A STRAYING ASSESSMENT OF AN INTRODUCED SOCKEYE SALMON STOCK ON NORTHERN AFOGNAK ISLAND AS DETERMINED BY TWO METHODS OF STOCK IDENTIFICATION

By

Robert T. Baer
and
Steven G. Honnold

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ABSTRACT

The Alaska Department of Fish and Game (ADF&G) genetics policy provides guidelines to protect naturally occurring salmon from a genetic intrusion of hatchery-reared salmon. A concern associated with this policy is that terminal fisheries, if not properly implemented and monitored, might increase the incidence of genetic intrusion of hatchery-reared fish into naturally occurring systems. The Terminal Harvest Areas (THA) in Foul Bay and Waterfall Bay have artificial barriers installed to prevent adult sockeye salmon *Oncorhynchus nerka* from migrating up-stream into freshwater. Sockeye salmon runs in both of these locations are a result of releasing juveniles into Hidden Lake (Foul Bay) and Little Waterfall Lake (Waterfall Bay). Both systems are stocked yearly because they are not conducive to maintaining self-sustaining anadromous salmon runs. The ADF&G genetics staff suggested that these terminal fishery salmon may stray into nearby wild sockeye salmon streams due to the artificial barriers. In a previous study conducted in 1998 and 1999, sockeye salmon escapements from Thorsheim Creek (near Hidden Creek) and Portage Creek (near Waterfall Creek) were sampled and analyzed to determine if any of the introduced sockeye salmon were straying into these natural systems. The study indicated an insignificant number of sockeye salmon strays into Thorsheim and Portage Creeks, although there was one segment of the Portage Creek escapement data that indicated a possible bimodal distribution. Based on the inconclusiveness of this study, it was suggested that a more detailed study be conducted to determine if Little Waterfall Creek sockeye salmon are straying to Portage Creek.

This study utilized the same methods to determine if Little Waterfall Creek sockeye salmon are straying to Portage Creek as well as stock identification and ground truthing methods. Scales were collected from adult sockeye salmon at Waterfall Bay Terminal Harvest Area and Portage Creek. The scales were visually examined to identify scale patterns within the first year of freshwater growth indicative of each stock. The scales were also examined under a compound microscope and several measurements were taken to describe the first freshwater year. The differences in these scale measurements were statistically quantified utilizing discriminant analysis. The results of the stock identification analyses suggests that significant straying of the Little Waterfall sockeye salmon into the Portage Creek sockeye salmon system is unlikely.

INTRODUCTION

The Alaska Department of Fish and Game (ADF&G), in cooperation with Kodiak Regional Aquaculture Association (KRAA), began evaluating the potential of stocking Kodiak area barren lakes in the late 1980s (Edmundson et al. 1994; Schrof et al. 2000; Honnold and Schrof 2001a; Honnold and Schrof 2001b). The intent was to develop "put-and-take" commercial salmon fisheries and harvest the resultant introduced runs. The ADF&G and KRAA began stocking juvenile sockeye salmon *Oncorhynchus nerka* into Hidden and Little Waterfall Lakes in 1992. The first adults ("jacks") returned in 1994 and the first harvestable runs were expected in 1995. In anticipation of the 1995 runs, escapement barriers were temporarily installed at the terminus of Hidden and Little Waterfall Creeks to prevent returning sockeye salmon from escaping into these systems. The barriers were intended to allow fishermen to catch all of the returning Hidden Lake sockeye salmon in the Foul Bay Terminal Harvest Area (FBTHA) and Little Waterfall sockeye salmon in the Waterfall Bay Terminal Harvest Area (WBTHA; Honnold et al. 1998). Both Hidden and Little Waterfall Lakes have been stocked annually with Afognak Lake stock juvenile sockeye salmon and terminal fisheries have occurred in FBTHA and the WBTHA each year since 1995.

The ADF&G genetics policy provides guidelines to protect natural stocks of salmon from genetic intrusion from hatchery-reared salmon (McGee 1995). With this policy in mind, the geneticists had concerns that due to the barrier net the returning introduced sockeye salmon may stray to other streams to spawn and possibly compromise the genetic integrity of nearby natural sockeye salmon stocks. Consequently, the use of a barrier net to eliminate escapement and improve the harvests in the WBTHA and the FBTHA was not considered compliant with ADF&G policy. The concerns of ADF&G geneticists were presented to ADF&G Kodiak area research biologists in 1997. Some of the potential impacts of introduced salmon stocks intermingling with natural salmon stocks include: introduction of deleterious alleles, loss of adaptive genetic variation, loss of reproductive success, outbreeding depression, and displacement of wild fish (Quinn 1993; Grant 1997; Unwin and Glova 1997; Wadle and Honnold 2000). Permits for stocking Hidden and Little Waterfall Lakes were reissued in 1997 with a stipulation that the straying rates of the Hidden Lake stock into Thorsheim Lake (which is located near the FBTHA), and the Little Waterfall stock into Portage Lake (which is located near the WBTHA; Figure 1), would be assessed (Honnold et al. 1998; Wadle and Honnold 2000).

In response, the ADF&G conducted studies to evaluate the frequency of stocked sockeye salmon straying to nearby systems with natural runs (Wadle and Honnold 2000). The straying evaluations were based on the premise that the scales of hatchery-reared sockeye salmon were visually discernible from the scales of natural sockeye salmon stocks (Nelson and Barrett 1994; Honnold et al. 1998). Hatchery reared juvenile fish fed in a controlled environment tend to grow at a faster rate than naturally rearing juvenile salmon (Honnold et al. 1999). The unique differences that were found in the scales' freshwater growth patterns were used to identify the two stocks. Adult scale samples were examined from the areas of concern (natural systems) and from the THAs (introduced systems). The scales were analyzed by comparing the number of circuli (concentric ridges formed in the scale that appear as rings) and the total growth from the focus to the first annulus (annual growth zones indicated by bands of closely spaced circuli; Mosher 1968). These differences in freshwater growth as observed by scale patterns made it possible to differentiate hatchery-reared sockeye salmon stocks from a naturally reared stock.

The 2000 study conducted at the FBTHA and the naturally occurring Thorsheim Creek provided evidence that there was an insignificant rate (less than 2%) of introduced Hidden Lake sockeye salmon straying into nearby Thorsheim Creek, in part due to the effectiveness of the terminal fishery (wadle and Honnold 2000).

The straying evaluation at Portage Creek did not identify any straying of the WBTHA fish; however, there was some evidence of overlap between the two stocks' scale samples. Data from 1998 showed two distinct distributions of circuli counts and freshwater growth, while the data in 1999 showed approximately 14.5% distribution overlap. However, this overlap itself, did not necessarily indicate straying; many populations can have overlap (Wadle and Honnold, 2000).

Due to the statistical uncertainties present in the Portage Creek and the WBTHA 2000 straying study, ADF&G recommended that additional data be collected from future runs in the hopes of developing a conclusive determination of the WBTHA straying rates. The purpose of this report is to present the results of the 2001 data analyses, which used two methods to differentiate the WBTHA fish from Portage Creek fish to determine the incidence of straying.

