Fishery Data Series No. 95-1

Assessment of the 1993 Return of Steelhead to the Karluk River, Alaska

by

Robert N. Begich

February 1995

Alaska Department of Fish and Game **Division of Sport Fish**

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
ounce	oz
pound	lb
quart	qt
yard	yd

Spell out acre and ton.

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s

Spell out year, month, and week.

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
id est (that is)	i.e.,
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	F, t, χ^2, etc.
confidence interval	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
standard length	SL
total length	TL
variance	Var

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by

Robert N. Begich
Division of Sport Fish, Kodiak

Alaska Department of Fish and Game
Division of Sport Fish
333 Raspberry Road, Anchorage, Alaska, 99518-1599
February 1995

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Robert N. Begich
Alaska Department of Fish and Game, Division of Sport Fish,
211 Mission Road, Kodiak, Alaska, 99615-6399, USA

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ABSTRACT

Beginning August 15, 1993, commercial set gill net and purse seine catches from selected waters along the southwest side of Kodiak Island were sampled for the incidental harvest of steelhead trout *Oncorhynchus mykiss*. The total estimated incidental commercial catch of steelhead from waters included in the Karluk study area, between August 15 and August 31, was 58 fish. A total of 21 steelhead were harvested for personal use and 17 were released from the set gill net fishery. Set gill net and purse seine fisheries harvested and sold an estimated five and 15 steelhead, respectively. Sport and subsistence fisheries harvested an estimated 189 and 382 steelhead, respectively.

The estimated abundance of spawning steelhead for the entire Karluk River drainage in the spring of 1994 was 9,116 fish (SE = 522). The majority of the spawning population was composed of initial spawners (81%), followed by repeat (18%) and multi-repeat (1%) spawners. Mean length for female initial and repeat spawners was 644 mm and 703 mm, respectively; and 588 mm and 671 mm, respectively for males. Multi-repeat spawning males and females had mean lengths of 789 mm and 720 mm, respectively. Mean length for all spawning steelhead was 627 mm.

Estimated spawning survival of steelhead was 51%. Spawning survival for females was 43% and 51% for males. Survival of male steelhead by spawning histories was 54% for initial spawners and 22% for repeat spawners; for females survival was 46% for initial spawners and 40% for repeat spawners. No multi-repeat spawning steelhead were observed during the recapture event.

Key words: Steelhead, *Oncorhynchus mykiss*, purse seine, set gill net, kelts, statistical area, Kodiak Island, Karluk River, Portage area, harvest, abundance estimate, survival, initial spawners, repeat spawners, multi-repeat spawners.

INTRODUCTION

The Karluk River contains the largest known steelhead *Oncorhynchus mykiss* population on Kodiak Island. From its source at the outlet of Karluk Lake, it flows approximately 35.2 km (22 mi) to its terminus at Karluk Lagoon and the Shelikof Strait (Figure 1). Adult steelhead begin immigration during late August and may continue immigration through the winter months. Steelhead overwinter, spawn and emigrate to sea as kelts from May through July.

Karluk steelhead are harvested in several fisheries. Adults are targeted in the Karluk River by sport anglers from September through November. In addition, adults are harvested in subsistence fisheries conducted by residents of Karluk Village during June through September and Larsen Bay during October through April. The autumn steelhead migration coincides with the return of coho salmon *Oncorhynchus kisutch* and late-run sockeye salmon *O. nerka* to the Karluk River. When commercial purse seine vessels and set gill net operators target these salmon stocks, steelhead are incidentally harvested in nearshore marine waters along the southwest portion of Kodiak Island. Emigrant kelts are harvested in commercial fisheries in these same waters during June. Additionally, Karluk steelhead are incidentally harvested by commercial gear in nearshore marine waters along the Pacific side of the Alaska Peninsula (Figure 2).

Postspawn steelhead (kelts) counts obtained at the Alaska Department of Fish and Game (ADF&G), Division of Commercial Fisheries Management and Development (CFMD) weir located at Karluk Lagoon have ranged from 210 to 4,910 since 1976 (Figure 3). The average annual kelt count of 2,385 fish from

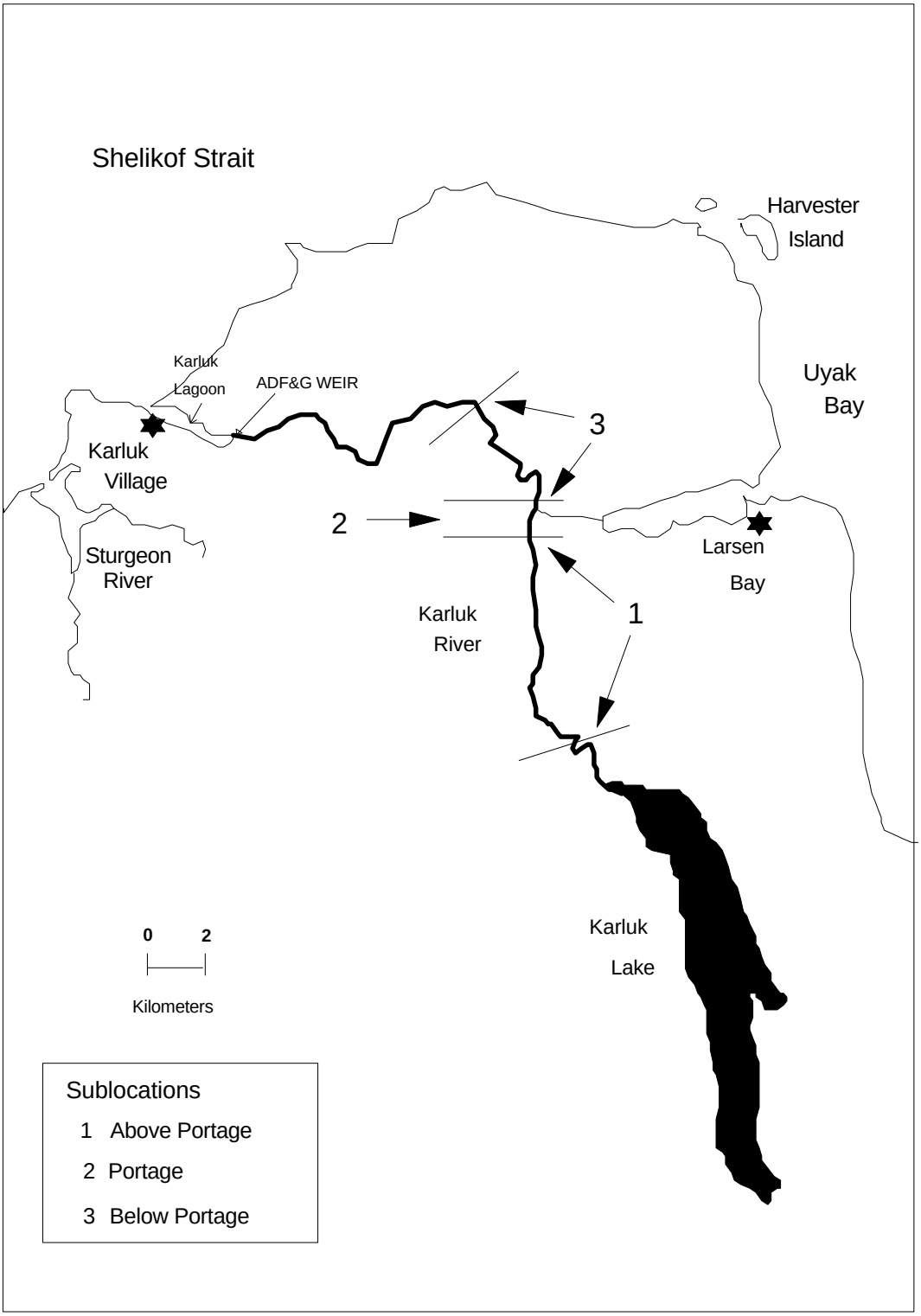

Figure 1.-Map of the Karluk River freshwater study area, sampling sublocations, Portage, Larsen Bay, weir and Karluk Village.

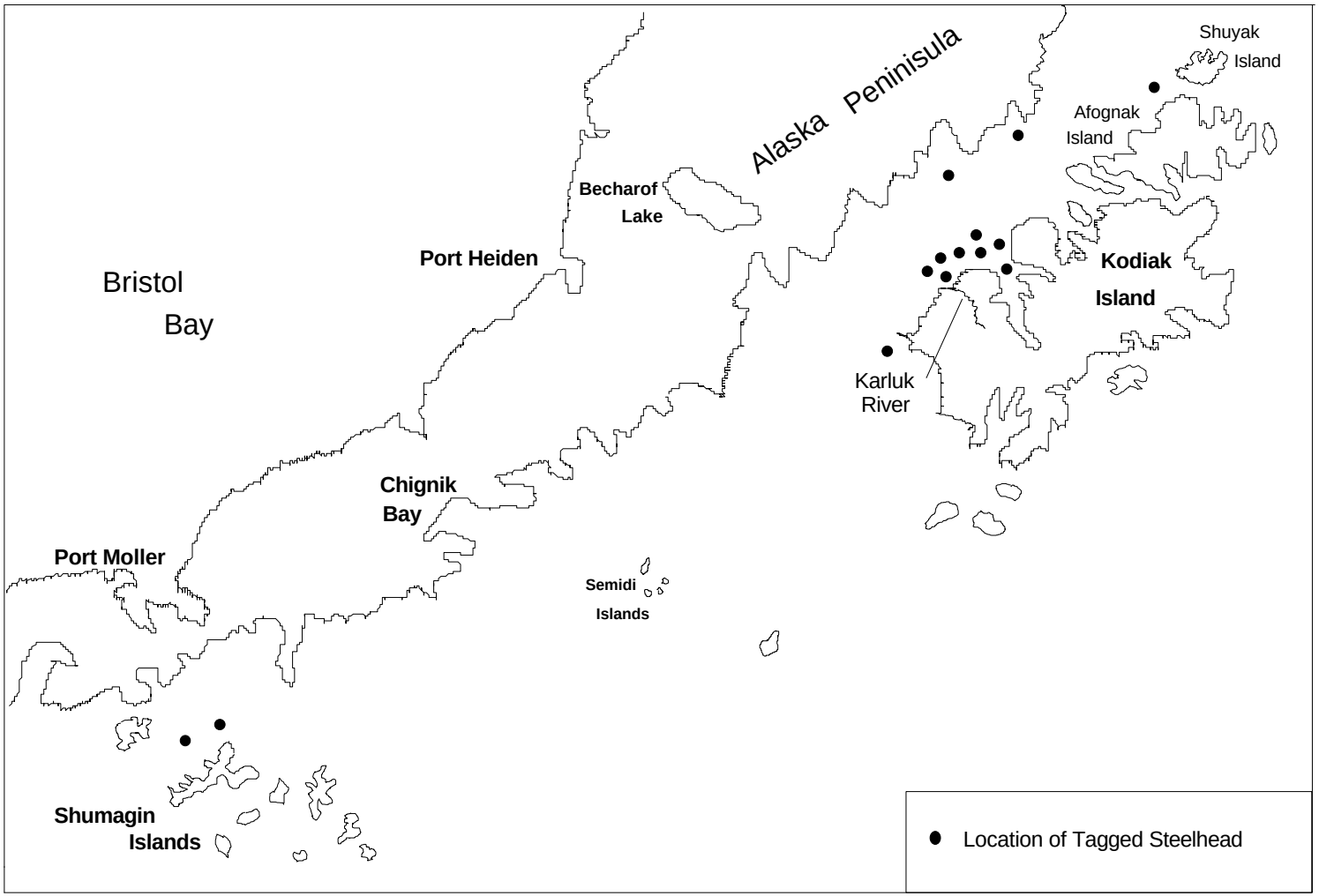

Figure 2.-Map of locations of Karluk River steelhead tag returns from Kodiak Island and Alaska Peninsula commercial salmon fisheries, from June 1992 through June 1994.

