APPENDIX 2-H

STOCK SEPARATION REPORT

COMPARISON OF SCALE PATTERNS FROM SOCKEYE SALMON SAMPLED FROM DIFFERENT STOCKS IN THE SUSITNA RIVER IN 1982

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ABSTRACT

Scale pattern analysis with linear discriminant functions was used to examine the probable fate of sockeye salmon fry spawned upstream of Curry Station on the Susitna River. Scale samples were taken from sockeye salmon collected at Talkeetna Station, at Curry Station, from the Tokositna River, and from the confluence of the outlet from Larson Lake and the Talkeetna River. Fish aged 1.3 dominate the samples and are used in the analysis. Growth during the first season of life (1977) is the most discriminating scale pattern variable. Scale patterns from fish sampled at Tokositna River and at Larson Lake are most different. Fish from Larson Lake grew slower for a longer period of time than did fish from the Tokositna River. Fish from Talkeetna Station on the Susitna River are more like fish sampled at Larson Lake on the Talkeetna River. Fish from Curry Station are misclassified as being from Tokositna River or from Larson Lake more often than from upstream of Curry Station. Sockeye salmon passing Curry Station are probably not a separate stock, but are strays from Talkeetna and Chulitna Rivers. Fry hatched upstream of Curry Station most probably die or move to the lower Susitna to rear.

INTRODUCTION

The Adult Anadromous Fisheries Studies of the Susitna Hydroelectric Project, Alaska Department of Fish and Game is charged with describing the fisheries resources in the Susitna River with estimating probable impacts of proposed dams in the upper river. To meet this end, personnel of the Department conducted extensive field studies on the Susitna River in 1981. Field sampling in 1982 was altered to provide information not obtained through the program in 1981. This report, authored by personnel of the Statewide Biology Group in cooperation with the Adult Anadromous Fisheries Project, contains analysis of this new information.

Although an estimated 2,804 sockeye salmon (Oncorynchus nerka) passed Curry Station in 1981 (ADFG 1981), no notable fry rearing activity was observed north of this station that year (Bruce Barrett, personal communication). About 98.5 percent of the sockeye adults caught at Curry Station have at least one freshwater check on their scales. If the spawn of the sockeye salmon that passed Curry Station did not remain upstream of this station to rear, then where did they go?

In 1982, personnel of the Adult Anadromous Fisheries Project collected scales from sockeye salmon adults from four sites in the Susitna River watershed and gave these scales to the Statewide Stock Biology Group for analysis. To indicate possible rearing locations for fry, we searched for similarities and differences among scales patterns with linear discriminant analysis.

METHODS

Sample Collection:

Scales were taken from escapements of sockeye salmon at Curry Station on the Susitna River, at Talkeetna Station, at the confluence of the outlet from Larson Lake and the Talkeetna River, and at the Tokositna River which is a tributary to the Chulitna River (Figure 1). Sockeye salmon were collected with fish wheels at Curry and Talkeetna Stations. Scales were collected from the left side of the fish approximately two rows above the lateral line and on the diagonal row downward from the posterior insertion of the dorsal fin (INPFC 1961).

Age Composition:

Sockeye salmon ages were determined through visual examination of scale samples. Scales were mounted on gum cards and impressions were made in cellulose acetate (Clutter and Whitesel 1956). Ages were recorded in European[1] notation. Because 1.3 fish predominate in the samples, only scales from these fish are used in the analysis.

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1 European formula: Numerals preceeding the decimal refer to the number of freshwater annuli; numerals following the decimal are the number of marine annuli. Total age is the sum of these two numbers plus 1.

