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NORTHWEST ALASKA DOLLY VARDEN STUDY 1989[1]

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ABSTRACT

Stock assessment of Dolly Varden *Salvelinus malma* in the Kotzebue Sound area of northwestern Alaska was continued during 1989. The spring subsistence fishery at Kivalina harvested 1,889 Dolly Varden with a mean fork length of 506 millimeters. The harvest was composed of 70.3 percent females and 29.7 percent males. A mark-recapture experiment estimated that 76,892 (standard error = 16,811) Dolly Varden over 400 millimeters in fork length overwintered in the Wulik River during the winter of 1988/89. During an aerial survey on 13 September 1988, 80,144 Dolly Varden were counted. The mean length of Dolly Varden in the overwintering population was 425 millimeters and the sex ratio was one male to 1.7 females. Recaptured Dolly Varden grew an average of 25 millimeters in fork length over the winter and movements as far as 1,540 kilometers were documented. An estimated 4,874 (standard error = 404) Dolly Varden were taken incidentally in the 1989 Kotzebue Sound commercial chum salmon fishery. Of that harvest, 3,093 (62.7 percent) were sold, and the remainder were used for personal consumption. Dolly Varden comprised 8.4, 9.9, 5.8, and 11.5 percent of catches in 146, 149, 152, and 159 millimeter stretch measure gill nets, respectively. The mean fork length of Dolly Varden harvested in the commercial fishery was 594 millimeters for females and 614 millimeters for males. The sex composition of the catch was 66 percent females and 34 percent males. The 1989 fall subsistence Dolly Varden harvest at Kivalina was 4,820 and 4,500 at Noatak. During 1989 aerial surveys of overwintering populations conducted on 4 October 1989, 56,384 and 5,090 Dolly Varden were counted in the Wulik and Kivalina rivers, respectively. Elevated levels of heavy metals in Red Dog Creek appeared to influence the distribution of overwintering Dolly Varden in the Wulik River 59 kilometers downstream from their source.

KEY WORDS: Dolly Varden, char, *Salvelinus malma*, chum salmon, *Oncorhynchus keta*, subsistence fishery, incidental catch, commercial fishery, movements, sex composition, mark-recapture experiment, population estimate, aerial survey, length composition.

INTRODUCTION

Anadromous Dolly Varden *Salvelinus malma*, hereafter referred to as char, occur in the northern form (Behnke 1980) in most coastal waters of Alaska from the Canada border to the Alaska Peninsula. Waters draining into Kotzebue Sound and the Chukchi Sea in northwestern Alaska contain populations of char which support several local subsistence fisheries and a sport fishery of recognized quality. The largest Dolly Varden in North America, and perhaps the world, occur in these waters. Char are also taken incidentally in the Kotzebue based commercial fishery for chum salmon, *Oncorhynchus keta*. Char overwinter, spawn, and rear in the Kivalina, Wulik, Noatak and Kobuk rivers (Figure 1) and enter the sea in summer to feed (DeCicco 1985). Summer spawners remain in freshwater during the year of spawning and spawn during August and September, then overwinter prior to migrating to the sea the following spring. Fall spawners move from overwintering areas to the sea in the spring, then return to freshwater in August to spawn in September and October and remain to overwinter (DeCicco 1989). Char return to natal streams to spawn but are less discriminating in selecting an overwintering system (Armstrong 1974, DeCicco 1985). Spawning populations are composed of a single stock while overwintering populations may contain several spawning stocks. Sport fisheries in the Kotzebue area focus on spawning and overwintering populations in rivers while subsistence fisheries mainly target overwintering mixed stock populations in rivers and the incidental commercial harvest is on mixed stock migrants in Kotzebue Sound.

Subsistence Fisheries

Char are harvested in local subsistence fisheries near Kivalina, Noatak, Sheshalik and Kotzebue. Due to migratory patterns, char are seasonally abundant in localities where they are harvested. Residents of Kivalina harvest char throughout most of the year, but approximately 80% of the annual harvest is taken with seines in the Wulik and Kivalina rivers during September and October (Burch 1985). Estimated fall harvests in Kivalina have ranged from 49,720 to 5,000 between 1959 and 1989 (Appendix A1). Char are either stored in willow cribs on the riverbank or taken back to the village in burlap sacks for later consumption. Char are also taken with hand held jigs during the winter and with rod and reel and gill nets in the spring. People of Noatak harvest char with seines in the fall and with hand held jigs during the winter, but only limited harvest data are available (Appendix A1).

Commercial Fishery

There is no directed commercial fishery for char in northwestern Alaska but char are harvested incidentally in commercial fishing district 331, the Kotzebue district (Figure 2). Gill nets up to 275 m (150 fathoms) in length with mesh sizes from 121 to 195 mm stretch measure are fished. Open skiffs powered by outboard motors are used to operate fishing gear and to transport fish to buyers in Kotzebue. All fish sold are recorded on State of Alaska fish tickets. Some harvested char are sold and some are retained for personal use (subsistence). In 1979 the Alaska Board of Fisheries adopted regulations opening this fishery on 10 July and running through 31 August. Initial openings are set at two 24 hour fishing periods per week during July and

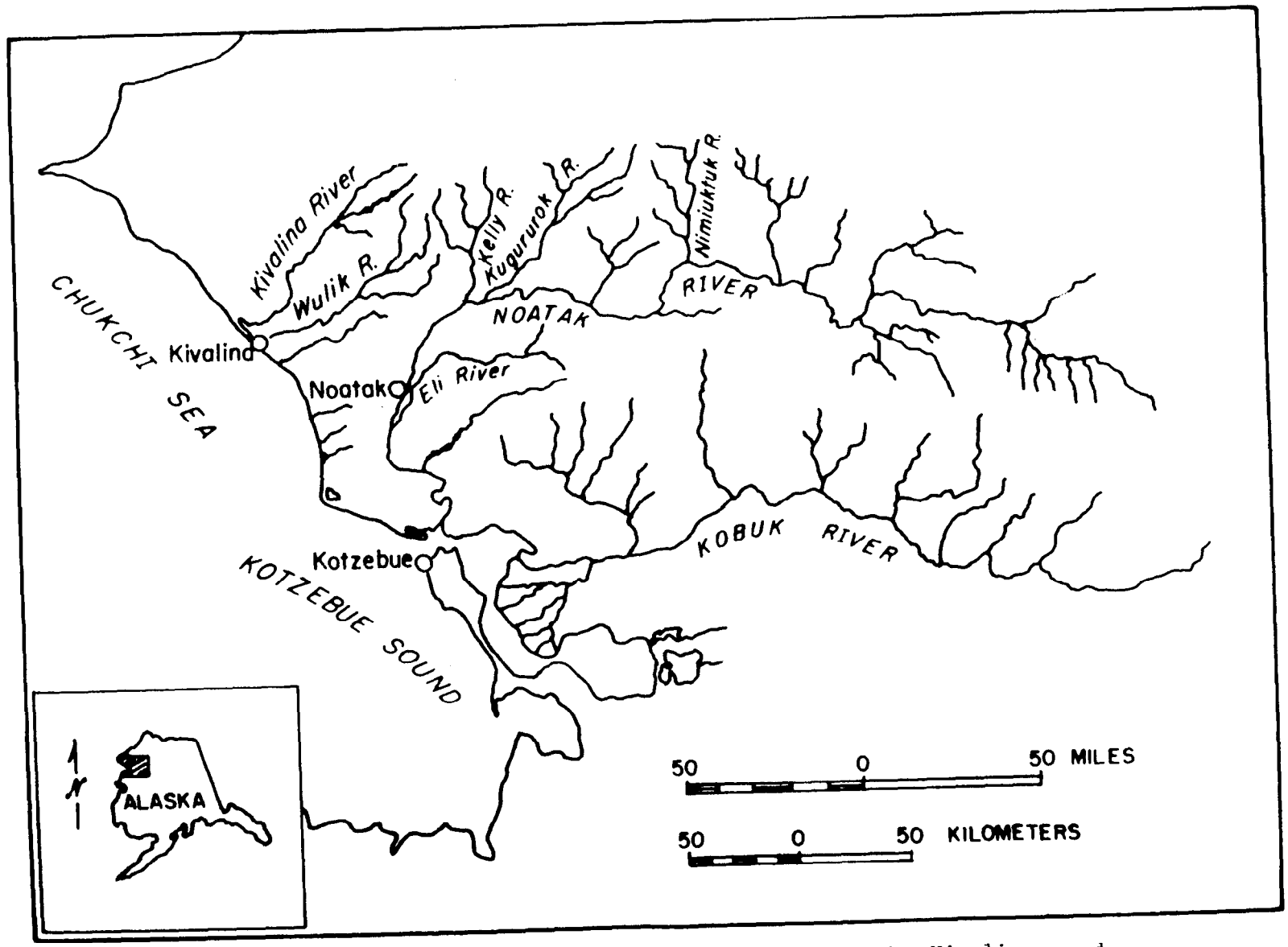

Figure 1. Study area including the watersheds of the Wulik, Kivalina, and Noatak rivers.