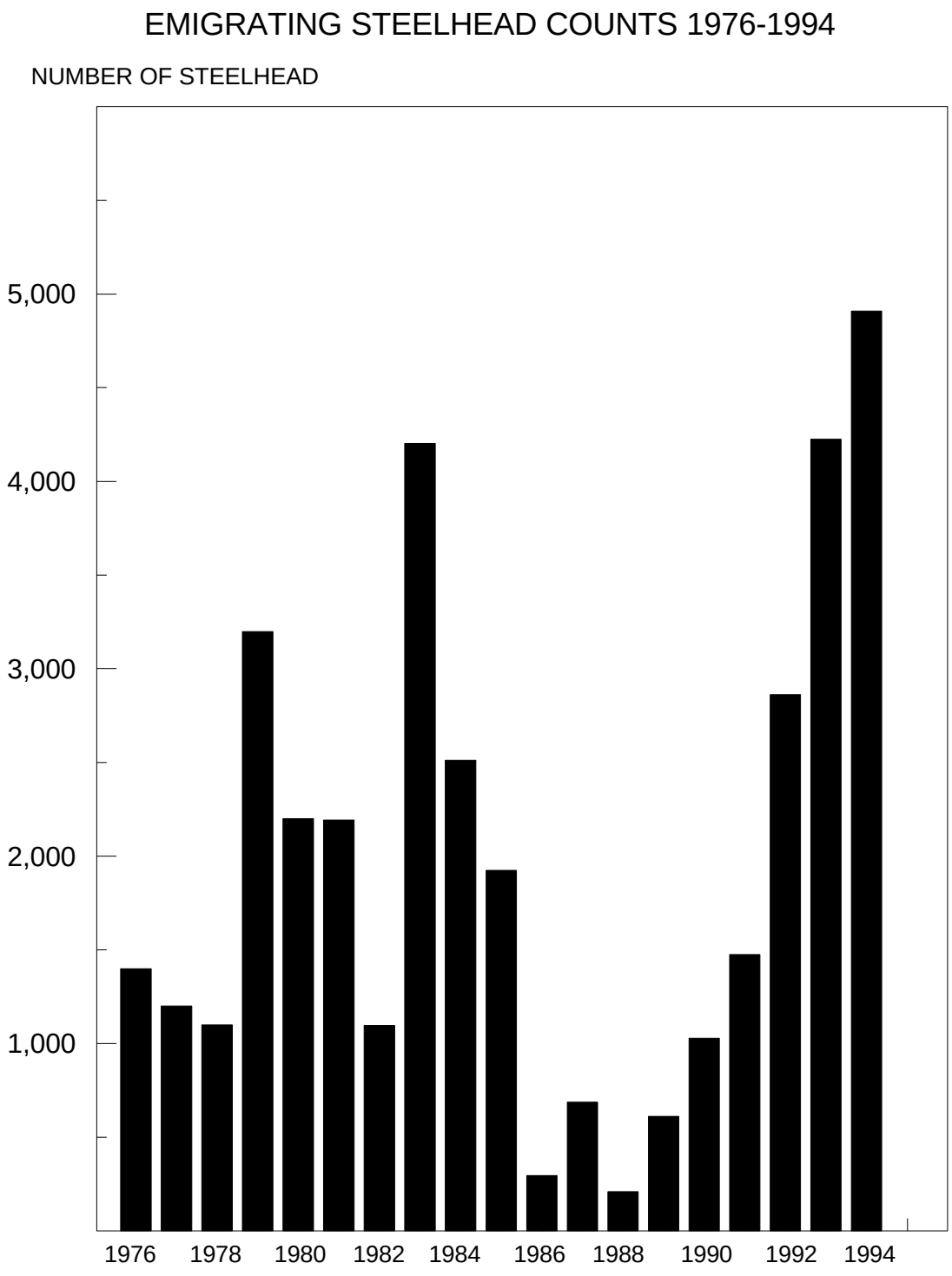

Figure 3.-Historic emigrating steelhead counts obtained at the Division of Commercial Fisheries Management and Development weir, Karluk River, 1976 through 1994.

1981 through 1985 declined to 566 fish from 1986 through 1990. This apparent decline of Karluk steelhead created concern about over-exploitation. However, from 1991 through 1994, average annual kelt counts increased to 3,334 kelts including a record count of 4,910 kelts in 1994.

In August 1991, a study was initiated to assess stock status of adult steelhead returning to and overwintering in the Karluk River. Estimated parameters included incidental commercial harvest of steelhead from marine waters near the Karluk River, sport and subsistence harvests within the Karluk River, and the number of spawning steelhead in the Karluk River from a single return year (Begich 1992, 1993).

This report is part of a continuing study to assess the stock status of adult steelhead returning, overwintering, and spawning at the Karluk River. Study objectives for the 1993 return are listed below.

Fishing Mortality:

1. Estimate the number of steelhead retained for personal use and the number released by commercial setnetters operating between West Point and Rocky Point from August 15 through September 30, 1993.
2. Estimate the number of steelhead harvested in the commercial purse seine fishery from August 15 to September 30, 1993 in selected commercial fishing statistical areas.
3. Estimate the number of steelhead sold in the commercial set gill net fishery between West Point and Rocky Point from August 15 through September 30, 1993.
4. Estimate the age, sex, and length composition of steelhead and the number of repeat spawners of Karluk River origin harvested in these commercial fisheries.
5. Census the number of steelhead harvested in the Karluk Village and Larsen Bay subsistence fisheries during 1993.
6. Estimate the number of steelhead harvested in the Karluk River sport fishery during 1993.

Spawning Population:

7. Estimate the number of spawning steelhead in the Karluk River during the spring of 1994.
8. Estimate the age, sex, and length composition of the spawning population.
9. Enumerate emigrating kelts through the Karluk River weir during spring 1994.
10. Estimate the age, sex, and length composition of the population of emigrating kelts.

ESTIMATION OF STEELHEAD BYCATCH IN SELECTED COMMERCIAL FISHERIES

METHODS

Commercial catches from waters of eight statistical areas between West Point and Sturgeon Head were sampled for the incidental harvest of steelhead (Figure 4). The sampling of these fisheries is based on the assumption that all steelhead harvested are of Karluk River origin. All eight statistical areas were open to commercial purse seine fishing. Three of these eight statistical areas are permanently closed to the harvest of salmon with set gill net gear. These fisheries are managed for the return of sockeye salmon, chinook salmon *O. tshawytscha*, pink salmon *O. gorbuscha*, and coho salmon to the Karluk River by CFMD Division, Kodiak.

Commercial catch sampling was to occur over a 6-week period and was divided into five

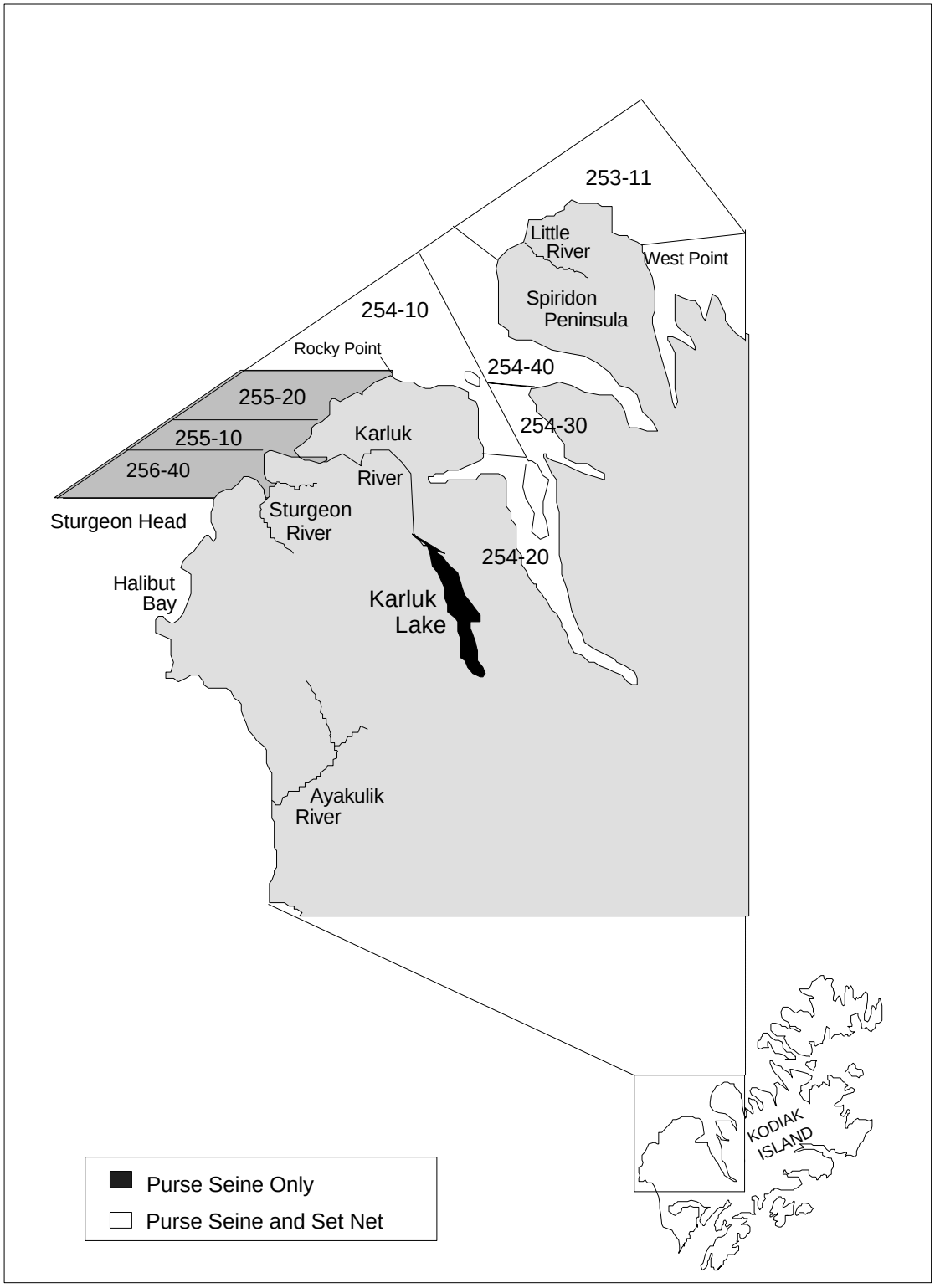

Figure 4.-Map of marine study area and Karluk River, 1994.

strata in order to detect temporal changes of steelhead bycatch:

Stratum	Date
1	8/15 - 8/31
2	9/01 - 9/07
3	9/08 - 9/14
4	9/15 - 9/21
5	9/22 - 9/30

No commercial catch sampling was conducted during strata 2 through 5 because commercial fishing was restricted during those strata due to a weak return of sockeye salmon to the Karluk River.

Set Gill Net Fishery

Prior to August 15, catch calendars were distributed to all set gill net permit holders operating within the Karluk marine study area. The data voluntarily recorded on the calendar included: name of permit holder; permit number; and number of steelhead caught, retained, and released by day. Calendar recipients were asked to mail the prepaid postage calendar to the Division of Sport Fish in Kodiak upon completion of fishing. Permit holders who did not return calendars were contacted by mail and asked to return calendars. This program provided data to estimate the number of steelhead retained and released by setnetters.

