FRED Reports

Sockeye Salmon Rehabilitation
at Upper Thumb River,
Karluk Lake, Alaska 1978 to 1984

by
Lorne E. White

Number 69

Alaska Department of Fish & Game
Division of Fisheries Rehabilitation,
Enhancement and Development

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ABSTRACT

This report describes the sockeye salmon, *Oncorhynchus nerka*, rehabilitation work at Karluk Lake, Kodiak Island, Alaska during 1978-1984. The primary objective of this project was to rehabilitate the Upper Thumb River subpopulation by fry and eyed-egg plants. Results of the 1978 to 1984 brood-year spawning operations indicate production of 54,975,000 eyed eggs, representing 81.9% survival to the eyed stage. A total of 2,042,000 fry were produced from incubation to fry stage (29.4% survival). Eyed-egg plant to fry survival was 41.2% (range 1.4% to 61.3%), resulting in a preemergent population estimate of 12,778,000 fry for the 1978 to 1983 brood years. The annual smolt migration has averaged 1,200,000 (range 821,000 to 2,000,000) from 1979 to 1984. Smolt size, length, and weight has decreased, when compared to earlier recorded periods. The age-2.0 smolts remain the dominate age group. Thumb Lake zooplankton has shown extreme fluctuations in number of copepods and cladocerans. Escapements from 1978 to 1984 into Karluk Lake have averaged 323,000 sockeye salmon per year (range 146,000 to 513,000); the catch has annually averaged 176,000 (range 93,000 to 258,000). The overall interception rate has been 35.2%. The return of 20,000 to 22,000 sockeye salmon to Upper Thumb River in 1983 and 1984, respectively, was the best recorded to that system since 1926 and coincides with the first returns from the rehabilitation effort.

KEY WORDS: Karluk Lake, sockeye salmon, *Oncorhynchus nerka*, rehabilitation, fry plants, egg plants, zooplankton.

INTRODUCTION

At one time, Karluk Lake on Kodiak Island, Alaska (Figure 1), supported a sockeye salmon, *Oncorhynchus nerka*, run of greater magnitude in relation to lake size than any other sockeye salmon producing system in the world. Since the early years of overexploitation (when the runs ranged from 1 to 5 million fish), the runs have declined. Recently (1978 to 1984), escapements have averaged only 323,000 sockeye salmon, and the catch has been mainly incidental to the Kodiak Island westside pink salmon, *O. gorbuscha*, fishery.

The Karluk sockeye salmon fishery began in 1881 with the establishment of the Smith and Hirsh saltery on Karluk spit. After 1881 the industry increased its operation to five canneries. These facilities operated until 1911, when all canning activity ceased on the spit; thereafter, operations continued at Larsen Bay.

Salmon fishing during these early days was carried out near the spit, and the catches were very large. Nearly four million sockeye salmon were taken in 1901; by comparison, the largest take since statehood has been 362,949 fish. Escapement data taken since 1921 (Table 1) depict a steady decline of the Karluk sockeye salmon run.

There are many theories advanced for the decline of the Karluk sockeye salmon; most stem from the belief that overexploitation by the fishing industry resulted in an upset of the complex biological relationships and life cycle of the Karluk sockeye salmon (Koenings and Burkett, 1987). As early as 1932, the federal government initiated an investigation to determine the cause for this decline. Early investigators, such as Barnaby (1944), observed that while marine survival was high for Karluk sockeye salmon, the freshwater survival was low (1% or less).

