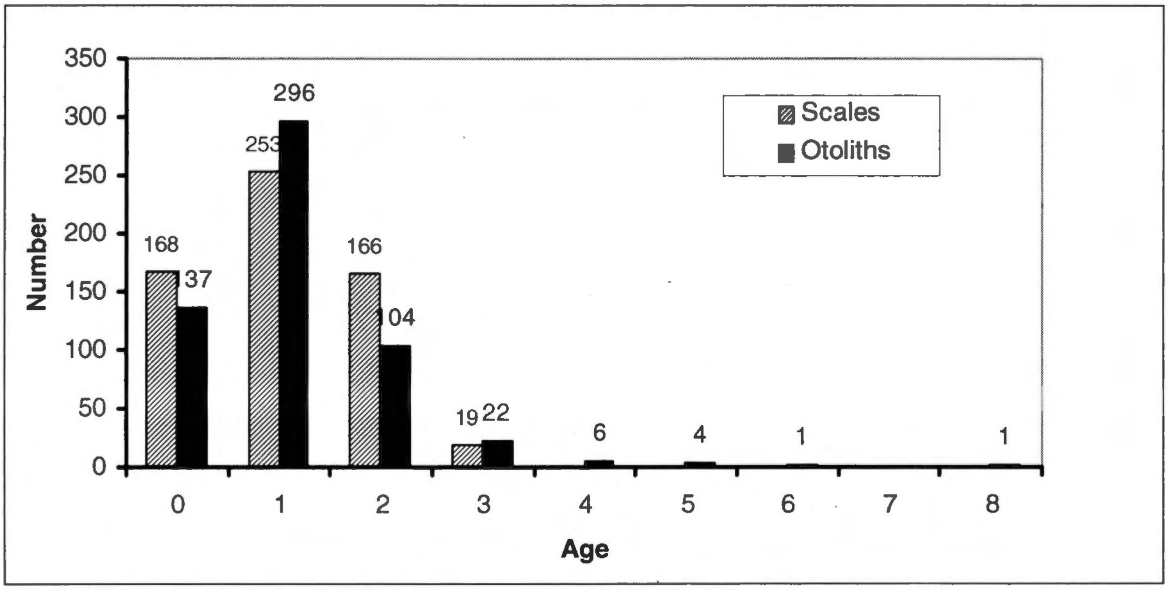

Figure 9. Age frequencies from scales and otoliths for *O. mykiss* from 11 populations in East Tennessee. Age frequencies for the two structures were not significantly different (P = 0.001).

3.2 Growth as Determined by Scales and Otoliths

Growth for the Doe River population, as represented by mean length at capture, was significantly greater (P = 0.0001) than that for the other study populations based on both scale and otolith ages. Therefore, it was separated from the other populations, which were pooled for subsequent analyses. The growth curve for the Doe River population mirrored that of the other pooled populations, but no fish older than age-3 were captured (Figure 10). Consequently, Doe River's growth curve for the population does not plateau like the other populations (Figure 10), suggesting that older fish may be present but were not captured.

Despite the relative inaccuracy of scale ages, mean lengths generated by scales and otoliths for each age group (0-3) were not significantly different for the Doe River or the pooled populations (P = 0.001). Additionally, there was a large amount of variability

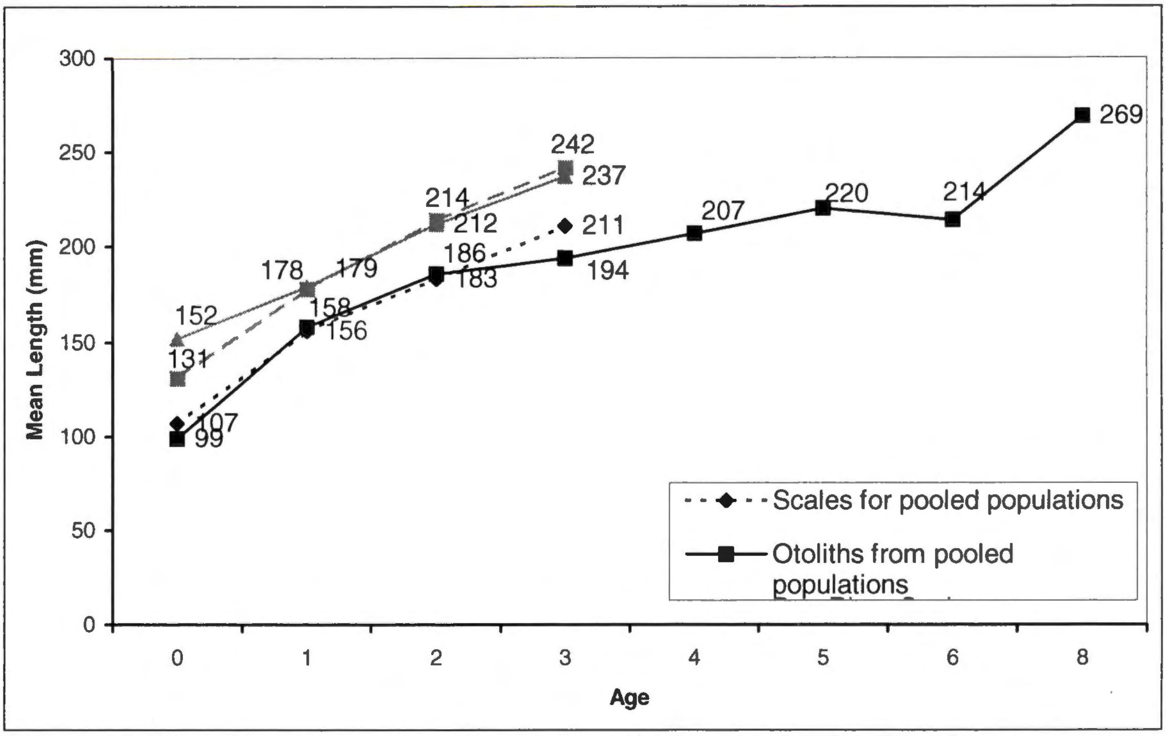

Figure 10. Mean lengths at capture based on otoliths and scales for *O. mykiss*.

in growth among the populations sampled. For example, based on otolith data for all populations, 200-mm (9 inch) fish ranged from one to six years old (Figure 11).

3.3 Validation of Scales and Otoliths

Examination of scales and otoliths from known age fish indicated that annular marks useful for aging are produced on both structures. However, otolith ages always agreed with the actual age of each fish, whereas there was less agreement for scale-derived ages. Overall, there was 93% agreement for age-1 fish, 72% agreement for age-2

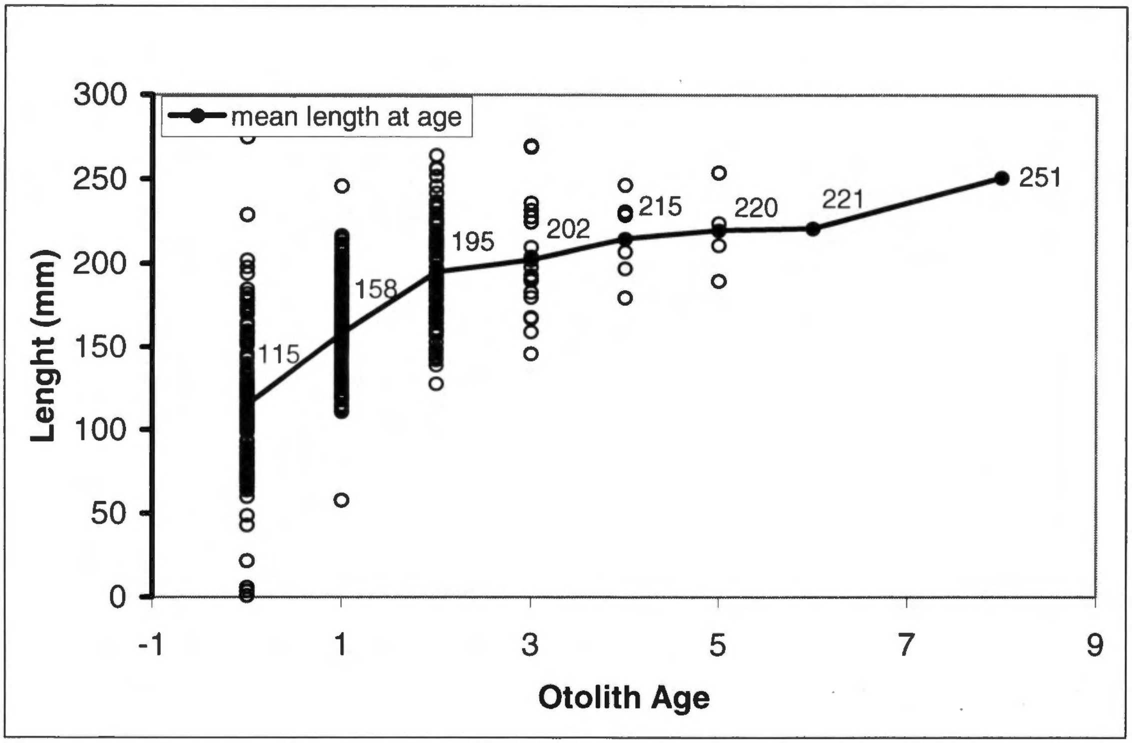

Figure 11. Corresponding lengths and otolith ages for *O. mykiss* (N = 591) from 12 East Tennessee populations. Values along the line are mean lengths at capture for each age.

fish, and 50% agreement for age-3 fish using the scale-derived age (Table 6). This clearly documents otoliths as the more accurate structure for aging wild rainbow trout from East Tennessee streams.

3.4 Catch Curve Mortality

There was no significant difference (P = 0.001) between corresponding mortality estimates by scales and otoliths. Scale-derived mortality rates ranged from 0.46-0.72 and averaged 0.61 (Table 7). Annual mortality rates based on otoliths ranged from 0.34 to 0.89 and averaged 0.55 (Table 7). Based on otoliths, Rocky Fork had the lowest mortality

Table 6. Comparison of scale and otolith ages for known-age fish (n = 43) from five East Tennessee streams. Known-age *O. mykiss* were marked and recaptured during 1998-2001 for validation of scales and otoliths.