Calendar returns were used to expand steelhead catches to the unreturned calendars. The total salmon harvest of permit holders who returned calendars was obtained by period from sales receipts (fish tickets). These data were used to estimate the ratio of steelhead retained or released to the number of salmon harvested. First a series of jackknifed steelhead-to-salmon ratio estimates of fish retained for personal use or caught and released were calculated by:

$$\hat{r}_i = \frac{\sum_{\substack{i=1 \\ i \neq j}}^{n} C_{si}}{\sum_{\substack{i=1 \\ i \neq j}}^{n} C_{oi}} \quad (1)$$

where:

C_{si} = harvest or release of steelhead in net i,

C_{oi} = catch of salmon in net i, and

n = number of set net sites which returned calendars.

Next the ratio estimate was calculated:

$$\hat{r}_q = n\hat{r}_g - (n-1)\bar{r} \quad (2)$$

where:

$$\hat{r}_g = \frac{\overline{C}_s}{\overline{C}_o} \quad (3)$$

with variance:

$$Var(\hat{r}_q) = \frac{(1-f)(n-1)}{n} \sum_{i=1}^{n} (\hat{r}_i - \bar{r})^2 \quad (4)$$

where:

$\bar{r}$ = the average of the $\hat{r}_i$;

f = finite population correction factor = n/N; and

N = total number of set net permit holders in study area.

The total number of steelhead taken in set nets (C_{ss}) for personal use or released was then estimated by:

$$\hat{C}_{ss} = \hat{r}_q C_{st}; \quad (5)$$

where:

C_{st} = total catch of species other than steelhead by all permit holders in the study area.

The variance of the estimate of steelhead taken for personal use or released is estimated by (Cochran 1977):

$$\mathrm{Var}(\hat{C}_{ss}) = C_{st}^2 \mathrm{Var}(\hat{r}_q) . \quad (6)$$

Tender-Sampled Set Gill Net and Purse Seine Fishery

The number of steelhead harvested by setnetters and purse seiners and sold to tender vessels for delivery to canneries was estimated. Sampling of these fisheries was conducted on an opportunistic basis.

During off-loading, each fish in the catch was sorted by species. Vessel operators were interviewed to obtain the number of steelhead sorted on the fishing grounds prior to sampling and included in the sample total. As many catches were sampled as possible during each fishing period.

Fish tickets from sampled deliveries provided the weight and number of salmon sold so that a series of jackknife ratio estimates of steelhead to salmon could be computed by (Cochran 1977):

$$\hat{r}_j = \frac{\sum_{\substack{j=1 \\ j \neq i}}^{v} C_{sj}}{\sum_{\substack{j=1 \\ j \neq i}}^{v} C_{oj}} \quad (7)$$

where:

C_{sj} = harvest of steelhead observed in vessel j,

C_{oj} = catch of salmon by vessel j, and

v = number of vessels sampled for steelhead.

Next the ratio estimate was calculated:

$$\hat{r}_v = v\hat{r}_h - (v-1)\bar{r} ; \quad (8)$$

where:

$$\hat{r}_h = \frac{\bar{C}_s}{\bar{C}_o} ; \quad (9)$$

with variance:

$$\mathrm{Var}(\hat{r}_v) = \frac{(1-f_v)(v-1)}{v} \sum_{j=1}^{v} (\hat{r}_j - \bar{r})^2 \quad (10)$$

where:

$\bar{r}$ = the average of the $\hat{r}_j$;

f_v = finite population correction factor = v/V; and

V = total number of vessels unloading fish (from fish ticket database).

The total harvest of steelhead in the purse seine and tender-sampled set net fisheries (C_{sp}) was then estimated by:

$$\hat{C}_{sp} = \hat{r}_v C_{tp} \quad (11)$$

where:

C_{tp} = total harvest of species other than steelhead p in the fishery.

The variance of the estimate of steelhead catch was estimated by:

$$\mathrm{Var}(\hat{C}_{sp}) = C_{tp}^2 \mathrm{Var}(\bar{r}_v) . \quad (12)$$

Steelhead observed in tender-sampled catches were measured from the tip-of-snout to the fork-of-tail (fork length) to the nearest millimeter, sexed and examined for tags or finclips. Four scales from the left side of the fish, two rows above the lateral line and on the diagonal from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin, were taken for age determination (Paget 1920). Scales were mounted on gummed cards, pressed on acetate to make an impression and aged with a microfiche reader.

Scale analysis incorporated the methods of Mosher (1969), Jones (*Unpublished*) and Wallis (*Unpublished*). For example, an assigned age of 2.2s1s is an age-6 repeat spawner which: (1) spent 2 winters (years) in fresh water prior to smolt emigration, (2) returned to spawn in fresh water during its second year at sea, (3) returned to the sea, and (4) returned to spawn again the following spring. The letter "s" represents a freshwater immigration (spawning event) and numbers represent years between events. This represents a departure from the traditional method used for age assignment of fall immigrant steelhead (Narver and Withler 1971). Utilizing these methods, the assigned age of this fish would have been 2.1ss.

Scales without a legible spawning check were defined as fish that were initial or first time spawners. Fish with one previous spawning check legible on the scale impression were defined as repeat or second time spawners. Multi-repeat spawners were fish with at least two previous spawning checks legible on the scale impression.

RESULTS

A total of 23 set gill net permit holders, of a total of 42 operating within the Karluk study area, returned catch calendars. From August 15 to August 31, sampled permit holders retained seven and released five steelhead (Table 1). During the same period, these same permit holders harvested 43,096 (32.2%) of the 133,862 salmon harvested by set gill net gear from the Karluk study area. The estimated retention of steelhead by set gill net permit holders was 21 steelhead with an additional 17 fish released (Table 1). No set gill net harvest from the study area was reported during September, due to weak returns and extended commercial closures.

From August 15 to August 31, 1,135,719 salmon were harvested by set gill net and purse seine gear within the Karluk marine study area (Table 2). One steelhead was observed in samples of set gill net harvested salmon and two steelhead were observed in samples of purse seine harvested salmon. The total estimated steelhead harvest in the tender sampled set gill net and purse seine fisheries was 20 fish, 5 by set gill nets and 15 by purse seines (Table 2).

Since no commercial set gill net harvest occurred during September and the purse seine fishery was restricted to a total harvest of 16,273 salmon during this month, no temporal changes in the steelhead bycatch were detected. One steelhead tag was returned by a set gill net operator within the study area during August.

Trends in set gill net steelhead harvest and release by area were evident (Table 3). No calendars were returned from statistical area 254-30; however, this section only accounted for 4% of the total set gill net harvest of salmon. Harvest and release of steelhead were highest in statistical area 254-10 where 23% of the total salmon harvest occurred. The estimated total catch of steelhead in this statistical area was 12 retained and 17 released (Table 3).

Age composition of the incidental harvest of steelhead was not calculated due to insufficient sample sizes.

ESTIMATION OF STEELHEAD HARVEST IN THE KARLUK RIVER SUBSISTENCE FISHERIES

METHODS

Karluk River steelhead are a component of subsistence fisheries of both Karluk Village and Larsen Bay. Karluk Village residents fish with beach seines within Karluk Lagoon during late May through September. Fishing effort increases with the influx and concentrations of immigrant sockeye and coho

Table 1 .-Estimated harvest and release of steelhead in commercial set gill nets near the Karluk River, August 15 through August 31, 1993.

8/15-8/31[a]	Total Salmon Harvested[b]	Sample Size[c]	Reported Number of Steelhead[d]	Ratio of Steelhead to Salmon	Estimated Number of Steelhead	SE	Relative Precision[e]
Harvest	133,862	43,096	7	0.000156	21	5.9	55%
Release	133,862	43,096	5	0.000115	17	12.9	150%

[a] No commercial set gill net harvest of salmon was reported for statistical areas included in the Karluk marine study area during September 1993.

[b] From fish tickets.

[c] Salmon harvest of permit holders who returned calendars.

[d] Obtained from catch calendar survey.

[e] Relative precision of 95% confidence interval.

Table 2.-Estimated harvest of steelhead from tender sampled commercial set gill net and purse seine catches near the Karluk River, August 15 through August 31, 1993.

8/15-8/31	Total Salmon Harvested[a]	Sample Size[b]	Steelhead Observed[c]	Ratio of Steelhead to Salmon	Estimated Steelhead Harvested	SE	Relative Precision[d]
Set Gill Net	133,862	27,975	1	0.000035	5	3.5	141%
Purse Seine	1,001,857	117,972	2	0.000017	15	14.2	186%

[a] From fish tickets.

[b] Number examined in sample.

[c] Number steelhead in sample.

[d] Relative precision of 95% confidence interval.

Table 3.-Set gill net harvest and release of steelhead by district section, August 15 through August 31, 1993.[a]

District Section	Number of Steelhead[b]	Proportion of Total Salmon Harvest[c]	Estimated Steelhead	Proportion of Estimated Steelhead Harvest[d]
Steelhead Harvested				
253-11	0	0.349	0	
254-10	4	0.229	12	0.571
254-20	2	0.193	6	0.286
254-30[e]		0.041		
254-40	1	0.188	3	0.143
Total	7	1.000	21	1.000
Steelhead Released				
253-11	0	0.349	0	
254-10	5	0.229	17	1.000
254-20	0	0.193	0	
254-30[e]		0.041		
254-40	0	0.188	0	
Total	5	1.000	17	1.000

[a] No set gill net harvest reported during time strata 2-5. All reported steelhead are from time strata 1.

[b] Obtained from catch calendar survey.

[c] Proportion of the total number of total salmon harvested from all strata.

[d] Proportion of the total number of total estimated steelhead harvested all strata.

[e] No catch calendars were returned by setnetters from this section.

salmon in Karluk Lagoon. Both emigrant (May through July) and immigrant (late August through September) steelhead are exposed to the Karluk Lagoon fishery.

Larsen Bay residents target steelhead at a mid river location known as the Portage area (Figure 1), which is accessed by a trail from the head of Larsen Bay. Typically, residents target prespawning concentrations of adults that overwinter in this part of the river with rod and reel from October through April.

ADF&G personnel conducted household interviews at both Karluk Village and Larsen Bay to determine the number of steelhead harvested by sampled households. Average harvest-per-interviewed-household was multiplied by the total number of households to estimate total harvest by each village.

The mean number of steelhead harvested for subsistence was estimated as:

$$\overline{C}_s = \frac{\sum_{a=1}^{n_s} C_a}{n_s}; \quad (13)$$

where:

C_a = harvest of steelhead in household a, and

n_s = total number of interviewed households.

The total harvest of steelhead by the village was estimated by:

$$\hat{C}_v = N_s \overline{C}_s; \quad (14)$$

where:

N_s = total number of households in the village.

The variance of harvest was estimated by (Cochran 1977:24):

$$\mathrm{Var}(\hat{C}_v) = \frac{N_s^2 (1-f)}{n_s (n_s - 1)} \sum_{a=1}^{n_s} (C_a - \overline{C}_s)^2; \quad (15)$$

where:

f = finite population correction factor = n_s/N_s.

RESULTS

Household surveys were conducted by Division of Sport Fish personnel at Karluk Village in July of 1994. Personnel interviewed six of the most active subsistence beach seiners in the village. These residents reported harvesting no steelhead during the autumn of 1993 or spring/summer of 1994 (Table 4).

ADF&G Division of Subsistence personnel conducted interviews at Larsen Bay, where 40 households reported harvesting 312 steelhead. Mean harvest-per-household was estimated at 7.8. Estimated harvest of steelhead by Larsen Bay residents from April 1, 1993 through March 1, 1994 was 382 (SE = 7) steelhead (Table 5).

Subsistence harvest of steelhead by these two villages has been sporadically estimated since 1982. Village harvests have ranged from 0 to 697 fish (Tables 4 and 5). Harvest estimates from both villages increased markedly from 1991 to 1992, then declined to previous levels. The Larsen Bay harvest has averaged 396 fish per year since 1990.