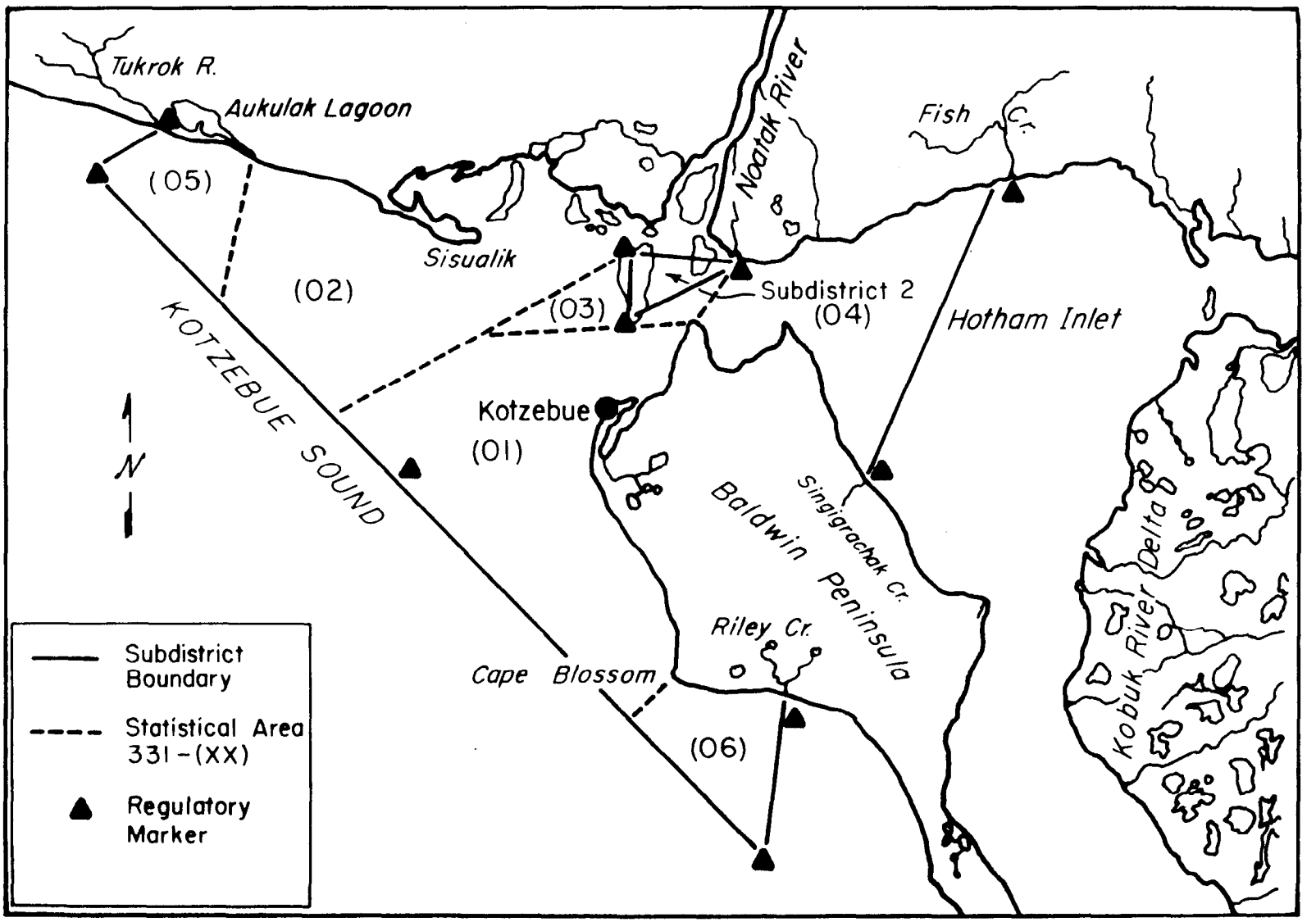

Figure 2. Commercial fishing District 331 and its subdistricts in Kotzebue Sound.

increased to two 36 hour fishing periods during August. Period length and openings can be changed by emergency order depending on the strength of the chum salmon run. The numbers of char sold in this fishery has ranged from 0 (no recorded sales) to 7,746 since 1966 (Appendix A2). For many years, the only char harvest data available are sales records from fish tickets and do not represent total catches in the fishery. In 1989, the Alaska Board of Fisheries created the new Subdistrict 2 near the mouth of the Noatak River (Figure 2). This subdistrict will remain closed except during salmon runs which are well above average (Merkouris and Lean 1989). Char are usually taken during mid to late August in the last three or four fishing periods.

Sport Fishery

Annual sport fish harvests from freshwater in northwestern Alaska have averaged an estimated 1,382 char since 1977 with the highest harvest of 3,804 in 1984 and the lowest of 199 in 1978 (Mills 1979-1989). Since 1985, harvests have remained around the 11 year average (Appendix A3; Figure 3). Although harvest and effort are relatively low, the quality of the fishery is high. Since 1967, 18 out of 87 Arctic char *Salvelinus alpinus/Salvelinus malma* qualifying for State of Alaska trophy fish certificates have come from the Kotzebue area. In addition, the current state record char, a fish weighing 7.9 kg was taken in the Wulik River in 1969.

The Alaska Department of Fish and Game has conducted research on char in the Kotzebue area intermittently since 1968 with the long term goals of assessing the status of char stocks and developing a better understanding of their biology. The objectives for this project in 1989 were to:

1. count the number of char in the spring subsistence harvest at Kivalina village and determine the sex ratio and mean length of that harvest;

2. estimate the number of char which overwintered in the Wulik River;

3. estimate the sex ratio and mean length of the overwintering population in the Wulik River;

4. estimate the Relative Stock Density (RSD Gabelhouse categories) of summer spawners remaining in the Wulik River;

5. estimate the number of char spawning in the Kugururok River with standard aerial survey techniques and assess the variability of counts by multiple counts of index areas;

6. estimate the number of char harvested incidentally in the Kotzebue Sound commercial salmon fishery; and,

7. estimate the number of char harvested in the fall subsistence fishery at Kivalina.

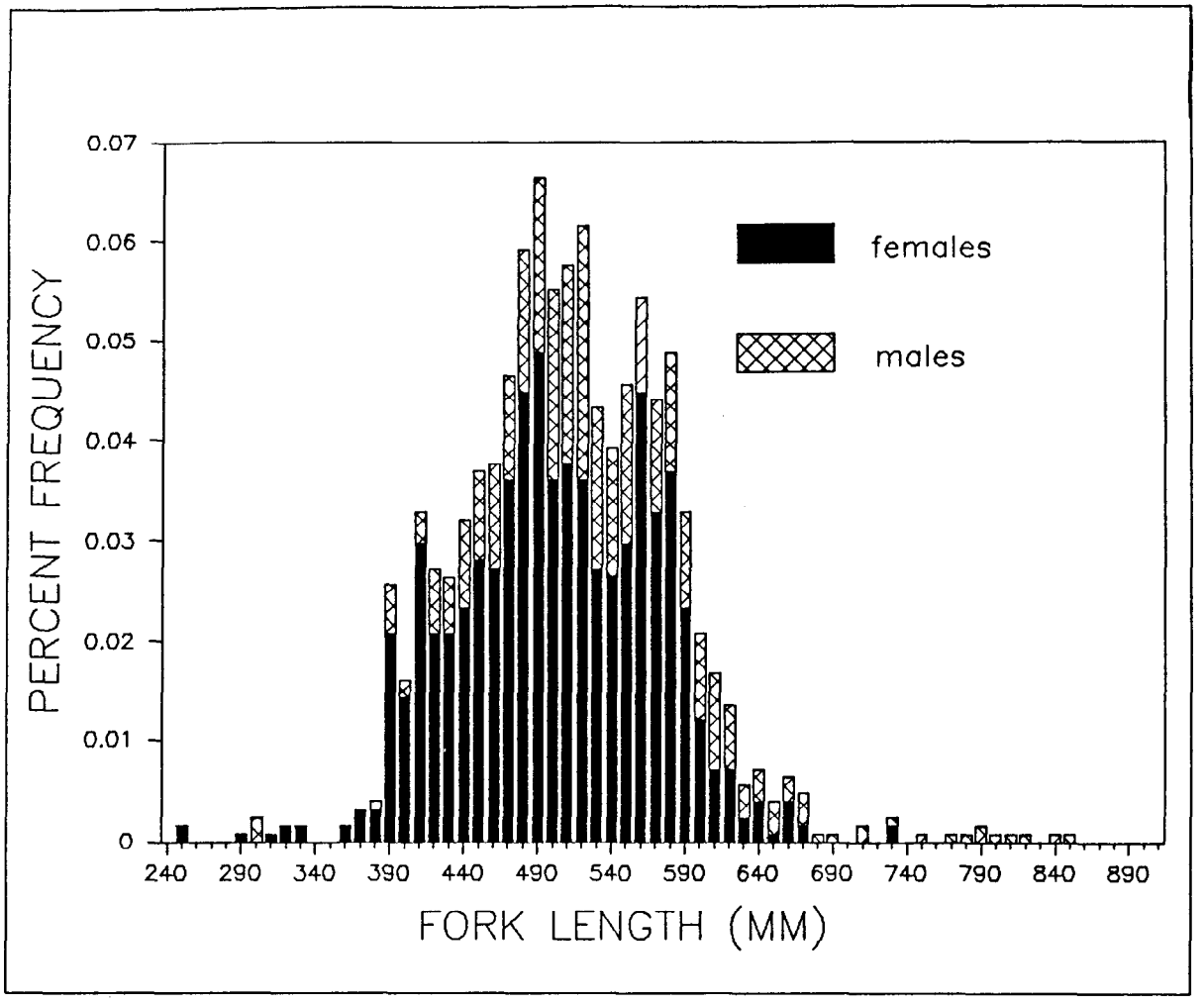

Figure 3. Length frequency by sex of the 1989 Kivalina spring subsistence harvest of char.

In addition, aerial counts of overwintering char in the Wulik and Kivalina rivers were conducted in response to environmental concerns in the vicinity of the Red Dog Mine.

METHODS

Kivalina Spring Subsistence Harvest

The spring subsistence fishery at Kivalina usually has both gill net and hook and line components. During the spring of 1989, char were caught on hook and line for only one day after which the water rose in elevation and became very turbid from spring runoff. Because of a much higher than normal snow pack, turbid conditions prevailed throughout the out-migration of char and almost the entire catch was by gill net. This condition made the collection of harvest data in 1989 easier than on a normal year. Char harvested in this fishery were counted when each participant, after having checked his/her net, returned to the village with their catch. Individual fish were measured to the nearest millimeter in fork length, sexed, and inspected for the presence of tags or tag wounds.

Estimates of mean length were generated with standard normal procedures. Simple averages and squared deviations from the means were used to calculate means and variances of the means:

$$\bar{l} = \sum_{i=1}^{n} \frac{l_i}{n}; \text{ and,} \quad (1)$$

$$V[\bar{l}] = \sum_{i=1}^{n} \frac{(l_i - \bar{l})^2}{n\,(n-1)}; \quad (2)$$

where:

l_i = length of fish i; and,

n = sample size.

The proportions of fish in sex categories were estimated as multinomial proportions. The proportions of each category were estimated with the following formulas (Cochran 1977):

$$\hat{p}_j = \frac{n_j}{n}; \text{ and,} \quad (3)$$

$$V[\hat{p}_j] = \frac{\hat{p}_j(1-\hat{p}_j)}{n-1} \quad (4)$$

where:

n_j = the number in the sample from group j;

n = sample size; and

$\hat{p}_j$ = the estimated fraction of the population that is made up of group j.

Population Abundance Estimate

A two stage mark-recapture experiment was used to estimate the number of char which overwintered in the Wulik River during the winter of 1988-1989. Two subsistence fishing crews from Kivalina were hired to seine char in the lower 20 km of the river from 14 - 17 September 1988 for the initial marking event. Char were tagged using individually numbered Floy FD 67 internal anchor tags, sexed using external morphological characteristics (head shape and relative length) and measured to the nearest millimeter in fork length. The spring 1989 subsistence fishery at Kivalina acted as the recapture event. Fish in the second event were captured using gill nets which varied between 76 mm and 102 mm in stretch measure. Char harvested in this fishery were counted, sexed, measured to the nearest millimeter in fork length and inspected for the presence of tags or tag wounds. A modified Peterson estimator (Chapman 1951) was selected to estimate the abundance of char over 250 mm FL. The population abundance estimate and the approximate variance of the estimate was calculated with the following formulas (Seber 1982).

$$\hat{N} = \frac{(E+1)(F+1)}{(G+1)} - 1; \text{ and,} \qquad (5)$$

$$\hat{V}[N] = \frac{(F+1)(E+1)(F-R)(E-R)}{(G+1)^2(G+2)}; \qquad (6)$$

where:

E = the number marked during the first period;

F = the number captured during the second period;

G = the number captured during the second period with marks from the first period; and,

N = abundance.