Stream	Scale age (n)	% agreement[a]	Otolith age (n)	% agreement[a]	Known-age (n)
Beaverdam Creek	1 (8)	80	1 (7)	100	1 (7)
	2 (1)	50	2 (2)	100	2 (2)
	3 (1)	100	3 (1)	100	3 (1)
Doe Creek	1 (3)	100	1 (3)	100	1 (3)
	2 (1)	0			
	3 (1)	50	3 (2)	100	3 (2)
Bald River	1 (4)	100	1 (4)	100	1 (4)
	2 (2)	100	2 (2)	100	2 (2)
North River	1 (6)	80	1 (5)	100	1 (5)
	2 (4)	75	2 (4)	100	2 (4)
	3 (0)	0	3 (1)	100	3 (1)
Tellico River	1 (9)	100	1 (9)	100	1 (9)
	2 (3)	100	2 (3)	100	2 (3)
	1 (30)	93	1 (28)	100	1 (28)
Total	2 (11)	72	2 (12)	100	2 (12)
	3 (2)	50	3 (4)	100	3 (4)

[a] With known-age fish

Table 7. Total annual mortality rates for *O. mykiss* from 11 East Tennessee populations.

Stream	Total annual mortality (%)	
	Scales[a]	Otoliths
Beaverdam Creek		53
Doe Creek	72	71
Laurel Creek	60	59
Doe River	65	60
Stony Creek		59
Bald River	60	60
North River		61
Tellico River		89
Jennings Creek	46	46
Rocky Fork Creek		34
Wolf Creek		80
Mean	61	55

[a] Mortality rates based on scale ages were only calculated for populations with at least two age-3 fish.

rate (34%), whereas Tellico River had the highest rate (89%). Rocky Fork was also the only population to have five age classes containing more than three fish.

CHAPTER IV

DISCUSSION

The main objectives of this study were to determine ages of *O. mykiss* using scales and otoliths, to compare differences between the methods, and to validate the accuracy of the two structures. Based on the information obtained in this study, otoliths are the preferred method because of their more accurate ability to correctly age *O. mykiss* when compared to scales. An overwhelming number of similar studies reached the same conclusion (Jessop 1972; Beamish 1973; Dutil and Power 1977; Beamish and McFarlane 1987; Habera et al. 1999; Hining et al. 2000).

Beamish (1973) stated that scale ages are unreliable beyond the age of maturity, and this was quite apparent for the scales of older fish in this study. Scales of older fish became increasingly difficult to read because they had often been regenerated or reabsorbed. In populations having older fish, such as Rocky Fork, it was usually very difficult to find even one scale from a sample that was readable. Even then, if several scales from the same fish were readable, their annuli counts often differed, resulting in different age assignments for the same fish. Hining et al. (2000) found that 67% of age-1 fish formed a second annulus on scales after 12-15 months at liberty, while only 32% of age-2 fish formed a third annulus. Therefore, rainbow trout thought to be age-2 may actually be older because of the low frequency of age-3 fish that had scales with more than two annuli (Hining et al. 2000). Otoliths do not present the same problem because bone growth is more precise and believed to have a higher priority in the utilization of calcium, which is probably reabsorbed in scales of older fish (Simkiss 1974).

This study found that reader agreement for scale age estimates decreased as fish age increased, while there was relatively constant reader agreement (>90%) for all otolith age estimates. Hining et al. (2000) also found that agreement for scales aged by two readers declined from 98% for age-1 to 12% for age-3, with no scales observed having more than three annuli. The agreement between readers for otolith age estimates in Hining et al. (2000) was also high (>82%), with no decline for older ages (otoliths with up to five annuli). This suggested that not only are scales less accurate than otoliths for aging wild rainbow trout, but they are also much less precise. Consequently, annuli counts from otoltihs should allow more confidence in the estimated ages obtained, regardless of the age-group investigated (Hining et al. 2000).

Despite differences in aging accuracy, mean lengths at capture (growth) did not differ greatly between the two aging methods. This was probably due to the inclusion of older fish with age-3 fish as determined by scales. Older fish would typically be longer, thus inflating the mean length for this age group. However, growth levels off beyond age-4, which explains why the difference in mean length between the two structures at age 3 is not larger.

Previous scale-derived age and growth data reported by Strange and Habera (1993, 1994, 1997, 1998) for 11 of the same streams were comparable to what was observed in the current study with the exception that some fish greater than age-3 where identified (Table 8).

Table 8. Previous growth and longevity data based on scale-derived ages for *O. mykiss* in 11 study streams in East Tennessee. (Strange and Habera 1993,1994, 1997,1998).

	Sample			Mean length at capture				
Population	Dates	n	0	1	2	3	4	5
Beaverdam Creek	1991-97	1,876	74	160	220	254	300	
Doe Creek	1993-97	1,032	101	167	215	250		331
Laurel Creek	1993	195	74	170	222			
Doe River	1996	182	68	171	203	246		
Stony Creek	1995	88	108	248	264	240		
Left Prong Hampton Creek	1994-97	1,006	58	130	167	195	230	273
Bald River	1991-97	1,590	98	163	208	233	241	
North River	1991-97	2,579	95	152	187	230		
Tellico River	1993-97	1,536	101	167	209	237		
Jennings Creek	1992	77	57	146	189	231		
Rocky Fork	1991-97	1,541	72	132	179	216		
Mean			82	164	206	233	257	302

The lack of any significant differences in age frequencies generated by scales and otoliths, is likely related to the low sample size for fish older than age 3 (n = 12). This lack of older fish can probably be attributed to drought extending back to 1998 (Habera et al. 2003). In the absence of drought-related impacts, enough older fish might have been present to influence a comparison of age frequencies for the two structures.

Age, growth, and mortality of *O. mykiss* in each population revealed some interesting characteristics. It appears that Rocky Fork and Left Prong Hampton had the oldest, but not necessarily the largest fish. Mean lengths at capture for ages 4 through 8 from Rocky Fork were all less than the mean length for age-3 fish from Doe Creek.

Younger fish also grew more slowly in Rocky Fork and Left Prong Hampton Creek, suggesting that these were slower growing (possibly stunted) populations. Conversely, Doe Creek and Doe River populations had some of the highest growth rates but apparently did not have any fish living longer then 3 years. Data obtained by Strange and Habera (1993, 1994, 1997, 1998) also indicated that Rocky Fork and Left Prong Hampton fish had mean lengths below the overall average and that growth in the Doe Creek and Doe River populations was typically above average (Table 8). Older fish (>age-3) were also observed in Left Prong Hampton Creek, which is consistent with the otolith data obtained in the current study.

Stream fertility is the major factor contributing to the productivity of a stream (Kwak and Waters 1997) and can influence growth rates. Rocky Fork is infertile, whereas Doe Creek and Doe River are comparatively quite fertile. Rocky Fork had a much lower alkalinity (15 mg/L of $CaCO_3$) and pH (6.9) than Doe Creek (75 mg/L of $CaCO_3$ and 7.8) (Table A1). The recent drought (Habera et al. 2003) may have also been more detrimental to some populations than others (resulting in fewer older fish). Sampling error may also have contributed to the absence of older fish in any population.

Strange and Habera (1998) reported somewhat higher total annual mortality rates (based on scales) than those determined in the current study (Table 9). They calculated an average total mortality rate of 0.68, whereas average total mortality (based on otoliths) was 0.55 in the current study. However, Strange and Habera (1998) did find that Tellico River had the highest mortality rate, which is consistent with the current study. Additionally, Strange and Habera (1998) also documented the Left Prong Hampton Creek population as having the lowest mortality rate. Although mortality was not calculated for

Table 9. Previous total annual mortality data for *O. mykiss* collected from seven East Tennessee populations. (Strange and Habera 1998)

Stream	Total Mortality (%) Scales
Beaverdam Creek	64
Doe Creek	66
Left Prong Hampton Creek	42
Bald River	79
North River	77
Tellico River	81
Rocky Fork Creek	67
Mean	68

the Left Prong Hampton Creek population in the current study, it likely would have been below average as well given the number of older fish found in that population.

This study determined that annuli counts from sectioned otoliths provide accurate and precise age data for rainbow trout in southern Appalachian streams. Annuli counts obtained from the scales of rainbow trout in southern Appalachian streams will likely provide inaccurate age estimates for fish older than age-3, and may not accurately distinguish many age-2 and age-3 rainbow trout.

While otolith data revealed that some wild rainbow trout in East Tennessee are substantially older (and growth is slower) than had been determined by scales, overall growth and mortality rates were not substantially affected. Currently, there are two basic management strategies for East Tennessee streams with wild rainbow trout: 1) no size limit and a 7-fish creel limit with no gear restrictions and 2) a 229-mm minimum size limit and a 3-fish creel limit with only single-hook artificial lures permitted. Eight streams in this study were subject to the first management strategy (Doe Creek, Laurel

Creek, Doe River, Stony Creek, Left Prong Hampton Creek, Tellico River, Jennings Creek, and Rocky Fork). The remaining streams were subject to the second management strategy (Beaverdam Creek, Bald River, North River, and Wolf Creek). Although older fish were found among both groups, they were neither sufficiently abundant (3.2% were older that age 3) nor sufficiently large (mean length, 220 mm) to suggest that alternative management strategies are presently necessary or should be considered. Wild trout anglers typically request management changes that will result in larger or more abundant fish, not older fish (J. Habera, TWRA, personal communication). Additionally, since food availability is the primary limiting factor in East Tennessee's wild trout streams (Habera and Strange 1993; Habera et al. 2003), there is little short of supplemental feeding (Strange and Habera 1994; Borawa et al. 1995) that could substantially increase abundance or size.

