IDENTIFICATION OF COLUMBIA BASIN SOCKEYE SALMON STOCKS USING SCALE PATTERN ANALYSES IN 1991

Technical Report 92-2

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Carolyn E. Pearson
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February 11, 1992

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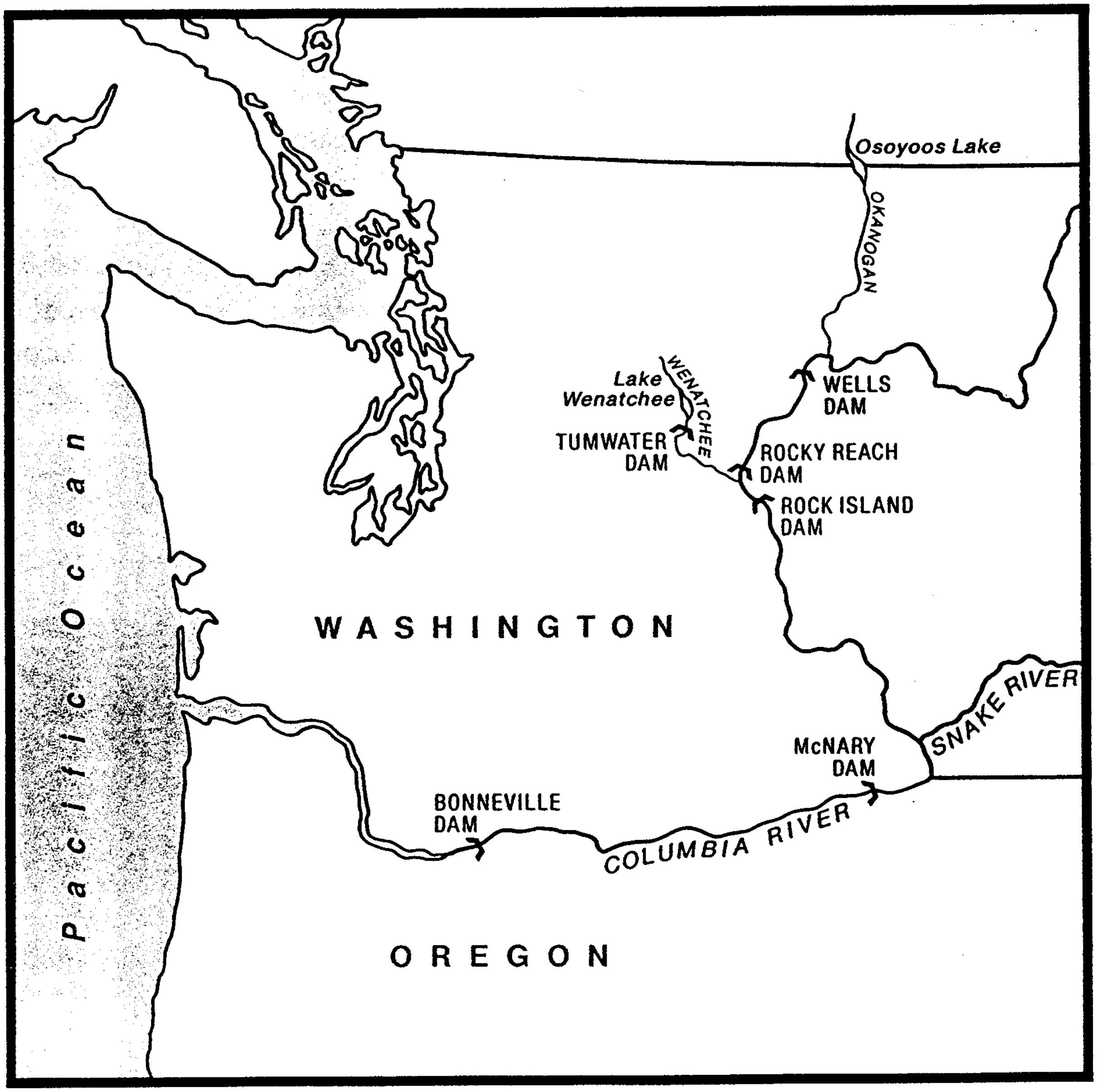
INTRODUCTION

Sockeye salmon *Oncorhynchus nerka* (Walbaum) is one of the five species of Pacific salmon native to the Columbia River Basin. Before white settlers developed the region, it is estimated the Columbia Basin supported an annual sockeye salmon run averaging over four million fish (Northwest Power Planning Council 1986). Since the mid-1800s, however, this sockeye salmon population has severely declined. The estimated number of sockeye salmon entering the Columbia River over the last three years (1989-1991) has averaged only about 55,000 fish (CRITFC 1991).

The Columbia Basin sockeye salmon run was once composed of at least eight principal stocks (Fulton 1970). Today, only two major stocks remain (Figure 1). Both are naturally produced, originating in the Wenatchee River-Lake Wenatchee system (Wenatchee stock) and in the Okanogan River-Osoyoos Lake system (Okanogan stock). Markedly different conditions exist in the two remaining Columbia Basin sockeye salmon spawning and rearing areas (Allen and Meekin 1980, Mullan 1986). Lake Wenatchee is oligotrophic, with relatively deep, cold, and biologically unproductive waters. Conversely, Osoyoos Lake has the shallow, warm, and agriculturally enriched waters characteristic of eutrophic lake habitats.

Before this study began (Schwartzberg and Fryer 1988), reliable methods for individual Columbia Basin sockeye salmon stock identification had not been developed to permit estimation of the overall run composition and the migratory characteristics of each component stock. Numerous potential research and management uses exist for such information. These include run-reconstruction studies to permit accurate population size forecasts, escapement monitoring, establishment of spawner-recruit relationships, and development of discrete-stock approaches to Columbia River mainstem harvest management. The Pacific Salmon Treaty, ratified by the United States and Canada in 1985 (PST 1985), requires that certain Pacific salmon populations be monitored to determine the influence of Treaty-imposed ocean harvest regulations on *transboundary* stocks. Some Okanogan stock sockeye salmon originating in Canadian waters but migrating through, and harvested in, the United States portion of the Columbia River might constitute such a stock. Stock identification research would aid in estimation of the proportion and absolute number of Canadian origin sockeye salmon caught within the United States.