Assumptions for the accurate use of the estimator are:

1. a closed population (neither recruitment nor mortality);

2. each fish has the same probability of being marked (or being recaptured), or marked char mix completely with unmarked char

between sampling events, and there is equal mortality between marked and unmarked fish;

3. marks are not lost; and,

4. marked fish can be recognized.

The population was assumed to be closed throughout the winter after the last fall in-migrating fish entered the river. Some fish undoubtedly did enter the river after the marking event, thus the estimate is germane to the time that the in-migration ended. Any mortality would occur as overwintering or winter fishing mortality and happen after all fish were on overwintering grounds, thus affecting marked and unmarked fish equally. This should not bias the estimate. Fish had the entire winter to mix, and the entire population except for the summer spawners which remain in the river, migrated through the spring fishery on their way to the sea, providing equal likelihood of capture. Growth recruitment over the winter was tested in accordance with Robson and Flick (1965) by comparing the length distribution of marked versus unmarked fish in the second sampling event using contingency tables. The hypothesis that the subsistence fishery (recapture event) was not size selective was tested by comparing the size distribution of fish marked in the fall with that of tagged fish recaptured in the fishery (Seber 1982). The test used was the Kolmogorov-Smirnov two-sample test (Conover 1980). The hypothesis that the subsistence fishery was not size selective was rejected. The abundance of each significant size class (as determined by contingency table analysis) was estimated separately as suggested by Ricker (1975) and then summed to obtain an abundance estimate. The variance of the estimate was the sum of the variances for each size class.

The mean length of the overwintering population in the Wulik River was estimated using standard normal procedures and the sex ratio was estimated as a multinomial proportion according to Cochran (1977). See the previous section for formulas.

Incidental Commercial Harvest

The incidental harvest of char in the commercial salmon fishery at Kotzebue was monitored by two crew members stationed in Kotzebue during the latter part of the fishery when most char were caught. Data for estimating the harvest was collected by interviewing commercial fishermen as they delivered fish to buying stations. Data collected from individual deliveries included the date and time of the delivery, the number of salmon and the number of char in each delivery, the mesh size fished and the area fished. Char were measured to the nearest millimeter in fork length, and their sex was determined by external examination. The number of char sold and the number kept for personal consumption was determined for each delivery by asking the fishermen and counting the number of char sold or kept.

Data from dockside interviews of Kotzebue area fishermen were analyzed for each fishing period and area in which char are intercepted. Estimates of the catch of char per period/area were calculated by two methods, each based on

information from fish tickets (Alaska Department of Fish and Game 1989). First, the average observed catch of char was expanded by fishing effort.

Expansion Estimate:

$$\hat{C} = \bar{c}\, D \tag{7}$$

where:

$\hat{C}$ = estimated catch of char;

$\bar{c}$ = average number of char per delivery estimated through interviews of fishermen; and,

D = number of deliveries from fish tickets.

The variance for these expansions also has a finite population correction factor:

$$V[\bar{Y}] = (1-d/D)D^2V[\bar{c}] \tag{8}$$

where:

d = the number of deliveries observed by the interviewers.

The second method of estimating the catch of char was based on the ratio of the number of char to the number of chum salmon observed in catches. This procedure takes advantage of any significant correlations between the catch of chum salmon and the catch of char among deliveries. The average ratios were calculated according to jackknife procedures in Efron (1982) because these procedures minimize the inherent bias of ratio estimators (Cochran 1977). Ratio estimates were biased when few deliveries are counted, but bias was negligible when many deliveries are counted and a jackknife procedure was used to calculate the ratio estimator (Quenouille 1956):

$$\hat{C} = r\, X_{CH} \tag{9}$$

where:

r = average ratio of char to chum salmon in the catch as estimated from the observed catches through jackknife procedures; and,

X_{CH} = number of chum salmon on fish tickets.

The variance of $\hat{Y}$ was calculated with a finite population correction factor:

$$V[\hat{C}] = (1-d/D)X^2V[r] \tag{10}$$

Although the catches of char were calculated with both procedures, only the more precise estimates were reported. The estimates based upon ratios are more precise than expansions by fishing effort only when the correlation between catches of char and chum salmon by delivery are large relative to the coefficients of variation for these variables (Cochran 1977).

For those fishing periods and areas in which no fishermen were interviewed, expansions to estimate harvest were based on the ratio of char caught to char sold averaged across periods and areas named during interviews.

$$\hat{C} = \hat{\bar{R}} X_{DV} \tag{11}$$

where:

$\bar{R}$ = ratio of the number of char caught to char sold averaged across fishermen interviewed in a period/area and among period/areas for which there is information; and,

X_{DV} = number of char sold.

$$V[\hat{C}] = X_{DV}^2 V[\hat{\bar{R}}] \tag{12}$$

$$V[\hat{\bar{R}}] = (1-a/A) \frac{\Sigma_1^a (\bar{R}_i - \hat{\bar{R}})^2}{a(a-1)} + \frac{\Sigma_1^a (1-d_i/D_i)\, V[\hat{R}_i]}{A} \tag{13}$$

where:

a = number of period/areas with interview data;

N = number of period areas;

A = the number of interviewed deliveries; and,

$\bar{R}_i$ = the ratio of char caught to char sold averaged over the fishermen interviewed who fished in period/area i.

Aerial Counts

Aerial counts of overwintering char were conducted using a PA-18 aircraft and standard aerial survey techniques.

RESULTS

Kivalina Spring Subsistence Harvest

The people of Kivalina harvested an estimated 1,888 char during the spring fishery in Kivalina Lagoon. Of these, 1,631 were counted from gill net catches and 157 were counted from hook and line catches. It is estimated that an additional 100 fish were taken on hook and line. Char ranged in fork length from 246 mm to 850 mm with a mean fork length of 506 mm (SE = 2.05, Figure 3). The mean fork length of females, 498 mm (SE = 2.28, range = 246-725 mm, n = 878,), was less than that of males, 529 mm (SE = 4.07, range = 378-850 mm, n = 371). The estimated proportion of females was 0.70 (SE = 0.04), and that of males was 0.30 (SE = 0.04; Appendix A4).

Population Abundance Estimate

An estimated 76,892 (SE = 16,811) char over 400 mm FL overwintered in the Wulik River during the winter of 1988-1989.

During the first sampling event (14 - 17 September 1988) 4,071 char were tagged in the lower 20 km of the Wulik River. During the second sampling event (the spring subsistence fishery), 41 tag recoveries were reported for 1,705 char examined. Of these, 1,249 char were measured for length and 32 tagged fish with length measurements were used in the calculation of population abundance.

The Kolmogorov-Smirnov two sample test was used to compare the cumulative distribution of fork lengths between char marked in September 1988 and those recaptured in June 1989. Because the number of char tagged was too great for the test to be run on the complete data set, the data for the marked fish were randomly divided in half and two tests were done. Both tests showed significant differences in length distributions ($D = 0.46$, $P < 0.05$, and $D = 0.51$; $P < 0.05$), indicating that size differences existed between the two groups of fish. The size differences probably resulted from gear bias in the second sampling event. Fish lengths were then grouped by size and a series of comparisons using contingency table analysis were conducted. The population was stratified into two length groups, fish from 400 mm to 549 mm FL in one group and fish larger than 549 mm FL in the other ($v^2 = 1.49$, $df = 1$, $P < 0.05$). The Kolmogorov-Smirnov two-sample test showed no significant difference ($D = 0.13$, $P = 0.64$) between the cumulative distribution of fork lengths of fish captured without tags and those with tags in the spring subsistence fishery (recapture event). The estimate was therefore calculated only for char over 400 mm in fork length. Of 826 char between 400 and 549 mm FL examined in the recapture event, 23 were tagged, and of 352 char over 549 mm FL, 8 were tagged. The 71 char less than 400 mm FL (one tag recovery) were ignored.

Because char do not feed when overwintering in freshwater (DeCicco 1985) it was expected that there would be little or no growth between sampling events. Upon examination of the lengths of recaptured fish, it was found that char grew an average of 25 mm over the winter (Table 1).

Table 1. Growth of char recaptured in the 1989 spring subsistence fishery at Kivalina.

Date Tagged	Fork Length[a]	Date Recovered	Fork Length	Sex	Growth Increment[a]	Growth Per Day[b]
9-17-88	460	6-20-89	477	F	17	0.06
9-17-88	430	6-22-89	457	M	27	0.10
9-17-88	460	6-19-89	492	F	32	0.12
9-17-88	630	6-14-89	670	M	40	0.15
9-17-88	465	6-20-89	489	F	24	0.09
9-17-88	540	6-20-89	568	M	28	0.10
9-14-88	466	6-21-89	498	F	32	0.11
9-15-88	422	6-20-89	456	M	34	0.12
9-15-88	450	6-19-89	465	F	15	0.06
9-15-88	460	6-14-89	480	F	20	0.07
9-15-88	450	6-19-89	472	F	22	0.08
9-15-88	557	6-14-89	588	F	31	0.12
9-15-88	496	6-14-89	521	M	25	0.09
9-15-88	393	6-19-89	406	F	13	0.05
9-16-88	445	6-22-89	470	F	25	0.09
9-16-88	455	6-19-89	472	M	17	0.06
9-16-88	388	6-14-89	408	F	20	0.07
9-16-88	473	6-22-89	498	M	25	0.09
9-16-88	395	6-21-89	419	M	24	0.07
9-16-88	470	6-20-89	485	M	15	0.05
9-17-88	545	6-19-89	564	F	19	0.07
9-17-88	460	6-19-89	485	M	25	0.09
9-15-88	510	6-19-89	532	F	22	0.08
9-15-88	481	6-16-89	510	M	29	0.10
9-14-88	519	6-14-89	544	F	25	0.09
9-16-88	627	6-14-89	668	M	41	0.15
9-16-88	368	6-17-89	391	F	23	0.08
9-16-88	522	6-22-89	565	M	43	0.15

[a] Millimeters.
[b] Millimeters per day.

The rate of capture of char by size in the recapture event was examined by calculating the cumulative average of the frequency distribution of the catch by fork length (Table 2). The rate of capture of fish less than 400 mm was similar to that of fish over 400 mm, and remained similar for fish to 564 mm. Consequently, no adjustments were made to account for growth recruitment.