REFERENCES

Aass, P. 1972. Age determination and year-class fluctuations of cisco, *Coregonus albula* L., in the Mjosa hydroelectric reservoir. Institute of Freshwater Research, Drottningholm 52:5-22.

Barnes, M. A., and G. Power. 1984. A comparision of otolith and scale ages for western Labrador lake whitefish, *Coregonus clupeaformis*. Environmental Biology of Fishes 10:297-299.

Beamish, R. J. 1973. Determination of age and growth of populations of the white sucker, *Catostomus commersoni*, exhibiting a wide range in size at maturity. Journal of the Fisheries Research Board of Canada 30:607-616.

Beamish, R. J. 1979. Differences in the age of Pacific hake (*Merluccius productus*) using whole otoliths and sections of otoliths. Journal of Fisheries Research Board Canada 36:141-151.

Beamish, R. J., and D. E. Chilton. 1977. Age determination of lingcod (*Ophiodon elongates*) using dorsal fin rays and scales. Journal of the Fisheries Research Board of Canada 34:1305-1313.

Beamish R. J., and G. A. McFarlane. 1983. The forgotten requirement for age validation in fisheries biology. Transactions of the American Fisheries Society 112:735-743.

Beamish R. J., and G. A. McFarlane. 1987. Current trends in age determination methodology. Pages 15-42 *in* R. C Summerfelt and G. E. Hall, editors. Age and growth of fish. The Iowa State University Press, Ames, Iowa, USA.

Beckman, D. W., and C. A. Wilson. 1995. Seasonal timing of opaque zone formation in fish otoliths. Pages 27-43 *in* D. H. Secor J. M. Dean, and S. E. Campana, editors. Recent developments in fish otolith research. University of South Carolina Press.

Belanger, S. E., and S. R. Hogler. 1982. Comparision of five ageing methodologies applied to walleye, *Stizostedion vitreum*, in Burt Lake, Michigan. Journal of Great Lakes Research 8:666-671.

Borawa, J. C., C. J. Goudreau, and M. M. Clemmons. 1995. Responses of wild trout populations to supplemental feeding. Federal Aid Project F-24. North Carolina Wildlife Resources Commission, Division of Boating and Inland Fisheries, Raleigh, North Carolina.

Brothers, E. B. 1987. Methodology approaches to the examination of otoliths in aging studies. Pages 319-330 *in* R. C. Summerfelt and G. E. Hall, editors. Age and growth of fish. Iowa State University Press, Ames Iowa.

Burt, J. E., and G. M. Barber. 1996. Elementary Statistics for Geographers, second edition. The Guilford Press, New York.

Cailliet, G. M., M. S. Cove, and A.W. Ebeling. 1986. Fisheries: A field and laboratory manual on their structure, identification, and natural history. Wadsworth Publication Company, Belmont California.

Casselman, J. M. 1983. Age and growth assessment of fish from their calcified structures-techniques and tools. NOAA Technical Report NMFS 8:1-17.

Carlander, K. D. 1974. Difficulties in ageing fish in relation to inland fishery management. Pages 200-205 *in* T. B. Bagenal, editor, Ageing of fish. Unwin Brothers Limited, Old Woking, Surrey, England.

Carlander, K. D. 1986. A history of scale age and growth studies of North America freshwater fishes. Pages *in* R. C. Summerfelt and G. E. Hall, editors. Age and growth of fish. Iowa State University Press, Ames, Iowa, USA.

Chilton, D. E., and R. J. Beamish. 1982. Age determination methods for fishes studied by the Groundfish Program at the Pacific Biological Station. Canadian Publication of Special Fisheries and Aquatic Sciences 60.

DeVries, D. R., and R. V. Frie. 1996. Determination of age and growth. Pages 483-508 *in* B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Dutil, J. D., and G. Power. 1977. Validite′ de la lecture des otolithes comparee a celle de la lecture des ecailles pour la determination de l'age de l'omble de fontaine, *Salvelinus fontinalis*. Naturalist Canada 104:361-367.

Everhart, W. H., and W. D. Youngs. 1981. Principles of fishery science, second edition. Cornell University Press Ltd., New York.

Goeman, T. J., D. R. Helms, and R. C. Heidinger. 1984. Comparison of otolith and scale age determinations for freshwater drum from the Mississippi River. Proceedings of the Iowa Academy of Science 91:49-51.

Golani, D., and A. Ben-Tuvia. 1985. The biology of the Indo-Pacific squirrelfish, *Sargocentron rubrum* (Forsska), a Suez Canal migrant to the eastern Mediterranean. Journal of Fish Biology 27:249-258.

Habera, J. W., and R. J. Strange. 1993. Wild trout resources and management in the southern Appalachian Mountains. Fisheries 18(1):6-13.

Habera, J. W., R. D. Bivens, B. D. Carter, and C. E. Williams. 1999. Region IV trout fisheries report: 1998. Fisheries Report No. 99-4. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Habera, J. W., R. D. Bivens, B. D. Carter, and C. E. Williams. 2001. Region IV trout fisheries report: 2000. Fisheries Report No. 01-03. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Habera, J. W., R. D. Bivens, B. D. Carter, and C. E. Williams. 2003. Region IV trout fisheries report: 2002. Fisheries Report No. 03-03. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Hansen, L. P. 1978. Age determination of roach, *Rutilus rutilus* L., from scales and opercular bones. Archiv fur Fischereiwissenshaft 29 (1/2):93-98.

Harrington, R. W., Jr. 1955. The osteocranium of the American cyprinid fish, *Notropis bifrenatus*, with an annotated synonymy of teleost skull bones. Copeia 20:267-290.

Harrison, E. J., and W. F. Hadley. 1979. A comparison of the use of cleithra to the use of scales for age and growth studies. Transactions of the American Fisheries Society 108:452-456.

Hining, K. J., J. L. West, M. A. Kulp, and A.D. Neubauer. 2000. Validation of scales and otoliths for estimating age of rainbow trout from southern Appalachian streams. North American Journal of Fisheries Management 20:987-985.

Jamieson, A., R. J. Turner, W. A. Dawson, and A. J. Birley. 1987. Atantic mackerel (*Scomber scombrus* L.) adenosine deaminase, esterase-D, and otolith. Journal of Conservation International Explorer 44(1):59-65.

Jearld, A., Jr. 1983. Age determination. Pages 301-326 *in* L.A. Nielson and D.L. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda Maryland.

Joeris, L. S. 1965. Structure and growth of scales of yellow perch of Green Bay. Transactions of the American Fisheries Society 86:169-194.

Jessop, B. M. 1972. Ageing round whitefish, *Prosopium cylindraceum*, of the Leaf River, Ungava, Quebec, by otoliths. Journal of the Fisheries Research Board of Canada 29:452-454.

Kwak, T. J., and T. F. Waters. 1997. Trout production and water quality in Minnesota streams. Transactions of the American Fisheries Society. 126:35-48.

Maraldo, D. C., and H. R. MacCrimmon. 1979. Comparison of ageing methods and growth rates for largemouth bass, *Micropterus salmoides* Lacepede, from northern latitudes. Environmental Biology of Fishes 4:263-271.

Mujib, K. A. 1967. The cranial osteology of the Gadidae. Journal of the Fisheries Research Board of Canada 24:1315-1375.

Newman, S. J. 2002. Growth rate, age determination, natural mortality and production potential of the scarlet seaperch, *Lutjanus malabaricus* Schneider 1802, off the Pilbara coast of north-western Australia. Fisheries Research 58:215-225.

Power, G. 1978. Fish population structure in Arctic lakes. Journal of the Fisheries Research Board of Canada 35:53-59.

Powers, J. E. 1983. Some statistical characteristics of ageing data and their ramifications in population analysis of oceanic pelagic fishes. Pages 19-27 *in* E.D. Prince and L.M. Pulos, editors. Proceedings of the international workshop on age determination of oceanic pelagic fishes: tunas, billfishes, and sharks. United States Department of Commerce, NOAA Technical Report, NMFS 8.

Radebe, P. V., B. Q. Mann, L. E. Beckley, and A. Govender. 2002. Age and growth of *Rhabdosargus sarba* (Pisces: Sparidae), from KwaZulu-Natal, South Africa. Fisheries Research 58:193-201.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada Bulletin 191.

Robillard, S. R., and J. E. Marsden. 1996. Comparision of otolith and scale ages for yellow perch from Lake Michigan. Journal of Great Lakes Research 22(2):429-235.

SAS Institute Inc. 2002. SAS User's Guide: Statistics, 2002 edition. SAS Institute Inc. Cary, North Carolina, USA.

Secor, D. H., J. M. Dean, and E. H. Laban. 1991. Manual for otolith removal and preparation for microstructure examination. Baruch Institute Technical Report 91-1, University of South Carolina, Columbia, SC, 85p.

Secor, D. H., J. M. Dean, and E. H. Laban. 1992. Otolith removal and preparation for microstructure examination. Pages 19-57 *in* D. K. Stevenson and S. E. Campana, editors, Otolith microstructure examination and analysis. Canada Special Publication Fisheries Aquatic Science. 117.

Sikstrom, C. B. 1983. Otolith, pectoral fin ray, and scale age determinations for Arctic grayling. Progressive Fish-Culturist 45:220-223.

Simard, A., and E. Magnin. 1972. Method of determination of the age and growth of lake trout, *Salvelinus namaycush*, Walbaum, of Lake L'Assomption and of Lake Tremblant, Quebec. Nature Canada (Quebec) 99:561-579.

Simkiss, K. 1974. Calcium metabolism of fish in relation to ageing. Pages 1-12 *in* T. B. Bagenal, editor, Ageing of fish. Unwin Brothers Limited, Surrey, England.

Sokal, R. R., and F. J. Rohlf, 1981. The principles and practice of statistics in biological research, second edition. W. H. Freeman and Company, San Francisco

Strange, R. J., and J. W. Habera. 1993. Wild Trout Report: 1992 Annual Report. Cooperators: Tennesse Wildlife Resources Agency and the University of Tennessee, Knoxville. Publication No. R11-2217-76-001-93.

