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ORIGINS OF SOCKEYE SALMON (Oncorhynchus nerka) IN THE COPPER RIVER FISHERY OF 1982 BASED ON SCALE PATTERN ANALYSIS

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March 1984

ALASKA DEPARTMENT OF FISH AND GAME
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Don W. Collinsworth
Commissioner

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ORIGINS OF SOCKEYE SALMON *(Oncorhynchus nerka)* IN THE COPPER RIVER FISHERY OF 1982 BASED ON SCALE PATTERN ANALYSIS[1]

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ABSTRACT

Using results of linear discriminant function analysis and age composition data, sockeye salmon *(Oncorhynchus nerka)* commercially caught in District 212 were allocated to two runs, one composed of stocks originating in the Upper Copper River basin (Upriver) and another originating in the Copper River Delta and Bering River watersheds (Delta/Bering). Linear discriminant functions were built with scale pattern measurements from fish of known origin sampled in the escapements of each run. Through jackknife procedures, functions correctly classified 74.0% of test fish aged 1.3 and 79.5% of test fish aged 1.2. Functions for fish aged 1.3 were used to estimate the proportions of Upriver and Delta/Bering in samples from weekly catches in subdistricts of District 212. There were statistically significant differences in the catch run composition among weeks, but not among subdistricts. The Upriver contribution (538,254 fish) to catches of fish aged 1.3 in District 212 occurred mostly in May and June while the Delta/Bering contribution (380,493 fish) was evenly distributed throughout the season; the 90% confidence interval for each estimated contribution was ± 114,000 fish. When expanded to include all age groups the run contribution of the Upriver and Delta/Bering runs to season catches were 611,057 and 582,327 fish, respectively. Upriver escapement was larger than Delta/Bering escapement. The accuracy of functions for fish aged 1.2 suggest that scale pattern analysis can be used in 1983 to allocate fish aged 1.3 from the same brood year. Scale measurements related to growth in freshwater provided the most discriminant power in functions for both brood years.

KEY WORDS: catch allocation, migratory timing, sockeye salmon, *Oncorhynchus nerka*, scale pattern analysis.

INTRODUCTION

The Copper River and Bering River commercial fishery districts are located on the Gulf of Alaska east of Prince William Sound. The Copper River District (212) extends from Cape Martin on the east to Hook Point, Hinchinbrook Island on the west, and is divided into three subdistricts (10, 20, and 30). The Bering River District (200) extends from Cape Martin on the east to Cape Suckling on the west and includes Katalla Bay (Subdistrict 10) and Controller Bay (Subdistrict 20) as well as nearshore waters to the east of Kayak Island (Subdistrict 30) (Figure 1). Effort and catches in these drift gill net fisheries have been highest in the five intertidal channels in District 212: Egg Island Channel (Subdistrict 10), Pete Dahl and Grass Island Channels (Subdistrict 20), and Kokinhenik and Softuk Channels (Subdistrict 30). In 1982 there were 525 permit holders eligible to fish both districts, and the combined catch of sockeye salmon *(Oncorhynchus nerka)* in the two districts was 1,325,229 for a total ex-vessel value to the fisherman of approximately $8.5 million.

Sockeye salmon returning to the Copper-Bering River Districts are a mixture of stocks from the Upper Copper River drainage, from the small watersheds in the Copper River Delta, and from the Bering River. Stocks from the Upper Copper River can be grouped into two runs, one which is intercepted by a subsistence fishery at the mouth of the Chitina River and one which is not (Figure 2; Roberson, personal communication). Stocks from the Delta can be grouped into many runs: Eyak Lake, McKinley Lake, 27-Mile Slough, Martin River Slough, 39-Mile Creek, Ragged Point Lake, Martin Lake, Little Martin Lake, and Tokun Lake. Stocks from the Bering River can be grouped into runs to Bering Lake, Kushtaka Lake, and Shepherd Creek. Aerial surveys and sonar projects indicate that escapements to the Copper River have been more numerous than to the Delta and to the Bering River.

The purpose of this report is to allocate the 1982 commercial catches of sockeye salmon in District 212 to either the Upper Copper River (Upriver run) or to the combined Copper River Delta and Bering River (Delta/Bering run). The portion of weekly catches in each subdistrict of District 212 were estimated with results of scale pattern analysis of fish aged 1.3[1] and catch and escapement age composition data. The total returns to the Copper/Bering River area were estimated with catch allocation and escapement data. Also, discriminant analysis on scales from fish aged 1.2 was conducted to investigate the separability of fish from the 1978 brood year for the 1983 fishing season.

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[1] European Formula - Numerals preceding the decimal refer to the number of freshwater annuli, numerals following the decimal are the number of marine annuli. Total age from the brood year is the sum of these two numbers plus one.

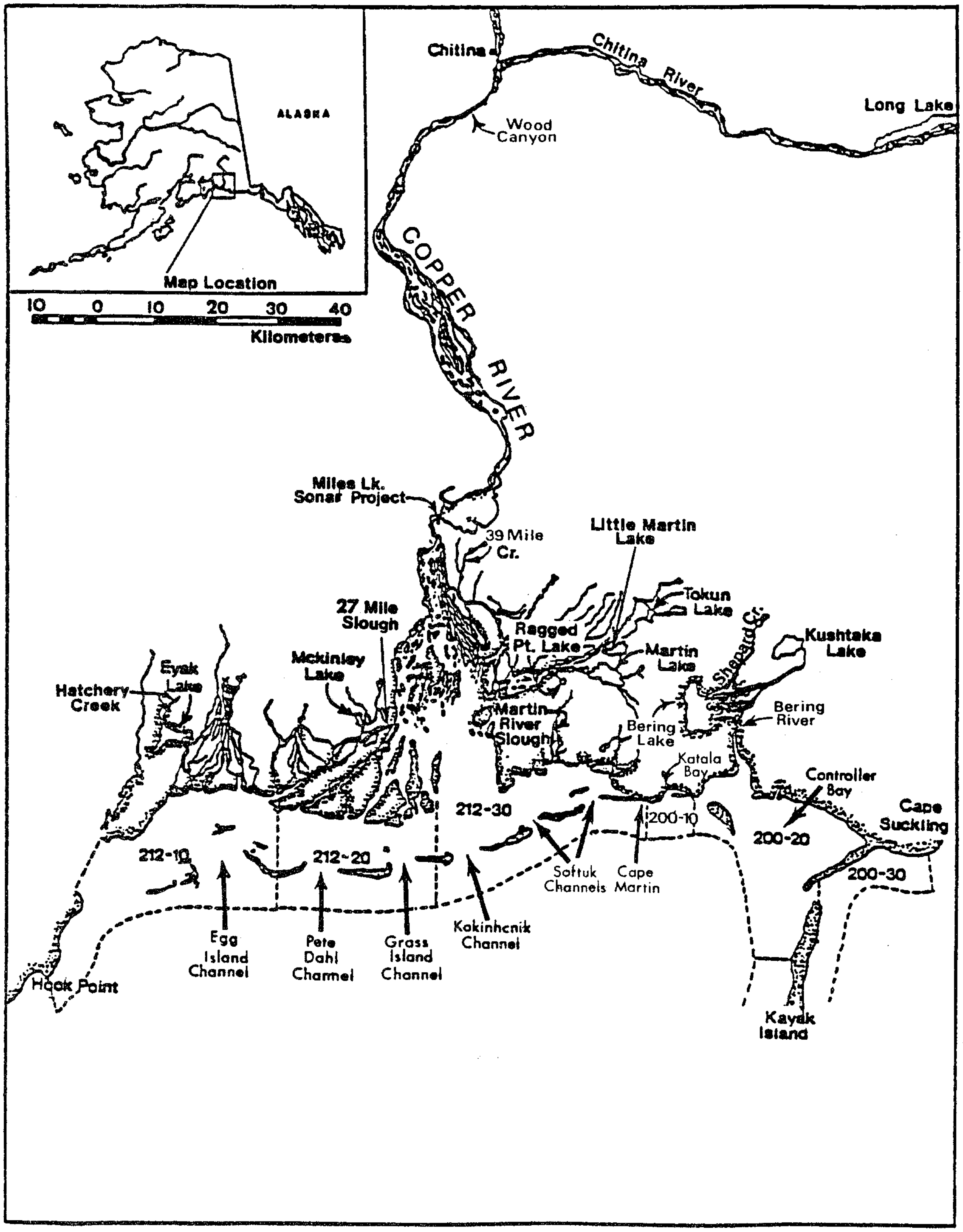

Figure 1. The Copper River and Bering River watersheds with adjoining fishing districts and sampling locations for sockeye salmon, 1982.