The estimated abundance of char from 400 mm to 549 mm FL overwintering in the Wulik River was 61,989 (SE = 12,135), and the estimated abundance of those over 549 mm FL was 14,903 (SE = 4,676). Both unstratified and stratified abundance estimates for this population were calculated. The variance of stratified estimate was less than that of the unstratified estimate and it was therefore considered to be the better of the two.

Mean Length and Sex Composition of Wulik River Char

The fork length of fish tagged in the first event ranged from 225 to 840 mm. Females ranged in fork length from 225 to 746 mm (n = 2,496) while males ranged from 260 to 840 mm (n = 1,468). Sex was not determined for 107 fish which ranged in fork length from 259 to 671 mm (Figure 4).

The mean fork length of char which overwintered in the Wulik River during the winter of 1988-1989 and were captured in the first sampling event was 425 mm (SE = 1.38). The mean length of females was 406 mm FL (SE = 1.65) and that of males was 461 mm FL (SE = 2.28). The sex ratio was 1 male to 1.7 females for the 3,964 fish for which sex was determined. The estimated proportion of males was 0.37 (SE = 0.01) and that of females was 0.63 (SE = 0.01; Appendix A4). Because both stratified and unstratified abundance estimates for char over 400 mm FL were of similar magnitude, 76,982 vs. 80,244, there is no indication that size bias occurred in the first sample. The mean size and sex ratio of fish over 400 mm Fl in the first sample should therefore be representative of the overwintering population for fish above 400 mm. The mean length of females over 400 mm in length was 480 mm FL (SE = 1.52), while the mean length for males was 501 mm FL (SE = 2.17), and the mean length of all fish over 400 mm FL was 490 mm FL (SE = 1.29). The sex ratio of fish over 400 mm FL was 1 male to 1.45 females. The estimated proportion of males was 0.41 (SE = 0.01) and that of females was 0.59 (SE = 0.01).

Incidental Commercial Harvest

An estimated 4,874 char (SE = 404, CV = 8.3%) were caught incidentally in the Kotzebue Sound commercial fishery for chum salmon during the last five fishing periods from 14 - 30 August 1989 (Table 2). Of these, 3,093 (62.7%) were sold. No char were recorded on fish tickets and none were reported taken prior to 15 August, so the estimated harvest is for the 1989 fishing season. Char moved through the fishery very rapidly with catches peaking during the first fishing period in which char were captured (Table 3). Catches were consistently highest in area 2 which is typical for the fishery as most char moving into Kotzebue Sound enter from the west with a movement of lesser magnitude entering from the south along the coastline of the Baldwin Peninsula (Figure 2). Char catches peak as chum salmon catches are beginning to decline near the end of the fishing season (Table 4; Figure 5).

Table 2. Cumulative average catch frequency by size of char in the 1989 Kivalina spring subsistence fishery.

Recovery Length[a]	Frequency Distribution[b]	Cumulative Average[c]
391	55	40.29
400	19	39.80
405	20	40.52
406	6	41.25
408	5	42.56
419	43	44.00
456	148	44.04
457	8	39.71
465	42	41.09
470	27	41.05
472	13	41.71
477	34	43.15
480	27	43.63
485	44	44.56
489	26	44.59
492	28	45.75
498	36	46.93
510	90	47.71
521	81	44.46
532	62	41.42
533	4	39.55
544	50	43.10
564	124	42.33
565	9	32.16
568	16	35.43
588	105	38.67
614	63	25.40
668	44	16.00
670	3	6.67
770	9	8.50
900	8	8.00

[a] Fork length (mm) of char tag recoveries from the spring fishery.
[b] Number of fish examined between adjacent sizes of fish recovered with tags.
[c] Average occurence of fish in this size class and larger.

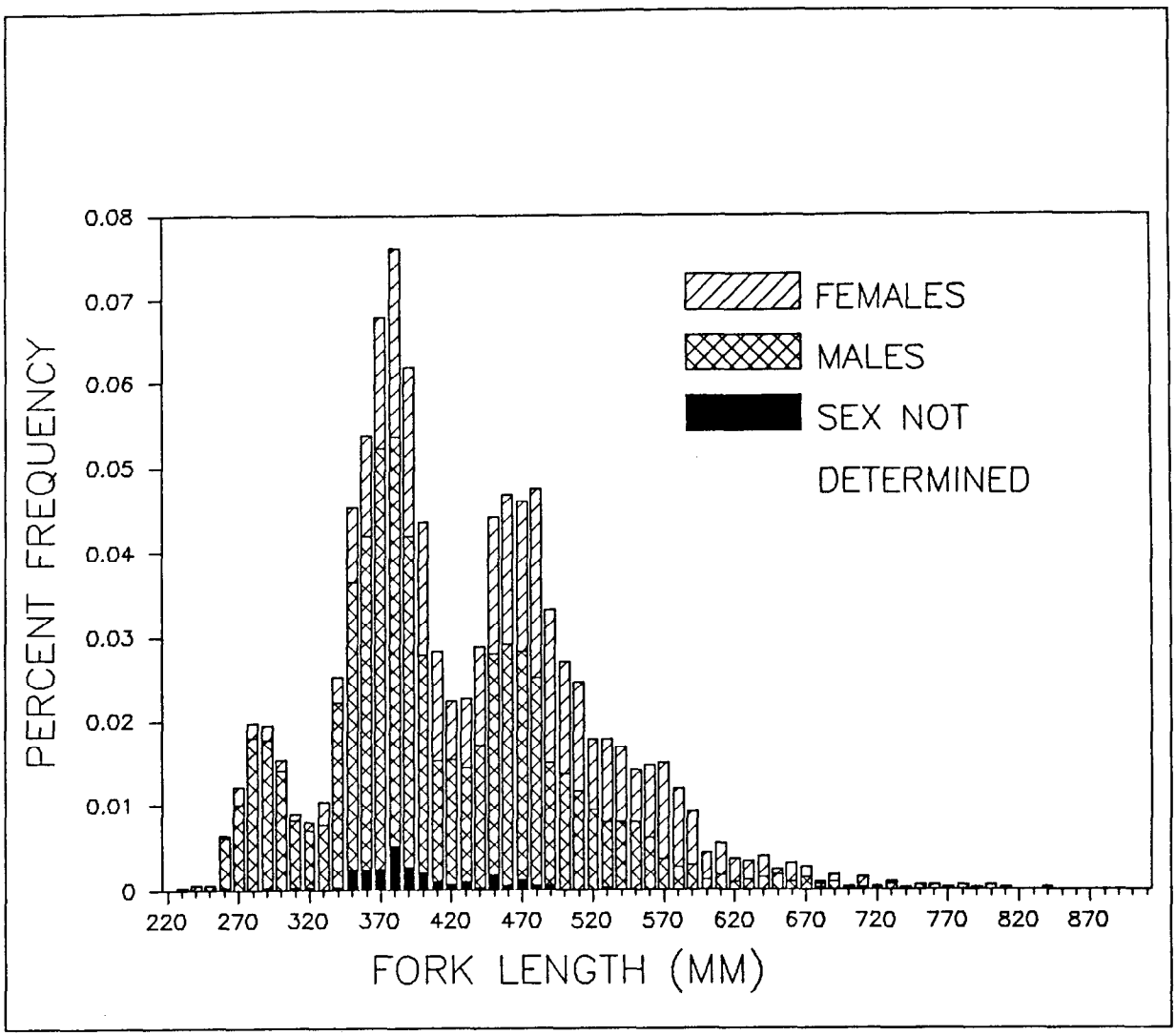

Figure 4. Length frequency by sex of char marked in the Wulik River during the fall of 1988.

Table 3. Estimated catch of char by fishing period and area in the Kotzebue Sound commercial salmon fishery during 1989.

Fishing Period	Area	Interviews: Deliveries (d)	Interviews: Char[a]	Interviews: Chum Salmon[a]	Fish Tickets: Deliveries (D)	Fish Tickets: Chum Salmon (X)	Fish Tickets: Char	Jacknife Ratio Estimates: Ratio (r)	Jacknife Ratio Estimates: SE	Expansion Estimates: Mean	Expansion Estimates: SE	Estimated Catch of Char: Catch	Estimated Catch of Char: SE	Estimated Catch of Char: CV[C][b](%)
Period 11	1	61	182	3,550	163	11,083	176			3.02	0.44	492	56	11.5
Aug 14-16	2	83	985	5,577	212	13,420	1,431	0.18	0.03			2,391	303	12.7
	3	10	14	453	21	1,087	20	0.03	0.01			34	9	27.4
	4	3	18	65	3	168	9			6.00	4.16	18	0	0.0
	5	3	144	354	7	515	266	0.30	0.25			156	98	63.3
	6	2	13	267	27	5,559	90			6.50	6.50	176	168	96.2
Period 12	1	42	167	1,553	98	3,797	212			3.98	0.77	390	57	14.7
Aug 17-19	2	20	163	746	85	3,747	551			8.42	2.11	716	157	21.9
	3	0	0	0	7	282	33	1.46[c]	0.41[c]			48	13	27.9
	4	0	0	0	3	117	0					0	0	0.0
	5	0	0	0	1	28	29	1.46	0.41			34	12	24.7
	6	0	0	0	1	2	2	1.46	0.41			2	1	40.6
Period 13	1	27	22	1,357	72	3,300	39			0.91	0.32	66	18	27.7
Aug 21-23	2	39	137	2,209	80	3,948	162	0.06	0.01			245	38	15.7
	3	4	7	219	10	547	9			1.75	1.75	18	14	77.5
	4	0	0	0	0	0	0					0	0	0.0
	5	0	0	0	2	160	12	1.46	0.41			14	5	34.8
	6	3	3	1,146	7	2,454	3	<0.01	<0.01			6	5	78.0

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Table 3. (page 2 of 2)

Fishing Period	Area	Interviews: Deliveries (d)	Interviews: Char[a]	Interviews: Chum Salmon[a]	Fish Tickets: Deliveries (D)	Fish Tickets: Chum Salmon (X)	Fish Tickets: Char	Jacknife Ratio Estimates: Ratio (r)	Jacknife Ratio Estimates: SE	Expansion Estimates: Mean	Expansion Estimates: SE	Estimated Catch of Char: Catch	Estimated Catch of Char: SE	Estimated Catch of Char: CV[C][b](%)
Period 14	1	0	0	0	32	1,570	16	1.46	0.41			19	7	34.2
Aug 24-26	2	0	0	0	24	1,130	14	1.46	0.41			16	6	35.6
	3	0	0	0	2	84	0					0	0	0.0
	4	0	0	0	0	0	0					0	0	0.0
	5	0	0	0	0	0	0					0	0	0.0
	6	0	0	0	13	1,761	11	1.46	0.41			13	4	34.4
Period 15	1	0	0	0	17	485	3	1.46	0.41			4	1	30.5
Aug 28-30	2	0	0	0	23	1,468	14	1.46	0.41			16	6	35.6
	3	0	0	0	2	33	0					0	0	0.0
	4	0	0	0	0	0	0					0	0	0.0
	5	0	0	0	0	0	0					0	0	0.0
	6	0	0	0	3	405	0					0	0	0.0
Totals		297	1,855	17,496	915	57,150	3,102					4,874	404	8.3

[a] Summed over all deliveries.