Description of the Study Area

Little Waterfall Lake (58° 22' N lat., 152° 33' W long.) is located on the north end of Afognak Island, approximately 65 km north-northwest of the city of Kodiak (Figure 1). Little Waterfall Lake's outlet stream is approximately 3.5 km long and drains into Little Waterfall Bay. A series of natural barrier falls, sporadically located throughout the 3.5 km stream, prevent adult sockeye salmon from migrating to upstream spawning habitat. During the months of June and July, a barrier net is erected at the stream terminus in Little Waterfall Bay to prohibit sockeye salmon from escaping into the lower reaches of the stream so the commercial fleet can effectively harvest the returning salmon. Portage Lake (58° 16' N lat., 152° 25' W long.) is located on the north end of Afognak Island, approximately 60 km north of the city of Kodiak (Figure 1). Portage Creek is approximately 1.6 km long and like Little Waterfall Lake, drains into Perenosa Bay. The distance between the terminus of Portage Creek and the WBTHA is approximately 25-water km.

METHODS

To determine the straying rate of sockeye salmon from the WBTHA to Portage Creek, a visual method to differentiate scale patterns was developed to assign the 2001 scale samples to their stock of origin. Due to the qualitative aspects associated with visual examination methods, a second method of stock separation was incorporated. A process called scale pattern analysis (SPA), utilizing a linear discriminant function (Fisher 1936), was used to assign the stock of origin to the unknown scale samples (Johnson and Wichern 1998).

Data Collection

Escapement and Harvest Enumeration

The Portage Lake sockeye salmon escapement numbers were estimated using aerial surveys from 1995 through 1999 and weir counts from 2000 and 2001. The WBTHA sockeye salmon harvest numbers were obtained from the ADF&G fish ticket harvest database.

Scale Sample Collection

Portage Lake sockeye salmon escapement samples were collected with a beach seine and weir trap within Portage Creek. In 2001 a sample goal of 1,200 sockeye salmon from the escapement was established. Age (scale), length and sex data were collected from each individual as outlined in INPFC (1963).

Sockeye salmon smolt were collected as in previous years with a beach seine at the terminus of Little Waterfall and Portage Creeks, and age, weight and length data were collected (ADF&G 2001). A sample goal of 200 sockeye salmon smolt was established for both systems for the outmigration year of 1998. Smolt age (scales) data collected in 1998 were used in conjunction with 2001 escapement and harvest age data as part of the stray detection methods.

Scale Age Designation

Both adult and smolt scales were obtained from the preferred area of each fish as described in INPFC (1963). Smolt scales were mounted on microscope slides and adult scales were mounted on gum cards and impressions were made on diacetates (Cluttler and Whitesel 1956). Both smolt and adult ages were determined by examining the juvenile scales and adult scale impressions using a microfiche reader fitted with a 48X lens following designation criteria established by Mosher (1968). A qualified scale ager, (one passing the annual ADF&G Westward Region scale aging test) determined both fresh and saltwater ages. Ages were recorded on sampling forms using European notation (Koo 1962) where a decimal separates the number of winters spent in fresh water (after emergence) from the number of winters spent in salt water. The total age of the fish includes an additional winter representing the time between egg deposition and emergence of fry.

Data Analysis

Standards "Knowns"

Visual Method. Standard or "known" data sets were established for the Portage Creek and the WBTHA sockeye salmon stocks using the following process:

1) Determination of the dominant adult age class from the 2001 escapement (Portage) and harvest (WBTHA) samples.

2) Determination of the smolt outmigration year of the dominant adult age class by back calculation (e.g., age 1.3 adults sampled in 2001 would have emigrated from freshwater to saltwater in 1998).

3) Visual characterization of the first year freshwater growth patterns on smolt scales for both stocks from the 1998 smolt samples Examining quantity and density of circuli, consistent imperfections or "false checks" within the circuli, and overall size and shape of the first annulus aided in defining the two stocks.

SPA Method. In addition to the visual observations, smolt scales from the appropriate emigration year were analyzed. Scale measurement data were collected using an optical pattern recognition system (OPRS), which is a digitizing software package developed by Biosonics, Inc. OPRS measurement procedures are described in Nelson 1999 (although a mouse and pad were used as an alternative to a digitizing tablet). These data were analyzed to build a discriminate analysis model. Two types of variables were used in the model:

1) The number of circuli within the first year of growth.

2) The freshwater growth distance (measured in mm) from the focus to the outside edge of each circuli in the first year's growth.

While a particular scale will have only one "number of circuli" variable, it will have many focus-to-circuli measurement variables. The model uses the same number of measurement variables for analyzing each scale, so the scale measurement with the least number of circuli within the first annulus was used to set the individual number of variables in the analysis.

Both linear and quadratic models were evaluated using the SAS™ statistical software package. After the model parameters were developed, the known standards were applied to the model and "classification" accuracy was determined using the number of known samples that were apportioned to the correct stock. Both backward and forward stepwise analyses were performed on the model to determine if classification accuracy of the model could be improved if one or more variables were removed. The model with the highest classification accuracy was used.

To account for the known misclassification inherent in the model, the Cook and Lord (1978) correction factor was applied to the model output. Using a quadratic discriminate method, classification errors for known samples from each stock were considered and a correction factor was applied. The correction factor utilized the error structure produced when the known standards were applied to the model to adjust the model estimates. A DOS based computer program automated the correction factor procedure.

Stock Identification

Visual Method. To determine each adult salmon's system of origin, the freshwater growth patterns were examined. Because the freshwater growth patterns found on scales from smolt maintain their characteristics throughout the salmon lifetime, it was possible to compare adult scales to standards set from the appropriate smolt outmigration samples. After we examined the two 'known' smolt stocks, we visually examined 300 randomly selected scales from the dominant age class of the 2001 Portage Lake escapement sample (unknowns). The 300 adult scales were randomly selected from the early, middle and late portions of the run. Knowing the unique freshwater growth pattern characteristics of Little Waterfall fish, we were able to visually classify Little Waterfall fish that strayed from the WBTHA to Portage Creek.

SPA Method. After visually examining the Portage Lake escapement sample, the same randomly selected scales from the "unknown" data set were measured using OPRS software. With the baseline model established, a two-way linear discriminant model was used to define the unknown samples to determine the proportions of the WBTHA stock within the Portage Lake escapement sample. The SPA method selected and identified scales that displayed similar freshwater growth traits as were found in the Little Waterfall smolt scales.

RESULTS

Data Collection

Escapement and Harvest Enumeration

Escapements of sockeye salmon into Portage Creek from 1995-2001 averaged 10,443 sockeye salmon (Table 1). The 2001 escapement estimate of 3,147 was the lowest on record.