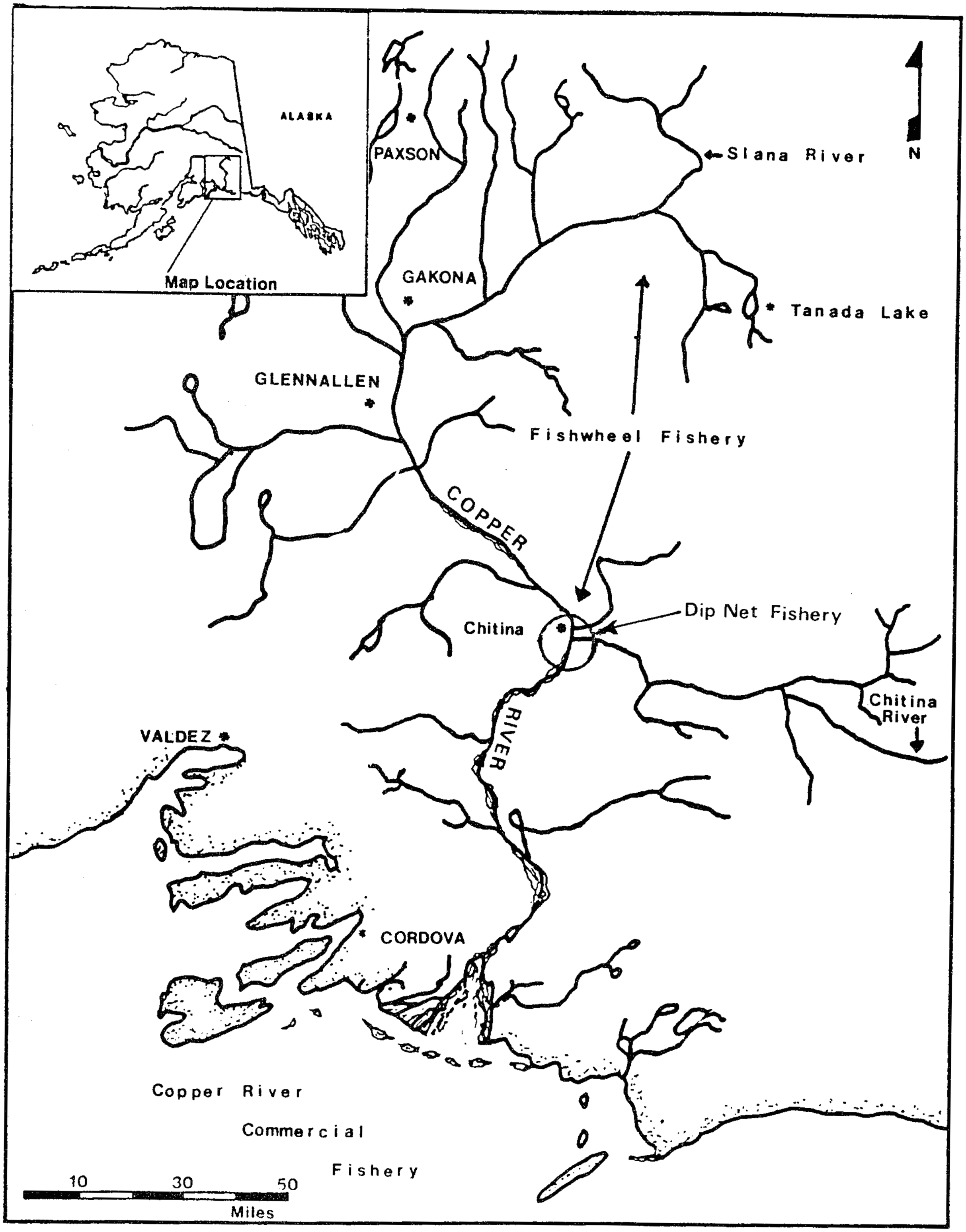

Figure 2. The Upper Copper River drainage showing the locations of the dip net and fishwheel subsistence fisheries.

METHODS

Discriminant Analysis

Because linear discriminant functions based on scale patterns have been used successfully to distinguish sockeye salmon returning to the Copper River from those returning to the Delta/Bering watersheds (Sharr 1983a), this technique was used to estimate the proportion that each of these runs represented in the 1982 catches in District 212.

Scale samples were taken almost every week from fish captured in four channels in District 212 and periodically from all the major escapements to the Upriver and Delta/Bering runs. Escapement samples provided scales of known origin that were used to build the discriminant functions, while weekly catch samples provided scales of unknown origin upon which the discriminant functions were applied to estimate the proportions of Upriver and Delta/Bering fish in the catches.

Information on scale patterns for each fish was obtained through counts of circuli and measurement of distances among circuli laid down during the summers and winters spent in freshwater and the first year in the ocean (Zones 1 through 5; Figure 3). Scale impressions were projected at 100x using equipment similar to that described by Bilton (1970) and modified by Ryan and Christie (1976). Counts and measurements were recorded from the projected image using a Talos Digitizing Tablet connected to a Vector Graphics microcomputer. Measurements taken along the anterior-posterior axis of each scale became the variables (Table 1) that constituted a standardized vector of data on the scale pattern of each fish.

Linear discriminant, two-way models (functions)[1] were constructed with scale pattern vectors derived from the escapement samples from the Upriver and the Delta/Bering runs. Scales representing the Delta/Bering group were subsampled according to relative run strengths of escapements as estimated through aerial surveys (Table 2). Scale representing the Upriver group were principally from the Chitina subsistence fishery catches and were subsampled according to the relative strengths of the early, middle, and late segments of escapement past the fishery as estimated from lagged counts at the Miles Lake sonar project (Sharr 1983b). Scales from Long Lake were also subsampled according to the relative strength of that escapement in the Upriver run (Sharr 1983b). All scale variables with measurements not normally distributed within each group were excluded from the information vectors and therefore from the models. Variables were added to the models according to the degree in which their means differed between the Upriver and Delta/Bering runs with those representing the largest differences added first. Variables were added until model accuracy ceased to improve. Accuracy was estimated with jackknife procedures[2]. Two models were constructed, one for fish aged 1.3 which

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[1] Two-way models are discriminant functions that distinguish the numbers of two groups, here Upriver fish and Delta/Bering fish.

[2] A jackknife procedure works as follows: (1) for standards with n fish, one fish is selected and a discriminant function is built on information from the remaining $n-1$ scales, (2) the selected scale is assigned to a group with the discriminant function, and (3) the procedure is repeated n times with a different scale selected each time. Accuracy is the percentage of fish correctly assigned an origin.

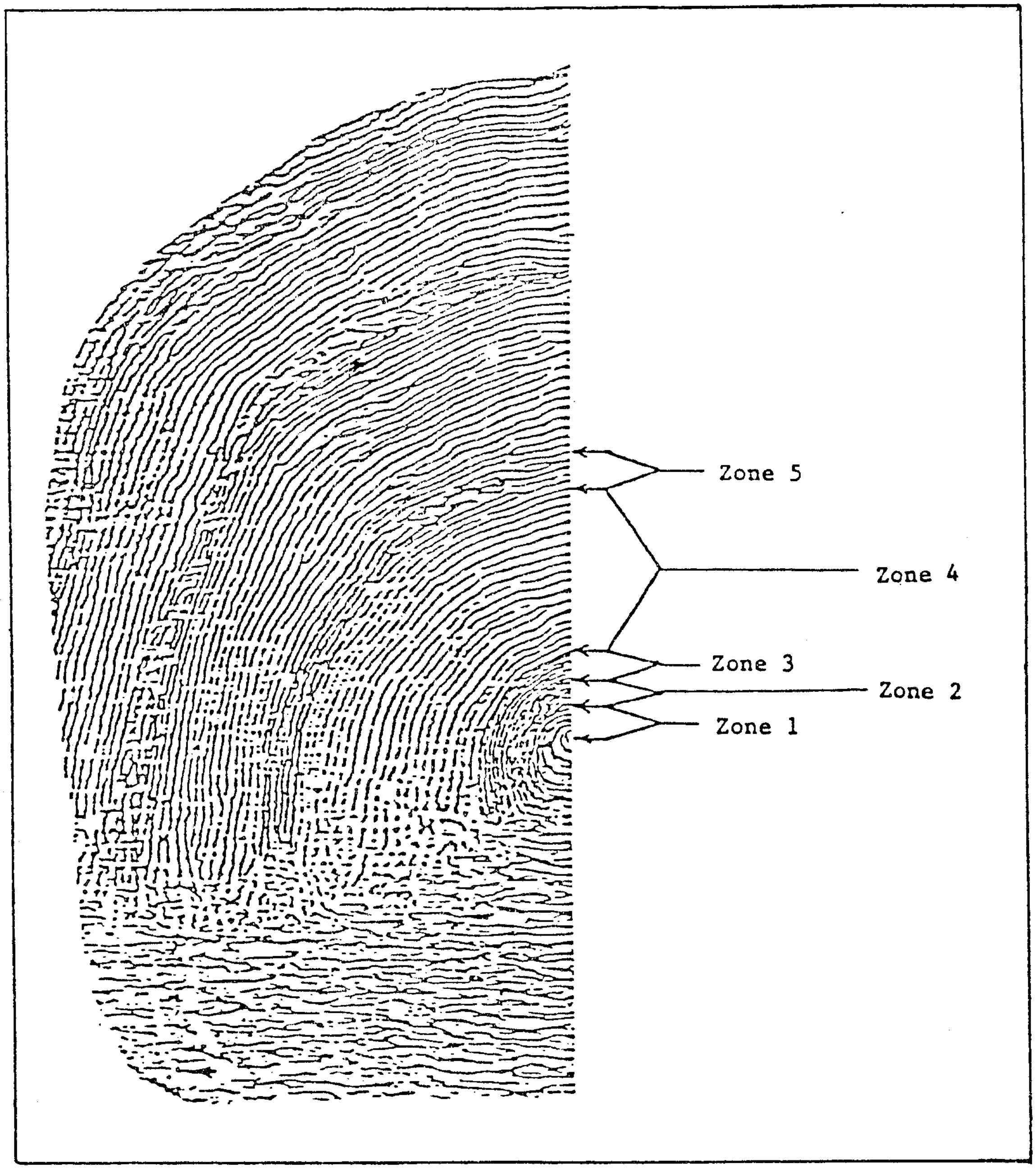

Figure 3. Scale from a sockeye salmon aged 1.3 showing zones measured to generate the variables used to build linear discriminant functions.

Table 1. Scale pattern variables used to build linear discriminant functions[1].