[b] Coefficient of Variation.

[c] Ratios and SE of ratios for all period/areas for which there was no interview data are ratios of char caught to char sold.

Table 4. Kotzebue Sound commercial chum salmon and estimated char catch summary with CPUE by permit hour, 7 - 30 August 1989.

		AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	AREA 6	TOTAL
	PERMITS	64	64	9	5	0	5	127
PERIOD 9	CS	15417	25919	1693	640	0	1072	44741
	CPUE CS	6.69	11.25	5.23	3.56	0	5.96	9.79
AUG 7-9	DELIVERIES	187	210	22	8	0	8	435
	CS/DEL	82.66	123.43	76.95	80	0	134	102.85
	PERMITS	64	93	10	0	4	3	138
PERIOD 10	CS	12620	24260	1313	0	2128	1725	42046
	CPUE CS	4.11	5.43	2.74	0	11.08	11.98	6.35
AUG 10-12	DELIVERIES	178	273	26	0	8	6	491
	CS/DEL	70.9	88.86	50.5	0	266	287.5	85.63
	PERMITS	55	73	8	2	2	12	126
	CS	11038	13420	1087	168	515	5559	31787
	CPUE CS	4.18	3.83	2.83	1.75	5.36	9.65	5.26
PERIOD 11	DELIVERIES	163	212	21	3	7	27	433
	CS/DEL	67.72	63.30	51.76	56.00	73.57	205.89	73.41
	DV SOLD	176	1431	20	9	266	90	1992
AUG 14-16	EST. DV	492	2391	34	18	156	176	3267
	CPUE DV	0.19	0.68	0.09	0.19	1.63	0.31	0.54
	EST. DV/DEL	3.02	11.28	1.62	6.00	22.29	6.52	7.55
	DV/CS	0.04	0.18	0.03	0.11	0.30	0.03	0.10
	PERMITS	41	37	2	3	1	1	80
	CS	3797	3747	282	117	28	2	7973
	CPUE CS	1.93	2.11	2.94	0.81	0.58	0.04	2.08
PERIOD 12	DELIVERIES	98	85	7	4	1	1	196
	CS/DEL	38.74	44.08	40.29	29.25	28.00	2.00	40.68
	DV SOLD	212	551	33	0	29	2	827
AUG 17-19	EST. DV	390	716	116	0	29	2	1253
	CPUE DV	0.20	0.40	1.21	0.00	0.60	0.02	0.33
	EST. DV/DEL	3.98	8.42	16.57	0.00	29.00	2.00	2.53
	DV/CS	0.10	0.19	0.41	0.00	1.04	1.00	0.16

- continued -

Table 4. (page 2 of 2)

		AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	AREA 6	TOTAL
	PERMITS	29	39	4	0	1	4	65
	CS	3300	3948	547	0	160	2453	10408
	CPUE CS	2.37	2.11	2.85	0	3.33	12.78	3.34
PERIOD 13	DELIVERIES	72	80	10	0	2	7	171
	CS/DEL	45.83	49.35	54.70	0.00	80.00	350.43	60.87
	DV SOLD	39	162	9	0	12	3	225
AUG 21-23	EST. DV	66	245	18	0	12	3	353
	CPUE DV	0.05	0.13	0.09	0.00	0.25	0.02	0.11
	EST. DV/DEL	0.92	3.06	1.80	0.00	6.00	0.43	2.06
	DV/CS	0.02	0.06	0.03	0.00	0.08	0.00	0.03
	PERMITS	17	13	1	0	0	8	35
	CS	1570	1130	84	0	0	1761	4545
	CPUE CS	1.92	1.81	1.75	0	0	7.78	2.71
PERIOD 14	DELIVERIES	32	24	2	0	0	13	71
	CS/DEL	49.06	47.08	42.00	0.00	0.00	135.46	64.01
		16	14	0	0	0	2	32
AUG 24-26	EST. DV	26	15	0	0	0	2	43
	CPUE DV	0.03	0.02	0.00	0.00	0.00	0.01	0.03
	EST. DV/DEL	0.81	0.63	0.00	0.00	0.00	0.15	0.61
	DV/CS	0.02	0.01	0.00	0.00	0.00	0.00	0.01
	PERMITS	10	9	1	0	0	2	17
	CS	485	1468	33	0	0	405	2391
	CPUE CS	1.01	3.4	0.69	0	0	4.22	2.93
PERIOD 15	DELIVERIES	17	23	2	0	0	3	45
	CS/DEL	28.53	63.83	16.50	0.00	0.00	135.00	53.13
		3	14	0	0	0	0	17
AUG 28-30	EST. DV	5	15	0	0	0	0	20
	CPUE DV	0.01	0.03	0.00	0.00	0.00	0.03	0.06
	EST. DV/DEL	0.29	0.65	0.00	0.00	0.00	0.00	0.44
	DV/CS	0.01	0.01	0.00	0.00	0.00	0.00	0.01

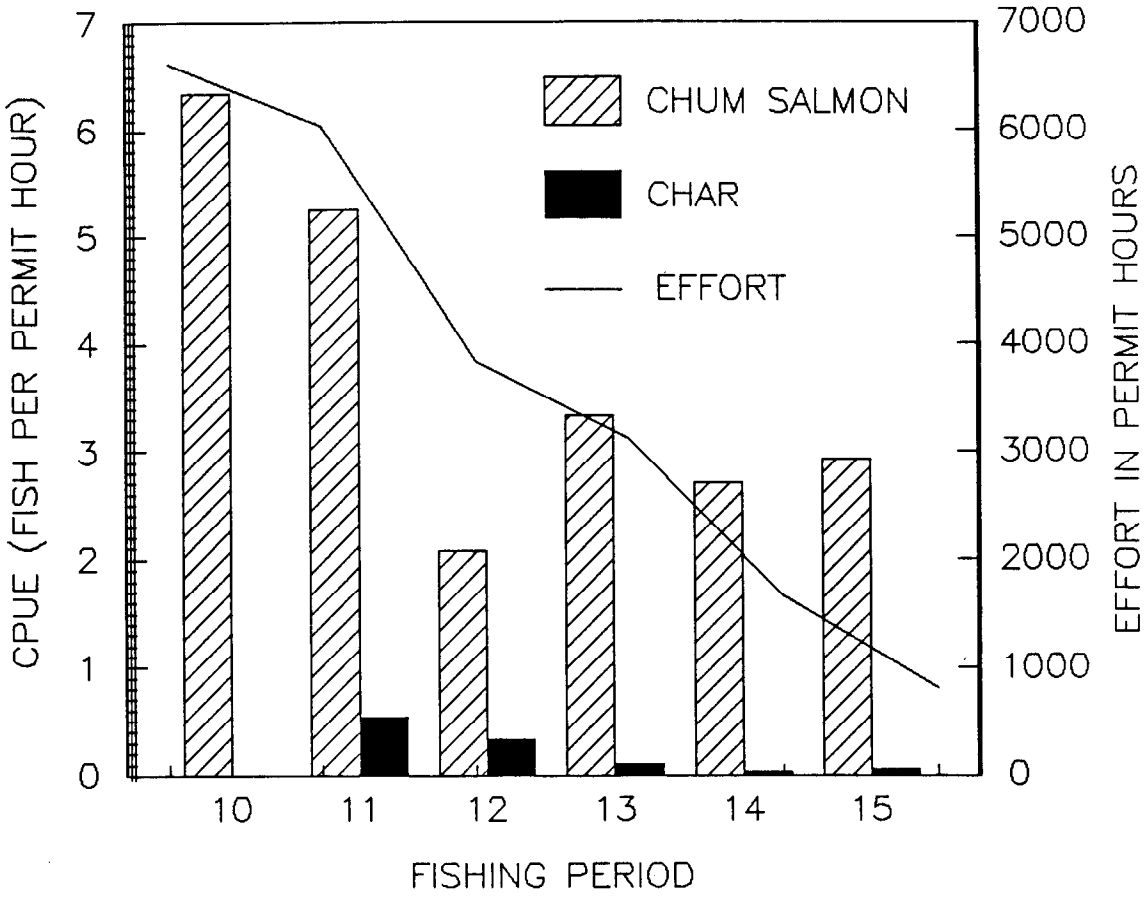

Figure 5. Effort and CPUE for char and chum salmon by fishing period in the 1989 Kozebue Sound commercial fishery.

The ratio of estimated char to chum salmon catch was 0.10 in fishing period 11 (14 - 16 August), and 0.16 in fishing period 12 (17 - 19 August). It then declined rapidly in subsequent fishing periods. The estimated catch of 3,267 char in fishing period 11 (14 - 16 August) was the highest for any fishing period. This was also the first fishing period in which char were taken. The char catch dropped to an estimated 1,253 fish in fishing period 12 (17 - 19 August) and then declined in subsequent fishing periods (Figure 6).

The ratio of char sold to char caught was 1:1.46 for all of the period/areas for which there were interview data. This ratio was used to expand the fish ticket data on char sold for all period/areas for which there were no interview data resulting in an estimate of 194 (SE = 22).

Area 2 of the Kotzebue fishing district produced the highest catches of char with an estimated 3,382 fish (68.6%) being taken (Figure 2). In Area 1 an estimated 979 char (19.9%) were taken. In the remainder of the subdistrict (Areas 3, 4, 5 and 6) an estimated 569 char (11.6%) were caught (Figure 7). Of the 57,140 chum salmon taken during the last five commercial fishing periods, 20,190 (35.5%) were taken in Area 1, 23,749 (41.6%) in Area 2, 10,180 (17.8%) in Area 6 and the remaining 3,021 (5.3%) were taken in Areas 3, 4, and 5.

Different mesh size nets caught different proportions of char (Table 5). Four mesh sizes ranging from 146 to 159 mm (5-3/4 to 6-1/4 inch) stretch measure were most frequently used in the commercial salmon fishery and although the ratios of char to chum salmon in catches were significantly different in different mesh sizes ($\chi^2 = 43.89$, $P < 0.0001$, $df = 3$), one mesh size (152 mm) accounted for most of the difference. When catches in the three other mesh sizes were compared, no significant differences were found in the proportions of char and chum salmon ($\chi^2 = 1.96$ $P > 0.25$, $df = 2$). Interviews from fishery participants using only a single mesh size were used in this analysis. Nets of 149 mm (5-7/8 inch) were the most commonly used in this fishery comprising 81.2% of the 261 interviews in which a single mesh size was used. Char comprised of 8.4%, 9.9% and 11.5% of catches in 146 mm, 149 mm and 159 mm nets respectively, while catches in 152 mm nets were composed of 5.8% char. As mesh size increased, the number of chum salmon per delivery increased ranging from a mean of 48.6 in 146 mm (5-3/4 inch) nets to a mean of 71.5 in nets of 152 mm (6 inch). Char per delivery increased from a mean of 4.5 in 146 mm (5-3/4 inch) nets to a mean of 6.54 in 149 mm (5-7/8 inch) nets. In 152 mm (6 inch) nets, the mean char catch dropped to 4.42. The mean number of chum salmon per delivery then decreased to 54 while the mean number of char increased to seven for nets of 159 mm (6-1/4 inch), but only two interviews concerned nets of this mesh size.