Figure 1. **Map of the Columbia Basin showing Bonneville, McNary, Rock Island, Rocky Reach, Wells, and Tumwater dams and the two present sockeye salmon production areas.**



The Columbia River Inter-Tribal Fish Commission's Stock Identification Project is designed to develop and apply techniques for identification of individual or aggregate stocks of Columbia Basin salmon originating above Bonneville Dam. The collection and dissemination of basic stock-specific biological information is also an important project goal. Scale pattern analysis (SPA) is the method of study currently being used for stock identification. SPA is a well established stock identification and classification technique (Clutter and Whitesel 1956, Henry 1961, Mosher 1963, Anas and Murai 1969). In many species of fish including Pacific salmon, the use of SPA as a tool for stock identification depends on a high correlation between individual fish growth and scale growth (Koo 1955, Clutter and Whitesel 1956). Fish growth and scale growth are influenced by genetic factors and by such environmental conditions as water temperature, length of growing season, and food availability. Stock identification based on SPA assumes that genetically or environmentally influenced growth patterns will differ throughout a species' range and that these differences will be exhibited in the scales of entire groups or stocks of fish. Scale samples from the Wenatchee and Okanogan sockeye salmon stocks in past years have differed (Schwartzberg 1988; Schwartzberg and Fryer 1989, 1990; Fryer and Schwartzberg 1991), presumably reflecting differences in freshwater spawning and rearing conditions. This report describes the age, length-at-age, and stock composition of Columbia Basin sockeye salmon in 1991.

METHODS

Sampling

Sampling Methods

Scales from mixed sockeye salmon stocks *(unknowns)* were obtained from fish sampled at the Bonneville Dam Fisheries Engineering and Research Laboratory, located at river km 225 on the mainstem Columbia River. Each stock was also sampled in terminal areas to obtain representative scale samples for each of the two Columbia Basin sockeye salmon groups *(knowns)*. Wenatchee stock scales were collected at Tumwater Dam on the Wenatchee River (river km 31), while Okanogan stock scales were obtained at Wells Dam on the mainstem Columbia River (river km 829).

Fish were trapped, anesthetized, sampled for scales and length measurements, allowed to recover, and released. Scales were collected and mounted according to methods described in Clutter and Whitesel (1956) and the International North Pacific Fisheries Commission (1963). Four scales per fish were collected to minimize the sample rejection rate. Fork length measurements were recorded to the nearest 0.5 cm. Observed mark and/or tag information was also recorded. The gender of specimens collected at Bonneville Dam could not be determined because all were in the earliest stages of sexual maturation. The gender of most specimens collected at Tumwater and Wells dams could be determined, and was recorded.

Sample Design

Sockeye salmon were sampled at Bonneville Dam two days per week in conjunction with a summer chinook sampling program. Sampling at Tumwater and Wells dams was conducted one to two days per week during the period in which significant numbers of sockeye salmon were migrating past those sites. The desired total sample size at all sites was a minimum of 500 fish which, in the past, has generally resulted in age composition estimates (Fryer, in preparation) within preferred levels of precision and accuracy ($d=0.05$, $\alpha=0.10$). The actual mixed stock (Bonneville Dam) composite sample size used for age composition estimation was 856 fish. The actual known stock composite sample sizes used for age composition estimation were 413 fish from Tumwater Dam and 473 from Wells Dam.

For SPA studies, the desired sample size was approximately 200 from each known stock group (Conrad 1985). The Wenatchee stock subsample consisted of 219 systematically selected Age 1.2 specimens (see the following section entitled 'Age Determination and Scale Measurements' for a description of the fish age notation used herein). The Okanogan stock subsample consisted of 183 systematically selected Age 1.2 specimens. Although a minimum desired sample size of 100 is recommended for unknown groups in SPA studies (Conrad 1985), 237 systematically selected Age 1.2 samples from the mixed stock were used in the analysis to permit more precise weekly stock composition estimates.

To further improve accuracy, composite age and length-at-age estimates based on the above described sampling methodology were adjusted post-season using a stratified sampling method that weighted weekly estimates to adjust for actual 1991 migration timing.