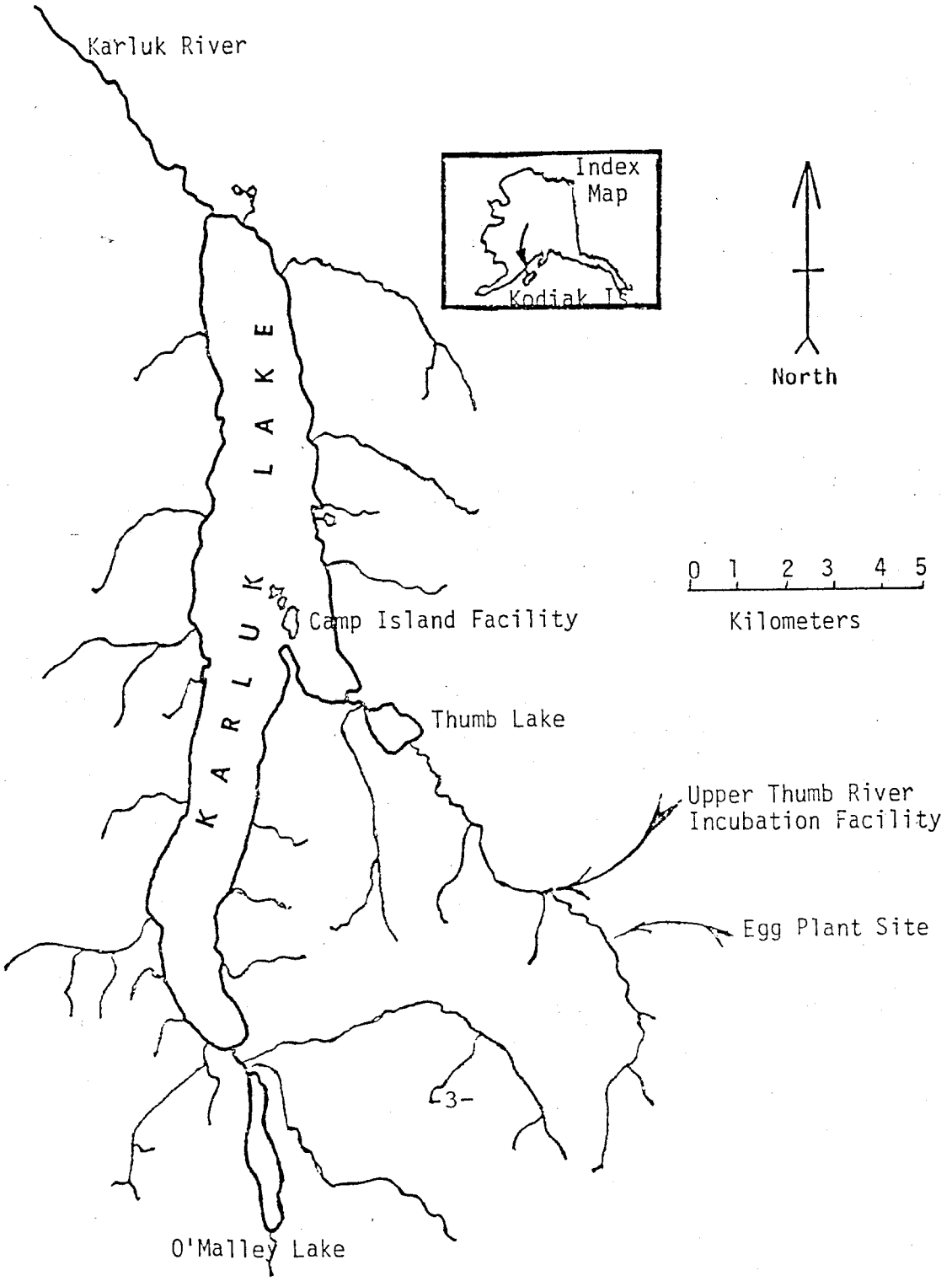

Figure 1. Karluk Lake, Alaska, showing major tributaries, important sockeye salmon spawning areas, and rehabilitation facilities.

Table 1. Karluk River 10-year average sockeye salmon run, 1882 to 1980, as well as 1981, 1982, 1983, and 1984.

Year	Average escapement	Average catch	Percent of average run caught	Total average run
1882-1890[1/]	-	1,326,397	-	-
1891-1900	-	2,503,987	-	-
1901-1910	-	2,205,012	-	-
1911-1920	-	1,342,637	-	-
1921-1930	1,182,125	974,198	45.6	2,136,323
1931-1940	972,238	799,054	45.1	1,771,292
1941-1950	656,200	487,351	42.6	1,143,551
1951-1960	403,150	146,135	26.6	549,285
1961-1970	389,445	219,939	36.1	609,384
1971-1980	338,662	107,030	24.0	445,692
1981	222,706	95,143	29.9	317,849
1982	164,407	146,755	47.2	311,162
1983	436,145	140,950	24.4	577,095
1984	420,268	258,375	38.1	678,643

1/ 9-year average.