Strange, R. J., and J. W. Habera. 1994. Wild Trout Report: 1993 Annual Report. Cooperators: Tennesse Wildlife Resources Agency and the University of Tennessee, Knoxville. Publication No. R11-2217-18-001-94.

Strange, R. J., and J. W. Habera. 1997. Wild Trout Report: 1996 Annual Report. Cooperators: Tennesse Wildlife Resources Agency and the University of Tennessee, Knoxville. Publication No. R11-2217-93-001-97.

Strange, R. J., and J. W. Habera. 1998. Wild Trout Report: 1997 Annual Report. Cooperators: Tennesse Wildlife Resources Agency and the University of Tennessee, Knoxville. Publication No. R11-2217-93-002-98.

Svalastog, D. 1991. A note on maximum age of brown trout, *Salmo trutta* L. Journal of Fish Biology 38:967-968.

Van Den Avyle, M. J. 1993. Dynamics of exploited fish populations. Pages 105-135 *in* C. C. Kohler and W. A. Hubert, editors. Inland fisheries management in North America. American Fisheries Society, Bethesda, Maryland.

APPENDIX
A

Appendix A1. Site locations and selected physical/chemical data for the 12 East Tennessee streams from which *O. mykiss* (N = 621) samples were collected.

Stream	County	Sample coordinates	Site length (m)	Average width (m)	Max depth (m)	Flow (ft^3/sec)	Temp. (°C)	Conductivity (µS/cm)	pH	Alkalinity (mg/L $CaCO_3$)	Percent of site as pool	Percent of site as riffle
Beaverdam Creek	Johnson	36°34'17"N 81°51'51"W	260	9.1	1.1	8.6	17.2	116	7.5	50	N/M	N/M
Doe Creek	Johnson	36°24'45"N 81°57'38"W	271	9.4	1.5	12.0	15.8	164	7.8	75	N/M	N/M
Laurel Creek	Johnson	36°35'89"N 81°45'04"W	338	10.4	1.2	N/M	17	170	7.6	70	N/M	N/M
Doe River	Carter	36°10'21"N 82°05'31"W	201	6.2	1.15	6.9	13.8	107	7.5	45	48	52
Stony Creek	Carter	36°25'12"N 82°04'14"W	106	11.3	2.7	N/M	21.8	144	7.6	70	40	60
Left Prong Hampton Creek	Carter	36°08'02"N 82°02'30"W	127	3.2	N/M	N/M	N/M	33	6.9	15	40	60
Bald River	Monroe	35°17'03"N 84°10'00"W	419	7.8	1.1	N/M	16.5	14	6.4	10	26	74
North River	Monroe	35°19'07"N 84°05'58"W	241	11.9	1.2	12.9	17.2	21	6.8	15	39	61
Tellico River	Monroe	35°16'27"N 84°05'19"W	148	12.5	1.25	61.8	16.5	13	6.8	10	43	57
Jennings Creek	Greene	36°05'21"N 82°40'46"W	316	N/M	1.2	N/M	20.7	23	6.7	15	35	65
Rocky Fork	Unicoi	36°02'44"N 82°33'38"W	129	5.3	1.3	1.5	15.4	29	6.9	15	57	43
Wolf Creek	Polk	35°09'43"N 84°22'32"W	184	N/M	0.77	N/M	20.4	23	6.9	10	60	40

APPENDIX
B

Appendix B1. Scale and otolith ages for *O. mykiss* (N = 41) collected in Beaverdam Creek, 9-4-2002.

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
BVD-1	91	225	1	2	2	2	2	2
BVD-2	58	186	1	1	1	1	1	1
BVD-3	99	220	2	1	2	2	2	2
BVD-4	4	76	0	0	0	0	0	0
BVD-5	59	191	2	1	1	1	1	1
BVD-6	52	178	2	2	2	1	0	1
BVD-7	73	212	2	2	2	2	2	2
BVD-8	48	179	1	1	1	1	0	Discarded
BVD-9	33	154	1	1	1	1	1	1
BVD-10	22	131	1	1	1	1	1	1
BVD-11	20	132	0	0	0	1	1	1
BVD-12	14	112	0	0	0	1	1	1
BVD-13	24	135	1	1	1	1	1	1
BVD-14	48	173	1	1	1	0	0	1
BVD-15	19	128	0	0	0	0	0	0
BVD-16	18	121	0	0	0	0	0	0
BVD-17	19	126	0	0	0	0	0	0
BVD-18	6	82	0	0	0	0	0	0
BVD-19	4	72	0	0	0	0	0	0
BVD-20	23	136	1	0	0	1	0	0
BVD-21	12	106	1	1	1	0	0	0
BVD-22	5	80	0	0	0	0	0	0

Appendix B1. (continued)

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
BVD-23	10	99	0	0	0	0	0	0
BVD-24	13	121	1	1	1	0	0	0
BVD-25	3	70	0	0	0	0	0	0
BVD-26	4	76	0	0	0	0	0	0
BVD-27	82	207	1	2	2	2	2	2
BVD-28	2	64	0	0	0	0	0	0
BVD-29	67	200	1	1	1	1	1	1
BVD-30	135	242	2	3	2	N/M	N/M	Discarded
BVD-31	60	191	2	1	2	2	1	Discarded
BVD-32	3	43	0	0	0	0	0	0
BVD-33	5	71	0	0	0	0	0	0
BVD-34	60	185	1	1	1	1	1	1
BVD-35	28	190	1	2	Discarded	3	3	3
BVD-36	55	180	1	2	1	1	1	1
BVD-37	36	171	1	1	1	1	1	1
BVD-38	87	214	1	2	1	2	2	2
BVD-39	78	205	1	1	1	1	1	1
BVD-40	29	142	1	1	1	2	2	2
BVD-41	32	155	1	1	1	1	1	1

[a] Kimberly Cooper
[b] Todd Sink

Appendix B2. Scale and otolith ages for *O. mykiss* (N = 62) collected in Doe Creek, 9-9-2002.

			Scale age			Otolith age		
Sampe ID#	**Weight (g)**	**Length (mm)**	**KC[a]**	**TS[b]**	**Agreed age**	**KC[a]**	**TS[b]**	**Agreed age**
DOEC-1	56	174	1	1	1	1	1	1
DOEC-2	40	170	1	1	1	1	1	1
DOEC-3	97	203	2	2	2	1	1	1
DOEC-4	53	179	1	1	1	1	1	1
DOEC-5	87	200	2	2	2	1	1	1
DOEC-6	32	149	1	1	1	1	1	1
DOEC-7	83	209	2	2	2	1	1	1
DOEC-8	78	192	2	2	2	2	2	2
DOEC-9	71	185	1	1	1	0	0	1
DOEC-10	32	150	1	1	1	1	1	1
DOEC-11	31	154	1	0	0	N/M	0	Discarded
DOEC-12	75	196	1	1	1	1	1	1
DOEC-13	63	194	1	2	1	1	1	1
DOEC-14	43	170	1	1	1	1	1	1
DOEC-15	26	140	1	1	1	1	1	1
DOEC-16	28	148	1	1	1	1	1	1
DOEC-17	29	141	1	1	1	1	1	1
DOEC-18	53	170	1	1	1	1	1	1
DOEC-19	16	121	0	0	0	1	0	0
DOEC-20	12	108	0	0	0	0	0	0
DOEC-21	12	106	0	0	0	0	0	0
DOEC-22	49	172	1	2	3	1	1	1

Appendix B2. (continued)

Sampe ID#	Weight (g)	Length (mm)	Scale age			Otolith age		
			KC[a]	TS[b]	Agreed age	KC[a]	TS[b]	Agreed age
DOEC-23	34	150	1	1	1	1	1	1
DOEC-24	21	134	1	1	1	0	0	0
DOEC-25	38	162	1	1	1	1	1	1
DOEC-26	28	144	1	1	1	1	1	1
DOEC-27	54	174	1	1	1	1	1	1
DOEC-28	62	189	2	2	2	2	2	2
DOEC-29	26	155	1	1	1	1	1	1
DOEC-30	36	157	2	2	2	1	0	Discarded
DOEC-31	42	164	1	1	1	1	1	1
DOEC-32	32	155	1	1	1	1	1	1
DOEC-33	32	147	1	1	1	1	1	1
DOEC-34	32	154	1	1	1	1	0	1
DOEC-35	49	180	2	1	1	1	1	1
DOEC-36	50	171	1	1	1	1	1	1
DOEC-37	11	103	0	0	0	0	0	0
DOEC-38	11	101	0	0	0	0	0	0
DOEC-39	17	119	0	1	0	0	0	0
DOEC-40	33	152	1	1	1	0	0	1
DOEC-41	31	149	1	0	1	1	1	1
DOEC-42	10	103	0	0	0	0	0	0
DOEC-43	26	139	1	1	1	1	0	1
DOEC-44	34	151	1	1	1	1	1	1

Appendix B2. (continued)

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
DOEC-45	6	86	0	0	0	0	0	0
DOEC-46	36	157	1	1	1	1	1	1
DOEC-47	26	143	0	1	0	0	0	0
DOEC-48	25	140	1	1	1	1	0	1
DOEC-49	23	138	1	1	1	1	0	1
DOEC-50	24	130	1	1	1	1	1	1
DOEC-51	80	199	3	2	2	1	1	1
DOEC-52	74	196	2	2	2	1	1	1
DOEC-53	94	215	2	2	2	1	1	1
DOEC-54	63	191	1	1	1	1	1	1
DOEC-55	82	202	N/M	3	Discarded	1	1	1
DOEC-56	138	227	2	2	2	2	2	2
DOEC-57	61	182	1	1	1	1	1	1
DOEC-58	65	193	2	2	2	1	1	1
DOEC-59	81	202	2	2	2	N/M	0	Discarded
DOEC-60	9	99	0	0	0	0	0	0
DOEC-61	54	178	1	1	1	1	1	1
DOEC-62	181	270	3	3	3	3	3	3

[a] Kimberly Cooper
[b] Todd Sink

Appendix B3. Scale and otolith ages for *O. mykiss* (N = 69) collected in Laurel Creek, 5-9-2002.