ESTIMATION OF STEELHEAD HARVEST IN THE KARLUK RIVER SPORT FISHERY

METHODS

Estimates of sport harvest, catch, and effort were obtained from postal surveys (Mills 1982-1994). In this survey, sport fishing statistics are estimated by location. Therefore, fishing effort (reported in angler-days) is the total fishing effort for the Karluk River and includes effort directed at other species, particularly chinook and coho salmon. Due to the small size of the Karluk River sport fishery

Table 4.-Subsistence harvest of steelhead from Karluk Village, 1982-1983, 1986, 1989, 1991, 1992 and September 1, 1993 through July 1, 1994.

Years	Total Reported Harvest[b]	Number Households in Sample	Mean Catch-per-Household	Number of Households in Community	Estimated Community Harvest[c]	SE
1982-1983[a]	233	20	11.65	26	303	13
1986[a]	77	19	4.05	27	109	20
1989[a]	14	14	1.00	17	17	35
1991[ad]	36	13	2.76	17	47	
1992[e]	57	9	6.33	17	107	5
1993[e]	0	6	0.00	17	0	

[a] Source: Community Profile Database, Division of Subsistence, Alaska Department of Fish and Game, Anchorage, Alaska.

[b] From household interviews.

[c] Product of mean catch-per-household and number of households in community.

[d] Standard error not available.

[e] Source: Alaska Department of Fish and Game, Anchorage, Division of Sport Fish survey, July 1993 and 1994.

Table 5.-Subsistence harvest of steelhead from Larsen Bay, 1982-1983, 1986, 1989, and 1990 through March 1994.

Years	Total Reported Harvest[b]	Number Households in Sample	Mean Catch-per-Household	Number of Households in Community	Estimate Community Harvest[c]	SE
1982-1983[a]	273	32	8.53	43	367	16
1986[a]	74	37	2.00	52	104	15
1989[a]	86	34	2.50	39	98	27
1990-1991[ad]	215	38	5.66	43	243	
1991-1992[ad]	230	35	6.57	40	263	
1992-1993[a]	614	37	16.60	42	697	6
1993-1994[ad]	312	40	7.80	49	382	7

[a] Source: Community Profile Database, Division of Subsistence, Alaska Department of Fish and Game, Anchorage, Alaska. Survey years 1990 through 1993 cover the period from April 1 of the survey year to March 31 of the following year, 1993-1994 data are preliminary.

[b] From household interviews.

[c] Product of mean catch-per-household and number of households in community.

[d] Standard error not available.

and the corresponding number of returns, estimates were not available in 1986, 1987, and prior to 1982.

RESULTS

The estimated sport harvest of Karluk River steelhead during the 1993 season was 189 fish (Table 6). This was the largest harvest reported since 1983, but was within the range of harvests reported since 1982. Release in the fishery has increased dramatically over those reported since 1990. Annual fishing effort from 1982 through 1985 averaged 1,363 angler-days and increased to 2,645 angler-days between 1989 and 1992. Annual effort has increased since the late 1980s with a record of 6,894 angler-days in 1993 (Mills 1983-1994).

ESTIMATION OF SPAWNING ABUNDANCE AND SURVIVAL

METHODS

Abundance

Steelhead overwinter in the upper Karluk River and tend to congregate in the Portage area of the river (Chatto 1987). Upon completion of spawning, surviving adults (kelts) emigrate through a weir located approximately 19 km (12 mi) downstream of the Portage area and 0.4 km above the tidal influence of Karluk Lagoon (Figure 1). This allowed for a mark-recapture experiment to estimate the abundance of the spawning population in the Karluk River drainage during the spring of 1994.

During April, fish were captured on hook and line, measured for fork length, sexed, scale sampled for age, tagged near the posterior insertion of the dorsal fin with a six-digit Floy FD-67 internal anchor tag, and a portion of the left pectoral fin was removed to serve as a secondary mark to assess tag loss. Sampling occurred in an 11.2 km (7 mi) section of the river around the Portage area. This section was divided into three sampling sublocations (Figure 1). Each location was sampled and effort was directed at multiple sites within each location where fish were known to congregate.

The experiment was designed to estimate abundance of the spawning population for the entire drainage. Steelhead likely overwinter and spawn in areas other than the sampled sublocations, including Karluk Lake, the upper river and the lower river. The first sampling event (mark event) for this experiment was the entire 11-day sampling experiment described above. The second sampling event (recapture event) occurred at the weir. If there was sufficient mixing of tagged and untagged steelhead during spawning and prior to emigration through the weir, the experiment should provide an estimate of spawner abundance for the entire Karluk River drainage. From May 9 through July 13, 1994, all emigrating steelhead were captured in a downstream trap that was incorporated into the weir. Upon entry into the trap, steelhead were captured with a dip net, examined for a finclip and tag, sexed, measured for fork length to the nearest millimeter, and all untagged kelts were tagged and given a secondary mark (finclip) as previously described. We attempted to collect scale samples from 140 fish per week as described in the previous section on estimation of bycatch in commercial fisheries.

Population abundance ($\hat{N}$) was calculated using Chapman's modification of the Petersen estimator (Seber 1982):

$$\hat{N} = \frac{(M+1)(C+1)}{(R+1)} - 1; \qquad (16)$$

where:

M = number of steelhead tagged and released in the first event,

Table 6.-Sport harvest and release of steelhead and total fishing effort from the Karluk River sport fishery, 1982-1993.[a]

Year	Effort[b]	Harvest	Released[d]
1982	1,552	90	
1983	2,142	241	
1984	534	150	
1985	1,223	167	
1986	[c]	[c]	
1987	[c]	[c]	
1988	990	18	
1989	1,313	20	
1990	2,191	86	
1991	1,646	128	628
1992	5,430	40	898
1993	6,894	189	3,446

[a] Source: Postal surveys as reported by Mills (1983-1994).

[b] Angler-days.

[c] No estimate due to insufficient number of returns.

[d] First estimated in 1991.

R = number of tagged fish recaptured in the second event, and

C = number of fish examined for tags in the second event.

The variance was estimated by:

$$\mathrm{Var}(\hat{N}) = \frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)^2(R+2)}. \quad (17)$$

The following assumptions were necessary for this closed population estimate (Seber 1982):

1. there is no recruitment to the population over the duration of the experiment;
2. no marks are lost;
3. all fish have the same probability of capture in the second sample or marked fish are randomly distributed among the unmarked fish;
4. marking does not affect the probability of capture; and
5. all marked steelhead are reported when recovered during the recapture event.

We have no reason to believe that there was any recruitment, immigration or emigration; therefore the first assumption was not tested. Contingency tables and chi-squared tests (Conover 1980) were used to compare the probability of capture (assumptions 3 and 4) among the geographic sublocations, sex, spawning history and marine age between the mark event and the recapture event. In addition, chi-squared tests were used to test capture rate (marked:unmarked ratio) at the weir due to spawning history and sex. Two-sample Kolmogorov-Smirnov tests (Daniel 1978) were used to determine if capture rates differed due to size. The first test compared the cumulative length distributions of fish marked in the first event with those recaptured in the second event and the second test compared the cumulative length distributions of all fish captured in the mark event with all fish captured in the recapture event. Differences in cumulative length distributions or capture rate among one of these groups may indicate whether the data must be stratified to provide an unbiased estimate of abundance (Seber 1982). All tests were conducted at $\alpha = 0.05$. The secondary mark (left pectoral finclip) provided the means to estimate tag loss (assumption 2).

Age and Length Composition

During the hook and line and weir operations, steelhead were sampled to estimate mean length-at-age and age composition. Samples were categorized by total marine age and spawning history as previously described.

The proportion of steelhead in each age category was estimated as:

$$\hat{p}_k = \frac{n_k}{n_t}; \quad (18)$$

where:

n_k = the number of steelhead in the sample from age category k,

n_t = the total number of steelhead in the sample.

The variance of the proportion by age was estimated as:

$$\mathrm{Var}(\hat{p}_k) = \frac{\hat{p}_k(1-\hat{p}_k)}{n_t - 1}. \quad (19)$$

Abundance by age was estimated as:

$$\hat{N}_k = \hat{N}\hat{p}_k, \quad (20)$$

with the variance (Goodman 1960):

$$V(\hat{N}_k) = V(\hat{N})\hat{p}_k^2 + V(\hat{p}_k)\hat{N}^2 + V(\hat{N})V(\hat{p}_k). \quad (21)$$

Spawning Survival

The survival of tagged fish (S_c) from the marking event (hook and line) to emigration and recapture at the weir was calculated by spawning history, total marine age and sex, by:

$$S_c = \frac{n_{cw}}{n_{ct}}; \quad (22)$$

where:

n_{cw} = number of tagged fish at the weir of class c, and

n_{ct} = number of tagged fish released during the marking event of class c.

RESULTS

Abundance

A total of 4,638 fish were examined for marks at the weir, of which 143 were marked (Table 7). Twelve percent (n = 18) of the marked steelhead had lost their tags. The probability of capture at the weir of fish released in the first event was not significantly different among the geographic sublocations of release ($\chi^2 = 1.661$, df = 2, P = 0.44), sex ($\chi^2 = 0.804$, df = 1, P = 0.37) or marine age ($\chi^2 = 5.212$, df = 2, P = 0.07). No multi-repeat spawning fish were recaptured during the second sampling event. The probability of capture did not differ among initial or repeat spawning history ($\chi^2 = 2.919$, df = 1, P = 0.09). No significant difference was detected between the cumulative length distributions of all fish marked on the spawning grounds and all recaptures at the weir (D = 0.135, P = 0.066, $n_1 = 281$, $n_2 = 142$) (test 1). A similar test of all fish marked on the spawning grounds and all captures at the weir did detect a significant difference in the length distribution of steelhead between events (D = 0.114, P = 0.002, $n_1 = 281$, $n_2 = 4,618$) (test 2). Since the probability of capture at the weir was equal for all sizes of steelhead, the result of test 2 is likely due to the large sample size (n = 4,899), allowing us to detect differences that are not biologically significant. Therefore a single unstratified estimate of abundance was calculated. The estimated abundance of steelhead in the Karluk River drainage during the spring of 1994 was 9,116 fish (SE = 522).

Temporal trends in the emigration of marked and unmarked steelhead through the weir were similar (Figure 5). There was no significant difference in the marked:unmarked ratio at the weir due to marine age ($\chi^2 = 2.681$, df = 2, P = 0.26) or sex ($\chi^2 = 2.586$, df = 1, P = 0.12). However, there was a significant difference in the marked to unmarked ratio at the weir among spawning histories ($\chi^2 = 8.78$, df = 1, P < 0.003). Within a spawning history, there were also significant differences in marine age between sexes at the weir for initial spawners ($\chi^2 = 256.42$, df = 2, P < 0.001), and repeat and multi-repeat spawners pooled ($\chi^2 = 34.725$, df = 1, P < 0.001). This was largely due to an increase in the number of initial spawning males relative to females and the number of repeat spawning females observed at the weir (Table 8 and Figure 6). Subsequent testing among and between sexes, spawning histories and time detected a significant difference in the number of initial spawning fish at the weir. Therefore, the age composition by sex and spawning history of the emigrating population was stratified.