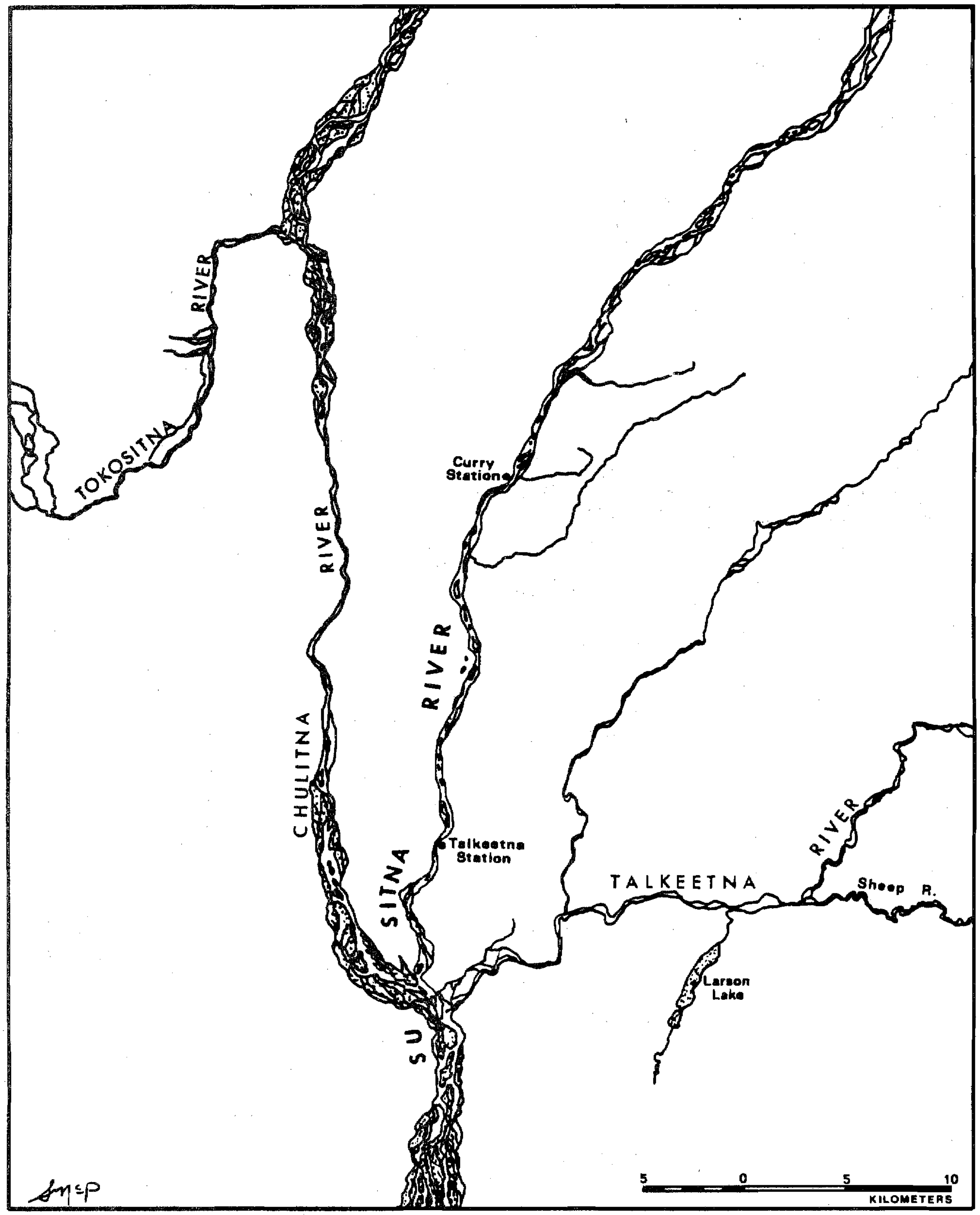

Figure 1. Map of Susitna River and sampling sites for sockeye salmon in 1982.

Comparison of Scale Patterns:

Scale Measurements:

Scale impressions were magnified to 100 power and projected onto a digitizing tablet using equipment similar to that described by Ryan and Christie (1976). Data were recorded onto computer diskettes from the digitizer tablet under control of a FORTRAN program executing on a microcomputer. Scale measurements were taken along a standardized axis approximately 20 degrees off the primary axis and perpendicular to the sculptured field. The distance between each circulus in each of three scale pattern zones was measured. The zones were: scale focus to the last circulus of the first freshwater annulus; the last circulus of the first freshwater annulus to the last circulus of the second freshwater annulus (the zone of plus growth); the last circulus of the second freshwater annulus to the last circulus of the first marine annulus. The three zones are shown in a photograph of a scale from an age 1.3 sockeye salmon (Figure 2). A set of 11 variables was then computed for each of these three zones (Table 1). Only normally distributed variables were used to build linear discriminant functions.

Although all scales were aged, not all scales were measured. Scales from sockeye salmon other than age 1.3 were not measured. Also, no more than 100 randomly selected scales were measured from each sample; 100 is a number sufficiently large for linear discriminant analysis. If a sample contains less than 100 scales from 1.3 fish, as do samples from Curry Station and from Tokositna River, all usable scales were measured.