			Scale age			Otolith age		
Sampe ID#	Weight (g)	Length (mm)	KC[a]	TS[b]	Agreed age	KC[a]	TS[b]	Agreed age
LC-1	147	247	3	3	3	4	4	4
LC-2	50	171	1	1	1	1	1	1
LC-3	59	182	1	1	1	1	1	1
LC-4	98	211	3	2	2	1	1	1
LC-5	53	175	1	1	1	0	0	1
LC-6	60	179	2	1	1	1	1	1
LC-7	35	156	1	1	1	1	1	1
LC-8	35	148	1	1	1	1	1	1
LC-9	8	93	0	0	0	0	0	0
LC-10	6	89	0	0	0	0	0	0
LC-11	106	212	2	2	2	2	2	2
LC-12	37	153	1	2	0	0	0	1
LC-13	122	231	3	2	3	4	4	4
LC-14	29	142	1	1	1	1	1	1
LC-15	58	182	1	1	1	1	1	1
LC-16	51	181	1	1	1	1	1	1
LC-17	75	204	3	2	2	2	2	2
LC-18	35	154	1	2	0	1	0	1
LC-19	111	237	3	2	2	2	2	2
LC-20	103	233	2	1	2	2	2	2
LC-21	46	164	1	2	0	0	0	1
LC-22	26	135	1	1	1	1	1	1

Appendix B3. (continued)

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Ototith age KC[a]	Ototith age TS[b]	Agreed age
LC-23	28	144	0	0	0	1	1	1
LC-24	30	145	0	0	0	1	1	1
LC-25	73	195	1	1	1	2	2	2
LC-26	140	254	3	2	Discarded	5	5	5
LC-27	58	189	1	1	1	2	2	2
LC-28	33	144	0	0	0	0	0	0
LC-29	142	236	2	2	2	3	3	3
LC-30	146	246	2	1	2	2	2	2
LC-31	78	203	1	2	1	2	2	2
LC-32	75	196	1	2	1	1	1	1
LC-33	47	168	0	0	0	1	1	1
LC-34	79	205	2	1	1	1	1	1
LC-35	18	119	0	0	0	0	0	0
LC-36	96	220	2	2	2	2	2	2
LC-37	154	159	3	2	3	3	3	3
LC-38	85	215	2	2	2	2	2	2
LC-39	55	174	1	2	1	1	0	1
LC-40	52	171	1	1	1	2	1	2
LC-41	25	134	0	0	0	1	1	1
LC-42	18	116	0	0	0	0	0	0
LC-43	8	42	0	0	0	0	0	0
LC-44	9	94	0	0	0	0	0	0

Appendix B3. (continued)

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
LC-45	5	78	0	0	0	0	0	0
LC-46	6	43	0	0	0	0	0	0
LC-47	5	72	0	1	0	0	0	0
LC-48	51	174	1	1	1	1	1	1
LC-49	67	191	2	2	2	2	2	2
LC-50	104	224	2	2	2	N/M	N/M	Discarded
LC-51	55	173	0	0	0	1	1	1
LC-52	32	151	0	0	0	0	N/M	Discarded
LC-53	127	143	2	2	2	2	2	2
LC-54	34	154	1	1	1	0	0	1
LC-55	34	152	1	1	1	N/M	0	Discarded
LC-56	22	135	1	1	1	1	1	1
LC-57	78	195	2	2	2	2	2	2
LC-58	112	223	1	1	1	2	2	2
LC-59	6	80	0	0	0	0	0	0
LC-60	7	85	0	0	0	0	0	0
LC-61	6	80	0	0	0	0	0	0
LC-62	75	203	2	3	2	2	2	2
LC-63	41	159	1	2	0	N/M	N/M	Discarded
LC-64	100	228	3	2	2	3	3	3
LC-65	14	111	0	0	0	0	0	0
LC-66	78	209	2	2	2	2	2	2

Appendix B3. (continued)

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
LC-67	30	141	1	1	1	1	1	1
LC-68	102	217	1	1	1	1	1	1
LC-69	90	198	1	1	1	N/M	N/M	Discarded

[a] Kimberly Cooper
[b] Todd Sink

Appendix B4. Scale and otolith ages for *O. mykiss* (N = 70) collected in Doe River, 9-10-2002.

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
DOER-1	101	216	1	1	1	1	1	1
DOER-2	136	231	2	2	2	3	3	3
DOER-3	71	190	1	0	1	1	0	Discarded
DOER-4	108	225	2	2	2	2	2	2
DOER-5	94	207	2	1	1	1	1	1
DOER-6	103	216	2	1	1	2	2	2
DOER-7	77	204	1	1	1	2	2	2
DOER-8	77	202	2	2	2	2	2	2
DOER-9	55	176	1	1	1	1	1	1
DOER-10	95	214	2	2	2	2	2	2
DOER-11	91	197	1	1	1	1	1	1
DOER-12	44	170	1	1	1	1	1	1
DOER-13	44	169	1	1	1	1	1	1
DOER-14	88	205	2	3	2	2	2	2
DOER-15	88	210	1	1	1	N/M	N/M	Discarded
DOER-16	97	210	2	2	2	2	2	2
DOER-17	69	183	1	1	1	1	1	1
DOER-18	72	191	1	1	1	1	1	1
DOER-19	63	178	1	1	1	N/M	0	Discarded
DOER-20	57	182	1	1	1	N/M	0	Discarded
DOER-21	119	226	1	1	1	2	2	2
DOER-22	86	205	1	2	2	2	2	2

Appendix B4. (continued)

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
DOER-23	57	180	0	0	0	0	0	1
DOER-24	30	148	0	0	0	1	1	1
DOER-25	77	188	2	1	2	2	2	2
DOER-26	44	165	1	1	1	N/M	N/M	Discarded
DOER-27	90	205	1	0	2	2	2	2
DOER-28	66	178	2	1	2	2	2	2
DOER-29	43	162	0	0	0	1	1	1
DOER-30	47	175	1	1	1	1	1	1
DOER-31	47	170	1	1	1	1	0	1
DOER-32	47	168	1	1	1	1	1	1
DOER-33	41	165	1	1	1	0	N/M	Discarded
DOER-34	38	160	1	1	1	0	N/M	Discarded
DOER-35	29	140	0	0	0	0	0	1
DOER-36	49	165	1	1	1	2	2	2
DOER-37	56	187	1	1	1	1	1	1
DOER-38	28	131	1	0	0	0	0	0
DOER-39	31	130	1	1	1	1	1	1
DOER-40	37	162	1	1	1	1	1	1
DOER-41	34	151	1	1	1	0	0	1
DOER-42	86	204	2	2	2	2	2	2
DOER-43	45	175	1	2	1	1	1	1
DOER-44	103	224	2	2	2	2	2	2

Appendix B4. (continued)

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
DOER-45	110	237	3	3	3	3	1	2
DOER-46	79	211	2	2	2	2	2	2
DOER-47	43	172	1	1	1	1	1	1
DOER-48	62	191	1	1	1	1	1	1
DOER-49	79	211	2	1	1	1	1	1
DOER-50	80	209	2	2	2	2	2	2
DOER-51	41	164	1	1	1	2	2	2
DOER-52	46	173	1	1	1	1	1	1
DOER-53	30	149	1	1	1	1	1	1
DOER-54	99	230	2	3	2	2	2	2
DOER-55	145	252	2	2	2	2	2	2
DOER-56	152	257	3	2	2	2	2	2
DOER-57	167	269	3	2	3	3	3	3
DOER-58	96	225	2	2	3	3	3	3
DOER-59	80	213	2	1	2	2	2	2
DOER-60	80	202	2	2	2	1	1	1
DOER-61	145	257	3	1	2	2	2	2
DOER-62	93	220	3	2	2	2	2	2
DOER-63	63	204	3	2	2	2	2	2
DOER-64	168	264	3	2	2	2	2	2
DOER-65	35	166	2	0	1	1	1	1
DOER-66	66	198	1	1	1	2	2	2

Appendix B4. (continued)

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
DOER-67	85	214	2	1	2	2	2	2
DOER-68	73	204	2	1	1	1	1	1
DOER-69	38	161	2	2	2	N/M	N/M	Discarded
DOER-70	47	172	1	1	1	1	N/M	1

[a] Kimberly Cooper
[b] Todd Sink

Appendix B5. Scale and otolith ages for *O. mykiss* (N = 52) collected in Stony Creek, 8-5-2002.