Biological Composition of the Spawning Population

The length and age composition of steelhead spawning in the Karluk River was divided into three categories by spawning history. These categories were then partitioned by total marine age (in years) among the sexes. The majority of steelhead sampled on the spawning grounds were initial spawners with total marine age of 2, 3 or 4 years (86%) and a mean length of 631 mm FL (SE = 1) (Tables 9 and 10 and Appendix A1). Fourteen percent of the prespawning concentration at the Portage area was composed of repeat (11%) and multi-repeat (3%) spawners with mean lengths of 674 mm FL (SE = 5) and 734 mm FL (SE = 9), respectively (Tables 9 and 10). Repeat spawning females were dominated by 4- and 5-ocean fish (95%) followed by 3-ocean fish (5%). Three and 4-ocean fish dominated the male repeat spawner age category (96%). The multi-repeat spawners

Table 7.-Summary of tagging data for steelhead released at Portage and recaptured at the Karluk River weir, Karluk River, 1994.

	Marking Event at Portage 4/4-4/14	Recapture Event at Weir 5/9-7/13		
Sublocation[a]	Number Tagged Fish Released	Recovered	Not Recovered	Percent Recovered
1	153	72	81	47.1
2	48	21	27	43.8
3	81	31	50	38.3
Total	285	124[b]	158	
Number Untagged		4,498		
Number Examined		4,638		
Percent Marked Recoveries		3.1		

[a] 1 = Above Portage; 2 = Portage Area; 3 = Below Portage.

[b] Does not include 18 fish which lost their tags and one fish that did not have its tag number recorded during the recapture event at the weir.

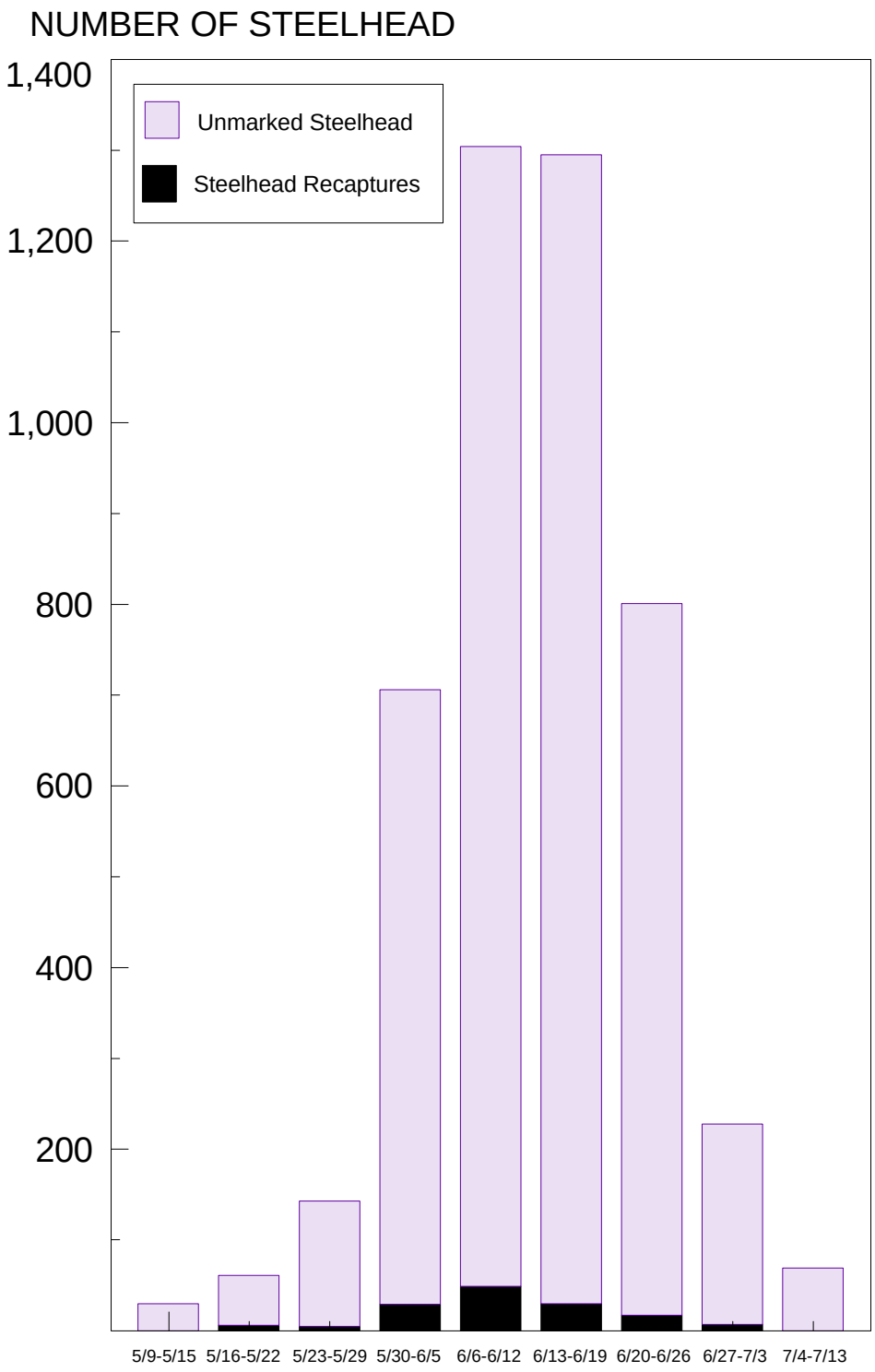

Figure 5.-Weekly comparison of marked and unmarked steelhead emigrating through the Karluk River weir, May 9 through July 13, 1994.

Table 8.-Sex composition, by week, of emigrating steelhead, Karluk River, 1994.

Spawning History	Sex	Weekly Totals May 9 through July 13									Total
		1	2	3	4	5	6	7	8	9	
Initial[a]	F	3	14	42	43	30	44	48	46	27	297
	M	13	19	22	53	63	71	44	66	18	369
Total		16	33	64	96	93	115	92	112	45	666
Repeat[b]	F	1	3	19	13	14	4	16	4	2	76
	M	5	8	17	18	13	4	4	1	0	70
Total		6	11	36	31	27	8	20	5	2	146
Multi-Repeat[c]	F	1	0	1	3	0	1	0	1	0	7
	M	2	1	0	0	0	0	0	0	0	3
Total		3	1	1	3	0	1	0	1		10
Total	F	5	17	62	59	44	49	64	51	29	380
	M	20	28	39	71	76	75	48	67	18	442
Total		25	45	101	130	120	124	112	118	47	822

[a] Adults spawning for the first time in spring of 1994.

[b] Adults spawning for the second time in spring of 1994.

[c] Adults spawning for the third or more times in spring of 1994.

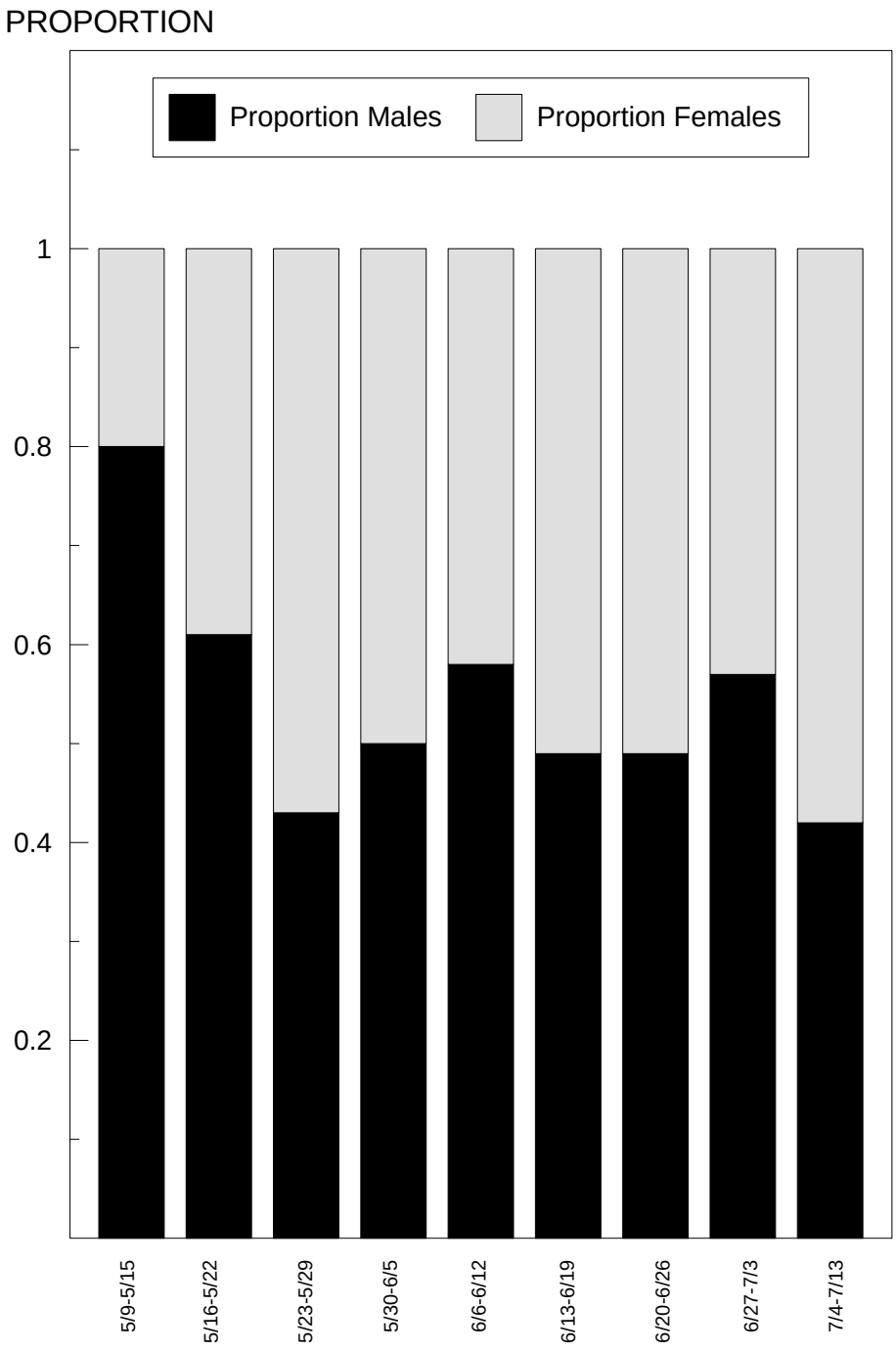

Figure 6.-Weekly comparison by sex of steelhead emigrating through the Karluk River weir, May 9 through July 13, 1994.

Table 9.-Length-at-age, by spawning history and sex, of hook and line captures of the spawning population of the Karluk River, April 1994.

		Females			Males			All		
Spawning History	Marine Age	Sample Size	Mean Length	SE	Sample Size	Mean Length	SE	Sample Size	Mean Length	SE
Initial[a]	2	10	553	4	72	548	1	82	549	1
	3	66	661	1	29	724	4	95	681	1
	4	5	757	37	9	788	21	14	777	14
Repeat[b]	3	1	610		3	563	26	4	575	20
	4	10	669	14	4	686	8	14	674	4
	5	5	723	11	2	695	34	7	729	11
Multi-Repeat[c]	5	2	692	26	0			2	692	26
	6	3	719	18	1	826		4	746	13
Totals										
Initial		81	654	1	110	614	2	191	631	1
Repeat		16	687	6	9	647	15	25	674	5
Multi-Repeat		5	715	16	1	826		6	734	9
Total		102	662	1	120	619	2	222	639	1

[a] Adults spawning for the first time in spring of 1994.

[b] Adults spawning for the second time in spring of 1994.

[c] Adults spawning for the third or more times in spring of 1994.

Table 10.-Age composition, by sex, of spawning steelhead trout in the Karluk River, April 1994.