Two(n)[2]	=	Distance from the beginning of the zone to the second circulus in the zone.
Four(n)	=	Distance from the beginning of the zone to the fourth circulus in the zone.
Six(n)	=	Distance from the beginning of the zone to the sixth circulus in the zone.
Eight(n)	=	Distance from the beginning of the zone to the eighth circulus in the zone.
Max(n)	=	Maximum distance between any two adjacent circuli in the zone.
Min(n)	=	Minimum distance between any two adjacent circuli in the zone.
Lmax(n)	=	Circuli count from the beginning of the zone to the location of Max(n).
Lmin(n)	=	Circuli count from the beginning of the zone to the location of Min(n).
NC(n)	=	Total circuli count across the zone.
ID(n)	=	Total distance across the zone.
NCH(n)	=	Number of circuli included in the first half of the distance across the zone.

1 Zones were measured along the anterior-posterior axis of the scale. Within each zone the total number of circuli were counted and the distances between pairs of adjacent circuli were measured. Distance measurements were recorded in hundredths of an inch.

2 Where *n* is the number of the zone (see Figure 3).

Table 2. Estimated escapements and age proportions used to subsample scales of known origin from the Upriver and Delta/Bering runs used to construct two-way discriminant functions for fish aged 1.3 and 1.2, 1982.

Run	Sample Site	Estimated Escapement	Percent Fish Aged 1.3 in Sample	Number of Fish Aged 1.3 in Escapement	Percent Total Escapement of Fish Aged 1.3	Subsample
			Fish Aged 1.3			
Upriver	Chitina [1]	439,213	73.3	321,863	97.8	194
	Long Lake	28,064	26.1	7,337	2.2	6
	Total	467,277		329,200	100.0	200
Delta/Bering	Eyak Lake	13,500	63.3	8,556	16.2	32
	McKinley Lake	23,000	29.6	6,817	12.9	26
	27-Mile Slough	5,500	22.6	1,229	2.3	5
	39-Mile Slough	13,000	45.7	5,915	11.2	22
	Martin River Slough	9,500	18.0	1,718	3.2	6
	Ragged Point Lake	11,500	16.4	1,888	3.6	8
	Martin Lake	14,800	20.6	3,047	5.8	12
	Little Martin Lake	6,020	13.4	813	1.5	3
	Tokun Lake	7,300	71.0	5,182	9.8	19
	Kushtaka Lake	3,350	55.8	1,868	3.5	7
	Shepard Creek	10,500	63.6	6,683	12.7	25
	Bering Lake	16,500	55.5	9,154	17.3	35
	Total	134,470		52,870	100.0	200

Run	Sample Site	Estimated Escapement	Percent Fish Aged 1.2 in Sample	Number of Fish Aged 1.2 in Escapement	Percent Total Escapement of Fish Aged 1.2	Subsample
			Fish Aged 1.2			
Upriver	Chitina [1]	439,213	20.8	91,544	83.4	83
	Long Lake	28,064	65.2	18,221	16.6	17
	Total	467,277		109,765	100.0	100
Delta/Bering	Eyak Lake	13,500	31.1	4,192	8.0	8
	McKinley Lake	23,000	57.3	13,160	25.0	25
	27-Mile Slough	5,500	41.0	2,248	4.3	4
	39-Mile Slough	13,000	38.6	4,993	9.5	10
	Martin River Slough	9,500	23.4	2,231	4.2	4
	Ragged Point Lake	11,500	26.4	3,035	5.8	6
	Martin Lake	14,800	61.9	9,166	17.4	17
	Little Martin Lake	6,020	53.4	3,187	6.1	6
	Tokun Lake	7,300	28.2	2,058	3.9	4
	Kushtaka Lake	3,350	26.1	874	1.7	2
	Shepard Creek	10,500	21.6	2,274	4.3	4
	Bering Lake	16,500	31.3	5,172	9.8	10
	Total	134,470		52,590	100.0	100

[1] Scales were subsampled by date to reflect the relative sizes of the early, middle, and late segments of the escapement past Chitina (Sharr 1983a).

was used to apportion catches, and one for fish aged 1.2 which was used to assess the accuracy of a model for fish aged 1.3 returning in 1983. Sharr (1983a) demonstrated the feasibility of such a test.

Catch and Escapement Statistics

Commercial catch data used in this report were compiled by the Division of Commercial Fisheries for each management district for each week of the fishing season and are based on tabulations of individual records of sales by fishermen (fish tickets). Samples from weekly catches from each subdistrict in District 212 provided scales and information about the sex and size of sockeye salmon. Ages of fish were determined through examination of scales. Because there were no significant differences in age and sex compositions among samples from the different subdistricts, the weekly samples were pooled across subdistricts to estimate the age and sex composition for the entire district.

Upriver escapement was estimated by subtracting Upper Copper River subsistence catches (Roberson 1982) from the estimates of escapement past the Miles Lake Sonar Project (Merritt and Roberson 1983a) as reported by Randall et al. (1983) while estimates of Delta and Bering River escapements were based on aerial survey data (Fridgen, personal communication) as compiled by Sharr (1983b). Subsistence catches at Chitina were assumed to be representative of the escapement past the fishery and were therefore sampled regularly throughout the season to obtain scales and information about the age and sex composition of the escapement. Fish escaping to Long Lake were sampled at a weir. Escapements which contribute significantly to the Delta/Bering run were sampled at least once during the season. The ages of fish in the samples were estimated through scale examination and length frequency analysis (Sharr 1983b). The estimate of escapement by age for the Upriver run is the sum of the estimates for escapement past the subsistence fishery and the Long Lake escapement. Similarly, the estimate of the Delta/Bering escapement by age is a sum of estimates for escapements contributing to that run (Sharr 1983b).

Catch Apportionment

Because fish aged 1.3 were the majority of the catch in District 212, the two-way model for fish aged 1.3 was used to estimate the proportions of Upriver and Delta/Bering fish in selected weekly catch samples from Egg Island, Pete Dahl, Kokinhenik, and Softuk Channels. Point estimates were corrected for misclassification error rates using the procedure of Cook and Lord (1978). The variance and the 90% confidence intervals for the estimates were computed using the procedures of Pella and Robertson (1979)[1] on the corrected estimates. For those weeks when the estimated proportions of the Upriver contributions (or Delta/Bering contributions) of salmon to the catch are not statistically different among channels, an average proportion was calculated for all channels as a unit:

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[1] According to Cook (1982), the procedures of Pella and Robertson (1979) produce confidence intervals and variances which are too big for the specified precision (here 90%).

$$\hat{\bar{S}}_i = \frac{1}{n} \sum_{k=1}^{n} \hat{S}_{ik}$$

Where:

$\hat{S}_{ik}$ = Estimated proportion of the fish caught in subdistrict k (10, 20, or 30) that originated from run i (Upriver or Delta/Bering)

n = Number of subdistricts in the mean.

The variance of the average proportion was calculated

$$V[\hat{\bar{S}}_i] = \left(\frac{1}{n}\right)^2 \sum_{k=1}^{n} V[\hat{S}_{ik}]$$

The estimated contribution of fish aged 1.3 from each run calculated as a product of the estimate of the average proportion, the estimate of the fraction of the catch of that age, and the catch:

$$\hat{C}_{i1.3} = C\hat{P}_{1.3}\hat{\bar{S}}_{i1.3}$$

Where:

C = Catch of fish during the week from the entire district.

$\hat{C}_{i1.3}$ = Estimated catch of fish aged 1.3 returning to run i.

$\hat{P}_{1.3}$ = Estimated proportion of fish aged 1.3 in the catch.

$\hat{\bar{S}}_{i1.3}$ = Estimated proportion of run i aged 1.3 in the catch.

The variance of the estimated catch of sockeye salmon aged 1.3 from the Upriver run (or from the Delta/Bering run) was calculated as an exact variance of a product according to Goodman (1960):

$$V[\hat{C}_{i1.3}] = C^2 V[\hat{P}_{1.3}\hat{\bar{S}}_{i1.3}]$$

$$V[\hat{P}_{1.3}\hat{\bar{S}}_{i1.3}] = V[\hat{P}_{1.3}]\hat{\bar{S}}^2_{i1.3} + V[\hat{\bar{S}}_{i1.3}]\hat{P}^2_{1.3} - V[\hat{\bar{S}}_{i1.3}]V[\hat{P}_{1.3}]$$

For those weeks when one or more of the estimated proportions s_{ik} proved significantly different, those contributions were estimated separately:

$$\hat{C}_{i1.3k} = C_k\hat{P}_{1.3}\hat{S}_{i1.3k}$$

Where:

c_k = Catch of sockeye salmon in channel k.

The variance for $\hat{C}_{i1.3k}$ was calculated in the same manner as described above according to Goodman (1960) only with c_k inserted for c and $\hat{s}_{i1.3k}$ inserted for the average proportion. Whenever their proportions were different than those of other channels, catches for Subdistrict 10 were apportioned using estimates for samples from Egg Island, catches for Subdistrict 20 using estimates for samples from Pete Dahl, and catches for Subdistrict 30 using the mean of the estimates for Kokinhenik and Softuk. Average proportions and contributions to the catch by run from remaining channels (those not significantly different) were calculated as stated above. The contributions for all channels were then added to produce a contribution to the entire fishery for that week; the variance of the entire contribution was calculated as a sum of the variances for each group of channels. In weeks 29, 31, and 33 catches were not sampled. The estimates of the run proportions in the catches in weeks 29 and 31 are interpolated, and in week 33 they are assumed to be the same as in the preceding week (week 32). The proportions of the catch contribution by age groups other than fish aged 1.3 from the Upriver run and from the Delta/Bering run are functions of the estimates for fish aged 1.3 and the ratio of fish aged 1.3 to fish of other age groups in respective escapements:

$$\hat{s}_{ij} = \frac{\hat{\bar{s}}_{i1.3}(\hat{A}_{ij}/\hat{A}_{i1.3})}{\sum_{m=1}^{N} \hat{\bar{s}}_{m1.3}(\hat{A}_{mj}/\hat{A}_{m1.3})}$$

Where:

$\hat{s}_{ij}$ = Estimated proportion of run i in the catches of fish aged j.