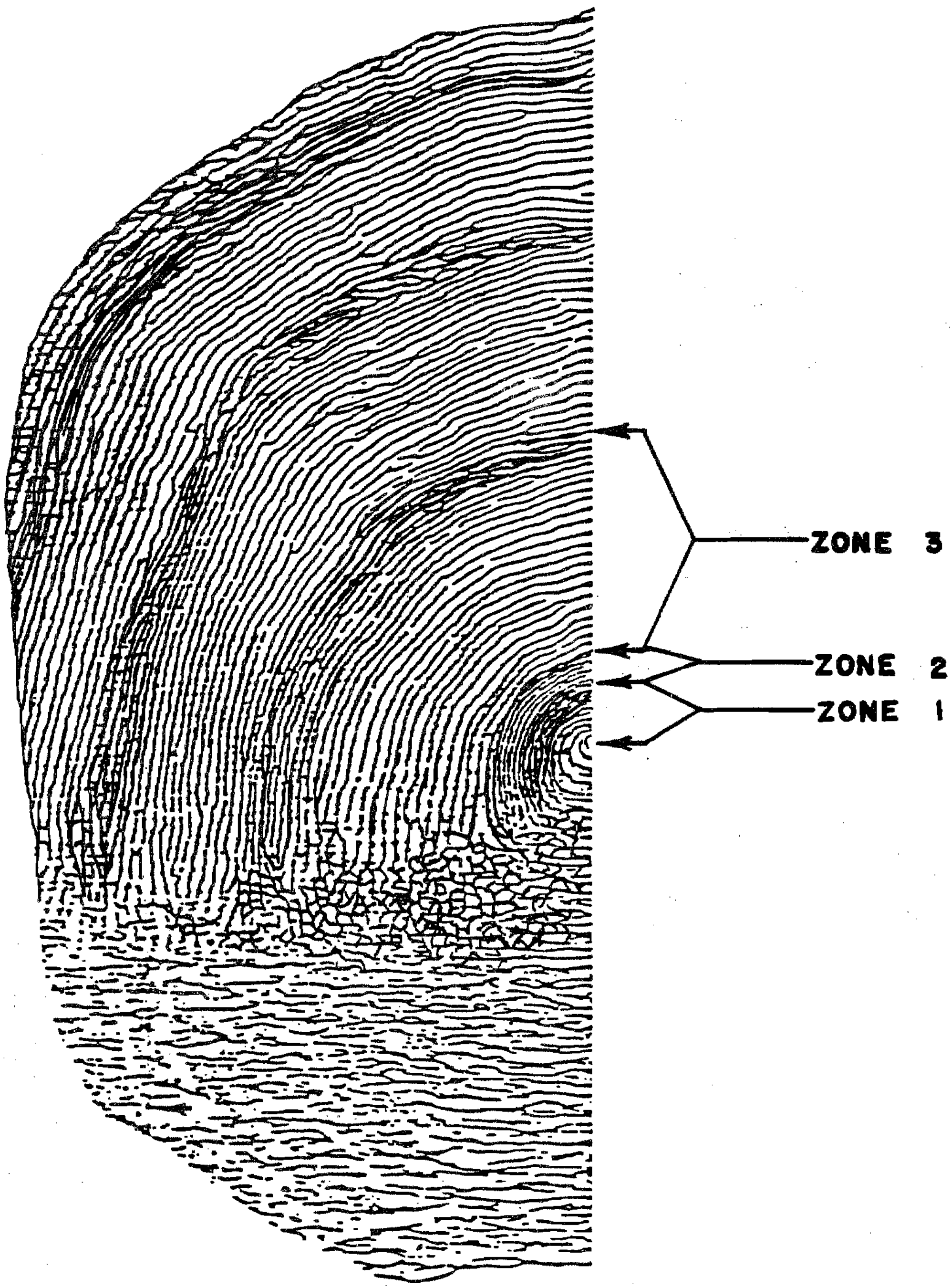

Figure 2. Photograph of a sockeye salmon scale showing the three zones measured.

Table 1. Variables computed from scale patterns for inclusion in the linear discriminant function analysis.

Variable Name	Description
NC(i) 1/	Number of circuli in zone (i).
ID(i)	Measured size of zone (i).
TWO(i)	Distance from the beginning of zone (i) to the second circulus of zone (i).
FOUR(i)	Distance from the beginning of zone (i) to the fourth circulus of zone (i).
SIX(i)	Distance from the beginning of zone (i) to the sixth circulus of zone (i).
EIGHT(i)	Distance from the beginning of zone (i) to the eighth circulus of zone (i).
MIN(i)	Distance between the two closest circuli in zone (i).
MAX(i)	The maximum distance between two contiguous circuli in zone (i).
LMIN(i)	The distance from the beginning of the zone (i) to the first circulus of variable MIN(i) in zone (i).
LMAX(i)	The distance from the beginning of zone (i) to the first circulus of variable MAX(i) in zone (i).
NCH(i)	The number of circuli in the first half of zone (i).
LENGTH	The fork length of the fish.

1/ Where i=1,2,3.

