Technical Report

Age and Growth Characteristics of Trout in Washington High Lakes

Washington Department of Fish and Wildlife
16018 Mill Creek Blvd.
Mill Creek, Washington 98012

Prepared by

Bob Pfeifer
Area Fishery Management Biologist
(Retired)
District Two
Region Four

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ACKNOWLEDGMENTS

The fish that were sampled for otoliths and scales were collected by hook and line or by sinking and floating gill nets. While I have caught my share of fish in the mountain lakes, most of the samples analyzed and reported herein were collected by others. I must acknowledge the huge contribution made by several very able sportsmen who accompanied me on many trips into our beloved mountains in Region Four. Some of these men were, and still are professional fishery manager/biologists employed by the Washington Department of Fish and Wildlife (WDFW). Listed in alphabetical order, these samplers include John Baskin, Jim Becker, Jim Cummins, Brian Curtis, Gerry Erickson, Bill Henkel, Larry Hirni, Pete Smith, and John Thomas. I used to tell people in only a half-kidding manner that I used these guys like gill nets to get my fish samples. They were that effective.

Growth data reported from other regions in Washington were very kindly provided by Jim Cummins and Eric Anderson in Region Three, Bob Lucas and John Weinheimer in Region Five, and Mark Downen in northern Region Four. Most, if not all of the data provided by Mark for northern Region Four were collected by Jim Johnston, the former Fishery Biologist for that area (retired). A relatively large data set from the Chelan County area was amassed by Area Fish Biologist Larry Brown (ret.); his data were forwarded to me by Brian Curtis of the Washington State Hi-Lakers.

The initial round of scale mounting and reading was performed by Don Swayne who is an interested angler-mountaineer in the Seattle area. Technical assistance was also provided by John Sneva, WDFW's headquarters-based scale reader.

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SUMMARY

Age and growth characteristics are reported for rainbow trout, cutthroat trout, eastern brook trout, brown trout, and lake trout from high lakes in Washington's Cascades mountain range. Samples were collected between the mid-1970s and 1999. Samples of known age were available from 117 rainbow trout and 53 cutthroat trout, primarily in the western side of the Alpine Lakes Wilderness Area. Overall, 2,930 samples were collected primarily from counties and areas north of Mount Adams.

Tables of basic statistics (mean, variance, standard deviation, minima and maxima) were developed for total length at age for all species. Plots were also prepared of the frequency distribution of length at age for rainbow trout that illustrate the high degree of overlap in length possible at given ages.

A plot of total length at age for rainbow trout and cutthroat trout of known age was developed to establish a baseline relationship. A tentative curve for eastern brook was included in this figure, but ages were not known in advance for the char.

Growth curves of mean length at age for rainbow trout, cutthroat trout, and eastern brook were distinct, with rainbow trout exhibiting the fastest growth, and brooks the slowest. The plotted mean growth curves were essentially parallel. However, plots of the frequency distribution of total length at age for several ages of rainbow trout showed substantial overlap in length at age, especially at Age 3 or older. For example, a rainbow trout 230 mm long at the time of annulus formation could be anywhere from Age 1 to Age 4, but is most likely Age 2 in the west central Cascades Mountains. Rainbow trout, the fastest growing species, were about 6 inches at Age 1, 9 inches at Age 2, 11 inches at Age 3, 12 inches at Age 4, and 13 inches at Age 5 (all total length). Cutthroat trout growth lagged rainbow trout growth by about 1.5 inches each year.

Miscellaneous length at age data from around Washington are included as an appendix.

LIST OF FISH SPECIES MENTIONED IN THIS REPORT

Brown trout (*Salmo trutta*)

Cutthroat trout (*Oncorhynchus clarki*)

Eastern brook trout (*Salvelinus fontinalis*)

Lake trout (*Salvelinus namaycush*)

Rainbow trout (*Oncorhynchus mykiss*)

1. INTRODUCTION

1.1 PURPOSE AND NEED

The primary purpose of this report is to summarize information currently available on the growth of various trout species stocked in Washington's Cascades mountain range. One of the most common information needs is whether growth observed in a particular lake is "unusual", "better than average", and so on. It is obvious to fishery managers that growth rates vary with the relative productivity of the various lakes in Washington's sub-alpine and alpine environments. Growth also varies between species to some degree, although reliable data were not made available to compare growth rates of differing species within the same lake.

The second purpose of this compilation was to prepare "typical" or average growth curves for the most commonly-stocked species that can be used as "reference" lines on plots of growth observed in individual lakes. That is, growth observed in rainbow trout in a given lake can be compared to growth observed in rainbow(s) in general in Washington's central Cascades within the same figure.

1.2 DATA LIMITATIONS

The paramount limitation in the data set is the lack of a control, or lack of known age in most of the aged fish samples. Therefore, the current data set does not allow rigorous comparisons of growth for fish of known age for all species across the geographic range of Washington's sub-alpine and alpine lakes. An example of this limitation is that it is currently not possible to compare a robust sample of 40 or more rainbow trout of known ages in lakes of widely varying productivity from the west side of the Cascades with rainbow trout in lakes in the Olympic Mountains, or from the southern Cascades, or from lakes in North Cascades National Park. However, this data set and this summary serve as a starting point. Broader analyses may be possible in the future as the scale analysis database is expanded.

The available data are segregated into two groups in this report: samples from fish populations of known age, and all others. Since almost no populations were sampled that contained fish that were marked to conclusively establish age, other indicators were used to assign fish to the "known age" group as described in Section 2.3.

None of the readily-available agency technical reports (e.g. Lucas 1989; Deleray and Barbee 1992; Lucas and Weinheimer 2003) gave sufficient detail on how scales and otoliths were analyzed. The information in these reports indicates that back-calculations for length at age were not attempted in most cases. Reported ages are for maximum age at the time of collection. Therefore, a primary feature of this report is that it segregates aging information from fish of known age from the other "total age" data that have been contributed. Further, this is the only agency report that provides length at age information for trout in high lakes, and details on how that information was obtained. Length at age information was developed by other area fishery biologists (e.g. Ken Williams, Larry Brown, Jim Johnston) for individual fish, but the details and results of their studies are not presented in any formal report.

The length at total age information provided by the other studies cited is certainly valuable, and is presented in the Appendices. Some of that much larger data set is summarized in Figures in this report, but the reader is cautioned to recognize that much of that information is from fish of unverifiable age, and its accuracy is dependant upon the quality of the hard parts read, and the readers' skill levels.

2. METHODS

2.1 FIELD PROCEDURES

The following procedures were used for all fish in the "known age" group. Using a sharp knife tip, a scrape of scales from an area of about 0.75 square centimeter was removed from both sides of the fish from 2 to 4 rows above the lateral line, and centered below the posterior insertion of the dorsal fin (Scarnecchia 1979; DeVries and Frie 1996). Each scale sample was wiped from the knife blade by inserting the blade inside a coin envelope, and squeezing the sides of the envelope to remove the scales. (Some scale samples were placed on waxed paper before they were inserted into the coin envelope.) A minimum of 20, and generally 40 or more scales were collected from each fish. Prior to scale or otolith sampling, each fish was blotted dry or wiped clear of excess water, then weighed to the nearest gram with a spring scale, and measured for total length to the nearest millimeter. The length and weight was logged to the coin envelope along with the lake name, date, fish species, and other information.