The first WBTHA commercial fishery occurred in 1995 as a result of stocking sockeye salmon into Little Waterfall Lake in 1992. Harvests have ranged from 8,623 sockeye salmon in 2000 to 36,496 in 1996 and have averaged 17,718 fish from 1995-2001 (Table 1). The 2001 WBTHA harvest was 16,023 sockeye salmon. Commercial harvest timing in the WBTHA occurs from 9 June through early July, which parallels the run timing of the brood source (Afognak Lake) used for the Little Waterfall Lake stocking (Figure 2). Peak harvests for the 2001 season occurred during the first week (June 9-15) the fishery was open and the majority of the fish were harvested by 25 June.

Scale Sample Collection

In 2001, a total of 986 readable scales were collected from the sockeye salmon Portage Creek escapement (Table 2). Scales were collected throughout the month of June with the majority of the scales being collected in the second week of June, paralleling the WBTHA and Afognak Lake (brood source) peak historical run timing.

In 1998, a total of 181 sockeye salmon smolt were collected from the outlet of Portage Creek and 199 were collected from the outlet of Little Waterfall Creek in the WBTHA (Table 3).

Scale Age Designation

The age composition of the 2001 Portage Lake escapement sample indicated that the age 1.3 component was the dominant age class (85.5%; Table 2). Of the 986 adult scales, 822 were designated as age 1.3. Age 1.3 adults emigrated from freshwater as smolt in 1998. Previously collected smolt scales in 1998 were obtained for developing the freshwater scale pattern stock standards or "knowns." Of the 181 smolt scales in 1998 at Portage Lake, 74.0% (134 smolt) were age 1. and of the 199 smolt scales in 1998 at Little Waterfall Lake 97.5% (194 smolt) were age 1. (Table 3).

Data Analysis

Standards "Knowns"

Visual Method. The 1998 sockeye salmon smolt outmigration age data was summarized from both Portage and Little Waterfall systems. A total of 139 Portage Creek age 1. smolt scales and 143 Little Waterfall Lake age 1. smolt scales were examined to evaluate and identify visual scale pattern differences between the two stocks. The scale characteristics of outmigrating age 1. sockeye salmon smolt exhibitedthe following visually discernable differences between Portage Lake and Little Waterfall Lake (Figure 3):

Portage Lake Stock

- Although not quantified, there was a small number of circuli and the overall size (focus to first annulus) also appeared small.
- The circuli were tightly spaced.

Little Waterfall Lake Stock

- Although not quantified, there was a large number of circuli and the overall size (focus to first annulus) also appeared large.
- The circuli within the first year of growth were widely spaced.
- The scales also displayed a consistent "stress check" or "false" annulus, which was commonly found four to five circuli from the focus.

SPA Method. The same 139 Portage and 143 Little Waterfall age 1. smolt scales that were visually analyzed were also digitized using OPRS. The distinguishing characteristics of the scales were determined after digitally measuring and marking each circuli within the first annulus of every scale (Figure 3):

Portage Lake Stock

- The number of circuli ranged from 5 to 13 with a median of 9 circuli (Figure 4).
- The scale size ranged from 0.1605 mm to 0.3595 mm with a median of 0.2316 mm (Figure 5).

Little Waterfall Lake Stock

- The number of circuli ranged from 13 to 22 with an average of 17 circuli (Figure 4).
- The scale growth ranged from 0.3170 mm to 0.5992 mm units with an average of 0.4449 mm (Figure 5).

Stock Identification

Visual Method. Of the 986 Portage Creek escapement scales collected in 2001, 822 (age 1.3 component) were useable for stock identification/separation purposes. After the two standard "known" smolt stocks were identified, a total of 300 randomly selected adult scales from the

Portage Lake run were visually examined. With knowledge of each systems' distinguishing growth pattern characteristics, each scale was assigned to its stock of origin (Figure 6 and 7). Of the 300 Portage Creek escapement scales three individuals (1%) were visually identified as strays from Little Waterfall Creek (Table 4).

SPA Method. The same 300 Portage Creek escapement scales that were visually identified were also digitized using OPRS (Figure 6 and 7). The 300 digitized "unknown" adult scales were then applied to the previously established standards "known" discrimanant model. After running the Cook and Lord correction factor, SPA identified four scales as Little Waterfall Creek strays (Table 4). This analysis suggests that 1.3% of the Portage Creek escapement sample originated from the WBTHA which translates into a 1.3% straying rate.

Comparison of Visual Method and SPA Method and Total Straying Rate

The SPA method identified the same three scale samples as the visual method as well as one other scale that the visual method did not detect. Satisfied with the consistency and accuracy of the visual identification method and due to the time constraints involved in digitizing scales and performing SPA, the visual method was used for the remainder of the 822 samples. A total of five of the 822 available scales or 0.61% displayed the same visual characteristics as the Little Waterfall Lake samples. Thus an estimated 19 Little Waterfall fish strayed from the WBTHA to Portage Creek in 2001 (Tables 1). This is equivalent to a straying rate of 0.1186% (19/16,023).

Applying this straying rate to previous years WBTHA harvests results in a low of 10 strays (0.08%) estimated in the 2000 Portage Creek escapement to a high of 44 strays (0.26%) in 1996. The average number of strays from 1995-2000 was 21 or 0.26% of the total Portage Creek escapement (Table 1).

DISCUSSION

The results of this study further corroborate the 2000 straying study; it is unlikely that enough Little Waterfall Lake sockeye salmon are straying from the WBTHA to adversely affect the genetic integrity of sockeye salmon in the Portage Lake drainage. The combination of methods used in this study was more conclusive and less subjective than the methods used in the 2000 study for the following reasons.

- This study used a larger number of baseline or "known" scales from the dominant sibling year to establish a solid known quantity.
- The "unknown" sample size was more than twice the sample size of the 2000 study.
- In addition to the visual scale identification method, SPA was incorporated. This additional stock separation tool was used to develop a quantitative separation of two "known" populations to minimize any concern of human error or biases in discerning stock of origin.
- 2001 was an ideal year for detecting strays into Portage Creek. There was a large run to the WBTHA while a very small escapement occurred at Portage Lake. Such circumstances

would suggest that if straying was occurring it would have had a high probability of detection within the 2001 sampling year.

- Finally, the Portage Lake escapement sample was collected during the peak of the Little Waterfall stock run timing.

As stated in the 2000 study, it has been suggested that if sockeye salmon encounter impassable barriers in the system they are imprinted to, return to they may attempt to find another system to spawn in. One of the reasons for the insignificant detection of straying found in this study may be due to the efficiency of the WBTHA fishery which harvests the majority of the salmon before they encounter the barrier net (Wadle and Honnold 2000).