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
STN-1	50	172	1	1	1	1	1	1
STN-2	90	214	2	3	2	1	1	1
STN-3	131	235	2	2	2	3	2	2
STN-4	62	192	1	1	1	1	1	1
STN-5	58	184	1	1	1	1	1	1
STN-6	84	214	2	2	2	1	1	1
STN-7	82	205	2	2	2	1	1	1
STN-8	72	199	1	1	1	1	1	1
STN-9	81	203	1	1	1	2	2	2
STN-10	111	226	1	2	2	2	2	2
STN-11	44	168	1	1	1	1	1	1
STN-12	30	154	0	0	0	1	1	1
STN-13	13	113	0	0	0	0	0	0
STN-14	4	74	0	0	0	0	0	0
STN-15	89	207	1	2	2	2	2	2
STN-16	108	199	1	2	2	1	1	1
STN-17	179	256	2	2	2	2	2	2
STN-18	106	217	2	2	2	2	2	2
STN-19	60	184	1	1	1	1	1	1
STN-20	139	148	1	2	2	2	2	2
STN-21	138	242	2	2	2	2	2	2
STN-22	80	193	1	2	1	1	1	1

Appendix B5. (continued)

Sampe ID#	Weight (g)	Length (mm)	Scale age		Agreed age	Otolith age		Agreed age
			KC[a]	TS[b]		KC[a]	TS[b]	
STN-23	80	201	1	1	1	1	1	1
STN-24	67	194	1	1	1	1	1	1
STN-25	45	160	1	1	1	1	0	1
STN-26	151	246	1	2	2	1	1	1
STN-27	82	198	1	1	1	1	1	1
STN-28	79	196	1	1	1	1	0	Discarded
STN-29	72	194	1	1	1	1	1	1
STN-30	36	155	1	1	1	1	1	1
STN-31	35	156	1	1	1	N/M	0	Discarded
STN-32	18	115	0	0	0	0	0	0
STN-33	100	215	1	3	2	1	1	1
STN-34	50	175	1	1	1	N/M	0	Discarded
STN-35	57	178	1	1	1	1	1	1
STN-36	17	120	0	0	0	0	0	0
STN-37	43	160	1	1	1	1	1	1
STN-38	53	178	1	1	1	1	1	1
STN-39	73	198	1	2	1	0	0	1
STN-40	50	171	1	1	1	0	0	1
STN-41	95	204	1	1	1	1	1	1
STN-42	107	220	2	2	2	2	2	2
STN-43	19	116	0	0	0	0	0	0
STN-44	6	80	0	0	0	0	0	0

Appendix B5. (continued)

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
STN-45	6	86	0	0	0	0	0	0
STN-46	14	107	0	0	0	0	0	0
STN-47	12	106	0	0	0	0	0	0
STN-48	13	110	0	0	0	0	0	0
STN-49	9	94	0	0	0	0	0	0
STN-50	6	85	0	0	0	0	0	0
STN-51	7	90	0	0	0	0	0	0
STN-52	8	93	0	0	0	0	0	0

[a] Kimberly Cooper
[b] Todd Sink

Appendix B6. Scale and otolith ages for *O. mykiss* (N = 48) collected in Left Prong Hampton Creek, 10-21-1998.

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
LPH-1	330	312	N/M	N/M	N/M	8	8	8
LPH-2	70	198	N/M	N/M	N/M	2	2	2
LPH-3	119	228	N/M	N/M	N/M	6	6	6
LPH-4	115	245	N/M	N/M	N/M	8	8	8
LPH-5	69	194	N/M	N/M	N/M	6	6	6
LPH-6	78	211	N/M	N/M	N/M	3	3	3
LPH-7	60	187	N/M	N/M	N/M	4	4	4
LPH-8	43	167	N/M	N/M	N/M	2	2	2
LPH-9	44	176	N/M	N/M	N/M	3	3	3
LPH-10	91	221	N/M	N/M	N/M	4	4	4
LPH-11	78	202	N/M	N/M	N/M	3	3	3
LPH-12	90	213	N/M	N/M	N/M	3	3	3
LPH-13	39	162	N/M	N/M	N/M	1	1	1
LPH-14	51	171	N/M	N/M	N/M	2	2	2
LPH-15	23	133	N/M	N/M	N/M	1	1	1
LPH-16	23	139	N/M	N/M	N/M	2	1	1
LPH-17	41	162	N/M	N/M	N/M	1	1	1
LPH-18	29	147	N/M	N/M	N/M	1	1	1
LPH-19	29	151	N/M	N/M	N/M	0	0	1
LPH-20	23	138	N/M	N/M	N/M	1	1	1
LPH-21	39	159	N/M	N/M	N/M	1	1	1
LPH-22	32	151	N/M	N/M	N/M	3	3	3

Appendix B6. (continued)

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
LPH-23	19	129	N/M	N/M	N/M	1	1	1
LPH-24	83	211	N/M	N/M	N/M	6	6	6
LPH-25	63	191	N/M	N/M	N/M	1	1	1
LPH-26	52	184	N/M	N/M	N/M	3	3	3
LPH-27	39	168	N/M	N/M	N/M	4	4	4
LPH-28	53	177	N/M	N/M	N/M	3	3	3
LPH-29	27	141	N/M	N/M	N/M	1	1	1
LPH-30	27	145	N/M	N/M	N/M	1	1	1
LPH-31	20	131	N/M	N/M	N/M	0	0	0
LPH-32	21	128	N/M	N/M	N/M	1	1	1
LPH-33	15	119	N/M	N/M	N/M	1	0	1
LPH-34	14	116	N/M	N/M	N/M	0	0	0
LPH-35	14	112	N/M	N/M	N/M	1	0	1
LPH-36	8	94	N/M	N/M	N/M	0	0	0
LPH-37	1	55	N/M	N/M	N/M	0	0	0
LPH-38	6	82	N/M	N/M	N/M	0	0	0
LPH-39	3	69	N/M	N/M	N/M	0	0	0
LPH-40	4	75	N/M	N/M	N/M	0	0	0
LPH-41	2	61	N/M	N/M	N/M	0	0	0
LPH-42	8	92	N/M	N/M	N/M	0	0	0
LPH-43	4	79	N/M	N/M	N/M	0	0	0
LPH-44	6	90	N/M	N/M	N/M	0	0	0

Appendix B6. (continued)

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
LPH-45	2	62	N/M	N/M	N/M	0	0	0
LPH-46	5	82	N/M	N/M	N/M	0	0	0
LPH-47	6	84	N/M	N/M	N/M	0	0	0
LPH-48	3	71	N/M	N/M	N/M	2	2	2

[a] Kimberly Cooper

[b] Todd Sink

Appendix B7. Scale and otolith ages for *O. mykiss* (N = 57) collected in Bald River, 9-30-2002.

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
BLDR-1	31	140	1	1	1	1	1	1
BLDR-2	40	131	1	1	1	1	1	1
BLDR-3	35	142	1	1	1	1	1	1
BLDR-4	54	161	1	1	1	1	1	1
BLDR-5	25	129	0	0	0	0	0	0
BLDR-6	91	193	3	2	3	2	3	3
BLDR-7	84	190	3	2	2	2	2	2
BLDR-8	34	138	1	1	1	1	1	1
BLDR-9	30	125	2	0	0	0	0	0
BLDR-10	43	162	1	1	1	1	1	1
BLDR-11	47	175	1	1	1	1	1	1
BLDR-12	47	170	1	1	1	1	1	1
BLDR-13	47	168	1	1	1	1	1	1
BLDR-14	42	139	1	1	1	1	1	1
BLDR-15	39	153	3	1	2	2	2	2
BLDR-16	31	135	1	1	1	1	1	1
BLDR-17	31	141	1	1	1	1	1	1
BLDR-18	70	167	2	2	2	2	2	2
BLDR-19	43	135	1	1	1	1	1	1
BLDR-20	26	140	1	1	1	1	0	1
BLDR-21	41	150	1	1	1	1	1	1
BLDR-22	23	137	0	0	0	1	0	0

Appendix B7. (continued)

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
BLDR-23	29	140	1	1	1	1	1	1
BLDR-24	51	143	1	1	1	2	1	1
BLDR-25	73	180	3	3	3	3	3	3
BLDR-26	21	131	0	0	0	0	0	0
BLDR-27	61	170	2	2	2	2	2	2
BLDR-28	92	207	1	2	2	2	2	2
BLDR-29	6	86	0	0	0	0	0	0
BLDR-30	3	73	0	0	0	0	0	0
BLDR-31	16	122	0	0	0	0	0	0
BLDR-32	24	135	1	1	1	1	1	1
BLDR-33	42	165	1	1	1	1	1	1
BLDR-34	23	136	1	1	1	1	0	1
BLDR-35	36	155	1	1	1	1	1	1
BLDR-36	18	129	0	0	0	0	0	0
BLDR-37	3	70	0	0	0	0	0	0
BLDR-38	29	142	1	1	1	1	0	1
BLDR-39	17	123	0	0	0	0	0	0
BLDR-40	41	159	1	1	1	1	1	1
BLDR-41	27	144	1	1	1	1	1	1
BLDR-42	49	173	1	1	1	1	1	1
BLDR-43	16	121	0	0	0	0	0	0
BLDR-44	2	66	0	0	0	0	0	0

Appendix B7. (continued)

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
BLDR-45	8	89	0	0	0	0	0	0
BLDR-46	7	94	0	0	0	0	0	0
BLDR-47	6	85	0	0	0	0	0	0
BLDR-48	7	89	0	0	0	0	0	0
BLDR-49	46	169	1	2	2	2	2	2
BLDR-50	6	83	0	0	0	0	0	0
BLDR-51	5	79	0	0	0	0	0	0
BLDR-52	23	135	1	0	0	0	0	0
BLDR-53	29	144	1	1	1	1	1	1
BLDR-54	30	152	1	1	1	1	1	1
BLDR-55	20	135	0	0	0	0	0	0
BLDR-56	4	75	0	0	0	0	0	0
BLDR-57	12	116	0	0	0	0	0	0

[a] Kimberly Cooper
[b] Todd Sink

Appendix B8. Scale and otolith ages for *O. mykiss* (N = 52) collected in North River, 9-30-2002.