In many cases otoliths (sagittae) were removed along with the scale samples. A transverse cut was made across the top of the head at the level of the posterior margins of the opercles. A second cut was made along the cranium midline extending from the first cut towards the nose, but only far enough to allow spreading of the bisected cranium to allow removal of the otoliths with the knife tip, or with a pair of small forceps. The otoliths were stored dry in the coin envelope along with the scale scrapes.

Fish at or near sexual maturity often had scales that were resorbed and difficult to remove. Otoliths were always taken in these cases under the expectation that the scales would be difficult or impossible to read. Scales from these fish were generally not read, especially since back-calculations cannot be made on scales with spawning checks. However, total age can often be ascertained by careful examination of both otoliths and scales.

2.2 LAB PROCEDURES AND BACK-CALCULATIONS

2.2.1 Scales

The dried scales were removed from the storage envelope, and 10 or more were teased apart using a dissecting needle and forceps. The scales were not given special cleaning procedures such as described by Whaley (1991). Occasionally some scales retained sufficient gurry that they needed to be rinsed in water by rubbing between two fingers, and were then blotted dry on a paper towel.

The scales were arranged in rows on a standard glass microscope slide, the slide was placed on an EyeCom 3000 Model EC 48-2 microfiche stage, and the slide then was covered with the microfiche's mechanical glass stage cover (Gray 1977). Scales were generally read at the "Low" magnification (47.5X), although a "High" magnification of 69.5X was available. Although some scales were pressed on acetate in the agency's aging lab prior to reading, I found viewing and interpreting the acetates in the microfiche more difficult, and unnecessary as it did not result in greater visual acuity or reading accuracy.

After visually scanning a representative sample of the mounted scales, a clean, clear scale from each fish's scale group was selected for measurements to enable back-calculation of fish length at age (Smith 1955; Whitney and Carlander 1956; Miller 1966; Hile 1970; Carlander 1981, 1983; DeVries and Frie 1996). A millimeter rule was placed on the microfiche reader screen to measure the total scale radius, and the distance from the focus to the annuli. Distances were read to the nearest half millimeter and recorded. When all measurements were complete, all scales were returned to the sample envelope and retained as part of a permanent collection.

2.2.2 Otoliths

The sagittae were not stored in glycerin or formalin or any other preservative, but were held dry within the coin envelopes. The bones were placed in a Petri dish containing sufficient clear, clean water to just fully immerse the bones. The dish was placed on black velvet, and the bones were inspected using a Nikon dissecting microscope having a magnification range of 10 to 20X. Inspection was generally made at 17-20 X. The sagittae were illuminated from above and to the side with white light whose intensity was controlled with a rheostat.

The otoliths were not given any special treatment such as grinding, polishing, sectioning, or staining (Hubert et al. 1987; Schultz and Taylor 1987; Maceina 1988). They were usually readable without these treatments. Otoliths were not measured, but were read principally to verify total age determinations made with the scales.

2.2.3 Calculations and Formulae

The Fraser-Lee method of back-calculation was used (see p. 501, DeVries and Frie 1996), and the adjustment factor *a* of the following equation was determined by the regressions shown in the Figures of Section 3.1.

$$L_i = \frac{L_c - a}{S_c} S_i + a \qquad \text{where}$$

L_i = back-calculated length of the fish when the *i*th increment was formed;

L_c = total length of the fish at capture;

S_c = radius of the scale at capture, and

S_i = radius of the scale at the *i*th increment.

a = the intercept of the regression of total fish length with the hard part measurement.

2.2.4 Databases

All biological data collected off of the fish in southern Region Four (southern Snohomish County through King County) were logged into Excel spreadsheets (WA_hlkage_grwth.xls and HlkBio.xls), both of which are available from the author. The data were also stored in the High Lake Systems database maintained by Dr. Mike Swayne of Trail Blazers, Inc.

2.3 SELECTION OF SUBSAMPLES

The fish length at age data were graphed and tabulated in two basic groups. The first group is fish taken from lakes where the age of the fish was known with a high degree of certainty. This group included 117 rainbow trout and 53 cutthroat trout from lakes in King and southern Snohomish County (Table 1). (Note: these samples are still available for "blind" aging to ascertain the accuracy of aging trout from Washington high lakes.) The bulk of the other samples were either wild trout or char from lakes in many areas of the Cascades, or were from fish where the actual age was not known with much, if any certainty, and the accuracy of the aging was largely dependant on the skill of the technician or biologist doing the readings.

Table 1. Number of trout age samples available for this 2003 analysis, by WDFW administrative district.

	Known Age Samples Pre-Reading		Unknown Age Samples Pre-Reading			
Administrative District	Rainbow	Cutthroat	Rainbow	Cutthroat	Eastern Brook	Lake Trout
Southern Region Four[1]	117	53	642	291	375	0
Northern Region Four[2]			298	447	192	0
Yakima and Chelan Counties[3]			78	473	54	15
Region Five[4]			26	10	29	0

[1] West Central Cascades; Pierce, King, and southern Snohomish Counties. [2] Northwest Cascades; Whatcom, Skagit, and northern Snohomish Counties. [3] East Central Cascades. [4] Southern Cascades; Lewis, Skamania, and Klickitat Counties.

2.3.1 Known Age Groups

Beamish and McFarlane (1983) explain the importance of having a way of assuring that the potential for error is minimized in the often subjective interpretation of scale or otoliths images. Age validation is having some method of knowing the age of fish whose hard parts are analyzed. Scales and otoliths from trout and char in Washington high lakes are no exception: spawning checks are often difficult to discern; annuli counts can vary between scales and otoliths from the same fish; and age determinations may vary between readers of the same samples.

In this data summary, sampled trout age was known, or validated in several ways. The most reliable was where fry were stocked into a lake that was known to be barren, or had never been stocked before, and the fish were later collected after rearing for several years or more. The second most common approach to be certain of fish age prior to scale reading was to collect fish of a stocked species that had not been stocked into a given lake before. Confidence was developed that the sampled fish were not naturally produced when all of the fish sampled were very close to the same size, had growth patterns in scales or otoliths that were very similar and consistent, and there was no apparent spawning habitat at the lake. In an extremely small number of cases marked fish were collected that had been part of an earlier experiment when stocked as marked fry.

Scale-based back-calculation of length at age for fish where there was high confidence in their age was only possible with 108 rainbow trout and 52 cutthroat trout. Plots of fish length versus scale radius found later in this report for these two species were only prepared from the known-age sub-sample. This was done with rainbow trout and cutthroat from lakes where hatchery fry of these species had been stocked. (Age determinations from scales and otoliths from the same fish were generally consistent, but the results from dual readings are not tabulated for this report. A far more prevalent problem was poor annuli visibility in the otoliths.)

2.3.2 Uncontrolled and Wild Fish Groups

The vast majority (94%) of the 2,930 samples were in the group where fish age was not known with much certainty prior to reading of scales or otoliths. Most of these readings were also total age only (e.g. 4+), with no back-calculation of length at earlier ages. A notable exception was made for eastern brook in order to be able to report at least a preliminary scale to body length relationship. All eastern brook sampled were from lakes where the char are produced naturally, and no brook trout fry stocking takes place. A length versus scale radius plot was made for 24 of these fish in order to report a preliminary relationship. The 24 scale samples represented the best that could be gleaned from the field collections. However no claim is made that there is 100% certainty in the age of these fish.