Classification Matrices:

Scale Patterns for sockeye salmon from each sample were compared with linear discriminant function analysis (Fisher 1936; Dixon and Brown 1976). To build a single discriminate function, a stepwise procedure was used to select those scale pattern variables with the most discriminating power. Variables were added to the function until those remaining could not meet the criterion for inclusion (a F ratio set at 4). To build a single classification matrix for all stocks, a jackknife procedure was used.[2]

Classification matrices were built for a Talkeetna-Curry-Tokositna-Larson comparison, for a Curry-Tokositna-Larson comparison, and for all possible two-way comparisons among samples from Curry Station, Tokositna River, and Larson Lake. Samples from Talkeetna Station were not used in any three-way or two-way comparisons because these samples could have contained fish that migrated on to Curry Station.

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2 A discriminate function is built on scale variables for all sampled fish but one. The function is then used to classify the stock of that one fish. Since the stock of that one fish is known, so therefore is the verity of its classification. The procedure is then repeated only with a new fish excluded. The jackknife procedure continues until all sampled fish are classified.

RESULTS

Age Composition:

Of the 853 sockeye sampled, over two-thirds are age 1.3 fish (Table 2). This dominance is consistant over all sampling sites save Curry Station where ages are almost evenly distributed. However, the age composition of the fish sampled at Curry Station is probably a poor estimate of the age composition of the sockeye salmon that passed this station because the sample is small and was taken over a 59-day period. Although more fish were sampled at Talkeetna Station, the sampling period is long here also and affects the precision of the estimate of age composition of fish that passed this station as well.

Comparison of Scale Patterns:

Variable Selection:

Most scale pattern variables in the samples are normally distributed (e.g., Figure 3). Each of the two most discriminating variables (SIX1 and NC1) have similar standard deviations in samples from Talkeetna Station, Tokositna River, and Larson Lake, but have different means (Table 3). For both these variables, their distribution in the sample from Curry Station is somewhat bimodal, especially for SIX1.

Table 2. Age composition of sockeye salmon samples from Curry Station, Talkeetna Station, Larson Lake (Talkeetna River), and Tokositna River (tributary to Chulitna River).

Location	Total	1.2	1.3 Sampled	1.3 Digitized	Other	Date Sampled
Curry Station	110	30	43	43	37	7/11 - 8/28/82
Talkeetna Station	378	56	291	100	31	6/7 - 9/9/82
Tokositna River	185	86	97	94	2	8/7 - 8/8/82
Larson/Talkeetna Confluence	180	31	147	100	2	8/6/82
Total	853	203	578	337	72	

1/ Scale pattern variable measured.