Source: Barnaby 1921 to 1936; United States Fish and Wildlife Service, weir reports and agent's reports, 1937 to 1956; ADF&G, Comm. Fish. Div., Area Annual Reports, 1957 to 1984.

From 1964 to 1968, Drucker (1970) found that the percentage of eggs surviving from potential deposition to actual deposition was very low (mean of 13.6%, range 3.0% to 23.3%).

Survey data collected from 1970 to 1975 (White 1976) corroborated theories of other researchers that related several factors to the depleted status of the Karluk sockeye salmon:

1. the present fry recruitment is far below the historic and present carrying capacity of the system;

2. the near elimination of discrete subpopulations of the run that were major producers; and

3. uneven distribution of spawners resulting in underutilization of the total spawning area.

In 1976 a bond issue that supplied funds for a major project to restore the Karluk sockeye salmon run was approved by State of Alaska voters. The Fisheries Rehabilitation, Enhancement and Development (FRED) Division implemented a plan to rehabilitate sockeye salmon at Upper Thumb River. Upper Thumb River was selected because historical records (Gilbert and Rich 1927) indicated that this tributary had formerly produced many more fish than it was at present.

This report summarizes the results of the rehabilitation effort at Upper Thumb River from 1978 through 1984.

REHABILITATION EGG TAKE, INCUBATION, AND EYED EGG PLANT 1978 TO 1984

Methods

Gametes for the rehabilitation project were supplied from sockeye salmon returning to Upper and Lower Thumb Rivers. Eggs were taken by incision and fertilized in a spawning bucket or plastic container. From 1978 to 1980, the eggs from six females and the milt from two to three males were used per bucket; from 1981 to 1984, the gametes from one female were stripped into individual containers and fertilized with the gametes from two to three males. During the latter period, each container of fertilized eggs was isolated until the eggs were water hardened and disinfected with a Betadine solution for 10 minutes. Water-hardened and disinfected eggs were then consolidated and transported 2.75 km to the incubation facility. In 1978 and 1979, eggs were incubated at Devil's Creek (Coast Guard base in Kodiak) and at the Kitoi Bay Hatchery (Afognak Island). In 1980 a new incubation facility was constructed on the east fork of Upper Thumb River (Figure 2), and subsequently, all eggs were incubated at this site. Eggs were incubated in 74-cm-diameter by 79-cm-deep compartments. Flows were maintained at approximately 30 liters per minute (lpm). On every third day during the entire green- to eyed-egg stage of incubation, eggs were treated with formalin at 1:1000 to 1:600 concentration for 15 minutes.

The eyed eggs were shocked and culled with a photoelectric egg picker and counted by volumetric displacement. Eyed eggs were carried (backpacked) from the incubation facility to the planting sites (0.5 km to 6.0 km) that were above the first and second falls on the east and north fork of Upper Thumb River (*see* Figure 1); these areas had no natural spawners.

Figure 2. Upper Thumb River, Karluk Lake streamside incubation facility.

With the aid of an egg-planting device (Figure 3) described by White (1980), eggs were planted in areas where the highest survivals could be expected, given our experience with pre-emergent sampling of fry in gravel. The probe end of the device was driven approximately 30 cm into the streambed, and eggs were hydraulically planted at the rate of 455 eggs/probe and at a distance of 15 cm or more between each plant.

Results

The 1978 to 1984 spawning operation results are shown in Appendix Table 1. The taking of eggs at Lower and Upper Thumb River has resulted in 46,606,000 eyed eggs from the early run of fish and 8,369,000 eyed eggs from the late run of fish. Green- to eyed-egg survival has averaged 81.9%. The egg-planting summary is shown in Appendix Table 2. There have been 44,111,000 eggs from early run fish and 3,822,000 eggs from late-run fish planted over the past 7 years. The density of the planted eggs has averaged 2,508 eggs/m^3 during this period.