$\hat{\bar{s}}_{i1.3}$ = Estimated proportion of the run i in the catches of fish aged 1.3.

$\hat{A}_{ij}$ = Estimated proportion of age j fish in the escapement of run i.

$\hat{A}_{i1.3}$ = Estimated proportion of fish aged 1.3 in the escapement of run i.

N = Number of runs.

The contribution of sockeye salmon age i was then calculated as:

$$\hat{C}_{ij} = C\hat{P}_j\hat{s}_{ij}$$

For those weeks with significantly different proportions by channel, $\hat{s}_{i1.3}$ in the above equation is the ratio of $\hat{C}_{i1.3}$ to the estimated number of fish aged 1.3 in the entire catch for that week. No variances were calculated for the compositions of the catches of other than fish aged 1.3

Because District 200 catches were not allocated they were not included in the total return estimate for either run but were included in a separate category (unassigned) when calculating the combined total return to Districts 200 and 212.

RESULTS

Catches and Escapements

The 1982 commercial catch of sockeye salmon in District 212 was 1,193,584 fish. Peak catches were made in the last week of May or statistical week 22 (Figure 4) and 95% of the catch was landed by the week ending 3 July (week 27). An estimated 601,747 sockeye salmon escaped the commercial fishery in Districts 212 and 200 in 1982 of which 467,277[1] returned to Upriver spawning areas and 134,470 to Bering/Delta spawning areas (Sharr 1983b). The subsistence fishery at Chitina harvested an additional 105,826[2] Upriver fish resulting in an estimated net Upriver escapement of 361,451 sockeye salmon.

Fish aged 1.3 comprised 77.0% of the sockeye salmon caught in District 212 in 1982, while fish aged 1.2 comprised 13.7% of the catch, and the remaining age groups (Other) comprised 9.3% of the catch (Figure 4). The proportion of fish aged 1.3 was particularly large in the early weeks of the fishery when catches were largest but declined steadily from 88.3% in the third week of May (week 21) to 53.9% by the end of the week ending 3 July (week 27). Conversely, in the same interval, the proportion of fish aged 1.2 increased from 2.9% to 35.8%. In succeeding weeks the ratio of fish aged 1.3 to fish aged 1.2 fluctuated erratically and the proportion of fish from other age groups was as high as 25% in the small catches in the first two weeks in August (weeks 32 and 33).

In the Upriver escapement, the portion of fish aged 1.3 was much higher than the portion of fish aged 1.2 (70.5% versus 23.5%) but in the Bering/Delta escapement fish aged 1.3 and fish aged 1.2 were present in approximately equal proportions (39.3% and 39.1%, respectively, Table 3). The portion of fish from other age groups was very small in the Upriver escapement but significant in the Delta/Bering escapement. For a more detailed description of the catch and escapement statistics see Sharr (1983b).

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[1] This is an estimate for all salmon which migrate past the Miles Lake Sonar Project (Merritt and Roberson 1983a). Randall et al. (1983) use this number as an estimate for sockeye salmon escapement past Miles Lake and for consistency the same assumption is made in this report. It should be noted, however, that Roberson (personal communication, 1984) estimates that approximately 2.5% of these fish are chinook salmon.

[2] This is an estimate based on reported catches through 15 February 1983, but also includes an estimate of unreported catches based on the number of unreturned permits and the ratio of sockeye salmon to other species in reported catches (Roberson, personal communication, 1984).

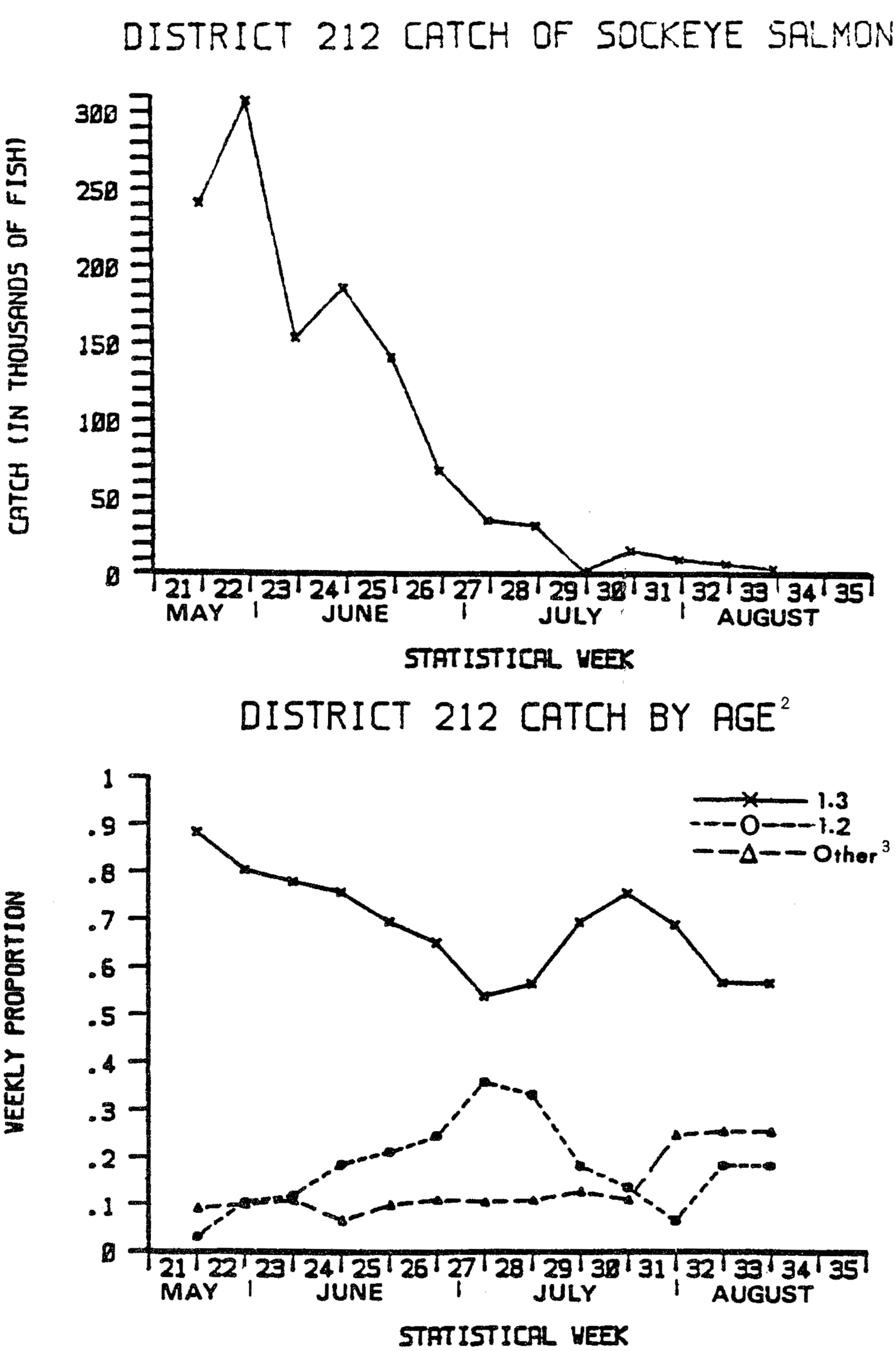


Figure 4. Numbers of sockeye salmon and proportions of fish aged 1.3, 1.2, and "Other" in weekly catches in District 212, 1982.

[1] Data taken from Appendix Table 1.

[2] Data taken from Appendix Table 2.

[3] Defined in Table 3.

Table 3. Age composition of the Upriver and Delta/Bering escapements of sockeye salmon, 1982.

	0.2[1]	1.1[1]	0.3[1]	1.2	2.1[1]	1.3	2.2[1]	1.4[1]	2.3[1]	3.2[1]	Total
Upriver[2]											
Numbers	2,682	122	8,229	109,765	61	329,200	7,283	645	9,168	122	467,277
Percent	0.58	0.03	1.76	23.49	0.01	70.45	1.56	0.14	1.96	0.02	100.00
Delta/Bering[3]											
Numbers	11,101	4,603	11,248	52,590	16	52,870	967	0	1,075	0	134,470
Percent	8.26	3.42	8.36	39.11	0.01	39.32	0.72	0.0	0.80	0.0	100.00

1 Referred to as "Other" in Figure 4.

2 The estimate of the Upriver escapement of sockeye salmon is from Roberson (1983) as reported by Randall et al. (1983). Roberson (1984) has advised that approximately 2.5% of these fish are chinook salmon. The numbers of fish were apportioned by age group using a weighted pool of data for the Upper Copper River escapement, the Upper Copper River subsistence catch, and the Long Lake escapement (Sharr 1983b).

3 Based on a weighted pool of data from the nine Delta and three Bering River systems sampled in 1982 (Sharr 1983b). Small rounding errors were discovered in Sharr's summary Tables 18 and 28 for Delta and Bering River escapements. Totals in this table are the correct.