CONCLUSION AND RECOMMENDATIONS

It is our conclusion that the temporary barrier net at the WBTHA does not cause adverse straying affects to nearby systems with natural sockeye salmon runs. We recommend continued use of the barrier net during the WBTHA sockeye salmon fishery and that the fishery continue to be executed as in past years to allow for maximum harvest of the introduced runs. If a fishery does not occur in the WBTHA, the barrier net should be removed to allow returning sockeye salmon to escape into Little Waterfall Creek, which would further reduce the incidence of straying. Further straying analyses within Perenosa Bay are desirable to monitor future runs; however due to budget constraints and limited funding there are no further studies scheduled.

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Table 1. Sockeye salmon harvest in the Waterfall Bay Terminal Harvest Area (WBTHA), escapement into the Portage Lake system, the associated ratio of WBTHA to the Portage Lake escapement, and the number and percentage of WBTHA strays based on the 2001 data, 1995-2001.

YEAR	WBTHA Harvest[a]	Portage Lake Escapement	Method of Escapement Enumeration[b]	Ratio of WBTHA to Portage	Estimated % of strays[c]	Estimated # of strays[c]
1995	14,608	15,000	Aerial	0.97	0.12%	17
1996	36,496	16,800	Aerial	2.17	0.26%	44
1997	27,868	14,600	Aerial	1.91	0.23%	33
1998	11,057	4,200	Aerial	2.63	0.31%	13
1999	9,353	5,900	Aerial	1.59	0.19%	11
2000	8,623	13,456	weir	0.64	0.08%	10
2001	**16,023**	**3,147**	**weir**	**5.09**	**0.61%**	**19**
7 yr avg (1995-2001)	17,718	10,443		1.70	0.26%	21

[a] Harvest numbers were derived from ADF&G harvest tickets.

[b] Aerial enumerations were derived from peak visual surveys. Escapement numbers were not expanded.

[c] The estimated percentage and number of sockeye salmon strays for the years 1995-2000 were derived from applying the 2001 stray estimate of .1195% to the WBTHA harvest for the corresponding year.

Table 2. Sockeye salmon age composition of the WBTHA harvest and the Portage Lake escapement, 2000 and 2001.

		Ages									Age 1.x
		1.1	1.2	2.1	1.3	2.2	1.4	2.3	2.4	Total	Total
Waterfall		4	218	0	139	18	0	21	0	400	361
2000	Percent[a]	0.8	53.5	0.0	35.5	4.6	0.0	5.6	0.0	100	90.3%
Harvest	Numbers	71	4,614	0	3,061	398	0	480	0	8,623	
Waterfall	Sample Size	6	205	3	280	1	1	1	0	497	491
2001	Percent[a]	1.2	40.8	0.6	56.9	0.2	0.2	0.2	0.0	100.0	98.8%
Harvest	Numbers	190	6,532	90	9,112	34	34	30	0	16,023	
Portage	Sample Size	1	192	0	585	42	0	203	1	1,024	778
2000	Percent[a]	0.2	18.7	0.0	58.0	4.4	0.0	18.6	0.1	100	76.0%
Escapement	Numbers	33	2,514	0	7,799	594	0	2,508	7	13,456	
Portage	Sample Size	2	16	1	822	2	8	131	4	986	840
2001	Percent[a]	0.3	1.7	0.2	85.5	0.1	0.7	11.4	0.2	100.0	85.2%
Escapement	Numbers	8	52	7	2,690	2	22	359	7	3,147	

[a]Percents are derived from weekly catch samples and numbers are representative of total run based on weekly age percentages.

Table 3. Age composition of Little Waterfall Lake and Portage Lake sockeye salmon smolt samples, 1997-1999.

	Year	Sample Dates		Ages			
				1	2	3	Total
Portage	1997	06/18-06/18	Percent	91.3	8.7	0.0	100
			Numbers	21	2	0	23
	1998	05/31-06/17	Percent	74.0	26.0	0.0	100
			Numbers	134	47	0	181
	1999	06/23-06/25	Percent	71.4	28.1	0.5	100
			Numbers	145	57	1	203
Waterfall	1997	06/02-06/20	Percent	98.0	2.0	0.0	100
			Numbers	201	4	0	205
	1998	05/30-06/11	Percent	97.5	2.5	0.0	100
			Numbers	194	5	0	199
	1999	06/02-06/25	Percent	100.0	0.0	0.0	100
			Numbers	197	0	0	197

Table 4. Results of visual and SPA methods used in determining straying WBTHA sockeye salmon in the Portage Creek escapement samples.

	Method	Sample Size	Strays Detected	% Strays Detected	Estimated Standard Error
Methods Tested	Visual	300	3	1.00	0.547
	SPA	300	4	1.33	0.631
Method used	Visual	822	5	0.61	0.466