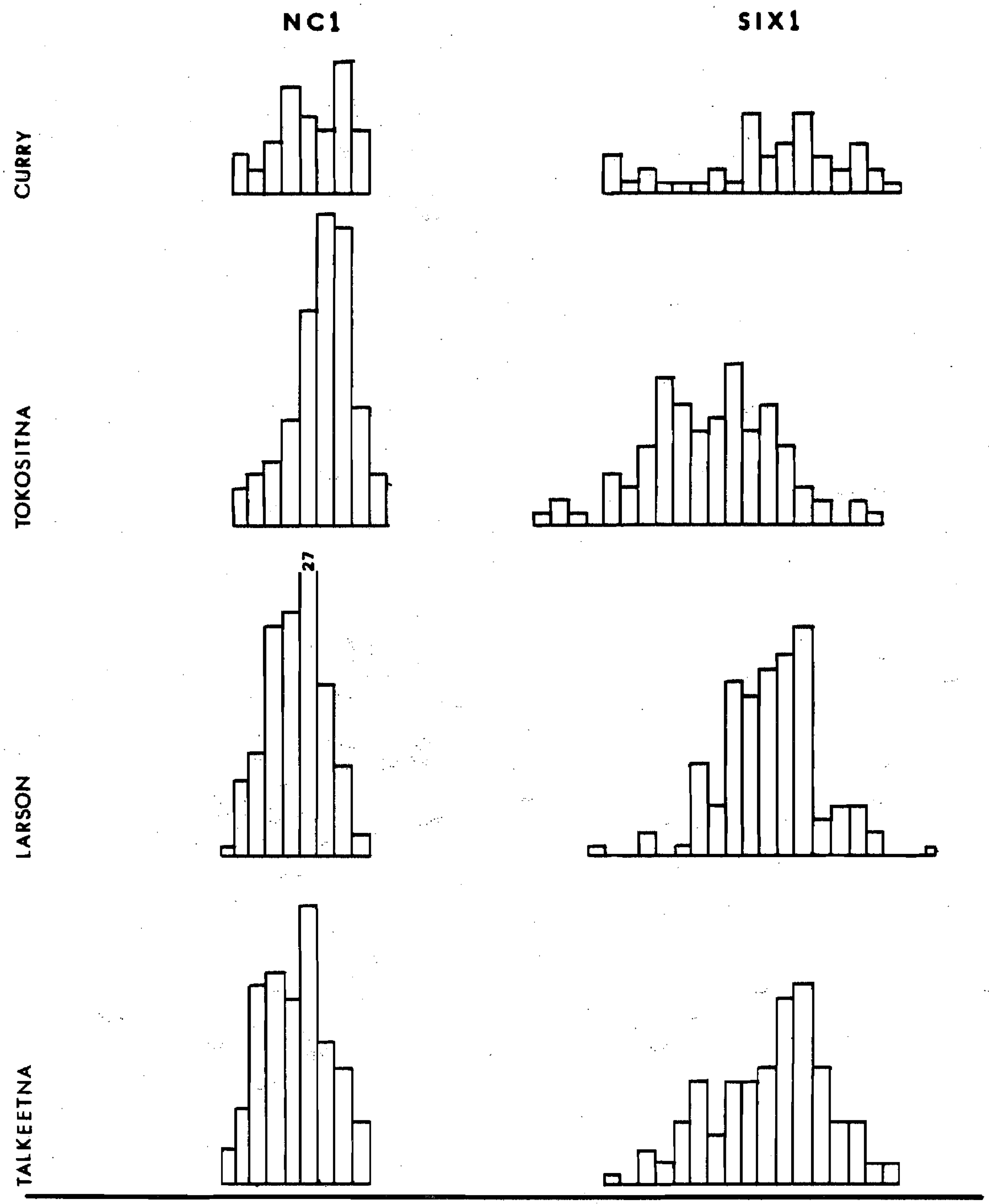

Figure 3. Frequency histograms of the most discriminating scale pattern variables used to compare stocks of sockeye salmon from within the Susitna River in 1982.

Table 3. Mean values and standard deviations of normally distributed scale pattern variables. 1/

Variable	Talkeetna St.		Curry St.		Tokositna River		Larson/Talkeetna	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
TWO1	42.6	5.2	42.2	6.5	46.1	6.7	42.2	5.3
FOUR1	64.6	7.9	64.7	10.3	71.9	8.8	64.5	7.1
SIX1	83.9	10.3	84.5	13.2	93.9	11.5	83.8	8.8
EIGHT1	96.6	25.4	91.0	36.3	98.6	41.8	97.9	19.6
MAX1	30.7	4.2	29.6	4.6	31.6	5.1	29.9	4.1
MIN1	6.2	1.4	6.4	1.6	7.1	1.9	6.0	1.3
NC1	10.9	2.0	9.9	2.1	9.3	1.9	10.7	1.8
ID1	125.8	22.3	118.7	22.7	125.6	27.9	123.9	19.4
NCH1	3.4	1.0	3.1	1.2	2.7	0.9	3.3	0.9
TWO2	20.5	4.9	22.2	4.6	21.6	7.2	20.6	4.1
FOUR2	28.7	20.0	37.5	17.8	38.6	19.2	36.5	14.4
SIX2	26.1	31.9	31.2	32.7	31.9	35.4	25.2	30.8
EIGHT2	8.4	25.4	17.8	35.4	15.3	34.2	5.5	20.3
MAX2	13.4	2.6	14.4	2.5	14.7	2.9	13.1	2.3
MIN2	8.2	2.0	8.1	1.7	9.2	1.9	7.9	1.8
LMAX2	2.9	1.8	2.9	1.9	2.8	1.7	2.8	1.8
NC2	4.9	2.1	5.6	2.2	5.3	2.3	5.3	1.6
ID2	51.7	22.8	62.2	23.4	61.9	26.6	54.0	16.9
NCH2	1.9	1.1	2.3	1.3	2.2	1.2	2.1	0.9
TWO3	30.3	7.2	30.8	5.6	32.0	6.2	29.0	6.1
FOUR3	62.7	11.1	63.1	9.5	65.7	9.2	59.9	10.7
SIX3	97.6	13.9	96.4	11.3	100.4	11.5	93.4	12.9
EIGHT3	133.8	16.6	131.0	13.4	135.7	13.8	129.3	15.1
MAX3	26.4	5.3	24.3	1.3	25.4	4.8	26.0	4.6
MIN3	9.5	1.6	9.3	1.7	9.6	1.5	9.2	1.6
LMAX3	8.9	5.5	8.9	5.5	8.7	5.2	9.5	4.9
NC3	22.6	2.4	23.6	3.4	22.9	2.6	22.9	2.4
ID3	357.3	40.6	362.3	47.9	361.3	38.5	[illegible]	36.3
LENGTH	576.4	35.5	565.1	43.2	574.3	26.4	579.7	27.9
NCH3	10.0	1.3	10.5	1.7	10.1	1.3	10.4	1.3

1/ Based on 100 fish sampled at Talkeetna station, 43 fish at Curry Station, 94 fish at Tokositna River, and 100 at the confluence of the outlet from Larson Lake and the Talkeetna River.