Classification Models

Scale characters that correspond to summer growth during freshwater life proved the most powerful in distinguishing Upriver fish from Delta/Bering fish. For fish aged 1.3 (1977 brood year), differences in plus growth (ID3) are the most powerful; for fish aged 1.2 (1978 brood year), differences in growth during the first summer (ID1) are the strongest. For fish aged 1.3, plus growth was greater for the Delta/Bering fish, and for fish aged 1.2 growth in the first summer was greater for Upriver fish (Table 4). Overall jackknifed classification accuracy of the model for fish aged 1.2 increased to 79.5% when variables ID5, ID2, and MAX4 were added and to 74.0% for fish aged 1.3 when the variable NCH4 was added. The model for fish aged 1.3 classified Upriver and Delta/Bering fish equally well but the model for fish aged 1.2 classified Delta/Bering fish with better accuracy than Upriver fish (84.0% versus 75.0%; Table 5).

Catch Allocations

The weekly catch composition estimates for fish aged 1.3 are not demonstrably different among channels except in the week ending 10 July (week 27) when Upriver fish contributed to the catches in all but the Egg Island Channel (Figure 5, Table 6). There appears to be a difference between Egg Island and Softuk channels in the first week of August (week 32), however; samples used for the two estimates represent very small catches and any differences which exist are not important to the catch allocation for all weeks. The mean estimates of the fraction of the Upriver fish in catches in District 212 are similar among weeks and greater than 50% from 16 May to 5 June (weeks 21 through 23), peak in the week ending 12 June (week 24; 81.0%) then decline steadily to zero in the week ending 24 July (week 30) (Figure 6, Table 7). After the week ending 29 May (week 22) total catches of both Upriver and Delta/Bering fish aged 1.3 declined steadily however, the rate of decline was less for Delta/Bering fish (Figure 7) and, by the week ending 26 July (week 26) Delta/Bering fish were more numerous than Upriver fish in catches in District 212.

For the entire 1982 season, the catch of fish of all age groups in District 212 was composed of approximately equal portions of Upriver and Delta/Bering fish (51.2% and 48.8%, respectively) (Table 8). The Upriver portion of fish aged 1.3 was higher than the Delta/Bering portion (58.6% versus 41.4%) but lower for fish aged 1.2 (32.2% versus 67.8%) and fewer fish from other age groups (18.2% versus 81.8%). The estimated, combined total return of sockeye salmon to Districts 212 and 200 in 1982 was 1,926,776 fish of which 56.0% were Upriver fish, 37.2% were Delta/Bering fish, and 6.8% were unclassified fish from the District 200 commercial catch (Table 9). The commercial catches of Upriver and Delta/Bering fish were approximately equal portions of the total return (31.7% and 30.2%, respectively).

DISCUSSION

There is strong evidence of temporal variation in the run composition of catches of sockeye salmon in District 212 but little evidence of spatial differences. Estimates of the run composition of catches in each channel are similar among channels within weeks but are different over weeks. Age composition data support

Table 4. Means and standard deviations of variables used to construct two-way linear discriminant functions for 1982.

Fish aged 1.3					
Variable		Upriver		Delta/Bering	
	F Value[1]	Mean	SD	Mean	SD
ID3	80.66	38.40	25.93	60.37	22.90
NCH4	49.01	8.48	1.36	9.07	1.14

Fish aged 1.2					
Variable		Upriver		Delta/Bering	
	F Value[1]	Mean	SD	Mean	SD
ID1	102.12	147.26	37.56	102.23	23.97
ID5	18.61	70.11	9.29	63.84	9.78
ID2	8.21	19.32	3.56	21.34	3.62
MAX4	5.33	27.61	6.11	25.64	5.02

[1] Values of F represent the relative strengths of the differences in the variables between discriminant groups.

Table 5. Jackknifed classification accuracies for linear discriminant functions, 1982.

Fish aged 1.3

Actual Run	Sample Size	Number of Fish Classified to Run		Percent Correct
		Upriver	Delta/Bering	
Upriver	200	148	52	74.0
Delta/Bering	200	52	148	74.0

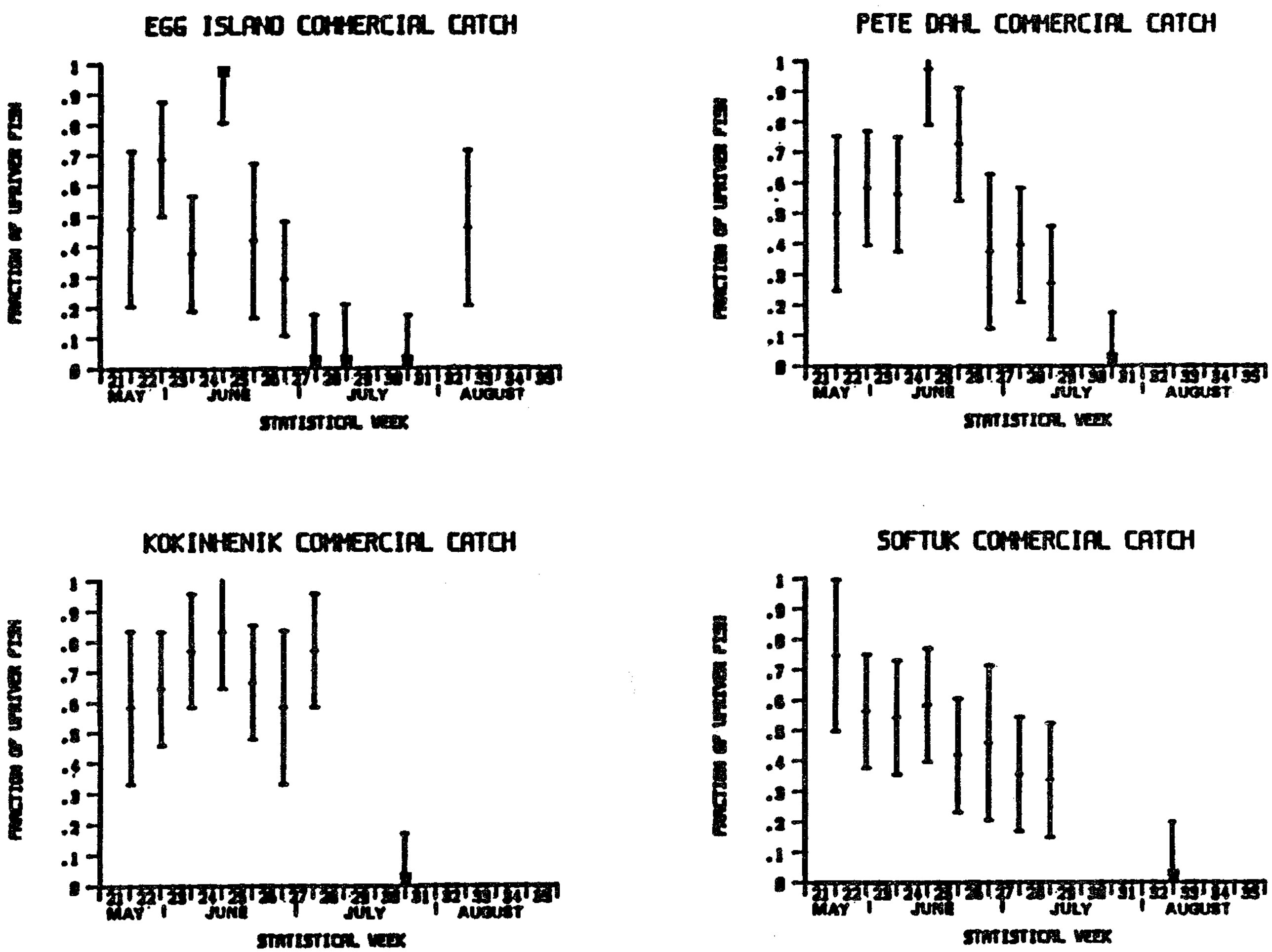
Overall percent correct = 74.0

Fish aged 1.2

Actual Run	Sample Size	Number of Fish Classified to Run		Percent Correct
		Upriver	Delta/Bering	
Upriver	100	75	25	75.0
Delta/Bering	100	16	84	84.0

Overall percent correct = 79.5

Figure 5. Upriver portion of the weekly sockeye salmon catches aged 1.3 in Egg Island, Pete Dahl, Kokinhenik, and Softuk Channels, 1982[1].



[1] The brackets around the point estimates correspond to the 90% confidence intervals. Asterisks are zero values adjusted up from negative estimates or values of 1.0 adjusted down from estimates greater than 1.0.

Table 6. Run composition estimates and associated 90% confidence intervals from scale pattern analysis of sockeye salmon aged 1.3 by entrance in District 212, 1982.