3. FINDINGS AND DISCUSSION

3.1 KNOWN AGE SAMPLES

3.1.1 Rainbow Trout

Based on a sample of 117 rainbow trout from 28 high lakes in King County, the average fish gains 5.9 inches in its first year, 3.1 in its second, 2.0 in its third, 1.1 in its fourth, 0.9 in its fifth, and growth in body length nearly ends at that point (Table 2). Growth through Age 2 in the geographic area sampled was somewhat faster than that reported by Lucas (1989) for waters in southwestern Washington, but the relationship reversed at Age 3 and older in King County. (Lucas [Pers. comm. April 2005] indicated that most of the rainbow trout he aged were from high lakes that had natural reproduction already occurring.) On average, a 12" rainbow trout in the sampled area was at least four years old, but some fish had attained that length by Age 2 in richer waters. Rainbow trout in very infertile lakes had not attained 10.75 inches at Age 6.

Figure 1 plots scale radius versus fish total length for 108 rainbow trout samples in King County high lakes. Most, if not all of these fish were Mount Whitney rainbow (Crawford 1979) initially reared at the Tokul Creek Hatchery on a spring water supply at a constant temperature of 47 F.

Although mean length at age increases each year (Table 2), in fact there is broad overlap in length at age, especially at Age 3 or older (Figures 2 and 3). For example, a rainbow trout 230 mm long at the time of annulus formation could be anywhere from Age 1 to Age 4 (but is most likely Age 2). Since the stock and early hatchery rearing history is the same for most of these fish, this variability most likely reflects varying lake productivity since the majority of the "known age" samples were taken from lakes where the stocking density was low.

3.1.2 Cutthroat Trout

Based on a sample of 53 cutthroat trout from 14 high lakes in King County, the average cutthroat trout gains 5.0 inches in its first year, 2.4 in its second, 1.8 in its third, 1.2 in its fourth, 0.3 in its fifth, and 1.0 inch in its sixth year (Table 3). This growth was substantially slower than that reported by Lucas (1989). However, Lucas (Pers. comm. April 2005) noted that most of these samples came from waters that later received more regular stocking, and he has since noticed a reduction in growth rates.) Since the Region Four sample was relatively small, these results for west slope cutthroat trout should be viewed and used with caution. The known age sample and these statistics should be enlarged when possible. It is interesting, however, that the growth increments did not change in the much larger, "uncontrolled" sample (Table 7, Section 3.2.2).

Figure 4 shows the observed relationship between scale size and total fish length for 52 cutthroat trout. Although it is risky to extend the regression line past the data points, both Figures 1 and 4 suggest the trout are fully scaled at about 60 mm total length. This is consistent with at least one study cited by Carlander (1969).

3.1.3 Combined Species

Limited numbers of samples are reported for each age in Tables 2 and 3 since back-calculated length at age data were only available from one other report (Lucas 1989). Although many ages were derived for fish from around the Cascades (Table 1), most represented fish length at the time of capture, and this was usually well after annulus formation (e.g. Age 2+, or Age 4+).

Figure 5 presents a plot of length at age for the known-age species (rainbow and cutthroat), but includes a preliminary line for eastern brook for comparative purposes. The reader should bear in mind that the age of the eastern brook was not as certain as for the other two species. Most of the data behind these plots were from fish taken from lakes in the Alpine Lakes Wilderness Area in King County.

Table 2. Western Washington Cascade high lake rainbow trout back-calculated total length at age.

Southern Region Four Known Age Sub-sample

mm	**Age 1**	**Age 2**	**Age 3**	**Age 4**	**Age 5**	**Age 6**
Mean	150.9	227.6	278.7	307.5	330.3	337.2
Variance	871.2	2022.8	2765.4	2933.9	2955.6	875.9
SD	29.52	44.98	52.59	54.17	54.37	29.60
Min	97	137	166	225	246	271
Max	224	349	432	478	495	367
Count	117	117	84	42	23	8

Inches	**Age 1**	**Age 2**	**Age 3**	**Age 4**	**Age 5**	**Age 6**
Mean	5.9	9.0	11.0	12.1	13.0	13.3
SD	1.2	1.8	2.1	2.1	2.1	1.2
Min	3.8	5.4	6.6	8.9	9.7	10.7
Max	8.8	13.8	17.0	18.8	19.5	14.4
Count	117	117	84	42	23	8
Annual Growth Increment:	5.9	3.1	2.0	1.1	0.9	0.3
Region 5 Growth Increment:	3.62	2.66	2.54	2.2		

Figure 1. Scale radius versus total length in rainbow trout, Washington Cascades high lakes.

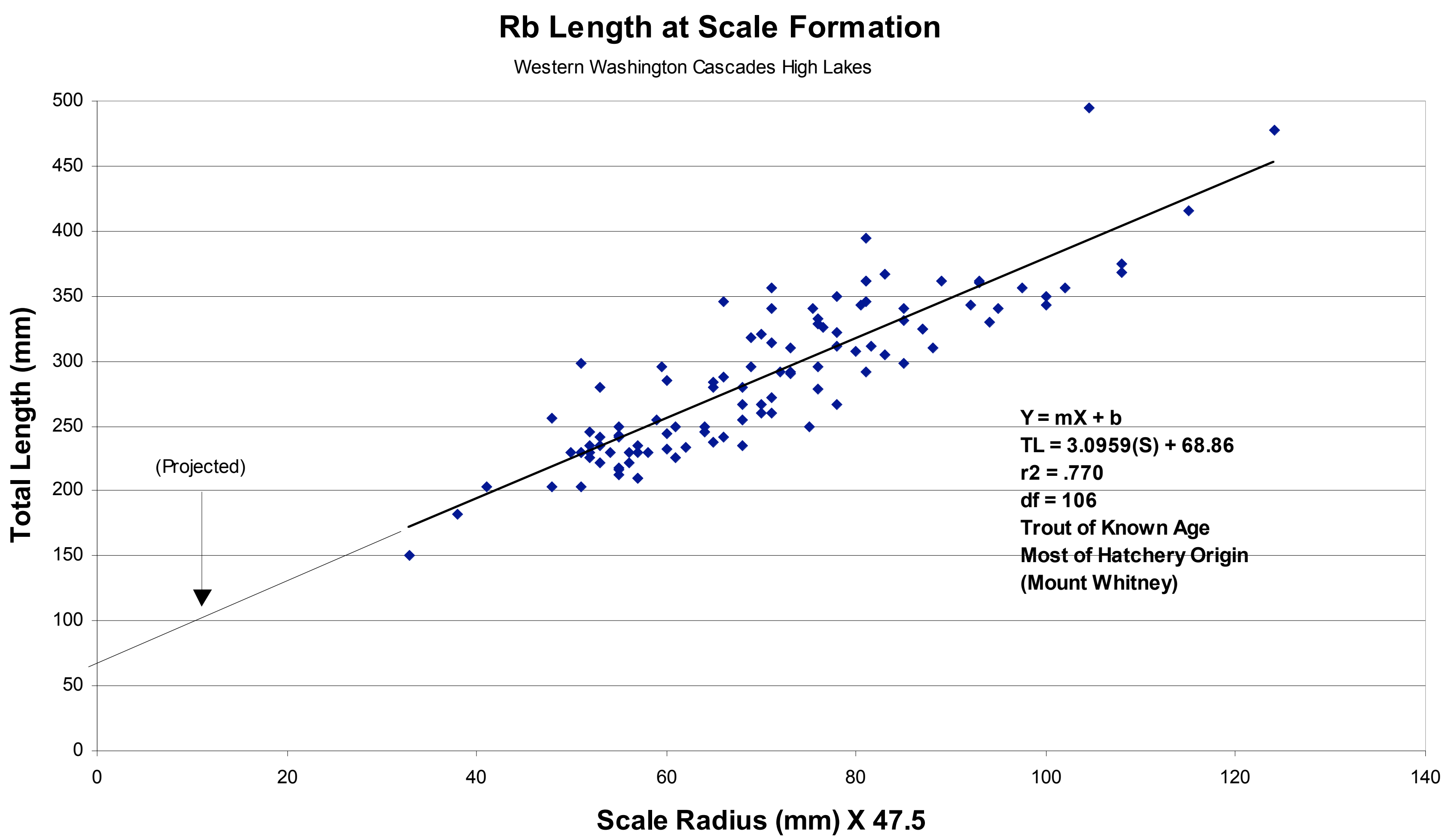


Figure 2. Frequency distributions of rainbow length at Ages 1-3 in Washington Cascades high lakes.