A total of 1,606 char from the catch in the commercial fishery were sampled for length and sex (Figures 8 and 9; Table 6). The mean fork length of females was 594 mm (SE = 2.74) and the mean fork length of males was 613 mm (SE = 3.53). The mean fork length of the combined sample was 600 mm (SE = 2.18). The fork length of intercepted char increased from a mean of 595 mm in fishing period 11 (14 - 16 August) to a mean of 634 mm in fishing period 13 (21 - 23 August). A one way analysis of variance showed significant differences between samples from the three fishing periods (F = 12.82,

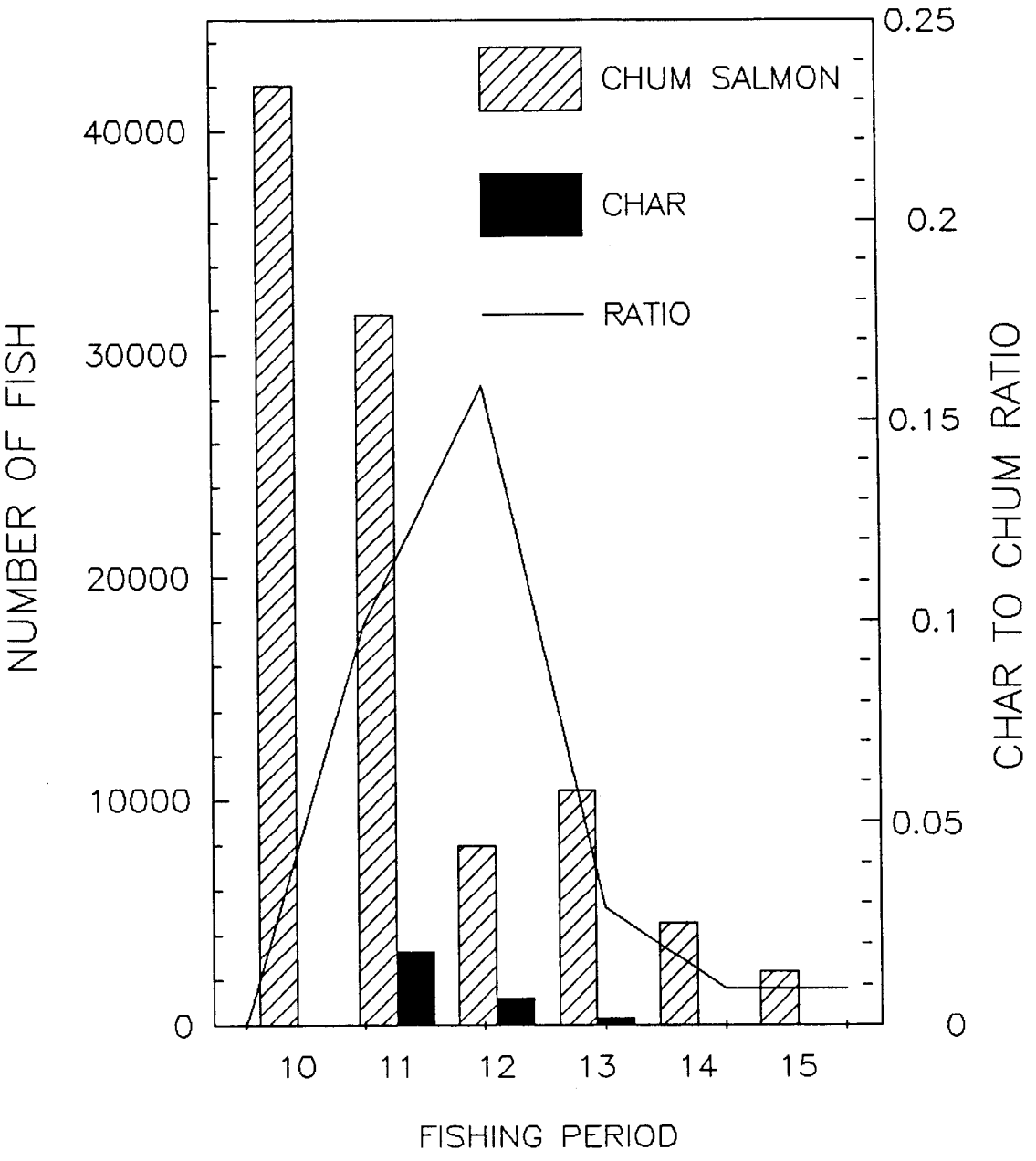

Figure 6. Catch composition of char and chum salmon by fishing period in the 1989 Kotzebue Sound commercial salmon fishery.

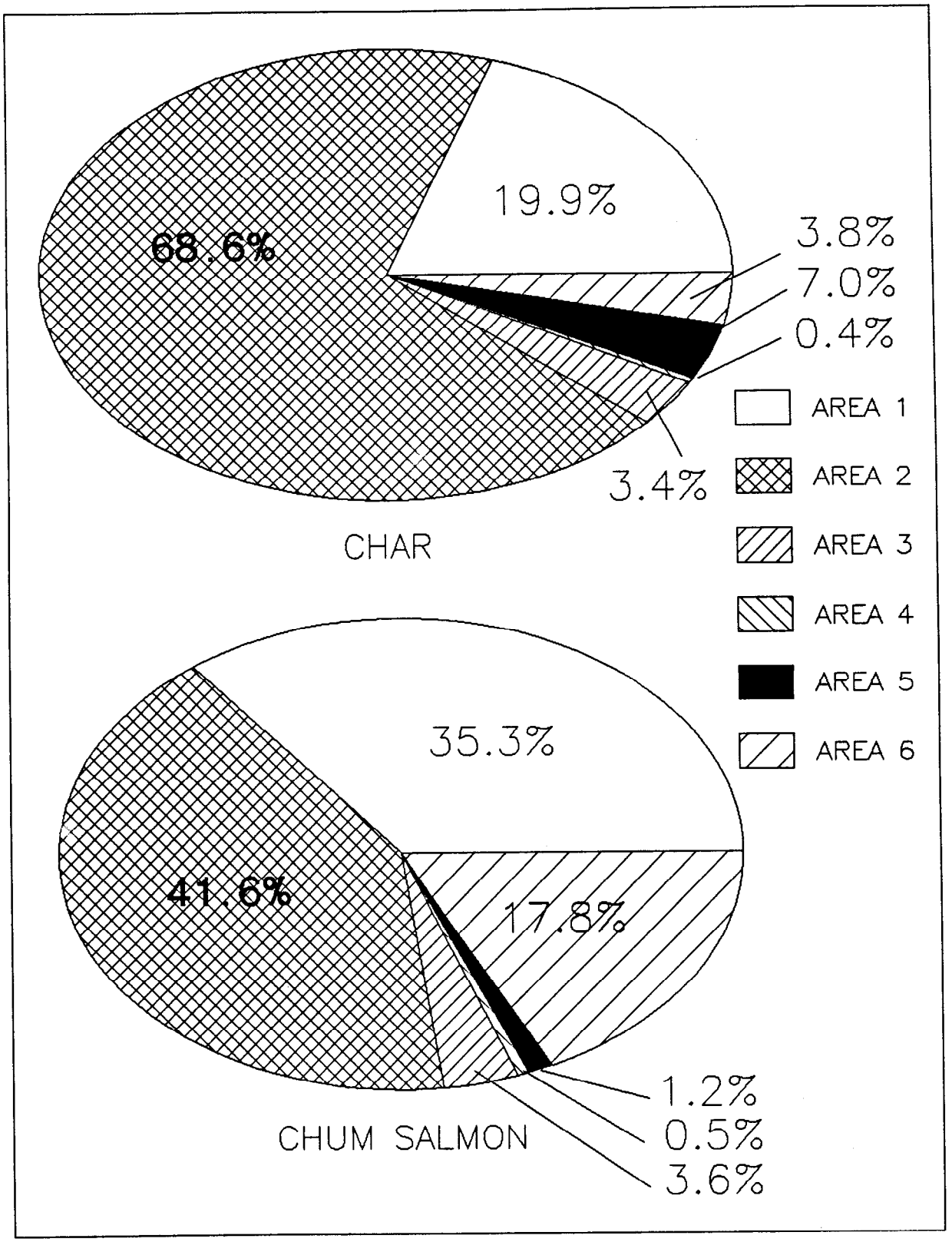

Figure 7. Estimated catches of char by area, periods combined, in the 1989 Kotzebue Sound commercial salmon fishery.

Table 5. Catches of char and chum salmon by gill net mesh size in the 1989 Kotzebue Sound commercial salmon fishery.

Mesh Size[a]	146	149	152	159
No. interviews	13	212	34	2
No. salmon	632	12,675	2,430	108
Salmon/int.	48.62	59.79	71.47	54
Variance	732.59	3,829.35	9,254.80	800.00
SE	7.51	4.25	16.50	20.00
No. char	58	1,386	150	14
Char/int.	4.46	6.54	4.42	7
Variance	50.77	192.79	123.70	98.00
SE	1.98	0.95	1.91	7.00
Char/salmon	0.09	0.11	0.06	0.13
Percent char	8.41	9.85	5.81	11.48

[a] Stretch measure in millimeters.