The age composition of the brood stock is summarized in Appendix Tables 3 and 4. The brood stock for the Upper Thumb River was composed of 4-year-old fish (7.1%), 5-year-old fish (49.8%), 6-year-old fish (39.6%), and 7-year-old fish (3.5%). Of the nine age groups represented in the spawning sample, ages 2.2 (43.3%) and 2.3 (31.0%) predominated.

Discussion

In the initial years from 1978 to 1981, a mean of only 5.6 million eggs were taken annually. This was a result of weak natural runs to Upper Thumb River (10,000 fish or less) and project plans that called for using not more than 50% of the natural stock for obtaining eggs. In contrast to this, a mean of 14.8 million eggs has been taken annually from 1982 to 1984.

Figure 3. Eyed sockeye salmon eggs being planted in Upper Thumb River, Karluk Lake, with aid of an egg-planting device.

This is a direct result of strong runs of fish to Upper Thumb River, coinciding with the first returning fish from the initial rehabilitation efforts in 1978 and 1979.

The average green- to eyed-egg survival of 81.9% (range 73.8% to 87.2%) is below the desired 90% survival level. Mortality can be attributed to the additional handling associated with the half-hour "backpack" from the spawning-operation site to the incubation facility in the latter years and hour-long charter flights in the former years. From 1978 to 1982, eggs from early and late-run sockeye salmon were taken to restore both of these runs to Upper Thumb River. The late-run green- to eyed-egg incubation phase of the project involved prolonged and, subsequently, expensive fish-cultural activities. The cold water experienced in the September and October periods resulted in eggs reaching the eyed stage from November to February. This problem, coupled with the interception of the late-run fish in the pink salmon fishery, resulted in the decision to take only early run eggs in 1983 and 1984. It is noteworthy that in 1984 all eggs were taken from Upper Thumb River; supplemental eggs were not needed from Lower Thumb River.

A total of 47.9 million eggs have been planted over the 7-year period. In 1983 and 1984, 12.3 million and 13.2 million eggs, respectively, were planted; because of such large numbers of eggs, new planting areas had to be explored and evaluated. The major area of expansion took place in the upper reaches of Upper Thumb River. This area is remote (5 to 6 km from the incubation site), requiring about 1.5 hours (backpacking time) to reach the site. There is only room for approximately 16 million eggs in Upper Thumb River before it becomes necessary to increase the planting density, plant other areas (e.g., North Fork), or plant eggs into the area presently used by the natural spawners.

REHABILITATION EGG PLANT TO FRY SURVIVAL

Background

Survivals of planted eggs through the fry stage were estimated by mark-recapture and preemergent fry sampling. Had one method failed to provide reliable data because of early spring floods, the other ensured a useable estimate.

Methods

Mark-Recapture Fry Sampling:

Survival estimates by the mark-recapture method were based on hand counts of fry caught in an index fan trap, described by Ginetz (1977). Fry were marked with Bismark brown Y solution, according to a method described by Ward and Verhoeven (1963), and released approximately 100 m upstream from the trap. The daily fry population estimate was based upon the ratio of marked to unmarked fish that were hand counted.

The mark-recapture population estimate is expressed mathematically in terms of:

N = total number of fish in the population
D = total number of marked fish in the population
n = number of fish sampled
d = number of marked fish recaptured in the sample
$\hat{N}$ = estimate of N

The estimate is computed according to Rawson (1984),

$$N = \frac{nD}{d}\left[1 + \frac{D-d}{Dd}\right],$$

and its confidence interval is obtained by using the following formula for estimating the variance of $\hat{N}$ (Rawson 1984):

$$\text{Var } (N) = n\ (n+d)\ D\ (D-d)/d^3.$$

Preemergent Fry Sampling:

In the spring of 1981 to 1984, fry were pumped out of the gravel at randomly selected and marked areas in the egg planting site. Fry were collected in a cylindrically shaped net (0.1 m^2 x 1.12 m) and then hand counted. The method used is similar to that described by McNeil (1964).