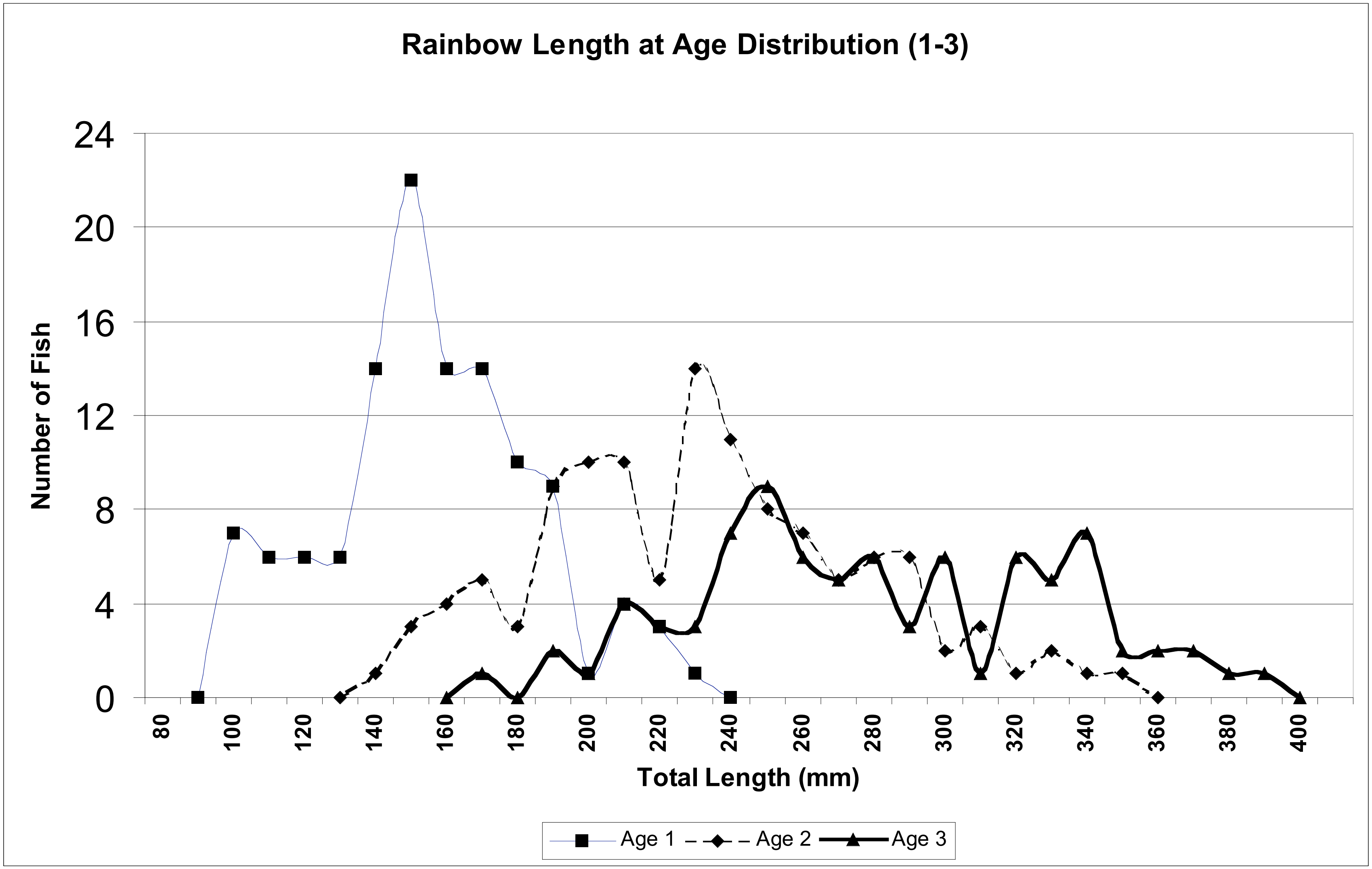


Figure 3. Frequency distributions of rainbow length at Ages 4-6 in Washington Cascades high lakes.