			Egg Island		Pete Dahl		Kokinhenik		Softuk	
Week	Dates	Group	Proportion	90% C.I.[1]	Proportion	90% C.I.[1]	Proportion	90% C.I.[1]	Proportion	90% C.I.[1]
21	5/16-5/22	Upriver	.46	±.25	.50	±.25	.58	±.25	.75	±.25
		Delta/Bering	.54		.50		.42		.25	
22	5/23-5/29	Upriver	.69	±.19	.58	±.19	.65	±.19	.56	±.19
		Delta/Bering	.31		.42		.35		.42	
23	5/30-6/05	Upriver	.37	±.19	.56	±.19	.77	±.19	.54	±.19
		Delta/Bering	.62		.44		.23		.46	
24	6/06-6/12	Upriver	1.00	±.19	.98	±.18	.83	±.19	.58	±.19
		Delta/Bering	0[2]		.02		.17		.42	
25	6/13-6/19	Upriver	.42	±.25	.73	±.19	.67	±.19	.42	±.19
		Delta/Bering	.58		.27		.33		.58	
26	6/20-6/26	Upriver	.29	±.19	.38	±.25	.58	±.25	.46	±.25
		Delta/Bering	.71		.62		.42		.54	
27	6/27-7/03	Upriver	0[2]	±.18	.40	±.19	.77	±.19	.36	±.19
		Delta/Bering	1.00		.60		.23		.64	
28	7/04-7/10	Upriver	0[2]	±.21	.27	±.19	[3]		.34	±.19
		Delta/Bering	1.00		.73				.66	
29	7/11-7/17	Upriver	[3]		[3]		[3]		[3]	
		Delta/Bering								
30	7/18-7/24	Upriver	0[2]	±.18	0[2]	±.18	0[2]	±.18	[3]	
		Delta/Bering	1.00		1.00		1.00			
31	7/25-7/31	Upriver	[3]		[3]		[3]		[3]	
		Delta/Bering								
32	8/01-8/07	Upriver	.46	±.25	[3]		[3]		0[2]	±.22
		Delta/Bering	.54						1.00	
33	8/08-8/14	Upriver	[3]		[3]		[3]		[3]	
		Delta/Bering								

[1] For groups in a two-way model the confidence intervals are the same for both. Confidence intervals were calculated according to the techniques of Pella and Robertson (1979) and are conservative (Cook 1982).

[2] The techniques of Pella and Robertson (1979) can give a negative estimate and an estimate greater than 1.0 for the other group. These estimates were adjusted to zero and 1.0, respectively.

[3] No estimates in this week.

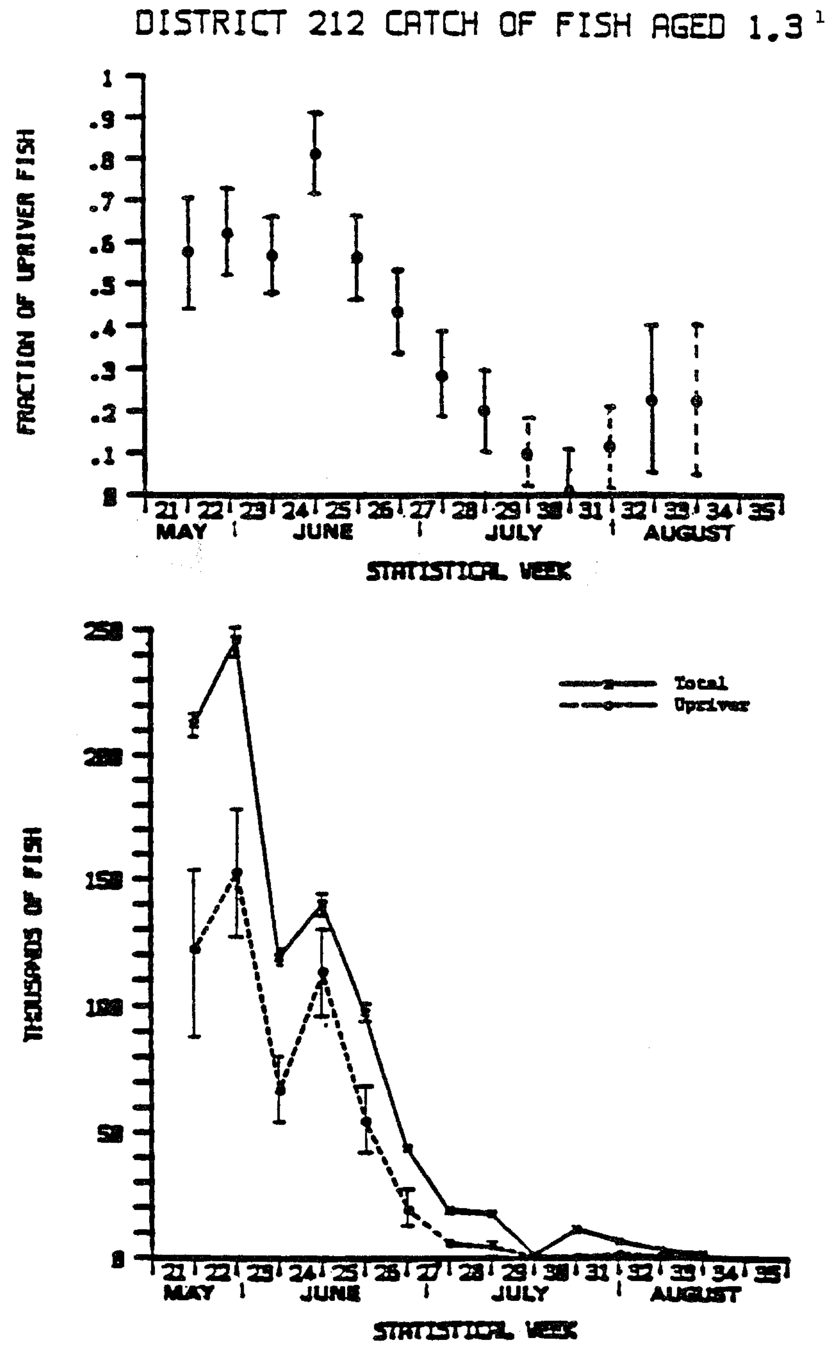


Figure 6. Upriver contribution to commercial catches of sockeye salmon aged 1.3 in District 212 in 1982[1].

[1] The brackets around the estimates correspond to the 90% confidence intervals. Dashed brackets indicate interpolated or extrapolated estimates. Due to the scale of the plot, confidence intervals spanning fewer than 5,000 fish are not shown.

Table 7. Estimated numbers of Upriver and Bering/Delta sockeye salmon aged 1.3 caught in District 212, 1982.

Week	Dates	System	Estimated Proportion	Estimated Numbers	Standard Error of Estimate	Coefficient of Variation
21	5/16-5/22	Upriver	.57	121,780	16,501	.14
		Delta/Bering	.43	90,751	16,484	.18
		Total	1.00	212,531		
22	5/23-2/29	Upriver	.62	152,333	13,557	.09
		Delta/Bering	.38	93,763	13,508	.14
		Total	1.00	212,531		
23	5/30-6/05	Upriver	.56	66,711	6,541	.10
		Delta/Bering	.44	51,992	6,526	.13
		Total	1.00	118,703		
24	6/06-6/12	Upriver	.81	112,802	7,815	.07
		Delta/Bering	.19	27,151	7,673	.28
		Total	1.00	139,953		
25	6/13-6/19	Upriver	.56	54,304	6,220	.12
		Delta/Bering	.44	43,189	6,200	.14
		Total	1.00	97,493		
26	6/20-6/26	Upriver	.43	18,706	13,107	.17
		Delta/Bering	.57	24,999	3,120	.13
		Total	1.00	43,705		
27	6/27-7/03	Upriver	.28[1]	5,337	678[2]	.13
		Delta/Bering	.72[1]	13,456	876[2]	.07
		Total	1.00	18,788		
28	7/04-7/10	Upriver	.20	3,563	1,243	.35
		Delta/Bering	.80	13,987	1,279	.09
		Total	1.00	17,550		
29	7/11-7/17	Upriver	.10[3]	115	51	.44
		Delta/Bering	.90[3]	1,021	63	.06
		Total	1.00	1,136		
30	7/18-7/24	Upriver		0	0[4]	
		Delta/Bering	1.00	11,421	183[4]	.02
		Total	1.00	11,421		

-Continued-

Table 7. Estimated numbers of Upriver and Bering/Delta sockeye salmon aged 1.3 caught in District 212, 1982 (continued).

Week	Dates	System	Estimated Proportion	Estimated Numbers	Standard Error of Estimate	Coefficient of Variation
31	7/25-7/31	Upriver	.12	1,497	209	.14
		Delta/Bering	.88	5,042	479	.10
		Total	1.00	6,539		
32	8/01-8/07	Upriver	.23	737	323	.44
		Delta/Bering	.77	2,482	334	.14
		Total	1.00	3,219		
33	8/08-8/14	Upriver	.23[5]	369	112	.44
		Delta/Bering	.77[5]	1,244	167	.13
		Total	1.00	1,613		
Total		Upriver	.59[6]	538,254	57,129	.11
		Delta/Bering	.41[6]	380,493	57,454	.15
		Total	1.00	918,747		

1 Because the estimated proportions in the Egg Island Channel differed from the estimated proportions in the other three channels, the catches in Subdistrict 10 were allocated with the Egg Island estimate and the pooled catches in Subdistricts 20 and 30 were allocated with the mean of the estimates for the other channels. The two allocations were combined to back calculate the relative proportions of Upriver and Delta/Bering fish in the catches in District 212.

2 Based on the sum of the variances of the estimates for Subdistrict 10 and for Subdistricts 20 and 30 combined.

3 Because there were no catch samples for this week the estimate is the mean of the estimates for weeks 28 and 29.

4 The estimated proportion of Upriver fish was actually negative and the proportion of Delta/Bering fish was greater than 1.0. The negative estimate was adjusted up to zero and the other estimate was adjusted down to 1.0. Because these adjustments did not alter the variances for the estimates the standard error of the estimates also remained the same.