		Females					Males				
Spawning History	Marine Age	Sample Size	Estimated Proportion	SE	Estimated Abundance	SE	Sample Size	Estimated Proportion	SE	Estimated Abundance	SE
Initial[a]	2	10	0.045	0.014	411	127	72	0.324	0.031	2,957	303
	3	66	0.296	0.031	2,710	294	29	0.130	0.023	1,191	210
	4	5	0.023	0.009	205	91	9	0.041	0.013	370	121
Repeat[b]	3	1	0.004	0.004	41	41	3	0.014	0.008	123	71
	4	10	0.045	0.014	411	127	4	0.018	0.009	164	82
	5	5	0.023	0.009	205	91	2	0.009	0.006	82	58
Multi-Repeat[c]	5	2	0.009	0.006	82	58	0	0.000			
	6	3	0.014	0.008	123	71	1	0.005	0.004	41	41
	7	0	0.000				0	0.000			
All Ages											
Initial		81	0.364	0.032	3,326	315	110	0.495	0.034	4,518	342
Repeat		16	0.072	0.017	657	160	9	0.041	0.013	369	121
Multi-Repeat		5	0.023	0.009	205	91	1	0.005	0.004	41	41
Total		102	0.459	0.032	4,188	321	120	0.541	0.033	4,928	347

[a] Adults spawning for the first time in spring of 1994.

[b] Adults spawning for the second time in spring of 1994.

[c] Adults spawning for the third or more times in spring of 1994.

were predominately females (70%) with total marine age up to 6 years. Both sexes were dominated by initial spawners (79% females and 92% males). Female initial spawners were larger with mean length of 654 mm (SE = 1) than males with mean length of 614 mm (SE = 2) ($F = 9.10$, $df = 1$, $P = 0.003$). Repeat spawning females were also larger than males: mean length of females was 687 mm (SE = 6) and mean length of males was 647 mm (SE = 15) ($F = 0.03$, $df = 1$, $P = 0.86$) (Table 9). For repeat and multi-repeat spawning fish there was a significant difference in length due to marine age ($F = 17.25$, $df = 3$, $P < 0.001$).

The majority of emigrating steelhead were males (52.5%), of which 87% were initial spawners with mean length of 588 mm FL (SE = 1) (Tables 11 and 12 and Appendix A2). Females comprised the remaining 47.5% of the emigration of which 78% were initial spawners with mean length of 644 mm FL (SE = 1). A total of 19% and 1% of all emigrating fish were repeat or multi-repeat spawners. Repeat spawners had mean lengths of 703 mm FL (SE = 1) for females and 671 mm FL (SE = 2) for males. Multi-repeat spawning females had a mean length of 720 mm FL (SE = 17) and males 789 mm FL (SE = 13) (Table 12).

Spawning Survival

Survival by sex and spawning history of marked fish was estimated from prespawn capture in April to postspawn weir emigration. Survival by marine age was not calculated due to small sample sizes. Overall survival was 43% for females and 51% for males (Table 13). Spawning survival of all steelhead was estimated at 51% (Table 13).

DISCUSSION

During 1993 the commercial salmon fishery was limited in the statistical areas targeted for sampling by this study. Therefore, the total estimated bycatch of steelhead was the lowest observed since sampling of these fisheries began in 1991 (Begich 1992, 1993). In addition to monitoring these fisheries, all emigrating steelhead passing through the weir at Karluk Lagoon during 1992 and 1993 were tagged (Begich 1992, 1993). No tagged steelhead were observed during commercial sampling in 1993 and one tag was voluntarily returned by commercial operators fishing within the Karluk study area during August of 1993. The percentage of the 58 steelhead caught that were repeat or multi-repeat spawners bound for the Karluk could not be estimated. Due to the proximity of the Karluk to other systems supporting steelhead populations (Figure 7) it is likely that steelhead bycatch is comprised of mixed stocks. Since commercial harvest has increased in these areas since the mid 1980s (Figures 8 and 9), future trends in harvest should continue to be monitored so that incidental steelhead harvests and Karluk stock contribution can be quantified.

The Karluk Village subsistence fishery targets immigrating salmon primarily beginning in May and continues until October. Effort increases in response to the influx of chinook, sockeye and coho salmon during those months. With large numbers of emigrant kelts available in this fishery during the latter part of May and June, and returning adults available in September, it is likely that steelhead were caught incidental to this directed subsistence salmon fishery. The reporting of catch and harvest of steelhead in this fishery needs to be included on subsistence harvest permits so that the impact of this fishery upon the steelhead population can be assessed. In Karluk Lagoon, state regulations allow the incidental harvest of steelhead for subsistence use in net fisheries directed at immigrating salmon.

The Portage area subsistence fishery by Larsen Bay residents is a directed fishery targeting overwintering steelhead. Current federal and

Table 11.-Age composition, by spawning history and sex, of steelhead emigrating through the Karluk River weir, May 9 through July 13, 1994.

		Females					Males				
Spawning History	Marine Age	Sample Size	Estimated Proportion	SE	Estimated Abundance	SE	Sample Size	Estimated Proportion	SE	Estimated Abundance	SE
5/09-5/22/94											
Initial[a]											
	2	0	0.000				7	0.146	0.051	9	3
	3	14	0.636	0.105	19	3	20	0.417	0.072	25	4
	4	3	0.136	0.075	4	2	5	0.104	0.045	7	3
Repeat[b]											
	3	0	0.000				1	0.021	0.021	1	1
	4	3	0.136	0.064	5	5	9	0.188	0.057	11	3
	5	1	0.045	0.039	1	1	3	0.063	0.035	4	2
Multi-Repeat[c]											
	5	0	0.000				1	0.021	0.021	1	1
	6	1	0.045	0.039	1	1	2	0.042	0.029	3	1
	7	0	0.000				0	0.000			
All Ages											
Initial		17	0.772	0.091	23	3	32	0.667	0.069	41	4
Repeat		4	0.182	0.072	6	2	13	0.271	0.065	16	3
Multi-Repeat		1	0.045	0.039	1	1	3	0.063	0.035	4	2
Total[d]		22	0.329	0.087	30	2	48	0.671	0.061	61	4

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Table 11.-Page 2 of 5.

Spawning History	Marine Age	Females: Sample Size	Females: Estimated Proportion	Females: SE	Females: Estimated Abundance	Females: SE	Males: Sample Size	Males: Estimated Proportion	Males: SE	Males: Estimated Abundance	Males: SE
5/23 - 6/05/94											
Initial[a]											
	2	5	0.041	0.018	18	8	39	0.355	0.046	148	19
	3	72	0.595	0.045	256	19	27	0.245	0.041	103	17
	4	8	0.066	0.023	28	9	9	0.082	0.026	34	11
Repeat[b]											
	3	2	0.017	0.006	7	3	8	0.073	0.013	30	5
	4	8	0.066	0.012	28	5	27	0.245	0.021	103	9
	5	22	0.182	0.019	78	8	0	0.000		0	
Multi-Repeat[c]											
	5	2	0.017	0.006	3	3	0	0.000		0	
	6	1	0.008	0.004	2	2	0	0.000		0	
	7	1	0.008	0.004	2	2	0	0.000		0	
All Ages											
Initial		85	0.702	0.042	302	18	75	0.682	0.045	285	19
Repeat		32	0.264	0.021	114	9	35	0.318	0.023	133	10
Multi-Repeat		4	0.025	0.008	15	10	0	0.000		0	
Total[d]		121	0.508	0.046	431	19	110	0.492	0.048	418	20

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Table 11.-Page 3 of 5.

Spawning History	Marine Age	Females: Sample Size	Females: Estimated Proportion	Females: SE	Females: Estimated Abundance	Females: SE	Males: Sample Size	Males: Estimated Proportion	Males: SE	Males: Estimated Abundance	Males: SE
6/06 - 6/19/94											
Initial[a]											
	2	11	0.118	0.034	141	40	113	0.748	0.035	1,049	49
	3	60	0.645	0.049	772	59	19	0.126	0.027	177	38
	4	3	0.032	0.018	39	22	2	0.013	0.009	19	13
Repeat[b]											
	3	1	0.011	0.003	13	4	8	0.053	0.006	74	8
	4	8	0.008	0.008	102	10	9	0.059	0.006	84	9
	5	9	0.097	0.009	116	10	0	0.000		0	
Multi-Repeat[c]											
	5	0	0.000		0		0	0.000		0	
	6	0	0.000		0		0	0.000		0	
	7	1	0.011	0.003	13	4	0			0	
All Ages											
Initial		74	0.796	0.042	952	50	134	0.887	0.026	1,245	13
Repeat		18	0.194	0.011	231	14	17	0.113	0.008	158	12
Multi-Repeat		1	0.011	0.012	13	4	0	0.000		0	
Total[d]		93	0.460	0.052	1,196	62	151	0.540	0.041	1,403	49

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Table 11.-Page 4 of 5.

Spawning History	Marine Age	Females: Sample Size	Females: Estimated Proportion	Females: SE	Females: Estimated Abundance	Females: SE	Males: Sample Size	Males: Estimated Proportion	Males: SE	Males: Estimated Abundance	Males: SE
6/20 - 7/13/94											
Initial[a]											
	2	18	0.125	0.028	68	15	111	0.835	0.032	461	18
	3	95	0.659	0.039	361	22	17	0.128	0.029	70	16
	4	8	0.056	0.019	30	10	0	0.000		0	
Repeat[b]											
	3	1	0.007	0.004	4	2	3	0.023	0.006	13	3
	4	11	0.076	0.011	41	6	2	0.015	0.005	8	3
	5	10	0.069	0.012	38	6	0	0.000		0	
Multi-Repeat[c]											
	5	0	0.000				0	0.000		0	
	6	0	0.000				0	0.000		0	
	7	1	0.007	0.004	4	2	0	0.000			
All Ages											
Initial		121	0.840	0.031	459	17	128	0.962	0.017	531	9
Repeat		22	0.152	0.015	83	8	5	0.038	0.008	21	4
Multi-Repeat		1	0.007	0.016	4	2	0	0.000		0	
Total[d]		144	0.497	0.042	546	23	133	0.503	0.044	552	24

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Table 11.-Page 5 of 5.

Spawning History	Marine Age	Females Estimated Abundance	Females SE	Males Estimated Abundance	Males SE	All Estimated Abundance	All SE
5/09 - 7/13/94							
Initial[a]							
	2	227	35	1,667	78	1,894	80
	3	1,408	74	375	44	1,783	79
	4	101	23	60	18	161	29
Repeat[b]							
	3	24	12	118	25	142	27
	4	176	31	206	33	382	44
	5	233	35	4	4	237	35
Multi-Repeat[c]							
	5	7	7	1	1	8	6
	6	5	6	3	3	8	6
	7	21	12	0		21	10
All Ages							
Initial		1,737	78	2,102	81	3,838	61
Repeat		433	47	328	41	761	60
Multi-Repeat		33	14	4	5	37	14
Total[d]		2,202	81	2,434	80	4,636	2

[a] Adults spawning for the first time in spring of 1994.

[b] Adults spawning for the second time in spring of 1994.

[c] Adults spawning for the third or more times in spring of 1994 .

[d] Total not estimated, observed counts at weir.

Table 12.- Length-at-age, by spawning history and sex, of emigrating steelhead, Karluk River, 1994.

		Females			Males			All		
Spawning History	Marine Age	Sample Size	Mean Length	SE	Sample Size	Mean Length	SE	Sample Size	Mean Length	SE
Initial[a]										
	2	34	553	3	270	544	1	304	545	1
	3	241	651	1	83	691	1	324	662	1
	4	22	708	3	16	783	10	38	740	4
Repeat[b]										
	3	4	634	19	20	589	4	24	596	3
	4	30	679	3	47	699	2	77	691	1
	5	42	726	2	3	776	21	45	730	2
Multi-Repeat[c]										
	5	2	705	24	1	800		3	736	39
	6	2	709	76	2	784	13	4	746	4
	7	3	737	38	0			3	737	38
All Ages										
Initial		297	644	1	369	588	1	666	612	1
Repeat		76	703	1	70	671	2	146	661	1
Multi-Repeat		7	720	17	3	789	13	10	741	12
Total		380	657	1	442	602	1	822	627	1

[a] Adults spawning for the first time in spring of 1994.