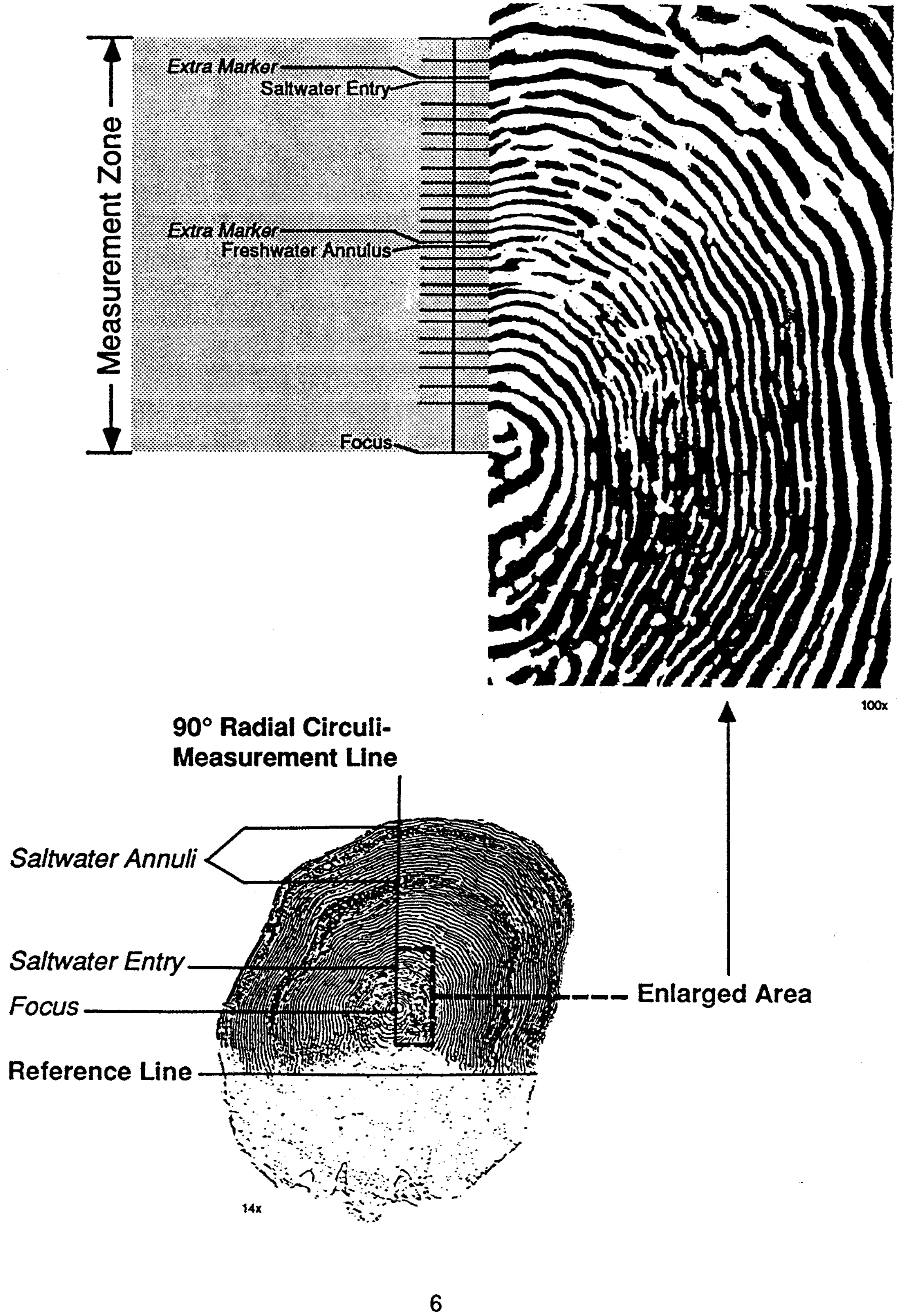
Age Determination and Scale Measurement

Salmon scales, under magnification, display numerous concentric rings (*circuli*) radiating outward from a central focal area. A freshwater-growth zone of narrowly spaced circuli (Figure 2) is clearly distinguishable from a zone of more widely spaced saltwater-growth circuli in scales of all Columbia Basin sockeye salmon, which typically spend one or two complete years in freshwater before migrating to the ocean. Fish age can be determined by counting *annuli*, which are zones of closely spaced circuli formed yearly during winter periods of slow growth.

All scales were examined visually and categorized by age using previously described techniques (Johnston 1905, Gilbert 1913, Borodin 1924, Van Oosten 1929). The method used for fish age notation is that recommended by Koo (1955), which is sometimes referred to as the *European* method. The number of winters a fish spent in freshwater (not including the winter of egg incubation) is described by an Arabic numeral followed by a period. The numeral following the period indicates the number of winters a fish spent in the ocean. Total age, therefore, is equal to one plus the sum of both numerals.

Scales were used to estimate the age composition of Bonneville Dam mixed stock as well as the Okanogan and Wenatchee known stock samples. Length-at-age

Figure 2. Age 1.2 Okanogan stock sockeye salmon scale showing growth and measurement zones.



relationships were also established for each stock. Otoliths from each known stock were used to support scale age estimation techniques and to corroborate scale age estimates. Validation of ages (Beamish and McFarlane 1983) was not possible as there were no fish of known age in any samples.

SPA of circuli in freshwater and early saltwater-growth zones was used to identify each known stock sample and to also classify mixed stock samples. The methodology was applied to Age 1.2 samples from all stocks. SPA was not used to classify fish of age classes other than 1.2 in the mixed stock sample. Certain age classes were found to be overwhelmingly present in only one of the two known stock samples. These age classes were assumed to be attributable to a single stock and this relationship was used to categorize mixed stock samples of given age groups.

A computer and video camera were used to measure, or *digitize*, scale features (BioSonics 1985). The system employed consisted of a microscope (2x, 4x, 6.3x, and 10x objectives; a 1.0x, 1.25x, and 1.5x magnification changer; and a 2.5x photocompensation adapter), a monitor, and a digitizing tablet connected to a personal computer (AT) with a video frame-grabber board. Acetate impressions of scales were placed in the microscope and projected onto the monitor. Using a keyboard and digitizing tablet, distances were measured along a radial line drawn through the scale. These measurements were then stored in a computer file. Only scales with distinct foci and circuli were used in scale measurement work.

One scale from each fish was selected, oriented diagonally with the clear (posterior) part of the scale in the lower left corner of the screen, and a reference line was drawn along its base (5x final microscope magnification and 65x projection magnification). The reference line was placed in the posterior field of the scale so that it bridged the end points of circuli in the first saltwater annulus (Figure 2). A radial line was then drawn perpendicular to the reference line, and circuli positions were measured at their points of intersection with the radial line (25x final microscope magnification and 325x projection magnification). All measurements were made to the outermost marginal edges of circuli. Additional circuli markers were placed to permit measurement of other key scale-features, specifically, freshwater annulus and saltwater-entry point. These features were respectively indicated by two sets of closely spaced circuli markers. The 'extra markers' were placed immediately after and adjacent to the original circuli position markers and were interpreted and removed by data analysis programs used in subsequent procedures (Appendix A). The freshwater annulus-position marker was placed beside the last circulus in the freshwater annulus and the saltwater-entry marker was placed immediately after the first circulus in the ocean zone.