Classification Accuracy:

The overall accuracy of the four-way model (all samples included) is almost 50 percent (Table 4). Fish from Larson Lake are most like those from Talkeetna Station while fish from Tokositna River are more unique. Fish from Curry Station are most often misclassified as being from either Tokositna River or Larson Lake and are misclassified more often than not. Guesssing at the origin of fish among four stocks would produce 25 percent accuracy; the accuracy for fish from Curry Station is little better than guessing while accuracy for the other samples is two to three times better.

The overall accuracy of the three-way model (Curry-Tokositna-Larson) is about 62 percent (Table 5). Accuracy in classifying Larson Lake fish and Tokositna River fish is much higher than that for Curry Station fish. Guessing the origin of fish among three stocks would produce a 33 percent accuracy, a level not even attained for fish from Curry Station. The percent of fish from Curry Station misclassified is split about evenly between the Tokositna River and Larson Lake.

The overall accuracies of the two-way models is about 70 percent for Curry-Tokositna (Table 6), about 69 percent for Curry-Larson (Table 7), and about 81 percent for Tokositna-Larson (Table 8). Guessing would produce an accuracy of 50 percent; all two-way models, especially the Tokositna-Larson, discriminate with accuracy much higher than 50 percent.

Table 4. Four-way jackknife classification matrix from discriminant analysis of scale patterns on sockeye salmon of age 1.3 sampled from escapements at Curry Station, Talkeetna Station, Tokositna Rivers, and Larson Lake in 1982.

Actual Group of Origin	Sample Size	Classified Group of Origin			
		Talkeetna St.	Larson/Talkeetna	Tokositna R.	Curry St.
Talkeetna St.	100	.43	.28	.15	.15
Larson/Talkeetna	100	.20	.46	.13	.21
Tokositna River	94	.08	.08	.67	.17
Curry St.	43	.08	.33	.26	.33

Overall classification accuracy = .495

Note: Underlined proportions represent proportion correctly classified. All other proportions are misclassified.

Table 5. Three-way jackknife classification matrix from discriminant analysis of scale patterns on sockeye salmon of age 1.3 sampled from escapements at Curry Station, Tokositna River, and Larson Lake in 1982.

Actual Group of Origin	Sample Size	Classified Group of Origin		
		Larson/Talkeetna	Tokositna R.	Curry St.
Larson/Talkeetna	100	.73	.11	.16
Tokositna River	94	.13	.66	.21
Curry St.	43	.40	.35	.25

Overall classification accuracy = .616

Note: Underlined proportions represent proportion correctly classified. All other proportions are misclassified.

Table 6. Two-way jackknife calssification matrix from discriminant analysis of scale patterns on sockeye salmon of age 1.3 sampled from escapements at Curry Station, Tokositna River, and Larson Lake in 1982.

Actual Group of Origin	Sample Size	Classified Group of Origin	
		Tokositna R.	Curry St.
Tokositna R.	94	.70	.30
Curry St.	43	.30	.70

Overall classification accuracy = .701

Note: Underlined proportions represent proportion correctly classified. All other proportions are misclassified.

Table 7. Two-way jackknife calssification matrix from discriminant analysis of scale patterns on sockeye salmon of age 1.3 sampled from escapements at Curry Station and Larson Lake in 1982.

Actual Group of Origin	Sample Size	Classified Group of Origin	
		Larson/Talkeetna	Curry St.
Larson/Talkeetna	100	.72	.28
Curry St.	43	.40	.60

Overall classification accuracy = .685

Note: Underlined proportions represent proportion correctly classified. All other proportions are misclassified.

Table 8. Two-way jackknife calssification matrix from discriminant analysis of scale patterns on sockeye salmon of age 1.3 sampled from escapements at Tokositna River and Larson Lake in 1982.

Actual Group of Origin	Sample Size	Classified Group of Origin	
		Larson/Talkeetna	Tokositna R.
Larson/Talkeetna	100	<u>.84</u>	.16
Tokositna R.	94	.22	<u>.78</u>

Overall classification accuracy = .809

Note: Underlined proportions represent proportion correctly classified. All other proportions are misclassified.

The scale pattern variables SIX1 (length to the sixth circulus in the first zone) and NC1 (number of circuli in the first zone) have the most discriminating power (Table 9). No variable appeared in all five models, but SIX1 appeared in four and NC1 appeared in three. Both variables accounted for much of the observed variation in in scale patterns, and both had their greatest independent effect in the Tokositna-Larson two-way model. The length of the first zone (ID1) did not appear in any discriminant function. About 85 percent of the scales from Tokositna River had eight circuli in the first zone while about 97 percent from Larson Lake had eight, yet there is little difference in average size of the zone between samples. Therefore as first year fry in 1977, fish in Tokositna River grew faster for a shorter period of time than did their counterparts in Larson Lake.