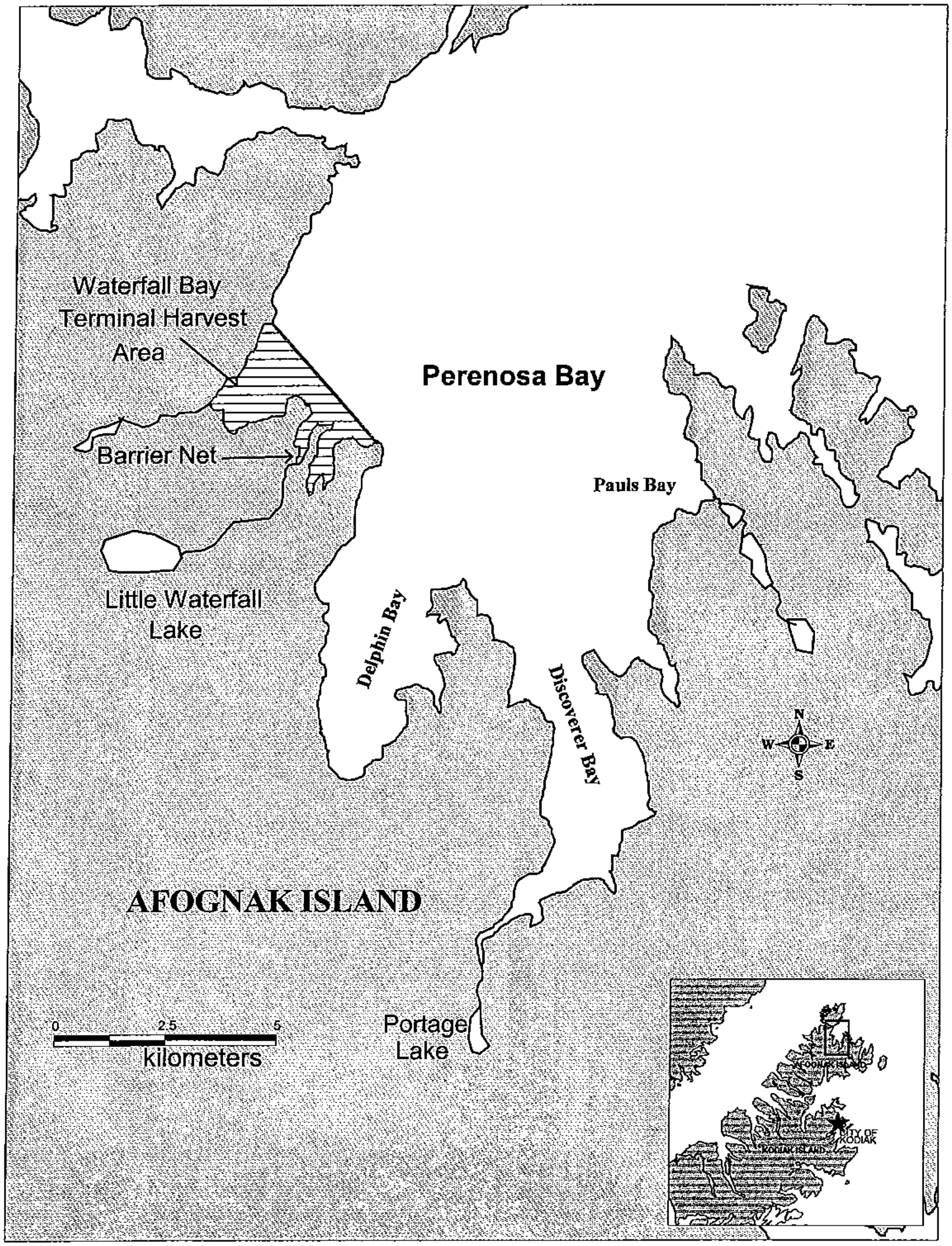


Figure 1. Location of the Waterfall Bay Terminal Harvest Area and Portage Lake on Afognak Island.