Results

Mark-Recapture Fry Population Estimate:

The average estimated survival from eyed egg to emergent fry at Upper Thumb River during the 6-year period (Table 2) was 33.7% (range 1.4% to 70.0%). Only 1 year of the late-run fry was evaluated by this method. Most late-run eggs were planted in springwater pools downstream of the fan trap used for the mark-recapture samples.

Preemergent Fry Sampling:

Preemergent fry sampling over a 5-year period (Table 3) resulted in an average survival estimate of 41.2% (range 1.4% to 61.3%). The mean survival for the early run fry was 41.5%, while the mean survival for the late run was 39.3%.

Discussion

During the period of estimating the population by mark-recapture methods (1979 to 1983), fishing time was lost each year because

Table 2. Mark-recapture fry population estimate from the eyed eggs planted in the Upper Thumb River, 1978 to 1983 brood years.

Brood year	Sample year	Run timing	Number of eyed eggs planted	Number fry estimated	95% C.I. Upper	95% C.I. Lower	Mean % survival
1978	1979	Early	2,583,000	724,000	-	-	28.0
1978	1979	Late	1,207,000	234,000	-	-	19.4
1979	1980	Early	1,449,000	21,000	24,000	20,000	1.4[1/]
1980	1981	Early	3,038,000	663,000	705,000	622,000	21.8
1981	1982	Early	2,344,000	1,643,000	1,689,000	1,597,000	70.0
1982	1983	Early	9,206,000	2,715,000	3,164,000	2,055,000	29.5
1983	1984	Early	12,284,000	4,811,000	5,154,000	4,469,000	39.1
Total or Average			32,111,000	10,811,000	-	-	33.7

1/ Low survival due to planting technique and floods in October and November, 1979.

Table 3. Preemergent fry population estimate of eyed eggs planted in the Upper Thumb River, 1979 to 1983 brood years.

Brood year	Sample year	Run timing	Number of eyed eggs planted	Number of preemergent fry estimated	Sample size	No. of fry/dig	Mean % survival
1979	1980	Early	1,449,000	20,000	80	5.5	1.4[1/]
1980	1981	Early	3,038,000	1,013,000	47	120.3	33.3
1980	1981	Late	1,168,000	537,000	14	230.1	46.0
1981	1982	Early	2,344,000	1,437,000	43	279.3	61.3
1981	1982	Late	655,000	272,000	20	188.6	41.5
1982	1983	Early	9,206,000	4,483,000	123	221.4	48.7
1982	1983	Late	792,000	219,000	40	125.8	27.6
1983	1984	Early	12,300,000	4,797,000	73	177.0	39.0
Total/Average, Early & Late:			30,952,000	12,778,000	443	158.5	41.2
		Late:	2,615,000	1,028,000	74	162.4	39.3
		Early:	28,337,000	11,750,000	369	157.7	41.5

1/ Low survival due to planting technique and floods in October and November, 1979

of high-water conditions. There were 5, 1, 2, 3, and 1 days of fishing time lost in 1979, 1980, 1981, 1982, and 1983, respectively. The fry population was unknown during these high-water periods. Fry trapping in 1984 was exceptional, because no fishing time was lost during a 3-day high-water period. In this short flood period, a total of 1,500,000 fry, or 31.2% of the population, migrated.

When comparing the preemergent and mark-recapture estimates (Table 4) over the years, the former exceeded the latter by 1,897,000 fry. This can possibly be attributed to fish that were not recorded (mark-recapture estimates) during the flood periods. As in 1983, a few hours lost in a flood period during the peak emergence period could bias the mark-recapture population estimate. However, when lost fishing time occurred in the beginning or end of the migration (e.g., 1980 and 1982), the two methods of estimation were in close agreement. Overall, the preemergent estimate appears to be more reliable because flooding has not affected the results.

The preemergent data have also been useful in identifying survivals by specific planting areas. Many streambed areas have been avoided after the sampling indicated low survival because of apparent streambed instability. The highest mortality (or disappearance of eggs and fry) appears to have been caused by flooding, which shifts streambed gravel. Longer and more severe floods create greater mortality. Water discharge records, kept by the United States Geological Survey (USGS) over an 8-year period at Upper Thumb River (USGS 1976 to 1983), indicated a mean discharge of 2.07 m^3/s. In 1979 a flood discharge of over 4.49 m^3/s was recorded for a 17-day period in October and a 10-day period in November. The preemergent index after this flood was 5.5 fry/dig, which was the worst preemergent survival datum recorded.