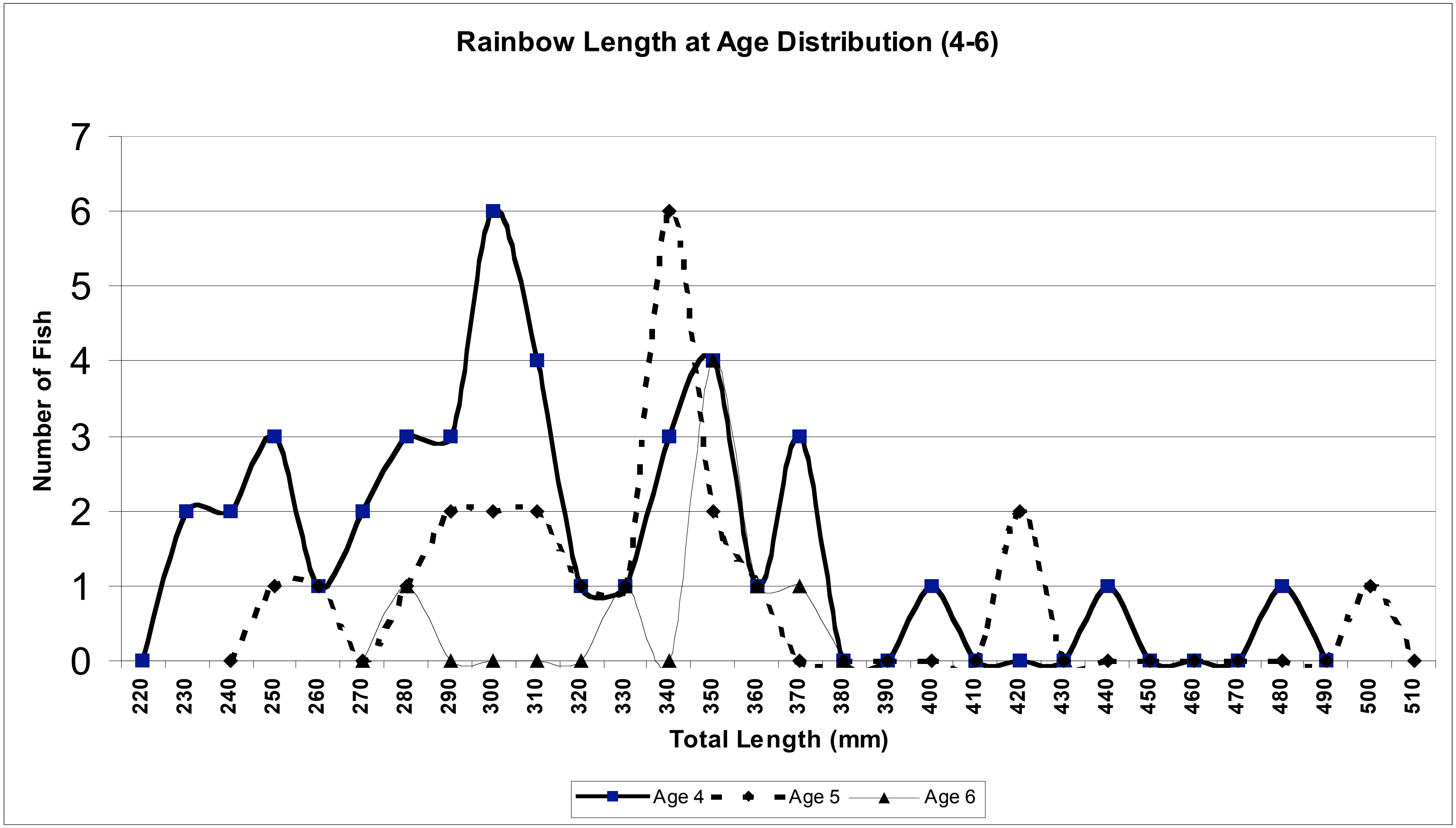


Table 3. Western Washington Cascade high lake cutthroat trout back-calculated total length at age.

Southern Region Four Known Age Sub-sample

mm	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
Mean	128.2	189.1	234.2	265.0	273.1	299.7
Variance	499.1	992.2	1549.0	2658.3	5776.6	6439.0
SD	22.34	31.50	39.36	51.56	76.00	80.24
Min	91	120	171	191	204	224
Max	198	277	343	383	403	422
Count	53	53	40	25	7	6

Inches	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
Mean	5.0	7.4	9.2	10.4	10.8	11.8
SD	0.9	1.2	1.5	2.0	3.0	3.2
Min	3.6	4.7	6.7	7.5	8.0	8.8
Max	7.8	10.9	13.5	15.1	15.9	16.6
Count	53	53	40	25	7	6
Annual Growth Increment:	5.0	2.4	1.8	1.2	0.3	1.0
Region 5 Growth Increment:	4.78	3.78	3.13	2.64	2.49	

Figure 4. Scale radius versus total length in cutthroat trout, Washington Cascades high lakes.

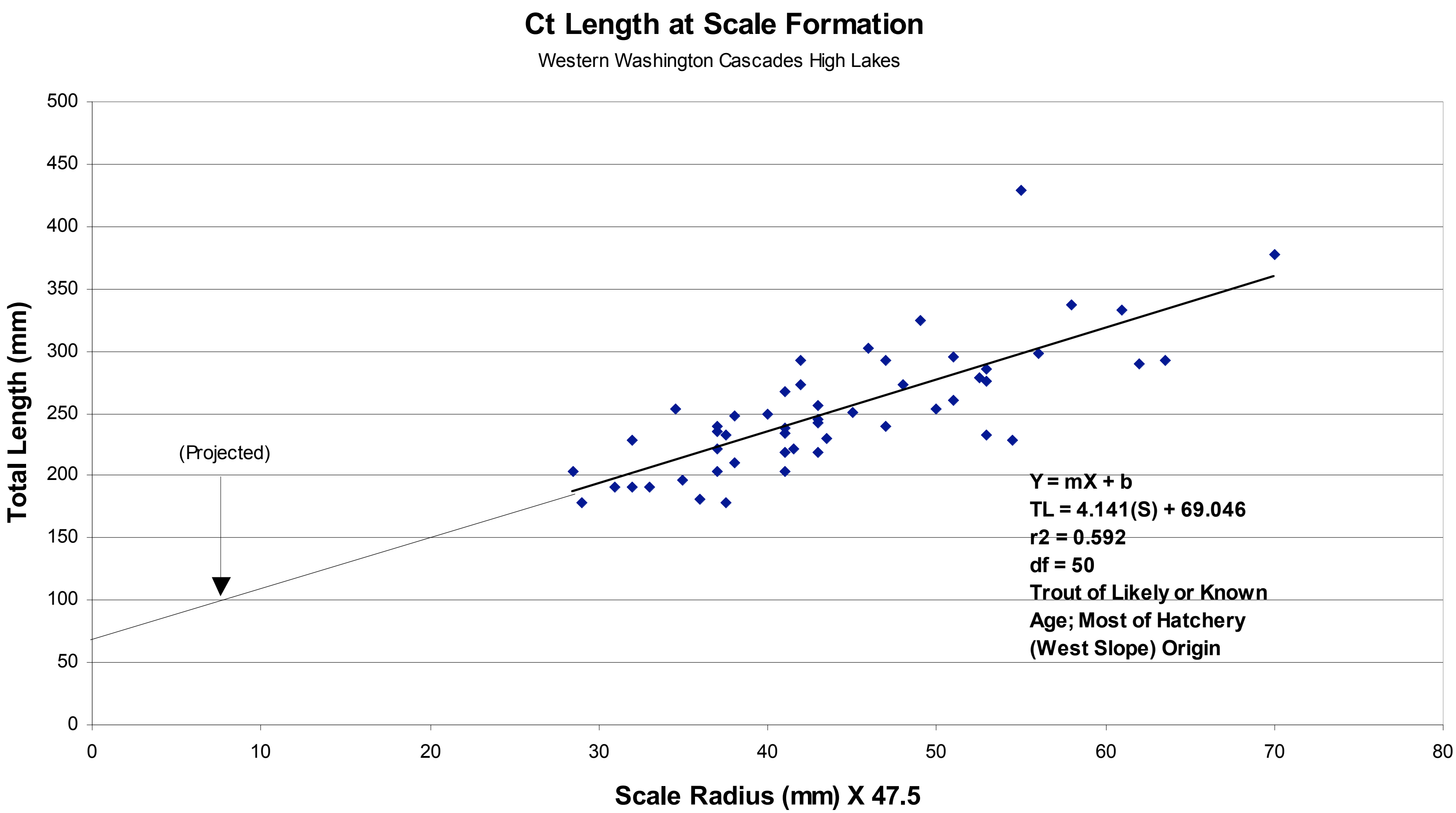
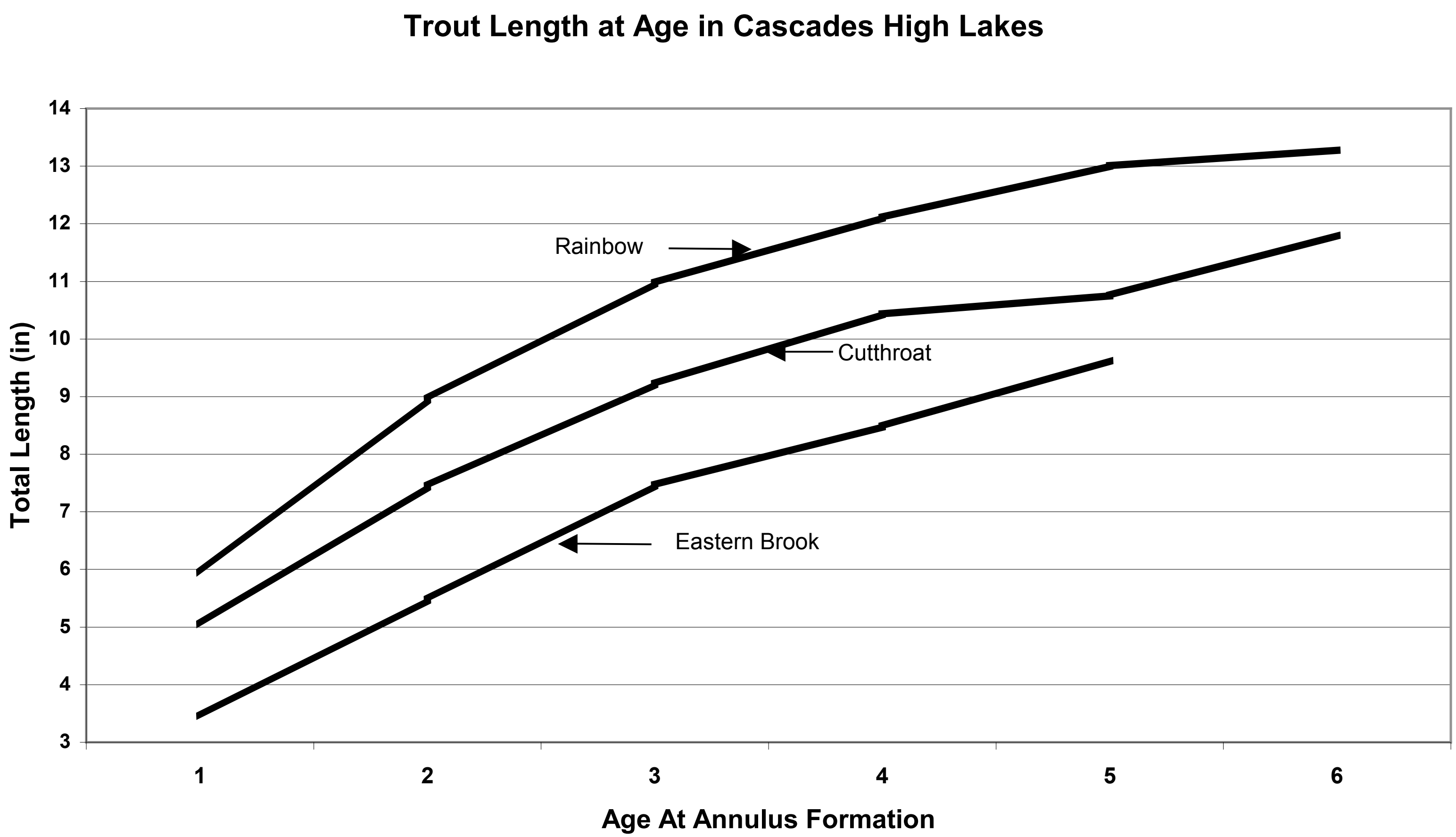