Statistical Analyses

A linear discriminant analysis technique developed by Fisher (1936) was used to differentiate stocks and classify unknown mixed stock samples. Linear discriminant analysis permits the simultaneous use of many variables to form classification functions that typify and identify groups. This methodology has proven useful for determining the origins of individual fish stocks from mixed stock samples (Bethe and Krasnowski 1977, Bethe et al. 1980, Major et al. 1978).

Variables, composed of selected scale-measurements within an area from scale focus to approximately circulus 27, were tested to find those that most effectively characterized differences in growth between the two stocks. As in studies of previous years, distances between four adjacent circuli (or triplets), were the primary variable tested (Davis 1987). Other variables briefly tested included distances between adjacent circuli (singlets), three adjacent circuli (doublets), and five adjacent circuli (quadruplets). Distance measurements and number of circuli from scale focus to saltwater-entry and from scale focus to freshwater annulus margin (anterior) were also among the variables tested.

Accuracy of the discriminant analyses was determined by classifying the pooled known stock samples from a particular analysis and then comparing results to actual (verifiable) known stock identities. A jackknife procedure (Lachenbruch 1975, Dixon et. al 1983) was employed to correct for systematically biased results that are created in known stock classification when the same samples are used for both calculating the discriminant function and determining its accuracy.

The discriminant function was then used to classify unknown mixed stock samples. To correct for misclassification, the method developed by Cook and Lord (1978) was employed. Variances on estimates were also computed (Pella and Robertson 1979). Stratified sampling techniques were used to make post-season corrections of stock composition estimates (Fryer in preparation).

A stepwise procedure (Dixon et. al 1983) was applied in the analyses, allowing variables to be entered and/or removed from a discriminant function at each stage of function development. The steps taken by the procedure were similar to those of a stepwise regression.

Relationship of Migratory Timing to Stock Composition

Tests were conducted to examine the relationship between migratory timing and stock composition in the mixed stock sample. This relationship was tested by regressing mean weekly stock composition estimates against the statistical week weighted by the inverse of the variance for each estimate (Neter et. al 1985).

Visual Scale Classification

Visual interpretation of freshwater scale-circuli patterns was studied based on the assumption that differences between Okanogan and Wenatchee sockeye salmon Age 1.2 scales were large enough to permit classification through visually observable characteristics alone. A blind experiment similar to one described by McPherson and Jones (1987) was used to test this hypothesis.

All unknown stock Age 1.2 samples collected at Bonneville Dam were also classified as being of Okanogan or Wenatchee origin using only visually observable characteristics. For all samples classified by visual means as well as through scale measurements and statistical techniques, the two classifications were compared.

RESULTS

Sample Design

A sample of 856 fish were used for age and length-at-age composition estimates of unknown stock sockeye salmon made in this study. Small sample sizes in Statistical weeks 23 and 31 resulted in the pooling of data from Statistical weeks 23 and 25 as well as Statistical weeks 30 and 31. Operational difficulties resulting from large numbers of shad migrating through the lower Columbia River in Statistical Week 24 resulted in the closing of the Bonneville Dam fish trap during that week. Therefore, no samples were collected during Statistical Week 24.

Age and Length-at-Age Composition

The predominant age class for known and unknown stocks was Age 1.2. This age class was estimated to comprise 80% of the Wenatchee known stock, 75% of the Okanogan known stock, and 76% of the Bonneville mixed stock (Tables 1 and 2). Mean fork-lengths by age class, with 90% confidence intervals, for the three samples are given in Figure 3.

Classification of Known Stock Samples

Among the variables tested, those resulting in the highest classification accuracies were triplets. The variables used by the stepwise procedure were the distances between the focus and third circuli, third and sixth circuli, sixth and ninth circuli, twelfth and fifteenth circuli, fifteenth and eighteenth circuli, eighteenth and twenty-first circuli and twenty-first and twenty-fourth circuli. For classification of Age 1.2 fish, 86% of the known stock samples were accurately classified by this variable set (Table 3). A total of 34 Wenatchee samples were misclassified as Okanogan stock, while 22 Okanogan samples were misclassified as Wenatchee stock. Application of a jackknife procedure produced no additional misclassifications.

Table 1. **Age composition estimates (%) of Columbia Basin sockeye salmon stocks sampled at Bonneville Dam in 1991.**

			Brood Year and Age Class					
Statistical Week	Sampling Dates	Sample Size	1988	1987		1986		1985
			1.1	1.2	2.1	1.3	2.2	2.3
23,25	6/03,19,20	134	0	60	0	40	0	0
26	6/26,28	205	0	76	0	23	<1	<1
27	7/03,05	191	5	65	1	29	1	0
28	7/10,12	191	2	96	0	2	0	0
29	7/17,19	96	19	64	9	5	2	0
30-31	7/24,26,31	39	23	56	20	0	0	0
Composite Sample		856	5	76	2	16	<1	<1

Table 2. **Age composition estimates (%) of Wenatchee and Okanogan sockeye salmon stocks sampled in 1991.**

Wenatchee stock

Statistical Week	Sampling Dates	Sample Size	1988 1.1	1987 1.2	1987 2.1	1986 1.3	1986 2.2	1985 2.3
31	7/31	101	0	68	0	31	1	0
32	8/07,08	296	0	88	0	10	2	<1
33	8/15	16	0	81	0	12	6	0
Composite Sample		**413**	**0**	**77**	**0**	**21**	**2**	**<1**

Okanogan stock

Statistical Week	Sampling Dates	Sample Size	1988 1.1	1987 1.2	1987 2.1	1986 1.3	1986 2.2	1985 2.3
29	7/16,17	16	13	75	13	0	0	0
30	7/24,25	160	11	82	4	3	0	0
31	7/30	186	18	74	6	1	1	0
32	8/05,06	111	25	67	7	1	0	0
Composite Sample		**473**	**17**	**75**	**6**	**2**	**<1**	**0**

Figure 3. Length-at-age estimates (with 90% confidence intervals) of sockeye salmon stocks sampled at Bonneville, Tumwater and Wells dams in 1991.