In summary, sampled fish from Tokositna River and Larson Lake are the most different, fish sampled at Curry Station are more like Tokositna and Larson Lake fish than they are unique, and fish sampled at Talkeetna Station are more like Larson Lake fish than any other. Differences (or the lack of differences) among samples are due to growth between hatching and the winter of 1977-8.

DISCUSSION

Scale pattern analysis is usually employed to separate the components of a mixed stock; for the stocks within the Susitna, scale pattern analysis is used to show similarities. As such, linear discriminant analysis provides

Table 9. Most powerful scale pattern variables in linear discriminant functions according to the number to the number of times they occur in five models and to their strength in the three- and two-way models.

Five Models	Four Models	Three Models	Two Models	One Model
---	SIX1	NC1	LENGTH	MAX2
		FOUR3	EIGHT2	SIX2
			MAX1	NC3
			MIN2	NCH3
				MIN3

Power	Curry-Tokoshima-Larson		Curry-Larson		Curry-Tokoshima		Tokoshima-Larson	
	Variable	F-ratio 1/	Variable	F-ratio	Variable	F-ratio	Variable	F-ratio
Most	SIX1	23.8	MAX2	9.8	SIX1	18.0	SIX1	47.6
Next	NC1	13.5	EIGHT2	5.7	LENGTH	4.5	NCI	33.3

1/ F-ratio on residual variances.

"necessary conditions" to show what happens to fry spawned upstream of Curry Station; it does not provide definitive proof. Our analysis does show that 1) scale patterns of sockeye salmon passing Curry Station in 1981 are more like patterns on scales of fish taken from the escapements to the Tokositna River and to Larson Lake than they are unique and 2) scale patterns on scales from Larson Lake and Tokositna River are distinct for the 1977 year class. From these two facts (and other information obtained in 1981), six hypotheses as to why no fry are found above Curry Station are possibly true:

1. Sockeye salmon adults that spawn in the sloughs upstream of Curry Station are homing to this area, and their fry rear in lakes and sloughs in both the Chulitna and in the Talkeetna watersheds. If true, fry must move down the Susitna to the tributaries then upstream. Imprinting must occur after spawning and before fry move out of the main river and upstream in the tributaries. Fry select a watershed in which to overwinter according to which side of the Susitna they travel along as they move downstream.

2. Sockeye salmon adults that spawn in the sloughs upstream of Curry Station are strays from either the Chulitna or the Talkeetna watersheds, and their fry rear in lakes or sloughs flowing into either the Chulitna or into the Talkeetna River. In either case, imprinting must occur after fry enter the tributaries.

3. Sockeye salmon adults that spawn in the sloughs upstream of Curry Station are strays from either the Chulitna or the Talkeetna watersheds, and their fry are displaced downstream to become 0-check fish.

4. Sockeye salmon adults that spawn in the sloughs upstream of Curry Station are strays from either the Chulitna or the Talkeetna watersheds, and their fry survive in small numbers, if at all.

5. A significant number of sockeye salmon adults that pass Curry Station are strays from either the Chulitna or Talkeetna Rivers and do not spawn above Curry Station, but move back downstream to enter their natal streams.

6. Sockeye salmon adults that spawn upstream of Curry Station are a separate stock whose fry rear in an area not sampled. Neither the Tokositna River nor Larson Lake are rearing areas, but some area that has a heterogenous environment with parts similar to both these areas.

Although all six hypotheses are possible, some are more probable than others. The distance between Curry Station and the Tokositna River and Larson Lake make the first hypothesis rather improbable. Sockeye salmon fry tend to imprint the memory their natal streams early. A long migration down the Susitna River then up either the Chulitna or Talkeetna Rivers before imprinting is rather improbable. Also, the long journey through swift water is not conducive to fry survival, and natural selection is against such a stock occurring.

The last hypothesis is unlikely as well. Scale patterns on fish taken at Curry Station show these fish not to comprise a unique group, but two groups, one with scale patterns similar to patterns on fish from Larson Lake and one with patterns similar to those on fish from the Tokositna River. The existance of a single rearing area that could produce such a group of scale patterns is not likely.

That fish moving past Curry Station are strays from the Chulitna and the Talkeetna watersheds is more probable than these fish being a separate stock. The estimated number of sockeye salmon passing Curry Station is only 2.1 percent of the sockeye salmon passing Sunshine Station (ADFG 1981); since the fish passing Sunshine Station contain all fish migrating to the Talkeetna, Chulitna, and the upstream Susitna Rivers, the small portion passing Curry Station could easily represent strays.