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
NTR-1	28	146	1	1	1	1	1	1
NTR-2	26	148	1	N/M	1	1	1	1
NTR-3	53	179	3	2	2	2	2	2
NTR-4	43	180	1	1	1	0	2	4
NTR-5	40	155	2	3	2	1	1	1
NTR-6	23	134	1	1	1	1	1	1
NTR-7	15	120	0	2	2	1	1	1
NTR-8	22	135	1	1	1	0	0	0
NTR-9	25	144	2	2	2	1	1	1
NTR-10	36	163	2	2	2	1	1	1
NTR-11	25	141	1	1	1	1	1	1
NTR-12	4	81	0	0	0	N/M	N/M	Discarded
NTR-13	6	86	0	0	0	0	0	0
NTR-14	33	153	0	1	0	N/M	N/M	Discarded
NTR-15	6	87	0	0	0	0	0	0
NTR-16	37	160	2	2	2	1	0	1
NTR-17	25	144	2	2	2	0	0	0
NTR-18	5	81	0	0	0	0	0	0
NTR-19	5	83	0	0	0	0	0	0
NTR-20	34	159	2	3	2	1	3	3
NTR-21	32	152	1	1	1	1	1	1
NTR-22	19	139	0	2	1	1	1	1

Appendix B8. (continued)

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
NTR-23	27	144	1	1	1	N/M	1	Discarded
NTR-24	6	87	0	0	0	0	0	0
NTR-25	6	90	0	0	0	0	0	0
NTR-26	17	128	1	1	1	1	1	1
NTR-27	38	157	1	1	1	1	1	1
NTR-28	34	157	2	2	2	1	1	1
NTR-29	37	160	1	1	1	1	1	1
NTR-30	43	167	1	1	1	1	1	1
NTR-31	28	144	1	1	1	1	1	1
NTR-32	25	145	1	1	1	1	1	1
NTR-33	65	191	2	0	2	1	1	1
NTR-34	28	148	1	1	1	1	1	1
NTR-35	43	172	2	1	2	2	2	2
NTR-36	14	115	0	0	0	0	0	0
NTR-37	19	133	0	0	0	1	0	0
NTR-38	23	141	0	2	2	1	1	1
NTR-39	37	150	1	1	1	1	1	1
NTR-40	23	144	1	1	1	1	1	1
NTR-41	70	198	3	2	2	1	0	1
NTR-42	55	187	2	2	2	2	2	2
NTR-43	24	141	2	2	2	1	1	1
NTR-44	4	78	0	0	0	0	0	0

Appendix B8. (continued)

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
NTR-45	5	80	0	0	0	0	0	0
NTR-46	17	128	0	0	0	0	0	0
NTR-47	6	89	0	0	0	0	0	0
NTR-48	39	161	1	1	1	1	1	1
NTR-49	18	129	2	3	2	1	1	1
NTR-50	71	204	2	3	3	3	3	3
NTR-51	27	146	2	2	2	1	1	1
NTR-52	50	174	2	2	2	2	2	2

[a] Kimberly Cooper
[b] Todd Sink

Appendix B9. Scale and otolith ages for *O. mykiss* (N = 64) collected in Tellico River, 10-3-2002.

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
TEL-1	31	141	2	2	2	1	1	1
TEL-2	25	136	1	1	1	1	1	1
TEL-3	29	140	1	1	1	1	1	1
TEL-4	21	121	2	2	2	0	0	0
TEL-5	23	119	0	0	0	0	0	0
TEL-6	26	123	0	0	0	0	0	0
TEL-7	36	146	1	1	1	1	1	1
TEL-8	61	171	1	0	2	2	2	2
TEL-9	33	148	1	1	1	1	1	1
TEL-10	48	135	2	2	2	1	1	1
TEL-11	26	134	0	0	0	0	0	0
TEL-12	37	148	1	1	1	1	1	1
TEL-13	43	141	1	1	1	1	1	1
TEL-14	31	126	1	1	1	1	1	1
TEL-15	34	131	1	3	2	1	1	1
TEL-16	40	142	1	0	0	1	1	1
TEL-17	28	129	0	0	0	1	1	1
TEL-18	20	119	0	0	0	0	0	0
TEL-19	20	121	0	0	0	0	0	0
TEL-20	35	140	1	1	1	1	1	1
TEL-21	31	141	0	1	0	1	1	1
TEL-22	28	132	1	1	1	1	1	1

Appendix B9. (continued)

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
TEL-23	13	99	0	0	0	0	0	0
TEL-24	16	108	0	0	0	0	0	0
TEL-25	14	109	0	0	0	0	0	0
TEL-26	81	181	2	2	2	2	2	2
TEL-27	29	137	1	1	1	1	1	1
TEL-28	32	140	1	1	1	1	1	1
TEL-29	20	119	0	0	0	0	0	0
TEL-30	26	121	1	1	1	1	1	1
TEL-31	29	137	1	1	1	1	1	1
TEL-32	61	182	2	2	2	1	1	1
TEL-33	30	141	3	2	2	1	1	1
TEL-34	59	182	2	2	2	1	1	1
TEL-35	37	153	2	1	2	1	1	1
TEL-36	42	163	2	1	2	N/M	0	1
TEL-37	43	160	2	1	1	1	0	1
TEL-38	60	185	2	2	2	2	2	2
TEL-39	21	122	1	1	1	1	1	1
TEL-40	35	154	0	0	0	N/M	0	Discarded
TEL-41	34	156	2	3	1	3	0	1
TEL-42	30	149	2	0	1	1	1	1
TEL-43	23	139	1	1	1	1	1	1
TEL-44	31	143	1	1	1	1	1	1

Appendix B9. (continued)

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
TEL-45	41	158	1	1	1	2	0	1
TEL-46	38	152	1	1	1	1	1	1
TEL-47	29	149	3	2	N/M	N/M	N/M	Discarded
TEL-48	37	149	2	3	2	1	1	1
TEL-49	36	151	1	1	1	1	1	1
TEL-50	18	145	1	1	1	0	0	1
TEL-51	27	135	1	1	1	1	1	1
TEL-52	29	140	1	1	1	1	1	1
TEL-53	41	161	1	1	1	1	1	1
TEL-54	12	107	0	0	0	0	0	0
TEL-55	8	94	0	0	0	0	0	0
TEL-56	30	143	1	2	1	1	1	1
TEL-57	79	189	2	2	2	1	1	1
TEL-58	9	96	0	0	0	N/M	N/M	Discarded
TEL-59	91	229	2	2	2	4	4	4
TEL-60	56	175	3	2	2	1	1	1
TEL-61	6	82	0	0	0	0	0	0
TEL-62	8	63	0	0	0	N/M	N/M	Discarded
TEL-63	46	170	3	1	2	N/M	0	Discarded
TEL-64	8	92	0	0	0	N/M	N/M	Discarded

[a] Kimberly Cooper
[b] Todd Sink

Appendix B10. Scale and otolith ages for *O. mykiss* (N = 33) collected in Jennings Creek, 10-3-2002.

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
JEN-1	53	179	2	2	2	1	1	1
JEN-2	40	159	1	1	1	1	1	1
JEN-3	84	192	2	1	2	2	2	2
JEN-4	62	183	2	1	1	1	1	1
JEN-5	48	166	1	0	1	1	1	1
JEN-6	48	162	1	1	1	1	1	1
JEN-7	41	163	1	0	1	1	0	1
JEN-8	24	144	1	1	1	1	1	1
JEN-9	46	168	1	1	1	3	3	3
JEN-10	21	130	0	0	0	1	1	1
JEN-11	66	183	1	1	1	2	1	1
JEN-12	29	142	2	0	2	2	2	2
JEN-13	85	201	1	3	3	1	1	1
JEN-14	8	90	0	0	0	0	0	0
JEN-15	7	82	0	0	0	0	0	0
JEN-16	7	83	0	0	0	0	0	0
JEN-17	6	78	0	0	0	0	0	0
JEN-18	4	71	0	0	0	0	0	0
JEN-19	4	70	0	0	0	0	0	0
JEN-20	4	73	0	0	0	0	0	0
JEN-21	3	68	0	0	0	0	0	0
JEN-22	1	49	0	0	0	0	0	0

Appendix B10. (continued)

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
JEN-23	2	58	0	0	0	1	1	1
JEN-24	124	232	3	3	3	3	3	3
JEN-25	101	213	2	2	2	2	2	2
JEN-26	71	187	2	2	2	2	2	2
JEN-27	100	212	3	2	2	2	1	2
JEN-28	54	172	1	1	1	2	N/M	Discarded
JEN-29	26	145	1	1	1	1	1	1
JEN-30	69	187	1	1	1	2	2	2
JEN-31	49	168	1	1	1	1	1	1
JEN-32	81	194	2	2	1	0	0	Discarded
JEN-33	48	173	2	2	2	2	2	2

[a] Kimberly Cooper
[b] Todd Sink

Appendix B11. Scale and otolith ages for *O. mykiss* (N = 68) collected in Rocky Fork, 9-11-2002.

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
RFC-1	88	211	2	2	2	5	5	5
RFC-2	37	167	1	1	1	3	3	3
RFC-3	110	224	2	2	2	5	5	5
RFC-4	18	129	1	0	0	0	0	0
RFC-5	24	148	1	1	1	2	2	2
RFC-6	24	144	1	1	1	2	1	2
RFC-7	124	251	2	2	2	8	8	8
RFC-8	81	207	2	2	2	4	4	4
RFC-9	29	151	1	0	0	0	0	1
RFC-10	10	112	0	0	0	0	0	0
RFC-11	35	159	1	1	1	0	N/M	Discarded
RFC-12	22	140	0	0	0	1	0	0
RFC-13	34	161	1	1	1	N/M	1	1
RFC-14	33	155	1	1	1	1	1	1
RFC-15	59	183	2	2	2	2	2	2
RFC-16	51	183	2	2	2	3	3	3
RFC-17	8	89	0	0	0	0	0	0
RFC-18	3	68	0	0	0	0	0	0
RFC-19	35	157	1	1	1	1	1	1
RFC-20	100	221	3	2	2	6	6	6
RFC-21	187	131	0	0	0	0	0	1
RFC-22	78	198	2	2	2	3	3	3

Appendix B11. (continued)