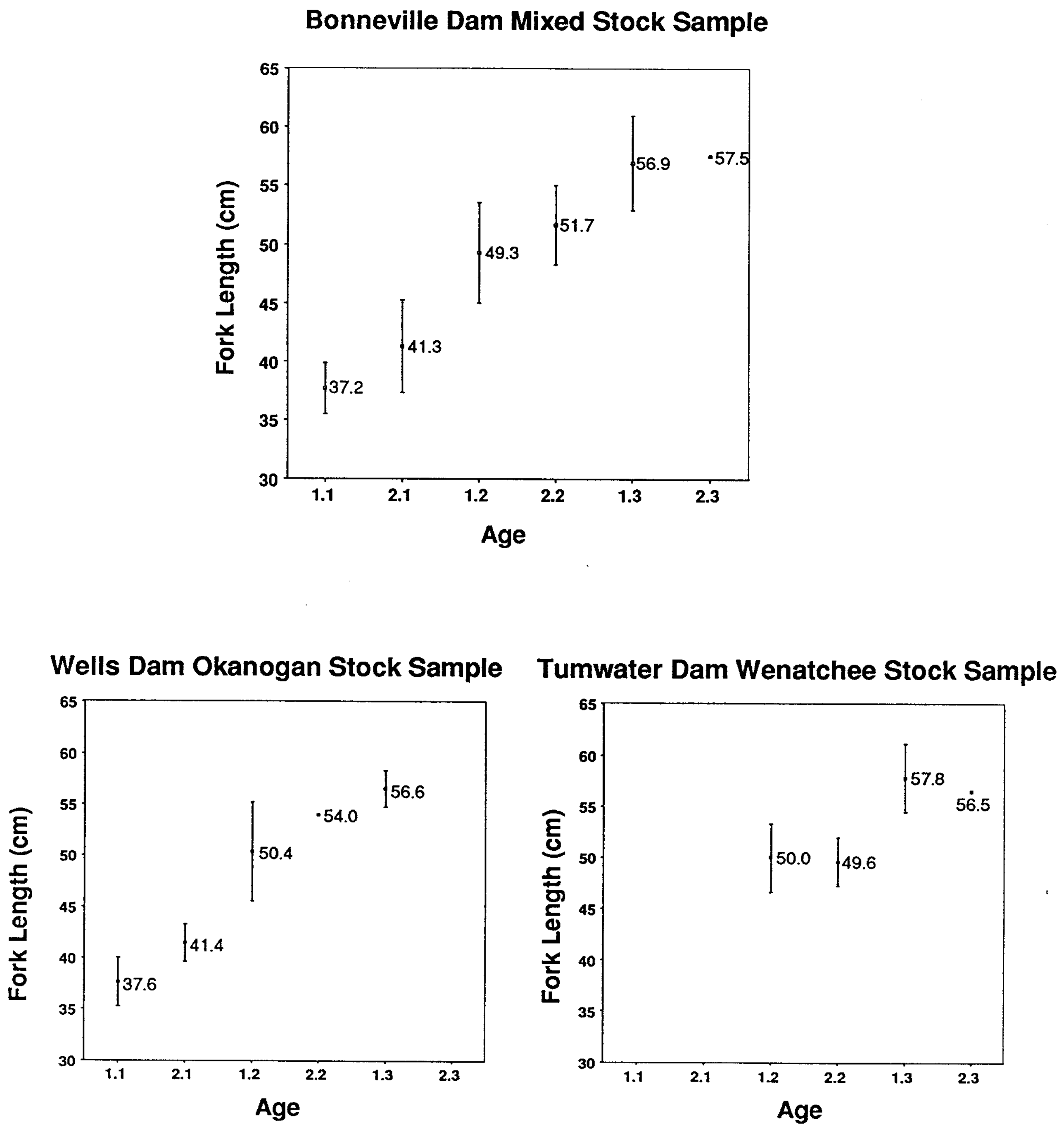


Table 3. **Known stock classification tests using linear discriminant analyses with Age 1.2 Columbia Basin sockeye salmon stocks sampled in 1991.**

Age 1.2 Known Stock Classification Test

Stock	Percent Correct	Sample Classification *Wenatchee*	*Okanogan*
Wenatchee	85	187	34
Okanogan	88	22	161
Composite Accuracy	86		

Classification of Unknown Mixed Stock Samples

After correcting for classification bias, and post-stratifying by migratory timing, 61% of the Age 1.2 sockeye salmon migrating past Bonneville Dam were estimated to be Okanogan stock. The remaining 39% of the migration was estimated to be Wenatchee stock. Confidence intervals (90%) ranged from 53% to 69% for the estimate of Okanogan stock and from 31% to 47% for the Wenatchee stock estimate.

In previous years, Age 1.3, 2.2, and 2.3 fish were much more common in the Wenatchee stock sample than in the Okanogan class sample. Therefore, all fish of these age classes in the Bonneville Dam mixed stock sample have, in the past, been generally classified as Wenatchee stock. Similarly, in previous years, no Age 1.1 and 2.1 fish were found in the Wenatchee sample, although fish of those age classes are relatively common in the Okanogan sample. Therefore, all Age 1.1 and 2.1 fish in the Bonneville Dam sample have been classified as Okanogan stock. These trends were again observed in 1991 and fish so classified.

Combining the results of SPA classification of Age 1.2 unknowns (based on linear discriminant analyses) with the classification of the remaining unknowns (based on age alone), 47% of the composite mixed stock sample was estimated to be Wenatchee stock and the remaining 53% Okanogan stock (Table 4). Using the above stock composition estimates, individual stock escapement estimates were made at Bonneville Dam. Of the 76,482 sockeye salmon recorded by Bonneville Dam visual fish counts, 35,947 were estimated to be Wenatchee origin and the remaining 40,535 Okanogan origin.

The estimated composition of mixed stocks for the five study years is presented in Figure 4.