Figure 5. Mean length at age for rainbow, cutthroat, and eastern brook trout in the west central Cascades of Washington.



3.1.4 Lake Trout

Lake trout were stocked into Pratt Lake on September 21, 1985 as advanced fry at 45/lb from the Tokul Creek Hatchery. One 483 mm lake trout of known age (14+) whose hard parts could be read was subsequently collected from Pratt with hook and line on July 13, 1999. These char were stocked into Pratt as an experiment to determine whether they had the ability to serve as a top predator to control stunted eastern brook (Pfeifer et al. 2001). Therefore, the fry faced stiff competition for food from the eastern brook for most of their tenure in the lake. The much larger growth increment to Age 1 was due to the hatchery growth. Otolith and scale patterns indicated moderate in-lake growth in the second and third year, then extremely slow growth with no obvious evidence of accelerated growth due to a shift to a fish diet in the scales or otoliths (Table 4).

Table 4. Total length at annulus and annual growth increment of one lake trout from Pratt Lake, King County, Washington, 1999. Growth between Age 4 and 14 was averaged due to unclear annuli.

Age:	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Length mm at Annulus:	98	137	181	225	248	271	295	318	342	365	389	413	436	459
Increment (mm)		38.5	44.0	44.0	23.7	23.1	23.7	23.1	24.2	23.1	23.7	23.7	23.7	23.1
Increment (in)		1.5	1.7	1.7	0.9	0.9	0.9	0.9	1.0	0.9	0.9	0.9	0.9	0.9

Data from a small number of lake trout from Chelan County high lakes are presented in Appendix Table 6. Overall, many more lake trout samples are needed to develop a more reliable record of their growth characteristics in Cascades high lakes. However, this species is only present in a few waters.

3.1.5 Brown Trout

Brown trout were stocked into Rock Lake in Snohomish County on July 14, 1990 as advanced fry at 60/lb from the Tokul Creek Hatchery. Three brown trout of known age (6+) whose hard parts could be read were subsequently collected from Rock with floating and sinking gill nets on September 27, 1996. These trout were stocked into Rock as part of an on-going experiment to determine whether they had the ability to serve as a top predator to control stunted eastern brook (Pfeifer et al. 2001). Therefore, as in Pratt Lake, the fry faced stiff competition for food for all of their tenure in the lake. The much larger growth increment to Age 1 was due to hatchery growth. Otolith and scale patterns indicated very slow in-lake growth in the second through fourth years, then a slowing of growth up to the point of capture (Table 5). This growth is of course atypical for brown trout, and is included here simply to document the growth observed for this species in a lake with excessive numbers of a competitive species.

Table 5. Total length at annulus and annual growth increment of brown trout from Rock Lake, Snohomish County, Washington, 1996.

Age:	1	2	3	4	5	6
Mean TL_{mm} at Annulus:	135	167	200	238	259	271
Increment (mm)	135	32	34	37	21	11
Increment (in)	5.31	1.27	1.32	1.47	0.84	0.44

3.2 UNCONTROLLED AGE SAMPLES

3.2.1 Rainbow Trout

Table 6 presents aging results from the full sample of collections made in southern Snohomish County and King County from the mid-1970s through 1999. Fish sampled were a combination of hatchery-origin and naturally reproduced rainbow trout.

Although the sample sizes for each age are much larger than the "controlled" groups in Table 2, annual growth increments are similar, with the exception that the larger uncontrolled set indicates about an inch of growth in the sixth year of life versus 0.3 inch.

Table 6. Western Washington Cascade high lake rainbow trout back-calculated total length at age from populations of hatchery and wild origin.

Full Southern Region Four Sample

mm	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
Mean	131.1	196.5	244.1	274.7	296.9	321.3
Variance	683.8	1959.4	2502.0	2610.0	2683.9	3036.0
SD	26.15	44.27	50.02	51.09	51.81	55.10
Min	81	98	127	171	191	210
Max	225	349	432	478	495	519
Count	602	602	510	333	201	86

Inches	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
Mean	5.2	7.7	9.6	10.8	11.7	12.6
SD	1.0	1.7	2.0	2.0	2.0	2.2
Min	3.2	3.9	5.0	6.7	7.5	8.3
Max	8.9	13.8	17.0	18.8	19.5	20.4
Count	602	602	510	333	201	86
Annual Growth Increment:	5.2	2.6	1.9	1.2	0.9	1.0

3.2.2 Cutthroat Trout

Table 7 provides the enlarged, "uncontrolled" data set for cutthroat trout from the same geographic region as for the rainbow trout in Table 6. Although the age groups are about three times larger than in Table 3, the annual growth increments are very similar.