Table 4. Preemergent and mark-recapture population estimates of all fry produced from eyed eggs planted at Upper Thumb River, Karluk Lake, 1978 to 1981 brood years.

Brood year	Sample year	Run timing	Mark-recapture population estimate	Preemergent population estimate	Preemergent estimate minus the mark-recapture estimate
1978	1979	Early	724,000	-	-
1978	1979	Late	234,000	-	-
1979	1980	Early	21,000	20,000	-1,000
1980	1981	Early	663,000	1,013,000	+350,000
1980	1981	Late	-	537,000	-
1981	1982	Early	1,643,000	1,437,000	-206,000

In October 1980 a 6-day flood period resulted in an index of 120.3 fry/dig, which is slightly below the 5-year average of 157.7 fry/dig for the early run. In 1981 there were only three flood days between October and November. This probably contributed to the index count of 279.3 fry/dig for 1981, which is the highest preemergent density recorded in the study period. In 1979, the worst year, the flood damage was apparent in not only a lack of live fry but also a lack of dead fry and eggs. There was physical evidence of streambed erosion; a portion of the egg-planting area was covered with gravel and had become part of a new stream bank. Fry that disappeared are assumed to have died; however, it is quite conceivable that some of the eggs or fry that are washed out of the egg-planting area may settle in low-velocity areas (downstream from the evaluation project) and survive.

The annual egg-to-fry survival for sockeye salmon that spawned naturally, based on the actual egg deposition, was 29.4% (range 19.0% to 42.8%) in the period from 1964 to 1967 (Drucker 1970). In our study the eyed-egg to-fry survival was 41.2% (range 1.4% to 61.3%: Table 3). Canadian spawning channel egg-to-fry survivals for sockeye salmon in 1983 averaged 46.3% (range 32.6% to 80.4%) at Upper Pitt, Weaver Creek, Gates Creek, and Nadina River (INPFC 1984). At Jones Creek, annual egg-to-fry survival of pink salmon was 37.7% (range 8.5% to 79.1%) over a 15-year study period (Fraser and Fedorenko 1983).

The pattern of fry emergence at Upper Thumb River was similar to that recorded previously by biologists at Karluk Lake (Drucker 1970). Migration was nocturnal. As the season progressed and daylight increased, the period of fry emergence shifted to later in the evening. The emergence period lasted from mid-March until mid-June, with the peak periods from the first week of April to the last week of May, depending upon floods or freshets that apparently trigger bursts of emergence.

REHABILITATION FRY PLANTS

Background

Experimental fry plants were recommended for the rehabilitation work at Upper Thumb River because this method could theoretically produce more fry/eggs taken than the egg-planting method.

Methods

Eyed sockeye salmon eggs were planted in cylindrically shaped incubators that are 120 cm high by 72 cm in diameter and filled with plastic saddles similar to those described by Leon and Bonney (1979). When possible, flows were maintained at approximately 30 lpm. Until the eggs approached the hatching stage, they were treated with formalin (at 1:1000) for 15 minutes every third day during the incubation stage. Emergent fry were hand counted at the beginning and end of the emergence periods; however, at the peak of the emergence period, they were counted by the displacement method.

From 1979 through 1981, eggs were incubated to the fry stage at the Kitoi Bay Hatchery (Afognak Island), and in 1982 and 1983 they were incubated at Upper Thumb River, Karluk Lake. For comparison of development indices (K_D) (Bams 1970), samples were taken from wild and incubator fry as well as from fry resulting from planted eggs. Approximately 50 fry were taken during each sample period. All samples were preserved in 10% formalin for 6 weeks before measuring. After 6 weeks, the fry were measured to the nearest millimeter and weighed to the nearest milligram.