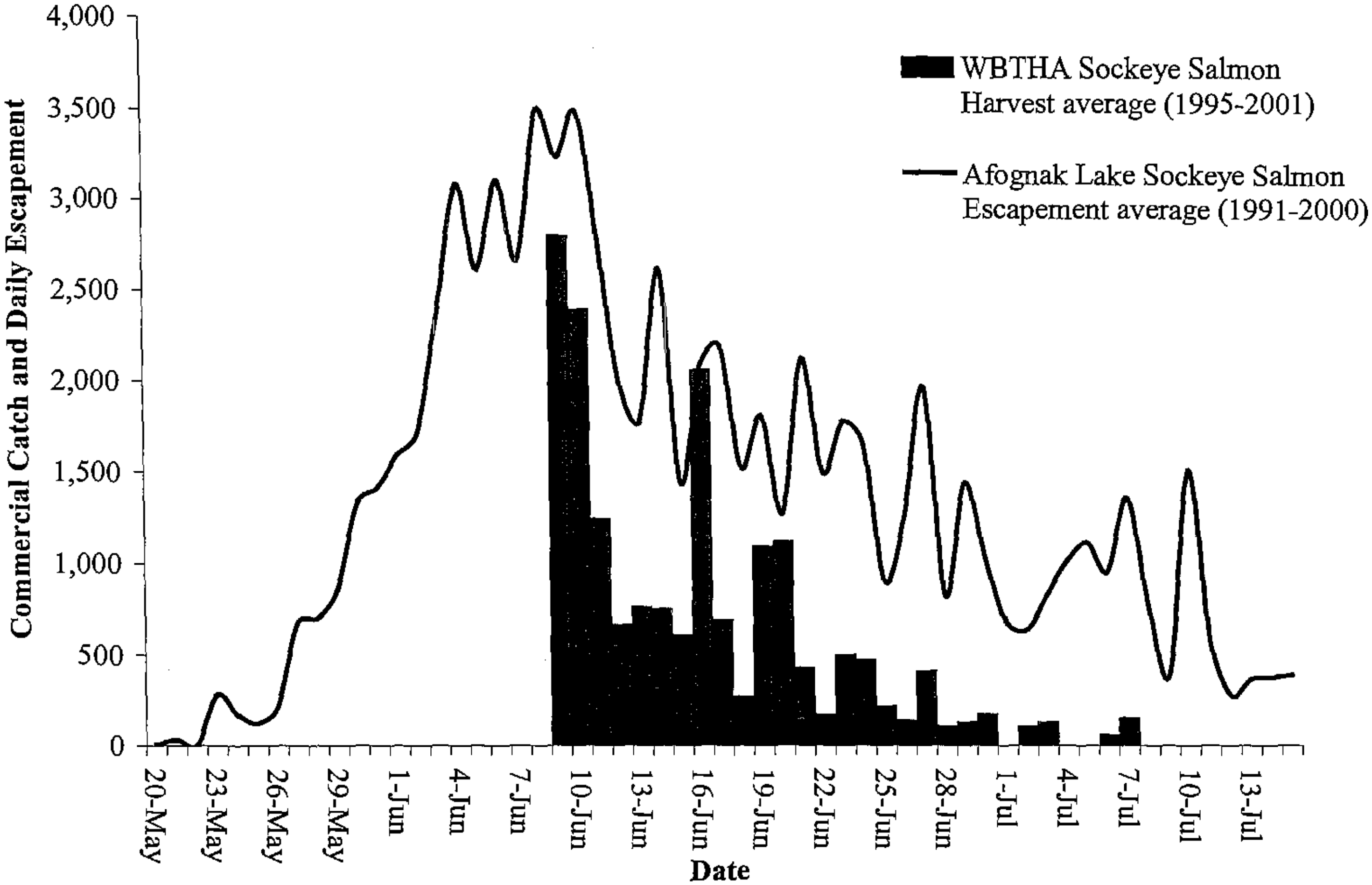
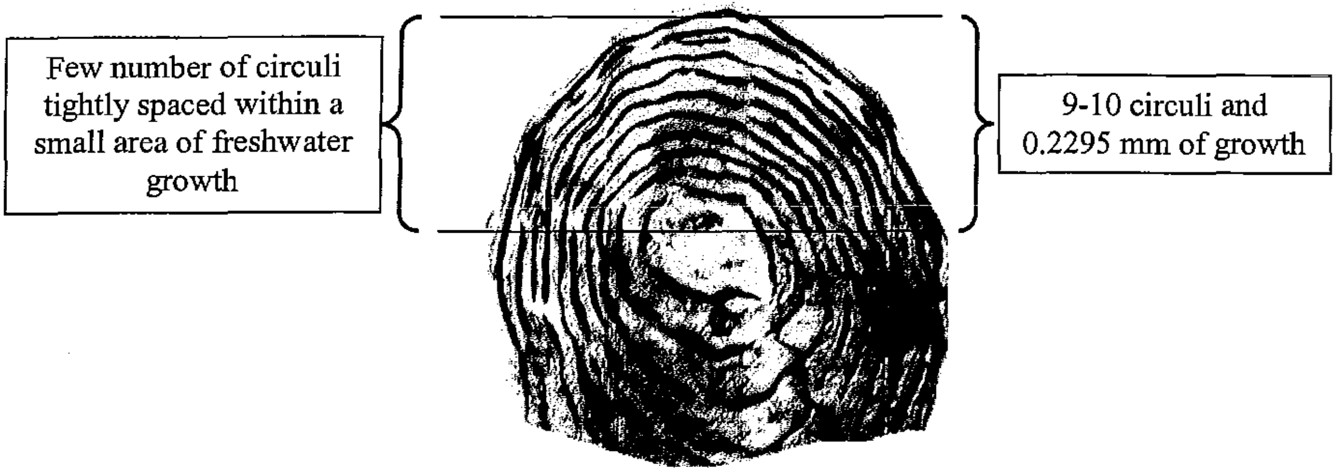
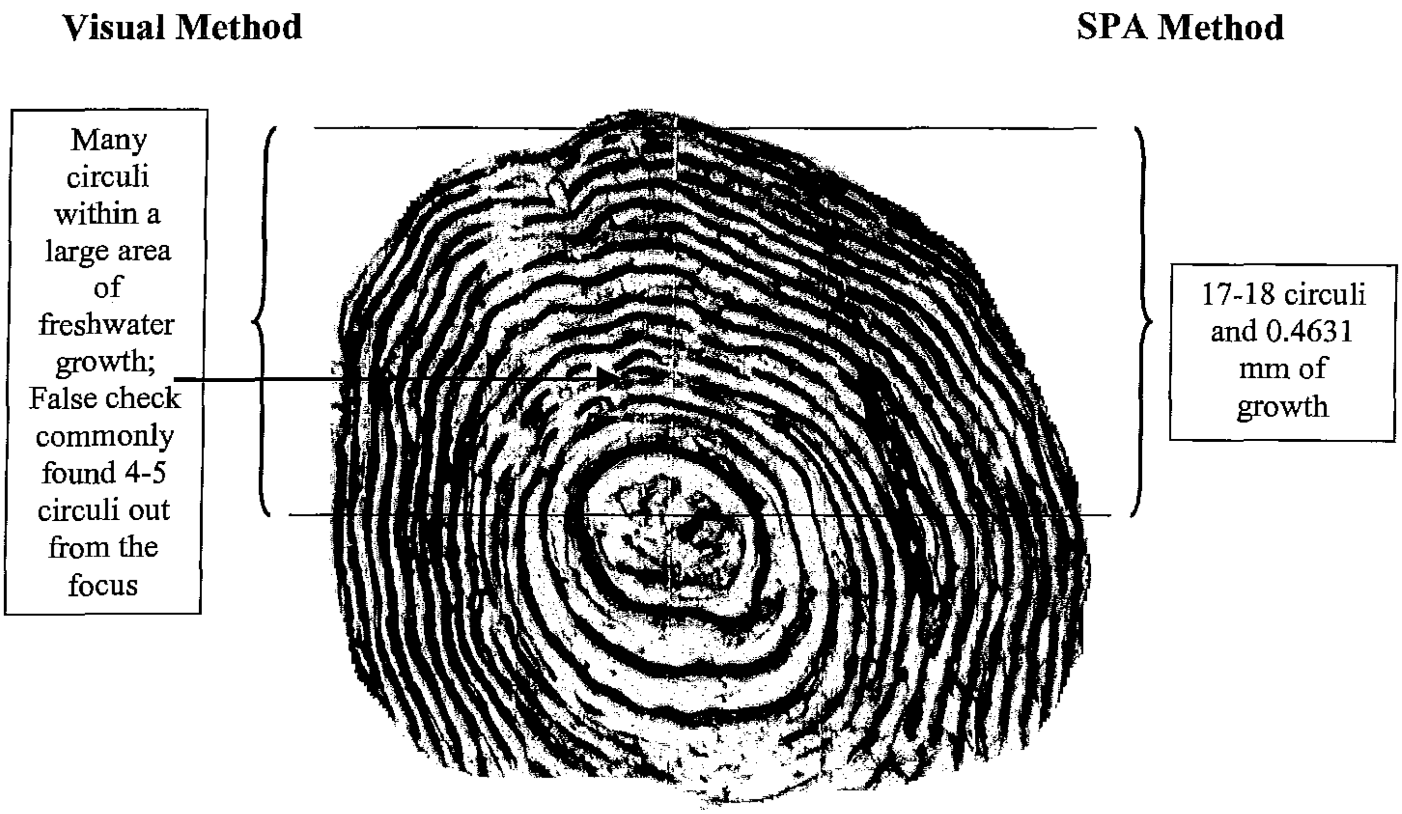