5 Because there were no catch samples for this week the estimate is the same as the estimate for week 32.

6 Calculated from the sums of the estimated numbers of Upriver fish and Delta/Bering fish in the weekly catches.

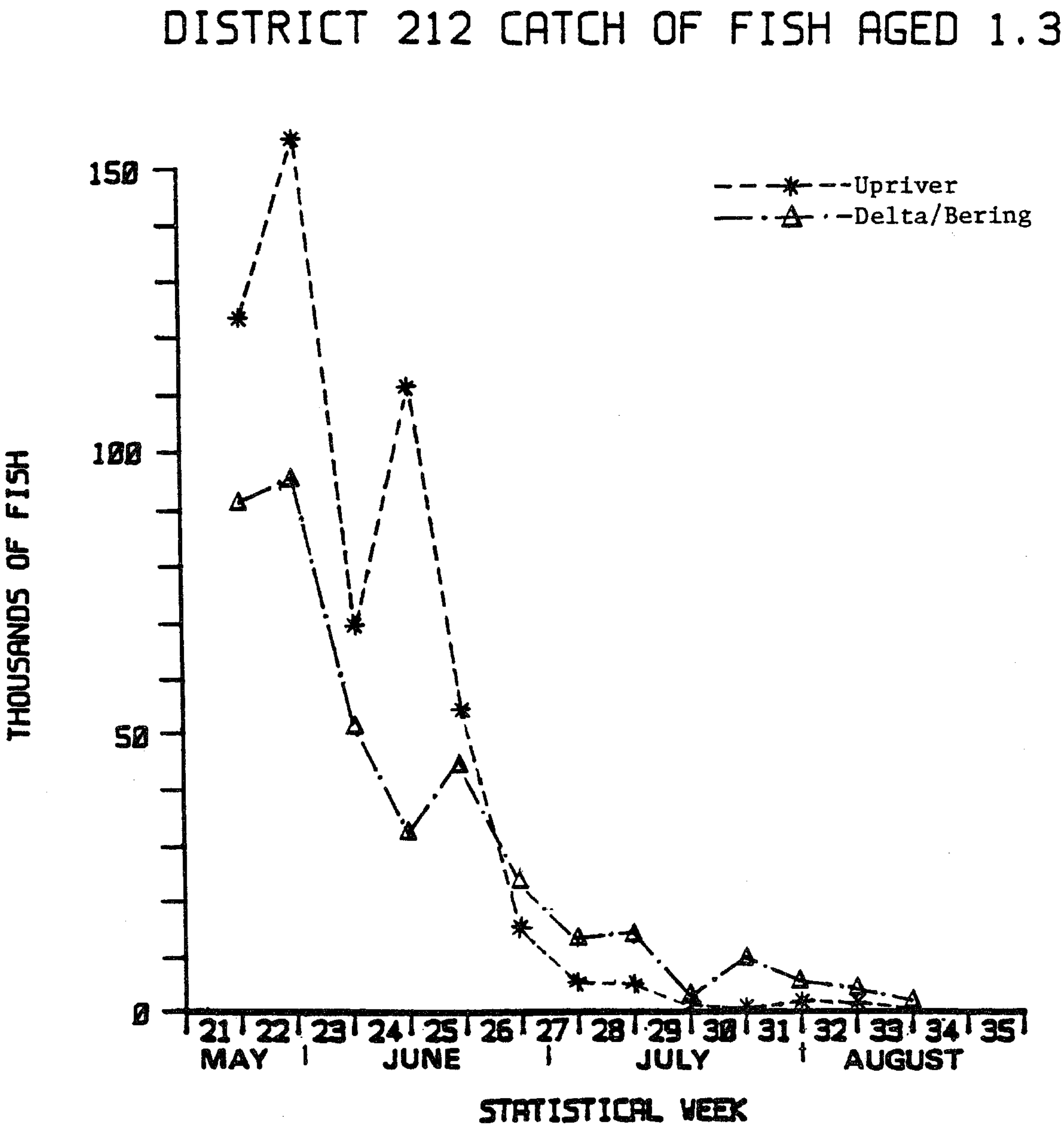


Figure 7. Upriver and Delta/Bering contributions to commercial catches of sockeye salmon aged 1.3 in District 212 in 1982.

Table 8. Age-specific run contributions of sockeye salmon to catches in District 212 based on expanded estimates from scale pattern analysis of fish aged 1.3, 1982.

	1.3		1.2		Other		Total	
Run	Percent	Number	Percent	Number	Percent	Number	Percent	Number
Upriver	58.6	538,253	32.2	52,484	18.2	20,319	51.2	611,056
Delta/Bering	41.4	380,494	67.8	110,509	81.8	91,325	48.8	582,328
Total	100.0	918,747	100.0	162,993	100.0	111,644	100.0	1,193,384

Table 9. Total return of sockeye salmon by run and age group to Districts 212 and 200 combined, 1982.

Run		1.3		1.2		Other		No Age		Total	
		Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number
Upriver											
	Commercial Catch [1]	27.9	538,254	2.7	52,484	1.1	20,319	0.0	0	31.7	611,057
	Subsistence Catch [2]	3.1	60,102	0.8	15,407	0.3	5,466	0.0	0	4.2	80,975
	Subsistence Catch [3]	1.0	18,159	0.3	5,281	0.1	1,411	0.0	0	1.3	24,851
	Escapement [4]	13.0	250,939	4.6	89,077	1.1	21,435	0.0	0	18.8	361,451
	Total	45.0	867,454	8.4	162,249	2.6	48,631	0.0	0	56.0	1,078,334
Delta/Bering											
	Commercial Catch [1]	19.7	380,493	5.8	110,509	4.7	91,325	0.0	0	30.2	582,327
	Escapement	2.8	52,869	2.7	52,590	1.5	29,011	0.0	0	7.0	134,470
	Total	22.5	433,362	8.5	163,099	6.2	120,331	0.0	0	37.2	716,797
Unassigned [5]											
	Commercial Catch	0.0	0	0.0	0	0.0	0	6.8	131,645	6.8	131,645
	Total	0.0	0	0.0	0	0.0	0	6.8	131,645	6.8	131,645
Total											
	Commercial Catch	47.6	918,747	8.5	162,993	5.8	111,644	6.8	131,645	68.7	1,325,029
	Subsistence Catch	3.1	78,261	1.1	20,688	0.4	6,877	0.0	0	5.5	105,826
	Escapement	15.8	303,808	7.3	141,667	2.6	50,446	0.0	0	25.8	495,927
	Total	67.5	1,300,816	16.9	325,348	8.8	168,967	6.8	131,645	100.0	1,926,776

1 District 212 catches only.

2 These catches were reported by date and the age composition is a weighted sum of the age composition estimates for catches from the early, middle, and late portions of the subsistence fishery.

3 This is a sum of reported catches for which dates were missing and estimated unreported catches (Roberson 1984) and were apportioned by age using the season total age composition of the Upriver escapement from Sharr 1983b).

4 This is the estimate for all salmon migrating past the Miles Lake Sonar Project minus the estimated subsistence catches of sockeye salmon. For the sake of consistency, we have used the Upriver escapement of sockeye salmon past Miles Lake (Merritt and Roberson 1983b) as reported by Randall et al. (1983), however it should be noted that Roberson (1984) estimates that approximately 2.5% of the estimate from sonar counts are chinook salmon. The age composition estimates for the Upriver escapement are from Sharr (1983b), however because subsistence catches lacking date of capture information were treated differently in this report the escapement in numbers of fish by age group appearing in this table differ from those presented by Sharr (1983b).

5 These are catches from District 200 and because samples from these catches were small, the catches were not apportioned by run and age group.

the results of scale pattern analysis. Because the 1982 escapement and catch samples are large and stratified through time, estimates of age composition are very precise and even subtle differences between samples are very significant. The escapements of the two runs contributing to the catches in District 212 had very different age compositions. If the ratio of the two runs in the catch differed among channels or among weeks there should have been corresponding differences in the age composition of the catch. There were no differences in age composition among channels but there were differences among weeks. Furthermore, the increases in the portion of fish aged 1.2 and "Other" correspond closely to increases in the estimated portion of Delta/Bering fish in the fishery as determined by scale pattern analysis.

Based on the run allocations of weekly catches of fish aged 1.3 in District 212, the migratory timing is more prolonged for the Delta/Bering run than for the Upriver run. Because effort was variable among weeks, catches cannot be used to compare the abundance through time of Upriver and Delta/Bering fish in the fishery. Perhaps catch per unit effort statistics could be modeled with data reported herein to compare abundance through time.

The estimate of the ratio of catch to escapement is higher for the Delta/Bering run than for the Upriver run based on the estimated run composition of the catch and escapement estimates for the two runs. The ratio would be even larger for the Delta/Bering run if fish captured in District 200 are bound mainly for the Bering River as current management practices would suggest (Randall et al. 1983). The difference between catch to escapement ratios of the two runs may be largely due to different methods used to estimate their escapements. Sharr (1983b) attempted to use aerial survey data included in the escapement indices reported by Randall et al. (1983) plus survey data from most, but certainly not all other spawning sites, in an effort to estimate the total Delta/Bering escapement. Randall (personal communication) has suggested that this estimate may represent as little as 50% of the actual Delta/Bering escapement and is certainly very imprecise. Some of the Delta/Bering spawning areas are frequently occluded, weekly surveys are often preempted by inclement weather, and because little applicable stream life data are available for any of the Delta stocks, it is difficult to estimate duplicate counts. Sonar estimates of Upriver escapement also have associated biases (Merritt and Roberson 1983b), but the estimates are daily, include all stocks contributing to the run, and are certainly more reliable and consistent than aerial surveys. The higher catch to escapement ratio for the Delta/Bering run could also be due a higher rate of exploitation of that run in the fishery although no evidence exists to support that hypothesis. Accurate daily escapement estimates of key Delta/Bering escapements would permit more meaningful comparisons with Upriver escapements and could provide important information about the timing of the run through the fishery.