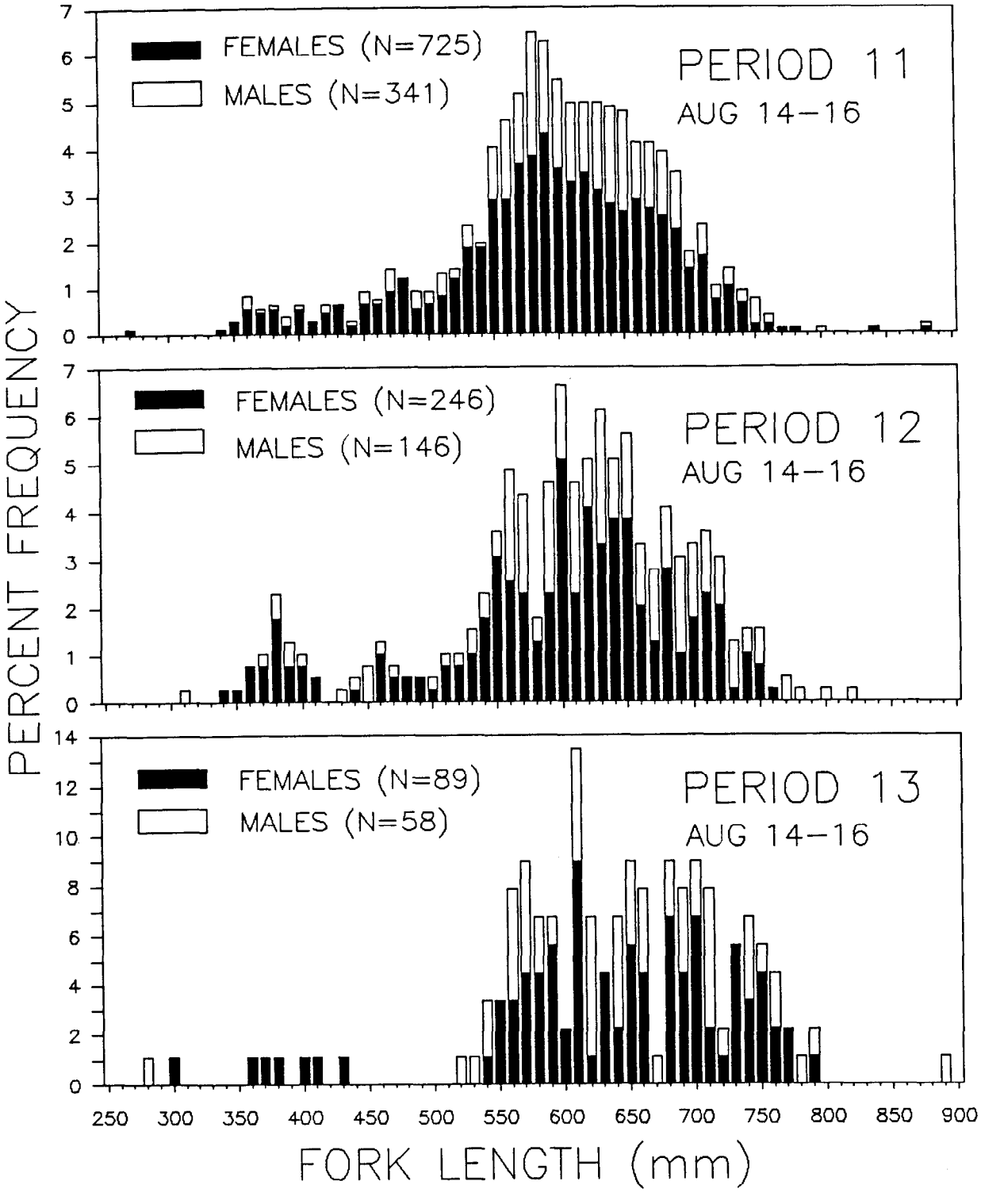

Figure 8. Char length and sex composition by fishing period in the 1989 Kotzebue Sound commercial salmon fishery.

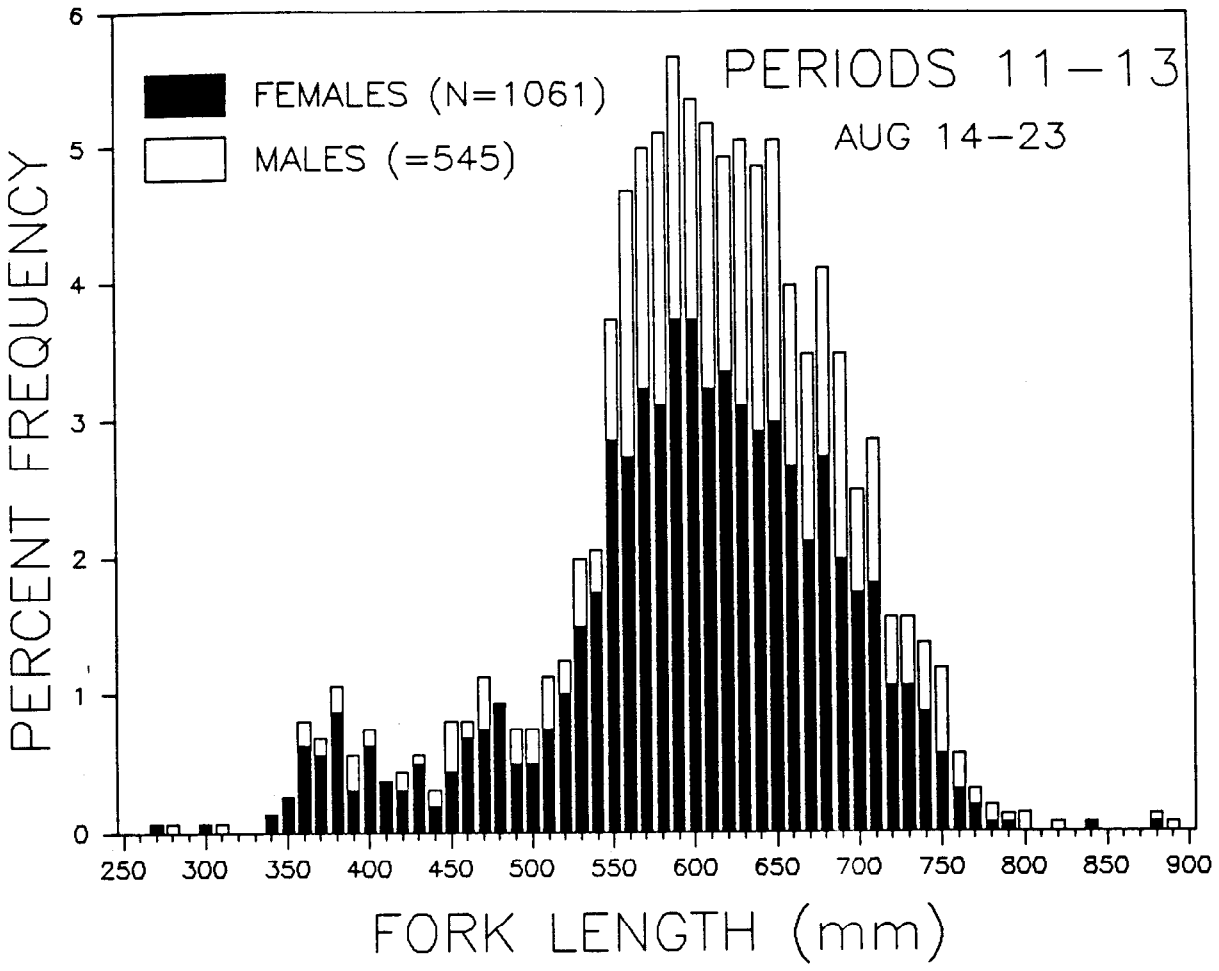

Figure 9. Char length and sex composition, fishing periods combined, in the 1989 Kotzebue Sound commercial salmon fishery.

Table 6. Length and sex composition by fishing period of char harvested in the 1989 Kotzebue Sound commercial salmon fishery.

	Period 11 (14-16 August)		Period 12 (17-19 August)		Period 13 (21-23 August)	
	Females	Males	Females	Males	Females	Males
Number of char	726	341	246	146	89	58
Smallest[a]	270	355	336	301	297	280
Largest[a]	872	880	754	820	785	885
Mean fork length[a]	590	607	592	615	629	641
Variance	7,288	5,637	8,938	8,682	9,727	8,149
SE	3.17	4.07	6.03	7.71	10.45	11.85
Sex composition[b]	68	32	63	37	61	39

[a] Fork length in millimeters.
[b] Percent.

$P < 0.01$). A Scheffe multiple range analysis grouped the samples from fishing periods 11 and 12 together suggesting that the significant difference was between the first two periods and the last period. These data indicate that most larger char migrated toward the end of the first movement of char into Kotzebue Sound in 1989.

Fall Subsistence Fisheries

The people of Kivalina harvested an estimated 4,820 char from the Wulik River during the 1989 fall seine fishery. Six fishing groups participated in the fishery, and unlike other years, all groups brought their fish back to the village rather than storing them in caches upriver (DeCicco 1985). Because the author was not available to sample the fishery as it occurred, the estimate is based on catches reported by the crew leaders of the various fishing groups. Catches were reported in sacks or tubs of fish and the crew leader estimated the number of fish in an average tub or sack. Fishermen reported that fish were larger than usual and estimated that a sack contained 30 char and that a tub contained 40 char. The total reported harvest was 114 sacks (3,420 fish) and 30 tubs (1,200 fish; Appendix A1).

The people of Noatak harvested an estimated 4,500 char from the Noatak River during the fall of 1989 (Knupfer pers. comm.[1]). This estimate was from a household subsistence survey conducted on 2 November by Alaska Department of Fish and Game, Division of Commercial Fisheries. Char were harvested with gill nets and seines.

Aerial Counts of Char

A total of 56,384 char were counted in the Wulik River and 5,090 in the Kivalina River during an aerial survey on 9 Oct 1989. The counts are intermediate for the Wulik River and at the lower range for the Kivalina River (Appendix A5). These counts were conducted during the investigation of the potential effects of a highly mineralized water discharge from the vicinity of the Red Dog Mine in the upper Wulik River drainage. The distribution of overwintering char in the Wulik River downstream of Ikalukrok Creek was normal (dispersed across the entire river) on 4 October at which time no influence of the upstream turbidity on Ikalukrok Creek could be visually detected in the Wulik. By 10 October all fish observed downstream of Ikalukrok Creek were along the north bank of the river, seeming to avoid Ikalukrok Creek water which enters from the south. At this time slightly turbid water with elevated zinc levels (0.47 mg/l) could be seen entering the Wulik River from Ikalukrok Creek.

Movements of Tagged Char

Three tag recoveries added interesting data to what is already known of the complex movements of Kotzebue area char (DeCicco 1989). One recovery was from a char taken near the mouth of the Egavik River in Norton Sound, a distance of 720 km and a second was from a fish taken near Savoonga on St. Lawrence

[1] Knupfer, Gary. 13 November 1989. Personal Communication. ADFG, PO Box 1030, Kotzebue, AK 99752.

Island, a distance of 528 km. The third recovery was from a fish taken 540 km upstream in the Anadyr River, USSR, a minimum distance of 1,560 km from the tagging location (Dr. N. P. Novikov pers. comm.[2]).

Objectives 4 and 5 were not achieved during the field season because of inclement weather and very high turbid water conditions during the limited time window available for the sampling event.