Table 7. Western Washington Cascade high lake cutthroat trout back-calculated total length at age from populations of hatchery and wild origin.

Full Southern Region Four Sample

mm	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
Mean	124.7	185.9	234.2	271.2	287.0	310.1
Variance	446.8	878.8	1425.3	1884.8	2858.3	3682.2
SD	21.14	29.64	37.75	43.41	53.46	60.68
Min	84	120	154	186	189	224
Max	198	277	343	383	403	422
Count	153	153	138	84	30	12

Inches	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
Mean	4.9	7.3	9.2	10.7	11.3	12.2
SD	0.8	1.2	1.5	1.7	2.1	2.4
Min	3.3	4.7	6.1	7.3	7.4	8.8
Max	7.8	10.9	13.5	15.1	15.9	16.6
Count	153	153	138	84	30	12
Annual Growth Increment:	4.9	2.4	1.9	1.5	0.6	0.9

3.2.3 Eastern Brook Trout

Eastern brook scales and otoliths were often exceedingly difficult to read. Only 23 samples from King and Snohomish County were deemed readable for individual annuli, and all of these fish were of wild origin. The findings are presented in Table 8. The reader is cautioned to not accept these values as being certain.

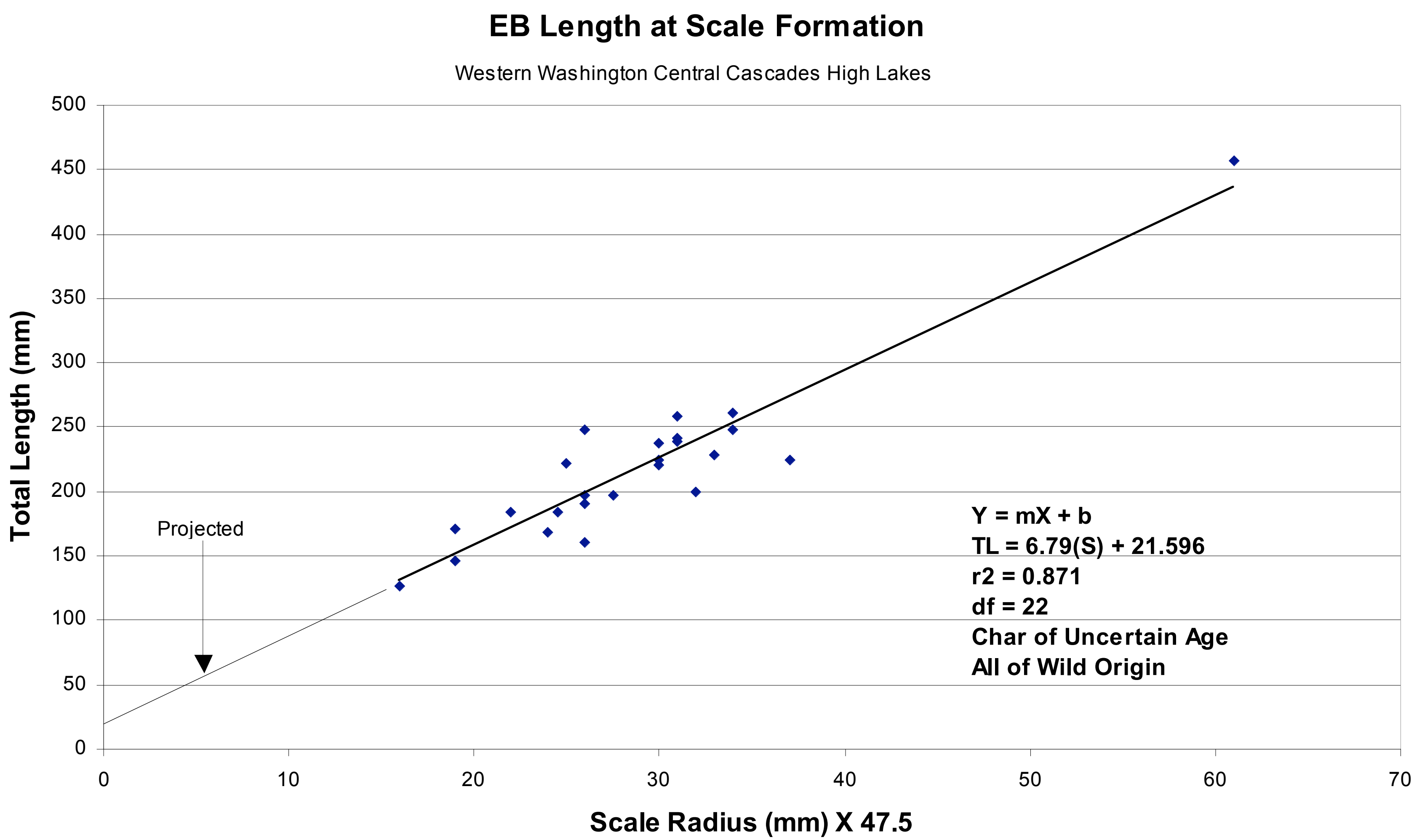
The preliminary scale to body length relationship from 24 char is plotted in Figure 6. This is a low sample size, and the one large, 454 mm brook trout has a large influence on the slope of the regression line. The projected length at scale formation is highly provisional since other studies report scale platelet formation in eastern brook at about 46 mm (Carlander 1969). These data can be greatly improved by acquiring information from fish of known age, such as from marked fish samples.

Table 8. Western Washington Cascade high lake eastern brook back-calculated total length at age from populations of wild origin.

Southern Region Four Wild Fish Sample

mm	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10
Mean	87.6	139.1	189.5	215.4	244.5	385.6	403.5	421.3	439.2	457.0
Variance	278.7	846.8	1359.8	987.6	2172.0					
SD	16.69	29.10	36.88	31.43	46.60					
Min	68	104	127	171	197	386	403	421	439	457
Max	127	214	259	296	350	386	403	421	439	457
Count	23	23	22	19	8	1	1	1	1	1
Inches	**Age 1**	**Age 2**	**Age 3**	**Age 4**	**Age 5**	**Age 6**	**Age 7**	**Age 8**	**Age 9**	**Age 10**
Mean	3.4	5.5	7.5	8.5	9.6	15.2	15.9	16.6	17.3	18.0
SD	0.7	1.1	1.5	1.2	1.8					
Min	2.7	4.1	5.0	6.7	7.8	15.2	15.9	16.6	17.3	18.0
Max	5.0	8.4	10.2	11.7	13.8	15.2	15.9	16.6	17.3	18.0
Count	23	23	22	19	8	1	1	1	1	1
Annual Growth Increment:	3.4	2.0	2.0	1.0	1.1	5.6	0.7	0.7	0.7	0.7

Figure 6. Scale radius versus total length in eastern brook trout in western Washington Cascades high lakes.



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5. APPENDIX

Age and Growth Data From Uncontrolled Samples

From Miscellaneous Regions in Washington State

Appendix Table 1. Length at age and growth increment data from Whatcom and Skagit County high lakes and rainbow trout populations of unknown age in the western Cascades, Washington.