Figure 2. Commercial harvest of sockeye salmon in the Waterfall Bay Terminal Harvest Area as compared to the escapement timing of the Afognak Lake brood source.



Age 1. Portage Lake Smolt



Age 1. Little Waterfall Lake smolt

Figure 3. Known age 1. sockeye salmon smolt scales from Portage Lake and Little Waterfall Lake with both visual and SPA methods of stock separation displayed.

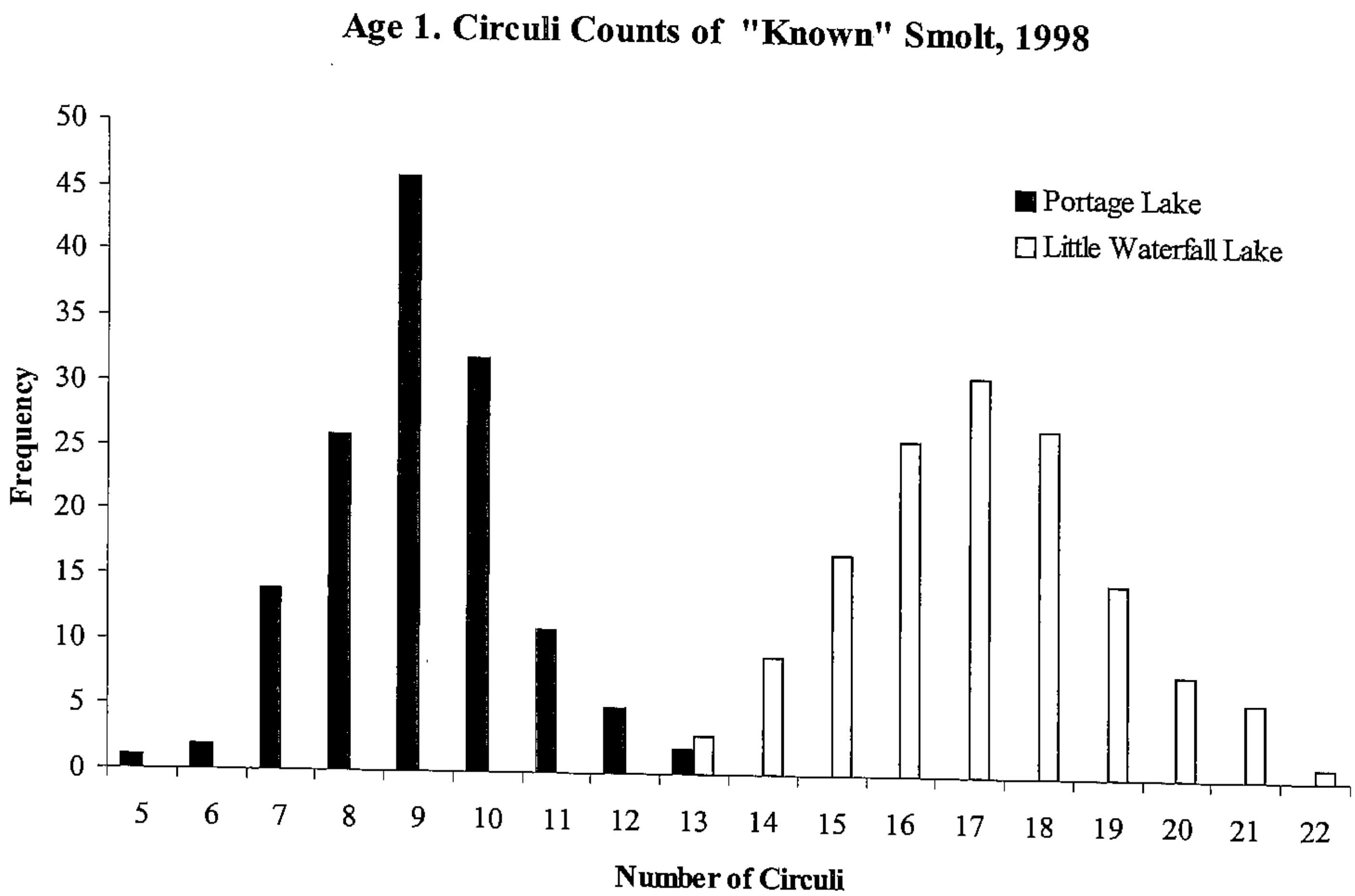


Figure 4. Frequency distribution of circuli counts from Portage Lake and Little Waterfall Lake "known" age 1. sockeye salmon smolt scales, 1998.

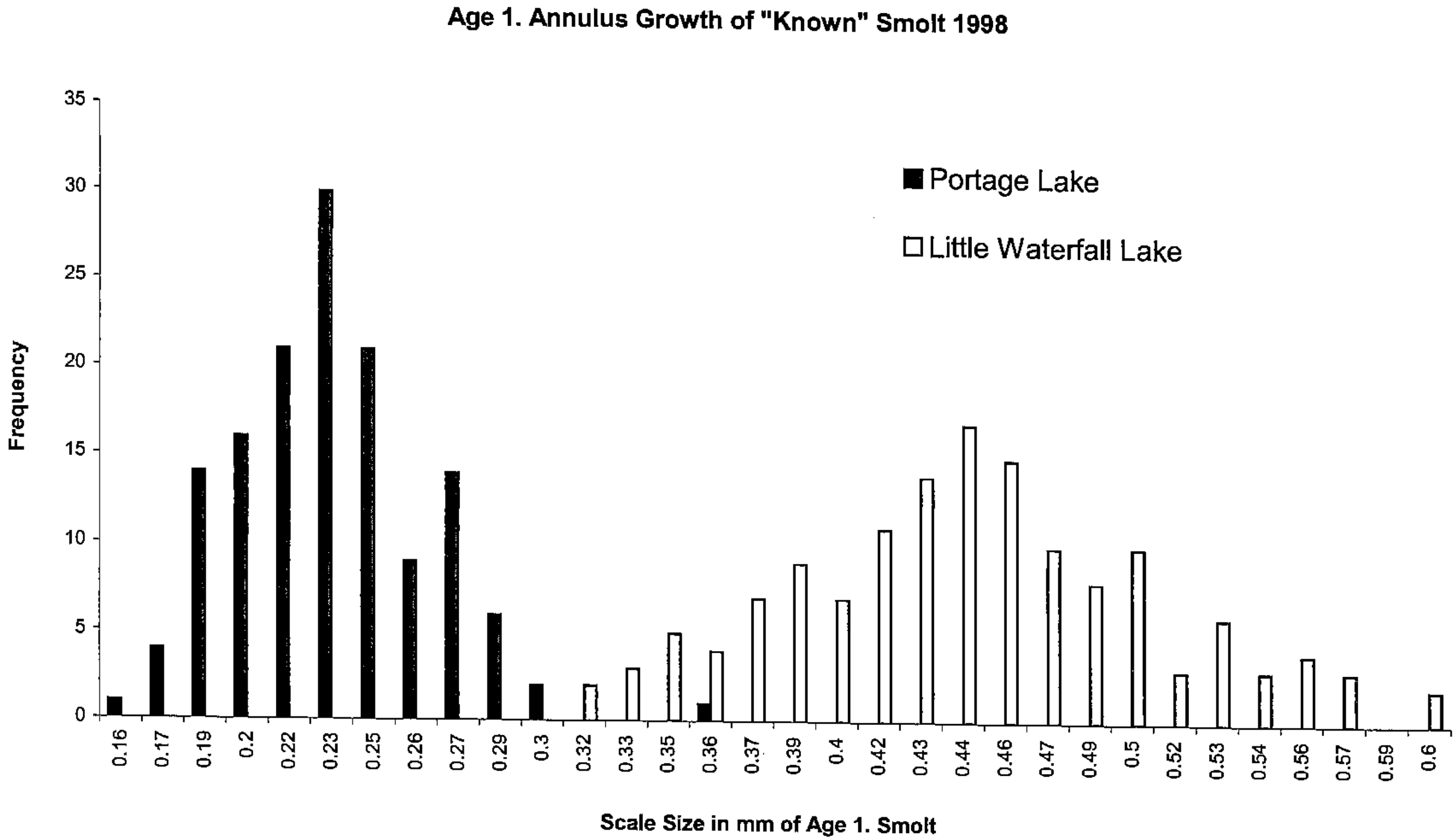


Figure 5. Frequency distribution of annulii growth from Portage Lake and Little Waterfall Lake "known" age 1. sockeye salmon, 1998.