DISCUSSION

The population estimate of overwintering char on the Wulik River was planned to be finished in the fall of 1988 with the fall subsistence fishery acting as the recapture event, but there was a very rapid freeze in late September and the fishery did not take place. This was the first time that weather conditions prevented a fall fishery for many years and most residents were unsure when it last happened. Had the fishery transpired as usual, the length range of the recapture sample would probably have been more similar to that of the marked sample because both would have been captured with the same seine gear. Gear bias resulting from gill net selectivity in the spring fishery, what became the recapture event, required that the estimate be confined to fish larger than 400 mm in fork length.

Growth of char over the winter (Table 1) was an unexpected result of the mark-recapture experiment. It is unknown exactly when this growth occurs. Because anadromous char feed heavily during the summer, the growth may occur as a delayed effect of summer feeding and take place soon after fish enter freshwater in the fall. Heiser (1966) found that char overwintering in Lake Eva increased an average of 2.3% in length and decreased an average of 19.1% in weight over the course of the winter. Johnson (1980) found that anadromous Arctic char at Nauyuk Lake continued to increase in length over the winter. Mathisen and Berg (1968) reported a similar length increase over the winter for Arctic char in the Vardnes River of northern Norway stating that winter growth continued at the expense of nutritional reserves.

The 1989 Kivalina fall subsistence harvest of 4,820 is below that of recent years which averaged 13,564 from 1981 to 1986 and very much below historical harvests which averaged 48,384 for the years 1959, 1960 and 1968 (Appendix A1). This reflects a general trend toward lower effort levels in recent years. Another significant contributing factor is that people are less willing to leave their fish upriver in traditional willow caches because of scavenging by brown bear. The trend in recent years is for local users to bring more of their catch back to the village. In 1989, virtually all of the catch was transported to the village. Fall water levels are usually very low when seining takes place, and a boat heavily laden with fish would be difficult or impossible to run back to the village so people take fewer fish. Historical catches were very large when there was little or no food available

[2] Novikov, N. P. 10 April 1990. Personal Communication. Letter to Douglas Eggers, Division of Commercial Fisheries, ADFG, PO Box 3-2000, Juneau, AK 99802.

at the village store and all families supported dog teams. These factors in combination have led to the downward trend in harvest levels.

This is the second year that the Kotzebue commercial fishery has been surveyed in detail in hopes of finding a way to minimize the interception of char while not significantly impacting the harvest of chum salmon. Significant additional chum salmon returns to the fishery are projected from the Sikusuilaq Springs Hatchery on the Noatak River. Adult returns of hatchery fish are projected to reach 81,750 by the year 1993 and over 500,000 by the year 2001 (Rob 1990). Additional chum salmon available to the fishery will probably result in increased fishing effort and an increase in the incidental catch of char. Bernard and DeCicco (1987) found that the char harvest in 1986 could have been reduced had a mesh size restriction been implemented. They found a trend toward more chum salmon and fewer char as mesh size increased. The fishery in 1986 was atypical, however, because there were more age 0.4 chum salmon in the catch than usual, and 0.3 age chum salmon were larger than in past years. The larger size of chum salmon was reflected in catches with more chum salmon per unit of effort being taken in larger mesh sizes. This relationship was not as clear in the 1989 fishery. The most frequently used mesh size, 149 mm (5-7/8 inch) accounted for 82% of the interviewed deliveries and caught more char and fewer chum salmon per delivery than 152 mm (6 inch) nets (Table 5), indicating that a change to 152 mm (six inch) nets might reduce the harvest of char. Six inch nets represented only 13% of the interviews but was the second most popular net size. Char move through the Kotzebue Sound fishery only for a short period of time usually at or near the end of the fishing season. A reduction in fishing period length during the char migration would reduce the char harvest. A closure during the peak of the char movement of Areas 2 and 5 (Figure 2), which encompass the main route used by char as they enter Kotzebue Sound, would also reduce the harvest. Either of these two actions would also reduce salmon harvests. Another method of reducing the char incidental harvest would be the voluntary release of live char by fishermen. This could only be effective with the cooperation of the local fishermen and the buyers.

During the 1989 commercial fishery, a relatively high proportion of char were sold (64%) because the price paid to fishermen for salmon was very low, and one buyer was paying more for char than for salmon. Some fishermen targeted char because of the higher price, resulting in a higher-than-average catch of char.

Although relatively small in number, the incidental catch of char in the commercial fishery are of spawning size (DeCicco 1985) and would probably have immigrated to and remained in the Noatak River to spawn during the upcoming year. Reducing the incidental harvest of spawning-sized char would contribute to the reproductive potential of the char population.

The movements indicated from two tag recoveries, one from Norton Sound and one from St. Lawrence Island, are of considerable interest because of the distance involved and the locations of capture. These fish which would not have left the Wulik River until sometime in June 1989 were recovered in August. It is not known if they were fish of Wulik River origin which had moved those distances during a feeding migration, or if they were of Bering Sea origin

which had fed in the Chukchi Sea during the previous summer. A third tag recovery from the Anadyr River, USSR, is of special interest. It is the first documented movement of a char between Alaska and the USSR and represents the longest documented movement of a Dolly Varden or Arctic char. Johnson (1980) reported that Mathisen and Berg (1968) and Jensen and Berg (1977) recorded the longest distance covered by an Arctic char as 940 km. Data on ocean movements of char are scanty, but most studies report movements as being coastal in nature (Johnson 1980, McCart 1980). Neither the movement to St. Lawrence Island (185 km from the Alaskan coast) nor the movement to the Anadyr River, USSR can be considered coastal. The amount of interchange between char stocks of Alaska and the USSR is not known, but could be considerable.

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APPENDIX A

Appendix A1. Estimated catches of char from subsistence fisheries in the Wulik and Noatak rivers.

Year	Season	Kilograms	Number	Source
Wulik River				
1959	Fall	39,000		Sarrio and Kessel (1966)
1960	Fall	57,000		Sarrio and Kessel (1966)
1964/5	Year[a]	42,725		Burch (1985)
1965/6	Year[a]	12,790		Burch (1985)
1968	Fall		49,152	Winslow (1969)
1969	Spring		8,402	Roguski and Winslow (1970)
1971	Fall		29,281	Yoshihara (1973)
1972	Fall		35,733	Yoshihara (1973)
1979	Fall		14,600	DeCicco (1982)
1981	Fall		15,000-18,000	DeCicco (1982)
1982	Fall		18,438	Braund and Burnham (1982)
1982	Winter	2,000		Braund and Burnham (1982)
1982/3	Year[a]	31,390		Burch (1985)
1983	Spring	5,500		Burch (1985)
1983	Fall		16,270	DeCicco (1984)
1983/4	Year[a]	31,121		Burch (1985)
1984	Fall		12,000	DeCicco (1985)
1985	Fall		10,500	DeCicco (1986)
1986	Fall		7,176	Bernard and DeCicco (1987)
1988	Fall	(no harvest)		This Report
1989	Spring		1,705	This Report
1989	Fall		4,820	This Report
Noatak River				
1962			27,623	ADFG (1984)
1963			4,130	ADFG (1984)
1969			32,350	ADFG (1984)
1970			3,700	ADFG (1984)
1971			5,320	ADFG (1984)
1972			1,492	ADFG (1984)
1979			9,060	ADFG (1984)
1980			7,220	ADFG (1984)
1981	Fall		4,920	DeCicco (1985)
1982	Fall		2,403	DeCicco (1985)
1983	Fall		4,450	DeCicco (1985)
1984	Fall		1,881	DeCicco (1985)
1989	Fall		4,500	Gary Knupfer (pers. comm.)

[a] The subsistence year was 1 July to 30 June.

Appendix A2. Historic incidental harvest of char in the Kotzebue Sound commercial salmon fishery[a].

Year	Number of Char Sold	Estimated Catch of Char
1966	3,325	...
1967	367	...
1968	3,181	...
1969	1,089	...
1970	2,095	...
1971	3,828	...
1972	7,746	...
1973	640	...
1974	2,605	...
1975	...	...
1976	...	...
1977	...	...
1978	1,229	...
1979	2,523	...
1980	3,049	...
1981	3	...
1982	3,447	...
1983	190	835
1984	347	1,090
1985	3,627	...
1986	5	2,526
1987	1,261	...
1988	761	...
1989	3,093	4,931

[a] Data were obtained from Alaska Department of Fish and Game (1966-1989).

Appendix A3. Historic Kotzebue area freshwater harvest of char[a].

Year	Noatak R.	Wulik R.	Other	Total
1977	133	184	152	469
1978	163	...	36	199
1979	145	718	909	1772
1980	182	...	112	301
1981	583	...	595	1177
1982	860	545	126	1531
1983	557	705	874	2136
1984	...	...	3804	3804
1985	694	...	836	1557
1986	520	...	780	1300
1987	844	...	528	1372
1988	...	...	965	965
mean	468	538	495	1382

[a] Data from Mills (1979-1989).

Appendix A4. Sex composition of Kotzebue area char samples[a].

Sample	No. Male	No. Female	Proportion Male	Proportion Female	Variance (P)	Male to Female Ratio
1989 Commercial Fishery	545	1061	0.34	0.66	<0.01	1:1.95
1989 Wulik R. Spring	371	878	0.30	0.70	<0.01	1:2.37
1988 Wulik R. Fall	1468	2496	0.37	0.63	<0.01	1:1.7
1986 Commercial Fishery	513	860	0.37	0.63	<0.01	1:1.68
1986 Kugururok R. Spawners	175	580	0.23	0.77	<0.01	1:3.31
1986 Wulik R. Fall	401	662	0.38	0.62	<0.01	1:1.65
1985 Wulik R. Fall	266	381	0.41	0.59	<0.01	1:1.43
1984 Noatak R. Spawners	229	651	0.26	0.74	<0.01	1:2.84
1983 Noatak R. Spawners	285	712	0.29	0.71	<0.01	1:2.5
1982 Noatak R. Spawners	432	807	0.35	0.65	<0.01	1:1.87
1981 Noatak R. Spawners	290	693	0.30	0.70	<0.01	1:2.39

[a] From Bernard and DeCicco (1987), DeCicco (1985) and DeCicco (Unpublished).

Appendix A5. Aerial counts of char overwintering in the Wulik and Kivalina rivers[a].

Year	Wulik River	Kivalina River	Surveyor or Source
1968	90,236	27,640	Winslow (1969)
1969	297,257	...	ADFG, Div. of CF[b]
1976	68,300	12,600	Alt (1981)
1979	55,030	15,744	Alt (1981)
1980	113,553	39,692	Alt (1981)
1981	101,826	45,335	DeCicco (1982)
1982	65,581	10,932	DeCicco (1983)
1984	30,923	5,474	DeCicco (1985)
1987	61,290	2,581	DeCicco
1988	80,144	...	DeCicco
1989	56,384	5,090	DeCicco

[a] All surveys flown with fixed winged aircraft.
[b] ADFG memo dated 7 October 1969 from Carl Yanagawa, C.F. Area Mgmt. Biologist, to George Van Wyhe, S.F. Regional Supervisor.