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
RFC-23	37	160	1	1	1	2	2	2
RFC-24	74	204	1	1	1	3	3	3
RFC-25	57	190	2	2	2	5	5	5
RFC-26	46	191	3	2	2	3	3	3
RFC-27	83	210	3	3	3	3	3	3
RFC-28	86	203	1	1	1	3	3	3
RFC-29	21	135	0	0	0	1	1	1
RFC-30	40	168	1	1	1	N/M	N/M	Discarded
RFC-31	35	159	1	0	1	2	2	2
RFC-32	29	158	1	1	1	1	1	1
RFC-33	26	149	1	1	1	2	2	2
RFC-34	14	118	0	0	0	1	1	1
RFC-35	28	146	1	1	1	3	3	3
RFC-36	30	155	1	1	1	1	1	1
RFC-37	5	82	0	0	0	0	0	0
RFC-38	3	70	0	0	0	0	0	0
RFC-39	3	60	0	0	0	0	0	0
RFC-40	18	134	0	0	0	1	1	1
RFC-41	11	116	0	0	0	0	0	0
RFC-42	4	69	0	0	0	0	0	0
RFC-43	5	78	0	0	0	0	0	0
RFC-44	64	194	1	1	1	2	2	2

Appendix B11. (continued)

Sampe ID#	Weight (g)	Length (mm)	Scale age		Agreed age	Otolith age		Agreed age
			KC[a]	TS[b]		KC[a]	TS[b]	
RFC-45	27	144	1	1	1	1	1	1
RFC-46	70	197	2	0	2	4	4	4
RFC-47	48	182	2	0	1	1	1	1
RFC-48	25	146	1	1	1	2	2	2
RFC-49	43	170	1	1	1	2	2	2
RFC-50	45	179	2	2	2	2	2	2
RFC-51	66	203	1	1	1	2	2	2
RFC-52	53	186	1	1	1	2	2	2
RFC-53	36	165	1	1	1	1	1	1
RFC-54	35	161	2	3	2	2	2	2
RFC-55	14	122	0	0	0	1	1	1
RFC-56	33	157	1	1	1	2	2	2
RFC-57	18	123	0	1	0	0	0	0
RFC-58	27	142	1	1	1	1	1	1
RFC-59	5	81	0	0	0	0	0	0
RFC-60	27	149	1	1	1	2	2	2
RFC-61	20	138	0	1	1	1	1	1
RFC-62	8	109	0	0	0	0	0	0
RFC-63	15	126	1	1	1	1	1	1
RFC-64	37	164	1	2	2	2	2	2
RFC-65	25	140	2	1	1	1	1	1
RFC-66	25	142	1	1	1	1	1	1

Appendix B11. (continued)

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
RFC-67	30	153	2	2	2	2	2	2
RFC-68	13	119	0	2	1	1	1	1

[a] Kimberly Cooper
[b] Todd Sink

Appendix B12. Scale and otolith ages for *O. mykiss* (N = 42) collected in Wolf Creek, 9-10-2002.

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
WFC-1	33	154	2	2	2	1	1	1
WFC-2	19	124	1	1	1	0	0	0
WFC-3	22	137	1	1	1	1	1	1
WFC-4	18	127	1	2	0	0	0	0
WFC-5	27	146	1	1	0	0	0	0
WFC-6	20	134	0	0	0	1	1	1
WFC-7	18	127	0	0	0	1	1	1
WFC-8	28	141	2	2	2	1	1	1
WFC-9	17	128	1	1	1	2	2	2
WFC-10	29	144	2	2	2	N/M	N/M	Discarded
WFC-11	21	133	1	1	1	1	1	1
WFC-12	49	171	2	1	2	2	2	2
WFC-13	57	184	2	3	2	N/M	N/M	Discarded
WFC-14	22	139	1	1	1	1	1	1
WFC-15	21	131	1	1	1	1	1	1
WFC-16	51	170	2	2	2	1	0	Discarded
WFC-17	37	160	2	0	1	1	1	1
WFC-18	26	136	1	1	1	1	1	1
WFC-19	49	139	2	4	2	2	2	2
WFC-20	14	115	1	1	1	1	1	1
WFC-21	22	131	1	1	1	1	1	1
WFC-22	27	145	2	2	2	1	1	1

Appendix B12. (continued)

Sampe ID#	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Otolith age KC[a]	Otolith age TS[b]	Agreed age
WFC-23	24	135	0	0	0	1	1	1
WFC-24	19	126	1	1	1	0	0	0
WFC-25	20	125	0	0	0	1	1	1
WFC-26	18	130	1	1	1	0	0	0
WFC-27	48	170	2	2	2	2	2	2
WFC-28	20	126	3	2	2	1	1	1
WFC-29	15	114	0	0	0	1	1	1
WFC-30	14	115	1	1	1	1	0	1
WFC-31	18	126	0	0	0	1	1	1
WFC-32	25	144	0	0	0	1	1	1
WFC-33	16	123	1	1	1	1	1	1
WFC-34	11	111	2	2	2	1	1	1
WFC-35	22	136	2	2	2	1	1	1
WFC-36	21	129	0	0	0	1	1	1
WFC-37	9	102	0	0	0	0	0	0
WFC-38	16	120	1	0	1	1	1	1
WFC-39	26	138	1	1	1	1	1	1
WFC-40	19	127	0	0	0	1	1	1
WFC-41	20	128	2	2	2	1	1	1
WFC-42	18	128	0	0	0	1	0	0

[a] Kimberly Cooper
[b] Todd Sink

Appendix B13. Scale and otolith samples from known-aged *O. mykiss* (n = 43) collected for validation from five East Tennessee streams.

Site	Known-age	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Ototith age KC[a]	Ototith age TS[b]	Agreed age
NTH	1	40	162	1	1	1	1	1	1
NTH	1	36	166	1	1	1	1	1	1
NTH	1	49	172	1	1	1	1	1	1
NTH	1	34	140	1	1	1	1	1	1
NTH	1	51	168	1	1	1	1	1	1
NTH	2	68	187	1	2	2	2	2	2
NTH	2	59	182	2	1	1	2	2	2
NTH	2	87	212	2	2	2	2	2	2
NTH	2	73	199	2	2	2	2	2	2
NTH	3	72	200	3	2	2	3	3	3
TEL	1	69	198	1	1	1	1	1	1
TEL	1	56	187	1	1	1	1	1	1
TEL	1	84	203	1	1	1	1	1	1
TEL	1	52	175	1	1	1	1	1	1
TEL	1	36	150	1	1	1	1	1	1
TEL	1	37	160	1	1	1	1	1	1
TEL	1	31	150	1	1	1	1	1	1
TEL	1	38	162	1	1	1	1	1	1
TEL	1	37	161	1	1	1	1	1	1
TEL	2	99	213	2	2	2	2	2	2

Table B13. (continued)

Site	Known-age	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Ototith age KC[a]	Ototith age TS[b]	Agreed age
TEL	2	81	192	2	2	2	2	2	2
TEL	2	102	220	2	2	2	2	2	2
DOEC	1	24	137	1	1	1	1	1	1
DOEC	1	52	175	1	1	1	1	1	1
DOEC	3	56	185	2	3	2	3	3	3
DOEC	3	95	219	3	2	3	3	3	3
BVD	1	74	200	1	1	1	1	1	1
BVD	1	49	177	1	1	1	1	1	1
BVD	1	31	154	1	1	1	1	1	1
BVD	1	32	157	1	1	1	1	1	1
BVD	N/M	N/M	N/M	N/M	N/M	N/M	N/M	N/M	Discarded
BVD	1	23	135	1	1	1	1	1	1
BVD	2	96	229	2	2	2	2	2	2
BVD	2	72	218	1	2	1	2	2	2
BVD	1	35	155	1	1	1	1	1	1
BVD	1	48	176	1	1	1	1	1	1
BVD	3	140	253	3	3	3	3	3	3
BLD	1	60	182	1	1	1	1	1	1
BLD	1	48	169	1	1	1	1	1	1
BLD	1	57	174	1	1	1	1	1	1

Appendix B13. (continued)

Site	Known-age	Weight (g)	Length (mm)	Scale age KC[a]	Scale age TS[b]	Agreed age	Ototith age KC[a]	Ototith age TS[b]	Agreed age
TEL	1	32	153	1	1	1	1	1	1
DOEC	2	94	209	2	2	2	2	2	2
DOEC	2	107	224	2	2	2	2	2	2

[a] Kimberly Cooper
[b] Todd Sink

APPENDIX
C

Appendix C1. Mean length of *O. mykiss* (N = 621) in each population for the 9 age classes based on otoliths.

	Mean Length at capture								
Population	0	1	2	3	4	5	6	7	8
Beaverdam Creek	92	166	203	190					
Doe Creek	111	169	203	270					
Laurel Creek	89	168	206	208	239	254			
Doe River	131	178	214	242					
Stony Creek	99	190	217						
Left Prong Hampton Creek	84	141	152	188	192		211		279
Bald River	104	149	176	187					
North River	101	150	178	182	180				
Tellico River	112	145	179		229				
Jennings Creek	74	162	182	200					
Rocky Fork Creek	95	144	165	188	202	208	221		251
Wolf Creek	126	131	152						
Mean	102	158	186	206	208	231	216		265

Appendix C2. Mean length of *O. mykiss* (N = 654) in each population for the 4 age classes based on scales.

	Mean Length at capture			
Population	0	1	2	3
Beaverdam Creek	93	166	210	
Doe Creek	113	160	199	221
Laurel Creek	114	175	213	212
Doe River	152	181	215	244
Stony Creek	102	183	217	
Bald River	104	148	176	187
North River	98	149	158	204
Tellico River	113	146	164	
Jennings Creek	77	169	185	217
Rocky Fork Creek	106	159	194	210
Wolf Creek	128	130	148	
Mean	109	161	189	214

VITA

Kimberly Lynn Cooper was born in Frederick, MD, on December 19, 1979. She was raised in Walkersville, MD, and attended Walkersville High School where she graduated in 1997. After graduation, she began her college education at The Ohio State University where she received her Bachelors of Science in Wildlife and Fisheries Science in spring of 2001. While attending Ohio State, she traveled to several countries in Africa where she studied much of their native wildlife. This experience inspired her to continue her education at the University of Tennessee. She received her Masters of Science in Wildlife and Fisheries Science in December 2003 and plans on using her education to get a job in a biological field.