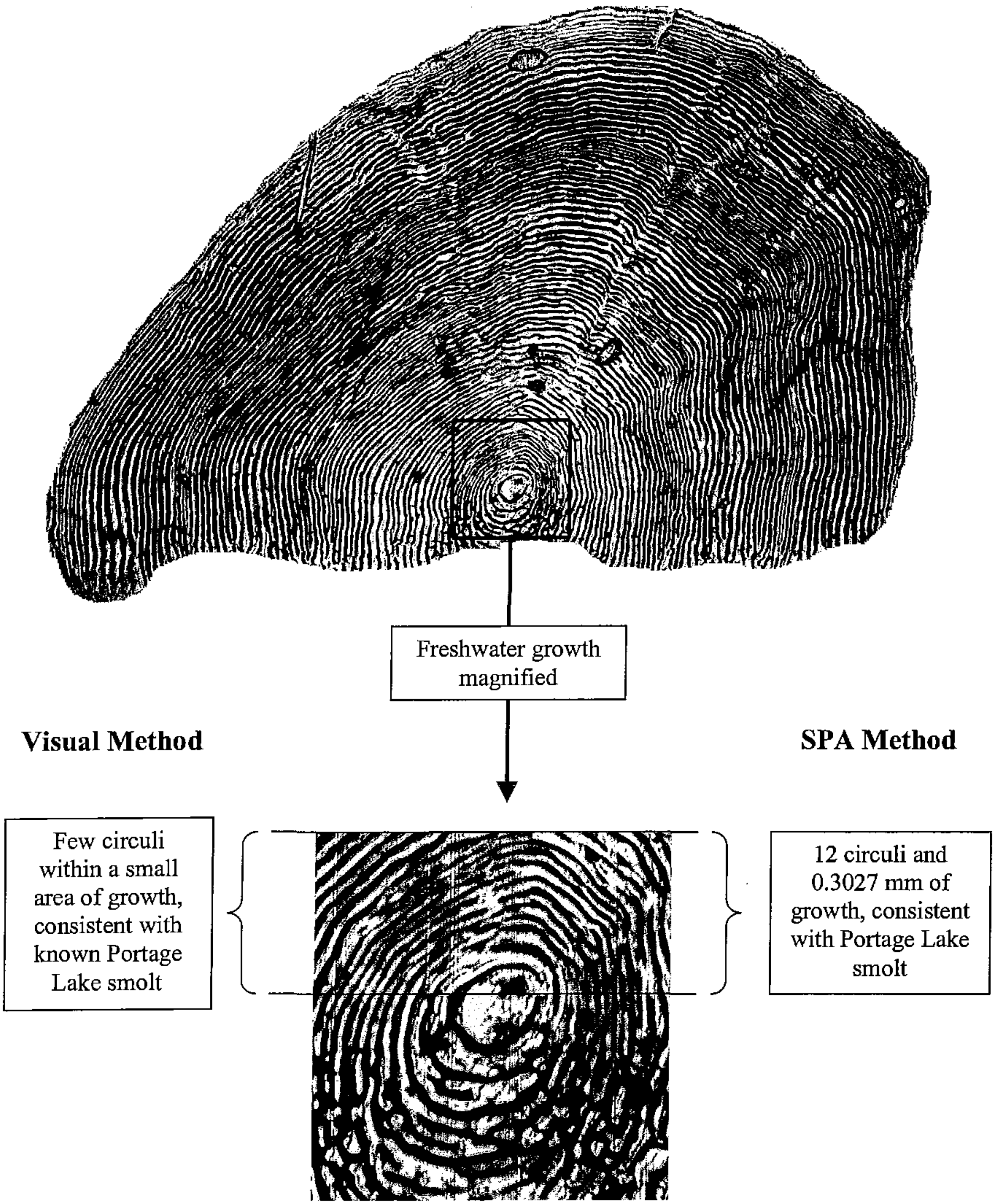


Figure 6. Scale pattern of age 1.3 sockeye salmon collected at Portage Creek and identified as Portage Lake stock.

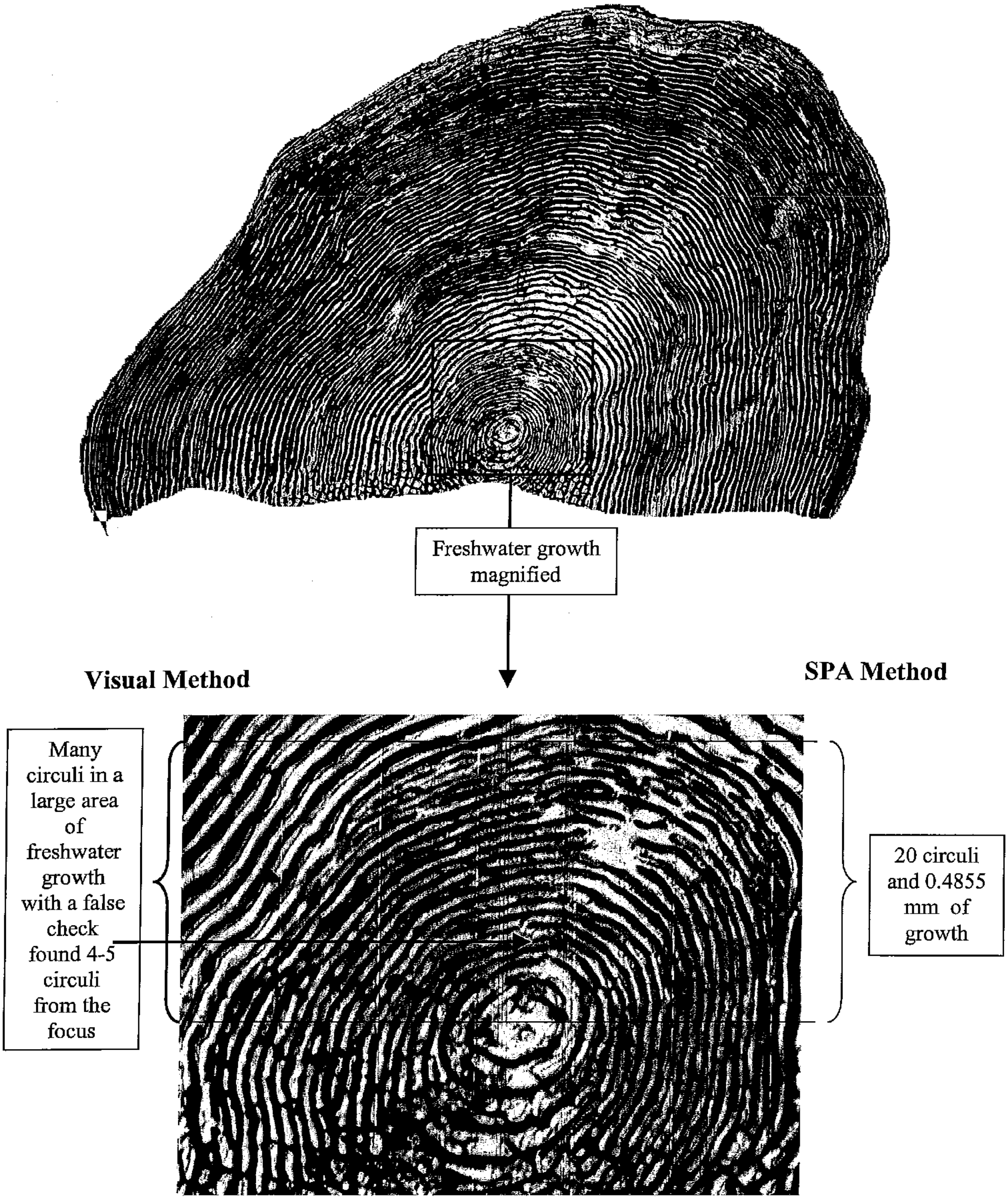


Figure 7. Scale pattern of age 1.3 sockeye salmon collected at Portage Creek and identified as Little Waterfall Lake stock.