NORTH REGION FOUR HIGH LAKE RAINBOW TOTAL LENGTH AT AGE +

mm	Age 1+	Age 2+	Age 3+	Age 4+	Age 5+	Age 6+	Age 7+	Age 8+
Mean	184.1	231.3	260.3	301.5	282.4	318.5	322.0	367.8
Variance	717.6	1908.2	2686.7	4603.3	2013.8	836.3		570.2
SD	26.79	43.68	51.83	67.85	44.88	28.92		23.88
Min	135	138	158	197	244	281		329
Max	218	311	477	439	334	350		392
Count	19	66	159	39	5	4	1	5

Inches	Age 1+	Age 2+	Age 3+	Age 4+	Age 5+	Age 6+	Age 7+	Age 8+
Mean	7.2	9.1	10.2	11.9	11.1	12.5	12.7	14.5
SD	28.3	75.1	105.8	181.2	79.3	32.9		22.4
Min	5.3	5.4	6.2	7.8	9.6	11.1		12.9
Max	8.6	12.2	18.8	17.3	13.1	13.8		15.4
Count	19	66	159	39	5	4	1	5
Annual Growth Increment:	7.2	1.9	1.1	1.6	-0.8	1.4	0.1	1.8

Appendix Table 2. Total length at age and growth increment data from Whatcom and Skagit County high lakes and cutthroat trout populations of unknown age in the western Cascades, Washington.

mm	**Age 1+**	**Age 2+**	**Age 3+**	**Age 4+**	**Age 5+**	**Age 6+**	**AGE 7+**	**Age 8+**	**Age 9+**	**Age 10+**	**Age 11+**
Mean	134.2	192.6	245.1	281.3	285.9	348.8	394.0	425.3	653.0	628.0	446.3
Variance	245.0	1207.5	1575.0	2161.7	1652.2	3135.5		2701.1			36906.2
SD	15.65	34.75	39.69	46.49	40.65	56.00		51.97			192.11
Min	108	127	166	200	232	257		389			315
Max	161	292	347	440	400	415		462			667
Count	19	104	162	105	35	14	1	2	1	1	3
Inches											
Mean	5.3	7.6	9.7	11.1	11.3	13.7	15.5	16.7	25.7	24.7	17.6
SD	9.6	47.5	62.0	85.1	65.0	123.4		106.3			1453.0
Min	4.3	5.0	6.5	7.9	9.1	10.1		15.3			12.4
Max	6.3	11.5	13.6	17.3	15.8	16.3		18.2			26.3
Annual Increment	5.3	2.3	2.1	1.4	0.2	2.5	1.8	1.2			

Appendix Table 3. Total length at age and growth increment data from Chelan and Yakima County high lakes and rainbow trout populations of unknown age in the eastern Cascades, Washington.

mm	**Age 1+**	**Age 2+**	**Age 3+**	**Age 4+**	**Age 5+**	**Age 6+**	**AGE 7+**	**Age 8+**	**Age 9+**	**Age 10+**	**Age 11+**
Mean		176.3	202.5	247.9	221.3	273.4	276.5	387.0	317.5	310.0	
Variance		140.3	4096.1	3690.2	1639.9	2836.4				1300.0	
SD		11.85	64.00	60.75	40.50	53.26				36.06	
Min		169	126	146	164	190	203		305	270	
Max		190	349	364	290	360	350		330	340	
Count		3	13	17	18	19	2	1	2	3	
Inches											
Mean		6.9	8.0	9.8	8.7	10.8	10.9	15.2	12.5	12.2	
SD		5.5	161.3	145.3	64.6	111.7					
Min		6.7	5.0	5.7	6.5	7.5	8.0		12.0	10.6	
Max		7.5	13.7	14.3	11.4	14.2	13.8		13.0	13.4	
Annual Increment		6.9	1.0	1.8	-1.0	2.0	0.1	4.4			

Appendix Table 4. Total length at age and growth increment data from Chelan and Yakima County high lakes and cutthroat trout populations of unknown age in the eastern Cascades, Washington.

mm	**Age 1+**	**Age 2+**	**Age 3+**	**Age 4+**	**Age 5+**	**Age 6+**	**AGE 7+**	**Age 8+**	**Age 9+**	**Age 10+**	**Age 11+**
Mean	141.4	171.8	216.0	233.4	236.2	252.7	261.3	273.4	270.5	286.0	344.0
Variance	2124.3	2759.0	1760.7	1966.0	1710.0	1498.2	1848.3	3992.4	1589.5	780.0	11242.0
SD	46.09	52.53	41.96	44.34	41.35	38.71	42.99	63.19	39.87	27.93	106.03
Min	100	110	155	149	140	169	200	172	210	260	240
Max	244	380	406	481	343	343	382	468	324	320	462
Count	8	40	59	118	101	66	41	19	11	5	5
Inches											
Mean	5.6	6.8	8.5	9.2	9.3	9.9	10.3	10.8	10.6	11.3	13.5
SD	83.6	108.6	69.3	77.4	67.3	59.0	72.8	157.2	62.6	30.7	442.6
Min	3.9	4.3	6.1	5.9	5.5	6.7	7.9	6.8	8.3	10.2	9.4
Max	9.6	15.0	16.0	18.9	13.5	13.5	15.0	18.4	12.8	12.6	18.2
Annual Increment	4.8	1.2	1.7	0.7	0.1	0.6	0.3	0.5	-0.1	0.6	2.3

Appendix Table 5. Total length at age and growth increment data from Chelan and Yakima County high lakes and eastern brook populations of unknown age in the eastern Cascades, Washington.

mm	**Age 1+**	**Age 2+**	**Age 3+**	**Age 4+**	**Age 5+**	**Age 6+**	**AGE 7+**	**Age 8+**	**Age 9+**	**Age 10+**	**Age 11+**
Mean	145.8	135.8	217.7	195.7	217.8	257.7	183.0	225.0	245.0	264.0	
Variance	1217.6	765.5	2107.7	852.9	862.2	4511.1					
SD	34.89	27.67	45.91	29.20	29.36	67.16					
Min	68	103	149	165	170	199	180				
Max	188	170	325	261	242	340	186				
Count	8	4	13	13	5	6	2	1	1	1	
Inches											
Mean	5.7	5.3	8.6	7.7	8.6	10.1	7.2	8.9	9.6	10.4	
SD	47.9	30.1	83.0	33.6	33.9	177.6					
Min	2.7	4.1	5.9	6.5	6.7	7.8	7.1				
Max	7.4	6.7	12.8	10.3	9.5	13.4	7.3				
Annual Increment	5.7	-0.4	3.2	-0.9	0.9	1.6		1.7	0.8	0.7	

Appendix Table 6. Total length at age and growth increment data from Chelan County high lakes and lake trout populations of unknown age in the eastern Cascades, Washington.

mm	**Age 1+**	**Age 2+**	**Age 3+**	**Age 4+**	**Age 5+**	**Age 6+**	**AGE 7+**	**Age 8+**	**Age 9+**	**Age 10+**	**Age 11+**
Mean		225.0	206.0	310.0	332.0	343.3	426.8		500.0	470.0	
Variance					3172.0	1433.3	738.3				
SD					56.32	37.86	27.17				
Min					290	300	400				
Max					396	370	457				
Count	0	1	1	1	3	3	4	0	1	1	
Inches											
Mean		8.9	8.1	12.2	13.1	13.5	16.8		19.7	18.5	
SD					124.9	56.4	29.1				
Min					11.4	11.8	15.7				
Max					15.6	14.6	18.0				
Annual Increment				4.1	0.9	0.4	3.3				