[b] Adults spawning for the second time in spring of 1994.

[c] Adults spawning for the third or more times in spring of 1994.

Table 13.-Spawning survival, by sex and spawning history, of steelhead marked on the spawning grounds and recaptured at the weir, Karluk River, 1994.

	Females			Males			All		
Spawning History	Number Marked	Number Recaptured	Survival	Number Marked	Number Recaptured	Survival	Number Marked	Number Recaptured	Survival
Initial[a]	82	38	0.463	109	59	0.541	191	99	0.518
Repeat[b]	15	6	0.400	9	2	0.222	24	8	0.333
Multi-Repeat[c]	5	0	0.000	1	0	0.000	6	0	0.000
Total[d]	102	44	0.431	119	61	0.513	282	143	0.507

[a] Adults spawning for the first time in spring 1994.

[b] Adults spawning for the second time in spring of 1994.

[c] Adults spawning for the third or more times in spring of 1994.

[d] Totals may not add due to illegible or regenerated scales.

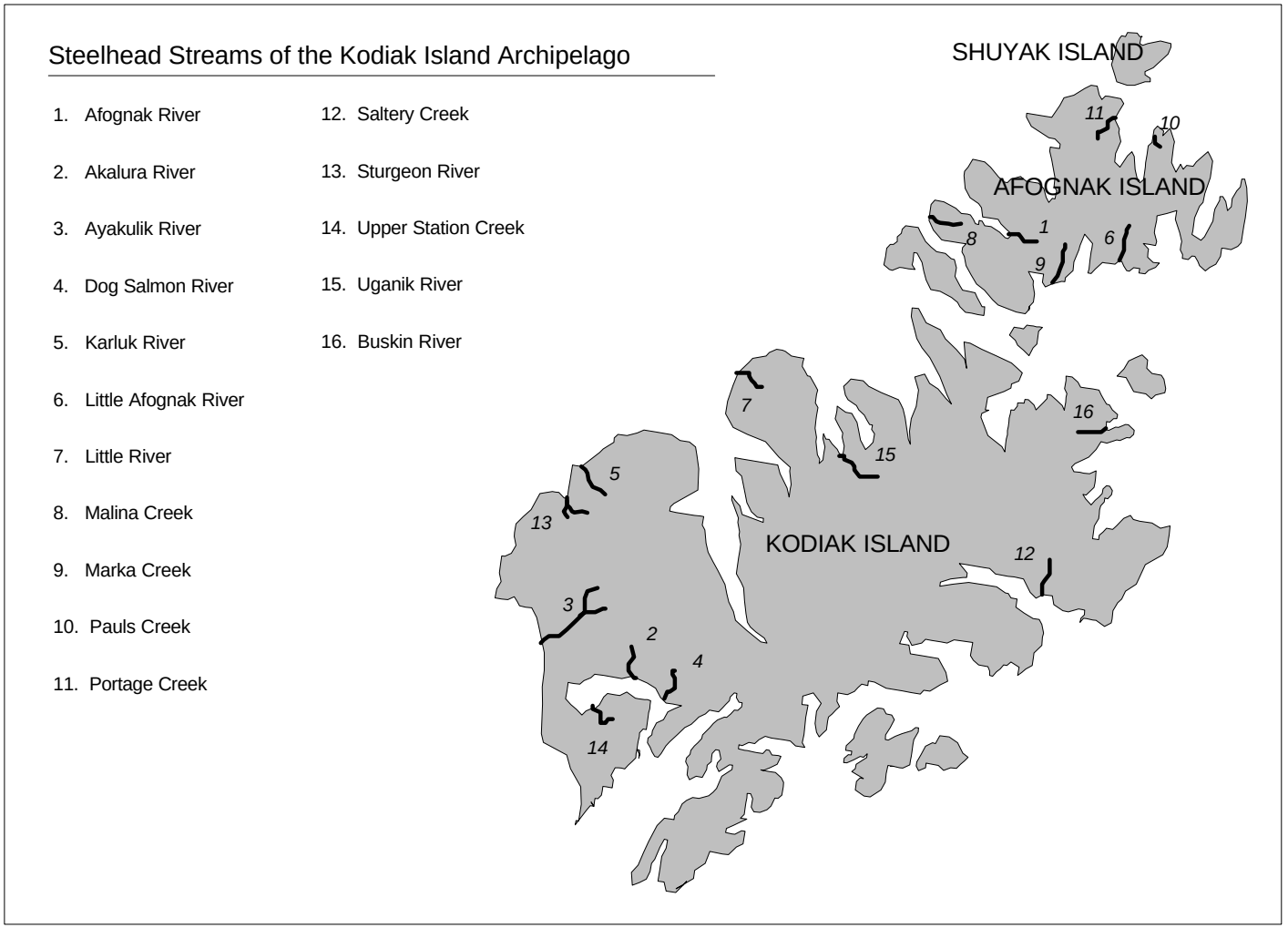

Figure 7.-Steelhead systems of the Kodiak Island Archipelago.

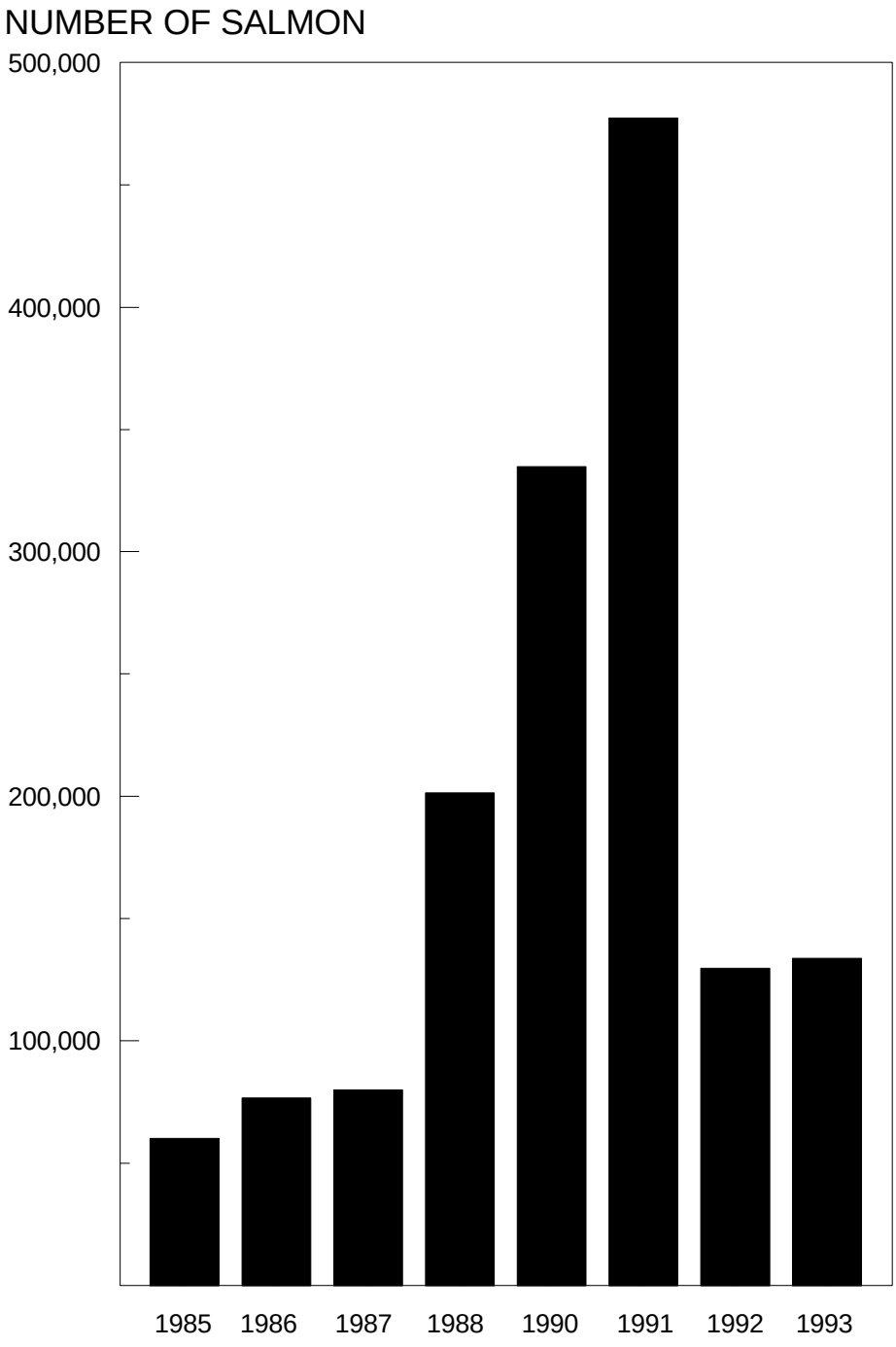

Figure 8.-Historic set gill net harvest of salmon from the five statistical areas included in the Karluk River marine study area, August 15 through September 10, 1985 through 1993. There was no set gill net fishery in 1989 due to the *Exxon Valdez* oil spill.

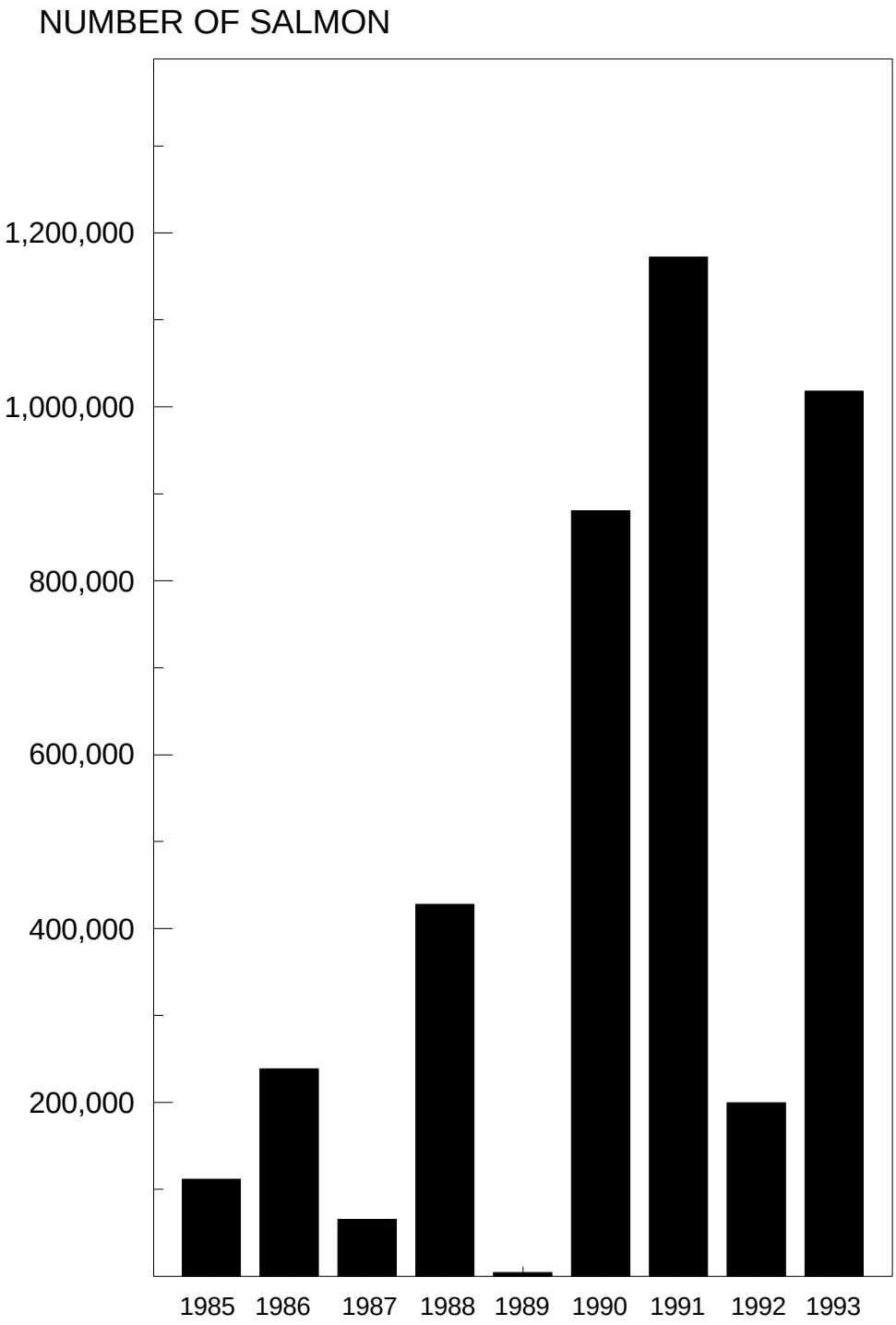

Figure 9.-Historic purse seine harvest of salmon from the eight statistical areas included in the Karluk River marine study area, August 15 through September 30, 1985-1993.