Relationship of Migratory Timing to Stock Composition

Weekly unknown mixed stock composition estimates (Table 4) show no significant relationship ($p>0.05$) between migratory timing and stock composition using linear regression techniques.

Table 4. **Stock composition estimates of Columbia Basin sockeye salmon stocks sampled at Bonneville Dam in 1991.**

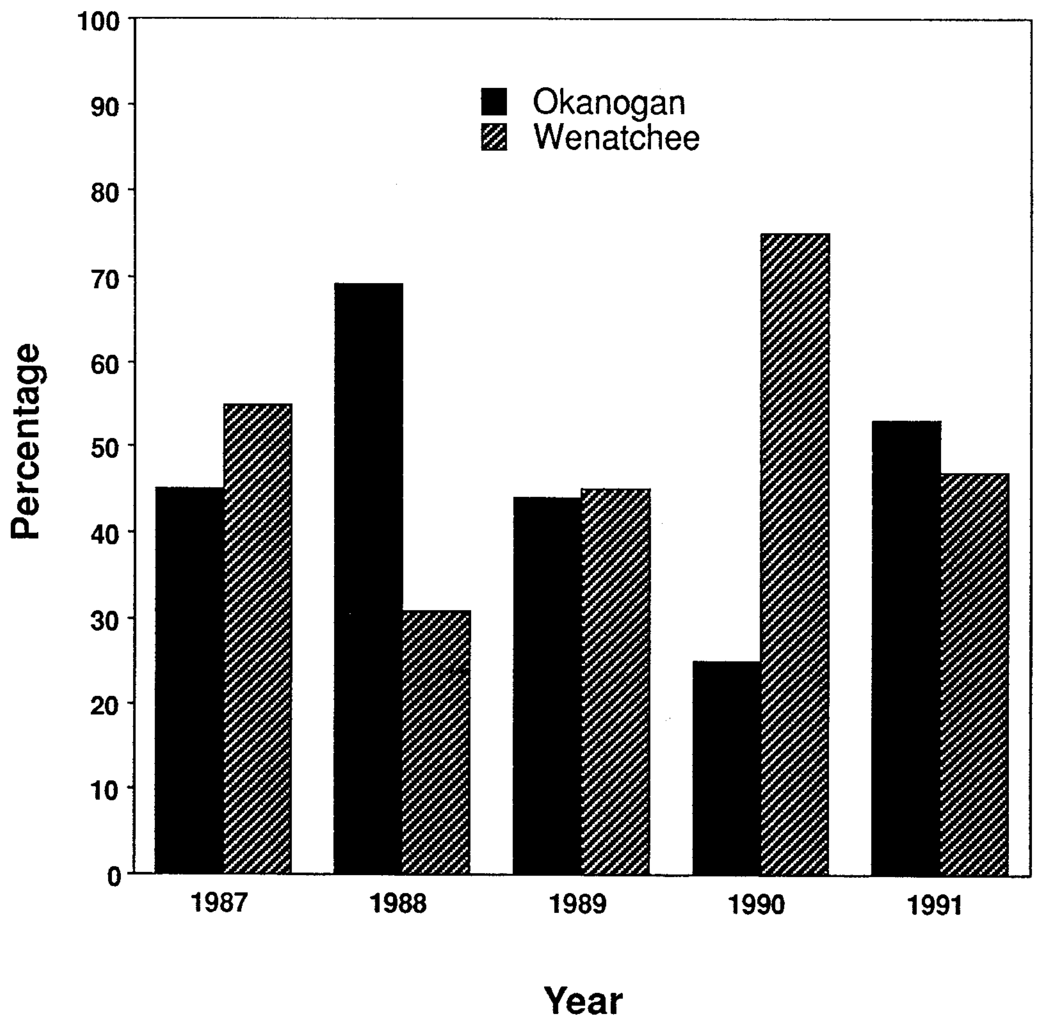
Classification of Only Age 1.2 Sockeye Salmon

Statistical Week	Sample Size	Sample Classification Wenatchee	Okanogan	Standard Error
25	32	18	82	11
26	37	20	80	11
27	48	48	52	10
28	65	37	63	9
29	30	84	16	11
30	23	25	25	14
Composite Sample	**233**	**39**	**61**	**5**

Classification of All Age Sockeye Salmon

Statistical Week	Sample Size	Sample Classification *Wenatchee*	*Okanogan*	Standard Error
25	134	50	50	8
26	205	40	60	9
27	191	60	40	7
28	191	38	62	9
29	96	62	38	9
30	35	15	85	12
Composite Sample	**856**	**47**	**53**	**4**

Figure 4. **Stock composition estimates of Columbia Basin sockeye salmon stocks sampled at Bonneville Dam from 1987 through 1991.**



Visual Scale Classification

Eighty-four percent of a subsample (n=70) of known stock origin was correctly identified strictly on the basis of the visual appearance of the scale patterns. Of the unknown stock Age 1.2 sample, 60% were classified to be of Okanogan stock. Of those unknown stock scale samples which were classified by both visual and statistical methods, 80% were classified similarly by both methods (Table 5).

Table 5. Comparison of classification of mixed stock sockeye salmon by visual and statistical means.

Age 1.2 Known Stock Classification Test

Classification by Discriminant Analysis	Percent Similar	Classification by Visual Observation	
		Wenatchee	*Okanogan*
Wenatchee	72	70	27
Okanogan	88	16	116
Composite Accuracy	80		

DISCUSSION

This paper reports results from the fifth year of a Columbia Basin sockeye salmon stock identification research project (Schwartzberg 1988; Schwartzberg and Fryer 1988, 1989, 1990; Fryer and Schwartzberg 1991). Wenatchee and Okanogan stock fish were identified using a linear discriminant analysis procedure. Classification accuracy in 1991 was 86%, which was the highest figure in three years. By comparison, the percentage accurately classified was 91% in 1987, 86% in 1988, 81% in 1989, and 65% in 1990.