What is the fate of the spawn from fish passing Curry Station? Again, the distances involved would make passage of fry down the Susitna and up the Chulitna or up the Talkeetna Rivers unlikely. More probably, fry would move down the Susitna River to overwinter in sloughs, move out to Cook Inlet as 0-check fish, or die. Any one (or all) of these three situations could have occurred in 1977. Whichever is the case, the result is extremely poor production from these fish. All 0-check fish represent only 1.5 percent of returning adults (Bruce Barrett, personal communication), and survival in river sloughs along the lower Susitna River must be substantial if the 2.1 percent of the spawning stock above Curry Station is important to the productivity of the Susistna River.

Fish passing Curry Station could have turned around and migrated back downstream, but this is not probable. Such a switch in direction would inflate estimates of escapement above the fishwheels at Curry Station although the estimate of the number passing the fishwheel would be correct. Yet peak spawning counts (a conservative estimate of the number of fish) in sloughs above Curry Station in 1981 are 1232, almost half the fish estimated passing the Station (ADFG 1981).

Most probably adult sockeye salmon passing Curry Station are strays from the Chulitna and Talkeetna Rivers and are not a separate stock. Most of thes fish spawn in sloughs above Curry Station, and their fry either move down to the Lower Susitna River to overwinter and/or die.

ACKNOWLEDGEMENTS

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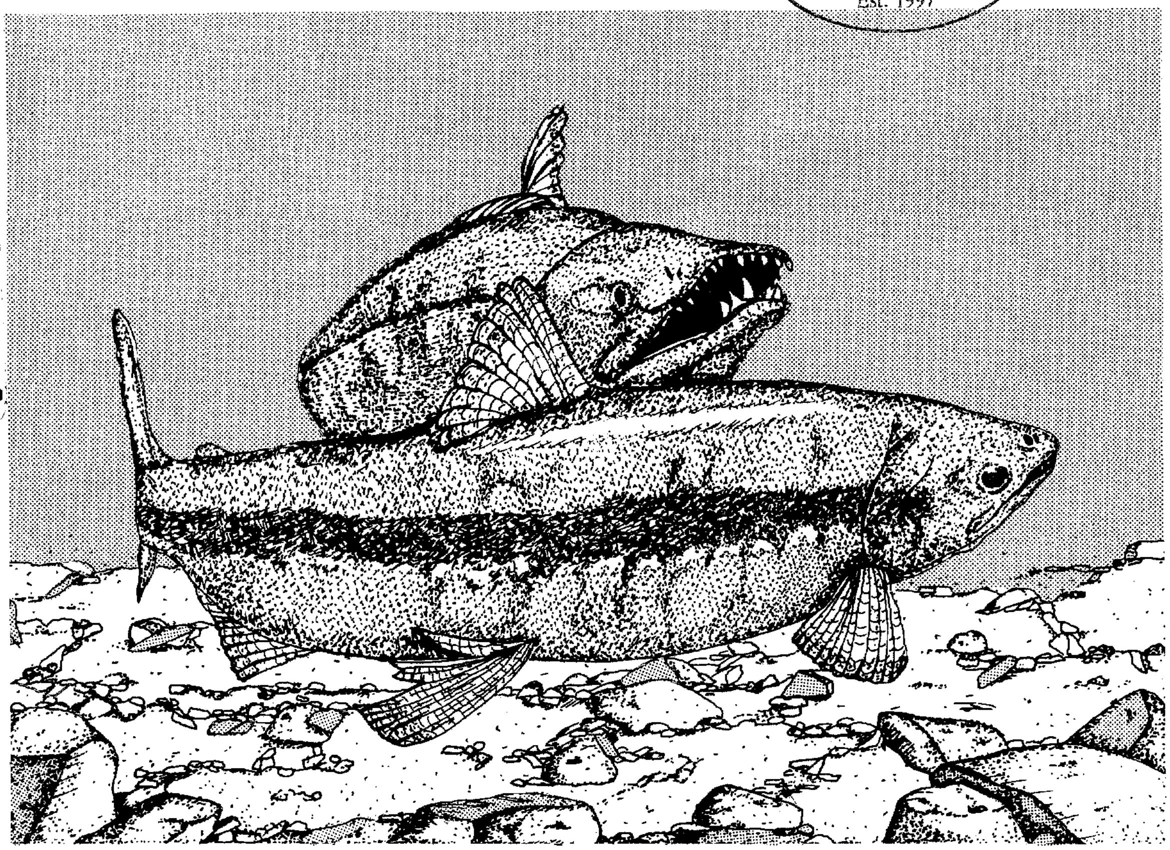
Appendix H:Comparison of scale patterns from sockeye salmon sampled from different stocks in the Susitna River in 1982



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