Based on the 1982 two-way model for fish aged 1.2 (1978 brood year), scale pattern analysis should separate Upriver from Delta/Bering fish aged 1.3 with greater accuracy in 1983 (1978 brood year) than it did fish aged 1.3 in 1982 (1977 brood year). As with models for the 1975 and 1976 brood years (Sharr 1983a), the scale variables selected as having the most discriminant power for the 1977 and 1978 brood year are related to the growth of fry in the rearing areas and in the model having the highest accuracy (1978 brood year), the most important variable in ID1 (first summer's growth). First summer's growth was consistently larger in Upriver fish and while both runs exhibited more first summer's growth in 1978 than in 1977, the increase was much larger for fish from the Upriver run. Sharr (1983a) suggests that climatic factors may be responsible for more first summer's growth in Upriver fish and variations between years but correlations of this nature require several years of scale pattern data to interpret in a meaningful manner.

The Upriver run past Miles Lake is composed of many stocks, and while aerial surveys help assess the escapements of some of these stocks, several originate in large, glacially occluded systems where visual estimates are not possible. Escapement to glacial sites such as Tonsina, Klutina, and Tazlina Lake may be quite large. For some of these stocks, estimates of migratory timing in the Copper River (Merrit and Roberson 1983b) can be roughly correlated to daily sonar estimates of escapement past Miles Lake but additional means of assessing their magnitude would be very useful. In 1981 and 1982, when samples at Chitina were large the variable (ID1) had some bimodal frequency which may be related to the mixture of stocks migrating Upriver. Some of these stocks rear in glacially occluded waters and some do not. Among Delta/Bering stocks, fish which rear in occluded waters typically exhibit less first summer's growth than those which rear in clear waters. This same relationship occurs among sockeye salmon stocks in other areas (Cross et al. 1983; McPherson et al. 1983). With spawning ground samples from the two groups of Upriver fish it may be possible to use scale pattern analysis to show that the mode with the smallest mean value corresponds to fish which rear in occluded waters, and that the mode with the largest mean corresponds to fish which rear in clear waters. The relative size of the modes could be related directly to the relative size of the escapements of the two groups, and when coupled with lagged escapement estimates from the Miles Lake Sonar Project, could be used to estimate total escapement of stocks which rear in glacial waters.

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APPENDICES

Appendix Table 1. Sockeye salmon commercial catches in the Copper River District by fishing period and statistical week, and cumulative catches by fishing period in numbers of fish and as percents of the total catch, 1982. Source: Randall et al. (1983).

Statistical Week	Period Dates	Fishing Time (Hrs)	Effort	Period Catch	Week Catch	Cummulative Catch	Cumulative as Percent of Total
21	5/17-5/18	36	6	2,778		2,778	2.3
	5/20-5/22	36	396	237.996	240,774	240,774	20.2
22	5/25-5/26	36	450	228,959		469,773	39.4
	5/28-5/29	24	438	77,837	306,796	547,570	45.9
23	5/31-6/01	24	444	67,105		614,675	51.5
	6/03-6/05	36	438	85,434	152,539	700,109	58.7
24	6/07-6/09	48	402	126,241		826,350	69.2
	6/10-6/12	36	276	58,827	185,068	855,177	74.2
25	6/14-6/16	48	438	116,972		1,002,149	84.0
	6/17-6/19	36	367	23,224	140,196	1,025,373	85.9
26	6/21-6/23	48	123	52,535		1,077,908	90.3
	6/24-6/26	36	123	14,679	67,214	1,092,587	91.5
27	6/28-6/30	48	64	19,171		1,111,758	93.1
	7/01-7/03	36	64	15,687	34,858	1,127,445	94.5
28	7/05-7/07	48	109	24,063		1,151,508	96.5
	7/08-7/10	36	109	7,270	31,133	1,158,778	97.1
29	7/12-7/14	48	10	1,326		1,160,104	97.2
	7/15-7/17	36	10	312	1,638	1,160,416	97.2
30	7/19-7/21	48	70	9,218		1,169,634	98.0
	7/22-7/24	36	70	5,911	15,129	1,175,545	98.5
31	7/26-7/28	48	87	7,110		1,182,655	99.1
	7/29-7/31	36	87	2,383	9,493	1,185,038	99.3
32	8/02-8/04	48	40	4,660		1,189,698	99.7
	8/05-8/07	36	40	1,032	5,692	1,190,730	99.8
33	8/09-8/12	84	194	1,414		1,192,144	99.9
	8/16-8/19	84	262	1,097	2,511	1,193,241	100.0
34	8/23-8/26	84	348	305		1,193,546	100.0
	8/30-9/02	84	373	31	336	1,193,577	100.0
35	9/06-9/09	84	308	7		1,193,584	100.0
	9/13-9/16	84	134	0	7	1,193,584	100.0

Appendix Table 2. Age and sex composition of the commercial catches of sockeye salmon in District 212 by calendar week, 1982.

		AGE GROUP											
		0.2	1.1	0.3	1.2	2.1	1.3	2.2	1.4	2.3	3.2	3.3	TOTAL
WEEK 21	5/16- 5/22												
PERIOD SAMPLE SIZE	1,509												
SEXES COMBINED	COUNT	0	0	1,436	7,021	0	212,531	2,712	320	16,754	0	0	240,774
	PERCENT	0.00	0.00	.60	2.92	0.00	88.27	1.13	.13	6.96	0.00	0.00	100.00
WEEK 22	5/23- 5/29												
PERIOD SAMPLE SIZE	2,699												
SEXES COMBINED	COUNT	454	0	5,229	31,373	114	246,096	6,934	341	16,255	0	0	306,796
	PERCENT	.15	0.00	1.70	10.23	.04	80.21	2.26	.11	5.30	0.00	0.00	100.00
WEEK 23	5/30- 6/05												
PERIOD SAMPLE SIZE	2,439												
SEXES COMBINED	COUNT	125	0	2,877	17,887	0	118,703	2,377	188	10,382	0	0	152,539
	PERCENT	.08	0.00	1.89	11.73	0.00	77.82	1.56	.12	6.81	0.00	0.00	100.00
WEEK 24	6/06- 6/12												
PERIOD SAMPLE SIZE	1,768												
SEXES COMBINED	COUNT	524	0	3,454	33,601	0	139,953	1,674	0	5,862	0	0	185,068
	PERCENT	.28	0.00	1.87	18.16	0.00	75.62	.90	0.00	3.17	0.00	0.00	100.00
WEEK 25	6/13- 6/19												
PERIOD SAMPLE SIZE	1,891												
SEXES COMBINED	COUNT	148	74	2,743	29,433	0	97,493	1,335	222	8,748	0	0	140,196
	PERCENT	.11	.05	1.96	20.99	0.00	69.54	.95	.16	6.24	0.00	0.00	100.00
WEEK 26	6/20- 6/26												
PERIOD SAMPLE SIZE	1,804												
SEXES COMBINED	COUNT	149	149	931	16,393	0	43,705	1,267	37	4,583	0	0	67,214
	PERCENT	.22	.22	1.39	24.39	0.00	65.02	1.89	.06	6.82	0.00	0.00	100.00
WEEK 27	6/27- 7/03												
PERIOD SAMPLE SIZE	1,473												
SEXES COMBINED	COUNT	474	71	1,586	12,472	0	18,788	473	47	923	0	24	34,858
	PERCENT	1.36	.20	4.55	35.78	0.00	53.90	1.36	.13	2.65	0.00	.07	100.00
WEEK 28	7/04- 7/10												
PERIOD SAMPLE SIZE	1,570												
SEXES COMBINED	COUNT	297	20	1,110	10,272	0	17,550	535	0	1,309	40	0	31,133
	PERCENT	.95	.06	3.57	32.99	0.00	56.37	1.72	0.00	4.20	.13	0.00	100.00
WEEK 29	7/11- 7/17												
PERIOD SAMPLE SIZE	338												
SEXES COMBINED	COUNT	20	0	54	296	0	1,136	25	0	107	0	0	1,638
	PERCENT	1.22	0.00	3.30	18.07	0.00	69.35	1.53	0.00	6.53	0.00	0.00	100.00
WEEK 30	7/18- 7/24												
PERIOD SAMPLE SIZE	1,261												
SEXES COMBINED	COUNT	72	36	192	2,064	12	11,421	432	12	876	0	12	15,129
	PERCENT	.48	.24	1.27	13.64	.08	75.49	2.86	.08	5.79	0.00	.08	100.00
WEEK 31	7/18- 7/31												
PERIOD SAMPLE SIZE	257												
SEXES COMBINED	COUNT	111	0	1,514	628	0	6,539	0	0	701	0	0	9,493
	PERCENT	1.17	0.00	15.95	6.62	0.00	68.88	0.00	0.00	7.38	0.00	0.00	100.00
WEEK 32	8/01- 8/07												
PERIOD SAMPLE SIZE	605												
SEXES COMBINED	COUNT	94	9	790	1,035	0	3,219	169	9	367	0	0	5,692
	PERCENT	1.65	.16	13.88	18.18	0.00	56.55	2.97	.16	6.45	0.00	0.00	100.00
WEEK 33	8/08- 8/14												
PERIOD SAMPLE SIZE	605												
SEXES COMBINED	COUNT	47	5	397	518	0	1,613	85	5	184	0	0	2,854
	PERCENT	1.65	.18	13.91	18.15	0.00	56.52	2.98	.18	6.45	0.00	0.00	100.00
PERIODS COMBINED													
SAMPLE SIZES COMBINED	18,219												
SEXES COMBINED	COUNT	2,515	364	22,313	162,993	126	918,747	18,018	1,181	67,051	40	36	1,193,384
	PERCENT	.21	.03	1.87	13.66	.01	76.99	1.51	.10	5.62	.00	.00	100.00