Age 1.2 was the predominant age class for both known stocks, as well as the mixed stock, in 1991. As has been observed in previous years, Age 1.3 sockeye salmon were present in significant numbers only in the Wenatchee stock. Similarly, Age 1.1 and 2.1 sockeye were present in significant numbers only in the Okanogan stock. Age 2.2 sockeye salmon composed the smallest percentage of the Wenatchee known stock and Bonneville mixed stock samples in the past five years.

Adult migrating salmon are visually counted, predominately during daylight hours, in fish ladders at most mainstem Columbia and Snake river dams. Except for a remnant Snake River stock (only nine sockeye salmon were counted at Lower Granite Dam in 1991), all Columbia Basin sockeye salmon stocks returning to spawning grounds pass Rock Island Dam (river km 729). Only Okanogan stock fish pass Rocky Reach Dam (river km 761). Using the difference between Rock Island and Rocky Reach dam counts as an estimate of the Wenatchee stock escapement, and using the Rocky Reach Dam count as an estimate of Okanogan stock escapement, 44% (27,440) of the 1991 escapement estimate at Rocky Reach Dam may be attributed to the Okanogan stock and 56% (35,675) to the Wenatchee stock. These percentages differ by nine percentage points from the results of the 1991 mixed stock classification estimate at Bonneville Dam (53% Okanogan stock, 47% Wenatchee stock; Table 4). This is the first year of the five study years (1987-1991) that the estimated stock composition derived using dam counts and SPA has differed by more than five percentage points.

At least three explanations are apparent for the difference between stock composition estimates presented in this report. One possibility may be that mixed stock sample was not representative of the population or that the classification methods used in this study are incorrect. These sources of error are suggested by the tendency for stock composition estimates in 1991, unlike previous years, to differ greatly from week to week. A second possibility could result from the failure of mainstem dam counts to account for the passage of fish at night. Currently, escapement estimates made at mainstem Columbia River dams assume that no night passage occurs and, therefore, fish are not generally counted between 2100 and 0500 hours (U.S. Army Corps of Engineers 1989). However, a project using video technology to monitor escapement at Tumwater Dam estimated that, during 1989 and 1990, 6.7% of the sockeye salmon passed between 2100 and 0500 hours (Hatch and Schwartzberg 1991). If sockeye salmon passed by Rocky Reach Dam uncounted in large numbers during nighttime hours, the percentage of fish of Okanogan origin could be underestimated. A third possible explanation for differences in dam count-based and SPA-based stock composition estimates could be a differential mortality on the upstream migration. The Rock Island Dam sockeye count was only 81% of the Bonneville Dam sockeye count. It is possible that the difference between these counts may represent mortality during the upstream migration. If the majority of this upstream mortality was suffered by the Okanogan stock, then the Bonneville Dam mixed stock classification estimate could be considered consistent with that estimated by dam counts. Support for this theory comes from observations of sockeye salmon condition at Wells and Tumwater dams. At Wells Dam, a large percentage of sockeye salmon observed appeared to be in poor condition, exhibiting scale loss and body wounds. Few fish were judged to be in poor condition at either Bonneville or Tumwater dams.

In 1991, the test made to detect a linear relationship between stock composition and migratory timing in the mixed stock unknown-origin sample produced no significant results. This differed from both 1989 and 1990 when the percentage of Wenatchee stock sockeye decreased as the migration progressed while the percentage of Okanogan stock sockeye increased. If a consistent and predictable relationship is found between stock composition and migratory timing, adjustment of potential future mainstem Columbia River sockeye salmon fisheries may be possible to permit harvest of a greater proportion of a particular stock.

Sampling at Wells Dam in 1991 offered the opportunity to test for size selectivity of the east and west bank fish traps. On both fish traps, bars with 7 cm spacing divert the fish into the fish trap. Therefore in 1988, it was speculated that the sample collected at the Wells Dam west bank fish trap underestimated Age 1.1 and 2.1 fish because it seemed likely that these fish could pass between the bars (Schwartzberg and Fryer 1989). (However any bias in resulting age composition estimates was likely minimal because it was also noted that few fish of these age classes were observed at either Bonneville Dam or on the Okanogan spawning grounds.) In 1990, a screen with a 5 cm mesh size was added to divert these smaller fish into the west bank fish trap which was used for sampling in that year. In 1991, the screen was moved to the east bank fish trap, where most sampling was conducted. However, some sampling in 1991 was conducted early in the migration at the west bank trap where no screen was installed. During four sampling days early in the migratory period, fish less than 44 cm in mean fork length made up 24% of the east bank sample (n=17) but only 2% of the west bank sample (n=44). It is possible that smaller fish may prefer the east bank ladder over the west bank ladder. However, because the difference in small fish abundance between the two ladders was significant ($p<0.05$), and a reasonable explanation for this difference is readily apparent, samples from the west bank fish ladder were not included in the results presented in this report.

A major shortcoming of scale pattern studies is the need for known stock samples before mixed stock samples can be classified. If scale samples can be classified visually with reasonable accuracy, then in-season management of fisheries becomes more feasible. The effort to visually classify samples collected at Bonneville Dam in 1991 was the result a request from Larrie LaVoy of the Washington Department of Fisheries who was trying to determine whether escapement of Wenatchee stock sockeye salmon would be high enough to permit a sport fishery in Lake Wenatchee. Age 1.2 sockeye salmon at Bonneville Dam were visually classified as 61% Okanogan stock which was very close to the 60% so classified by statistical methods. All other age groups were, as previously explained, assumed to be stock specific and so classified. A test of visual classification of known stock scale samples resulted in 84% accuracy compared to 86% achieved by statistical means. The results of these tests of visual classification indicate that, at least in 1991, this method achieves results very similar to those derived measuring scales and using statistical techniques.

This research will be continued in 1992. Work will continue to develop an accurate age, length-at-age, and stock composition database for the Columbia Basin sockeye salmon population. This information will aid fisheries managers in predicting changes in population sizes and in the stock composition of the sockeye salmon population.