state regulations prohibit the directed harvest of steelhead trout for subsistence use in the Kodiak area. Furthermore, it is illegal to use rod and reel to harvest steelhead for subsistence purposes. Steelhead may be taken on the upper Karluk River by rod and reel from June 15 through March 31 with a limit of 2 fish per day of which only 1 may be in excess of 20 inches in length. The high catchability and concentrations of these fish make them extremely vulnerable to harvest during the winter and spring months. Dissemination of information on current state and federal regulations for the Karluk River should be directed at residents of Larsen Bay to fully protect the spawning population and attain an orderly and lawful winter/spring sport fishery. Harvest reporting in this fishery encompasses adult steelhead from 2 return years (Table 5). To ensure apportionment of the harvest to the proper return year, interdivisional cooperation and sampling methodology should be developed.

Sport harvest of steelhead in the Karluk River is low. From 1991 through 1993 approximately 93% of all steelhead caught were released. It is not known if the autumn steelhead fishery is inherently catch and release or if this level of release is an effect of regulations prohibiting the harvest of steelhead between April 1 and June 14. Furthermore, fishing effort on the Karluk River has increased over 200% since 1990. Therefore, future trends in effort and harvest need to be monitored.

The estimated abundance of 9,116 spawning steelhead is the highest estimate since this investigation began (Table 14). During 1994 no emigrating steelhead were observed in the lower river by Karluk Village residents or ADF&G personnel prior to the onset of weir installation on May 7, 1994. Therefore, the estimate of a 51% spawning survival is a maximum. Conversely, during 1992 and 1993, steelhead were observed in the lower river and Lagoon prior to weir installation. Estimates of survival for these years are minimums. Furthermore, spawning survival to emigration has decreased since 1992 (Table 14). Continued monitoring will provide relationships between kelt and spawner abundance.

The component of initial spawners (81%) in the Karluk River during 1994 was within the range reported since this study began, 1992 (78%) and 1993 (87%) (Begich 1992, 1993). The majority of the Karluk population has been comprised of males in 2 of the last 3 years. This might be explained by the polygamous spawning behavior and the pairing of multiple accessory males with one female. Conversely, during the last 2 years the majority of steelhead emigrating the Ayakulik River have been females (49% male:51% female in 1993 and 45% male:55% female in 1994) (Appendix B1 and B2). Future inriver sampling and tag returns from the Karluk should provide insight into the temporal fluctuations of the sex and age composition of the population.

The majority of the fish sampled at the Karluk during 1994 were 4 to 6 years in total age (Appendix A1 and A2). These fish would be the progeny of returning adults from 1987 through 1989, years with three of the four lowest historic kelt counts on record (Figure 3). This information warrants further investigation into both historic weir data and continued monitoring of spawning and emigrant populations so that relationships can be identified and total returns assessed.

During 1992 and 1993, 2,584 and 4,084 steelhead emigrating from the Karluk River were tagged. During 1993, 236 fish tagged in 1992 were recaptured at the weir and during 1994, 487 fish tagged in 1992 were recaptured at the weir. Returns of repeat spawning adults are not understood and may significantly

Table 14.-Population estimates and spawning survival to weir emigration by sex of Karluk River steelhead, 1992 through 1994.

	Females			Males			All		
Year	Estimated Spawning Population	Weir Count	Estimated Spawning Survival	Estimated Spawning Population	Weir Count	Estimated Spawning Survival	Estimated Spawning Population	Weir Count	Estimated Spawning Survival
1992	1,602	999	0.624	2,505	1,583	0.632	4,107	2,584	0.667
1993	4,687	2,654	0.549	2,339	1,428	0.500	7,026	4,084	0.583
1994	4,188	2,203	0.431	4,928	2,435	0.513	9,116	4,638	0.507
Mean							6,750	3,768	0.586

contribute to future total adult returns. Therefore, timely and efficient passage of post-spawn downstream migrants in steelhead systems weired for enumeration of immigrating salmon is of paramount importance. Furthermore, a total of 225 fish (5.5%) from the 1993 emigrant population returned to spawn at the Karluk River during 1994. Continued investigation of the Karluk steelhead population will provide insight into the impact of emigrating kelts on future adult returns and repeat spawning life history phenomena.

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APPENDIX A

Length-at-Age Data for Steelhead from the Karluk River Study Area, 1994

Appendix A1.-Length-at-age of hook and line captures of the spawning population, Karluk River, April 1994.

	Females			Males			All		
Age Class	Sample Size	Mean Length	SE	Sample Size	Mean Length	SE	Sample Size	Mean Length	SE
2.2	2	549	1	33	543	2	35	543	2
2.3	23	658	28	15	729	4	38	686	3
2.4	2	835	108	3	743	40	5	780	24
3.3	12	667	8	3	565	8	15	677	6
3.4	1	709		1	720		2	715	3
2.2s1	1	610		1	530		2	570	19
2.3s1	5	654	11	0			5	654	11
2.2s2	2	670	10	3	684	12	5	678	7
2.3s2	2	741	22	2	695	34	4	718	9
2.2s2s1	1	692		0			1	692	
2.3s1s1	1	726		0			1	726	
3.2s2s1	1	667		0			1	667	
2.2s2s1	1	692		0			1	692	
2.2s2s2	0			1	826		1	826	
R.2	8	554	6	39	553	2	47	553	1
R.3	31	662	2	11	720	9	42	677	2
R.4	2	703	17	5	829	12	7	793	11
R.2s1	0			2	580	39	2	580	39
R.3s1	3	694	28	0			3	694	28
R.2s2	0			1	693		1	693	
R.3s2	3	745	21	0			3	745	21
R.3s2s1	1	790		0			1	790	
Total	102	662	1	120	619	2	222	639	1

Appendix A2.-Length-at-age of emigrating steelhead captured at the Karluk weir, Karluk River, 1994.

	Females			Males			All		
Age Class	Sample Size	Mean Length	SE	Sample Size	Mean Length	SE	Sample Size	Mean Length	SE
2.2s	22	544	5	149	543	1	171	543	1
3.2s	0			2	574	6	2	574	6
2.3s	118	648	1	47	680	3	164	657	1
3.3s	16	667	7	4	741	8	20	682	6
2.4s	11	701	7	10	770	18	21	734	7
3.4s	2	731	19	0			2	731	19
2.2s1s	3	646	24	13	583	6	16	595	6
2.3s1s	11	675	8	4	734	23	15	691	7
2.2s2s	3	669	6	21	704	3	24	699	3
3.2s2s	2	702	73	1	683		3	695	35
2.3s2s	27	719	3	1	687		28	720	3
2.2s2s1s	1	729		1	800		2	765	35
2.2s2s2s	0			1	770		1	770	
2.3s2s2s	3	737	39	0			3	737	39
2.3s2s1s	1	787		0			1	787	
R.2s	13	570	10	118	544	1	132	547	1
R.3s	105	652	1	34	700	3	139	664	1
R.4s	9	712	7	6	804	15	15	749	8
R.2s1s	1	596		7	599	11	8	598	9
R.2s2s	3	697	7	19	689	3	22	690	3
R.3s1s	12	686	7	1	675		13	685	6
R.3s2s	13	732	5	2	781	37	15	739	5
R.4s1s	2	775	25	0			2	775	25
R.2s2s1s	1	681		0			1	681	
R.2s2s2s	1	631		1	797		2	714	41
Total	380	657	1	442	602	1	822	627	1

APPENDIX B

Length-at-Age Data for Steelhead from the Ayakulik River, 1994

Appendix B1.-Length-at-age of emigrating steelhead captured at the Ayakulik weir, Ayakulik River, 1994.

	Females			Males			All		
Age Class	Sample Size	Mean Length	SE	Sample Size	Mean Length	SE	Sample Size	Mean Length	SE
2.2s	4	646	14	14	539	5	18	563	6
2.3s	25	649	2	17	667	5	42	652	2
3.3s	0			1	693		1	693	
2.4s	0			1	838		1	838	
2.2s1s	1	652		0			1	652	
2.2s2s	0			2	733	8	2	733	8
2.3s1s	5	734	12	1	755		6	742	5
3.3s1s	1	782		0			1	782	
2.3s2s	8	740	4	3	752	4	11	743	4
2.2s2s2s	1	718		0			1	718	
2.3s2s1s	1	759		1	783		2	771	12
2.3s2s2s	2	730	9	0			2	730	9
2.3s1s1s	2	746	23	0			2	746	23
R.2s	2	536	24	7	549	8	9	546	6
R.3s	8	684	9	8	611	11	16	686	5
R.2s1s	1	667		1	609		2	638	28
R.2s2s	0			2	706	4	2	706	4
R.3s1s	4	728	14	1	649		5	712	5
R.3s2s	6	723	11	0			6	723	11
R.3s2s1s	1	808		0			1	808	
R.3s1s1s	1	790		0			1	790	
Total	73	689	2	59	639	3	132	667	1

Appendix B2.-Length-at-age by spawning history and sex of emigrating steelhead, Ayakulik River, 1994.

		Females			Males			All		
Spawning History	Marine Age	Sample Size	Mean Length	SE	Sample Size	Mean Length	SE	Sample Size	Mean Length	SE
Initial[a]	2	6	609	19	21	542	2	27	557	4
	3	33	658	2	26	674	3	59	665	1
	4	0			1	838		1	838	
Repeat[b]	3	2	660	7	1	609		3	643	16
	4	10	736	6	6	714	11	16	728	4
	5	14	732	4	3	752	21	17	734	5
Multi-Repeat[c]	5	3	761	18	0			3	761	18
	6	3	762	24	1	783		4	767	16
	7	2	730	9	0			2	730	9
Initial		39	650	2	48	620	3	87	633	2
Repeat		26	728	3	10	715	10	36	725	2
Multi-Repeat		8	753	1	1	783		9	757	7
Total		73	689	2	59	639	3	132	667	1

[a] Adults spawning for the first time spring of 1994.

[b] Adults spawning for the second time spring of 1994.

[c] Adults spawning for the third or more times during spring of 1994.