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Appendix A. Data handling and manipulation for scale pattern analysis.

During the scale data acquisition process, information associated with each scale data record is stored along with actual scale measurements in four separate fields of the data record *header* (Optical Pattern Recognition System, OPRS; BioSonics Inc. 1985). The sample number, denoted by the appropriate scale card and the sample position number (separated by a period) is recorded in the *sample id* field. Thus, sample number 3 on card number 1 would be recorded as 1.03. The estimated age of the fish from which the scale sample was taken is recorded in the *specimen id* field while the length, sex (M, F, or U), and stock (if known) are recorded in the field labeled *other.* In addition to this user supplied information, the header includes system supplied data including a sequential record number, the microscope magnification conversion factor, a microscope lens calibration factor, a record validity indicator, the total number of circuli in the record, and the angle of the radial line used.

Once circuli measurements are made and a scale data record is saved to the computer's hard disk, scale measurement data cannot be further edited. The operator may, however, edit user supplied header information. The desired record can be located and displayed (by using the OPRS *EDT* page and the *display data* command). Each record is displayed and contains header information and distance measurements from the scale focus to each circulus measured in *sampling units* (Figure A1). Measurements in sampling units can range from 1 to 700 and must be multiplied by the microscope magnification conversion factor to determine metric distances from the scale focus to each marked circulus. Each circulus measurement is stored on a separate line.

To more effectively edit and prepare data for further statistical analysis, the *convert to ASCII* feature of the EDT page is used. This command creates an ASCII file that can be manipulated by a program we have written that detects the extra markers in each record (marking freshwater annulus margin (anterior) and saltwater entry point), converts scale data measurements to actual metric distances, and stores this information in a more compact format (Figure A2). Using still another program, the information necessary to perform statistical analyses is extracted from this file and transferred to statistical software.

Figure A1. A sample OPRS data record for a single sockeye salmon scale freshwater-growth-zone measurement.

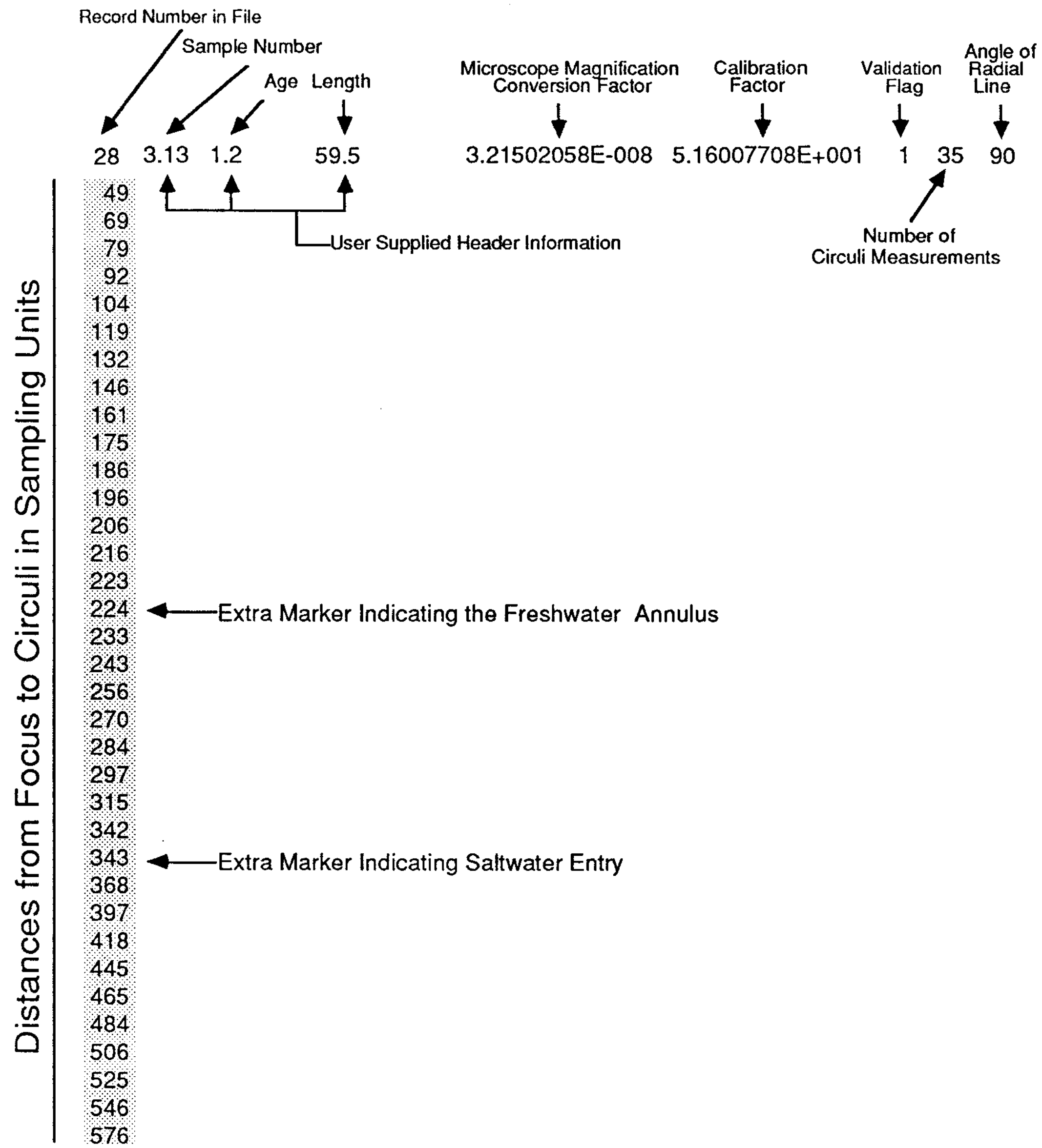

Figure A2. **A sample compact-format data record for a single sockeye salmon scale freshwater-growth-zone measurement.**