Results

Attempts to use the Kitoi Bay Hatchery as an incubation site for Karluk sockeye salmon were mostly unsuccessful. A total of 1,591,000 fry were released from 2,860,000 eyed eggs. All early

stock sockeye salmon were destroyed in the spring of 1980 because of a major epizootic of infectious hematopoietic necrosis (IHN). As a result of the epizootic, incubation of sockeye salmon was discontinued at Kitoi Bay and continued exclusively at Upper Thumb River, Karluk Lake.

The overwinter incubation at Karluk was only a partial success because of intermittent pipeline-freezing problems that caused low survivals during the 1982 to 1983 test period. Only 451,000 fry were produced from 1,680,000 eyed eggs (Table 5).

Size and development of incubator fry, wild fry, and egg-planted fry are compared in Table 6. Incubator fry released in 1980 were within the normal size range observed for the egg-planted and wild fry. However, the 1981 fry were smaller in length and lighter in weight than any comparative group. Differences were not tested for significance.

The number of hatchery fry and those resulting from the planted eggs produced by the project are shown in Figure 4. Over the 6-year period, the major production has been from eyed-egg planting. The only exceptional year was in the 1979 brood year, when flood waters reduced the egg-planting operation, both in terms of eggs placed in the stream and survival of fry.

SMOLT INVESTIGATIONS

Background

Each May, from 1979 to 1982, FRED Division placed a sonar smolt counter in Karluk River, approximately 5 km downstream from Karluk Lake outlet. In 1983 and 1984, the United States Fish and Wildlife Service (USFWS) estimated the smolt population by a mark-recapture method. Smolt data are important, as they measure the final freshwater stage of sockeye salmon production and indirectly provide a measure of lake productivity (Koenings and Burkett, 1987).

Table 5. Sockeye salmon fry stocking at Upper Thumb River, Karluk Lake, 1978 to 1982 brood years.

Brood year	Stocking year	Run timing	Number of eyed eggs	Number of fry planted	Survival (%)	Incubation site
1978	1979	Late	876,000	521,000	59.5	Kitoi Bay
1979	1980	Early	2,408,000[1/]	0	0.0	Kitoi Bay
1979	1980	Late	1,984,000	1,070,000	53.9	Kitoi Bay
1981	1982	Late	397,000	174,000	43.8	Upper Thumb
1982	1983	Late	1,283,000	277,000	21.6	Upper Thumb
Total or Average:			6,948,000	2,042,000	29.4	

[1/] All early run sockeye salmon at Kitoi Bay were destroyed because of the presence of IHNV.

Table 6. Mean lengths, weights, and development indices (K_D) of Thumb River sockeye salmon fry from Karluk Lake, 1977 to 1983 brood years.

Brood source	Sample date	Sample size	Length (mm) Mean	Length (mm) Standard deviation	Weight (mg) Mean	Weight (mg) Standard deviation	Index (K_D) Mean	Index (K_D) Standard deviation
			WILD FRY					
Upper Thumb	04/19-04/24/78	97	27.8	2.3	174.6	18.3	2.0[1/]	0.2
Upper Thumb	04/21-05/13/79	51	28.2	1.4	140.1	22.4	1.8	0.1
Upper Thumb	04/10-04/29/80	197	29.2	0.9	169.2	18.8	1.9	0.1
Upper Thumb	04/01-05/08/81	300	28.7	1.0	166.5	22.0	1.9	0.1
Overall		645	28.5	1.4	162.6	20.4	1.9	0.1
			EGG PLANT FRY					
Upper & Lower Thumb	04/12-06/14/79	397	28.5	1.3	166.2	21.6	1.9	0.9
Upper Thumb	04/08-04/24/80	190	29.4	1.2	165.3	18.4	1.9	0.1
Upper Thumb	05/01-05/25/84	150	29.0	1.0	177.2	25.7	1.9	0.1
Overall		737	29.0	1.2	169.6	21.9	1.9	0.4
			INCUBATOR FRY					
Lower Thumb	04/17-04/30/80	198	28.2	0.9	166.7	19.5	1.9	0.1
Lower Thumb	06/24-07/02/81	187	24.7	0.9	122.1	14.0	2.0	0.1
Overall		385	26.4	0.9	144.4	16.7	1.9	0.1

[1/] High K_D due to possible weight gain due to natural rearing.

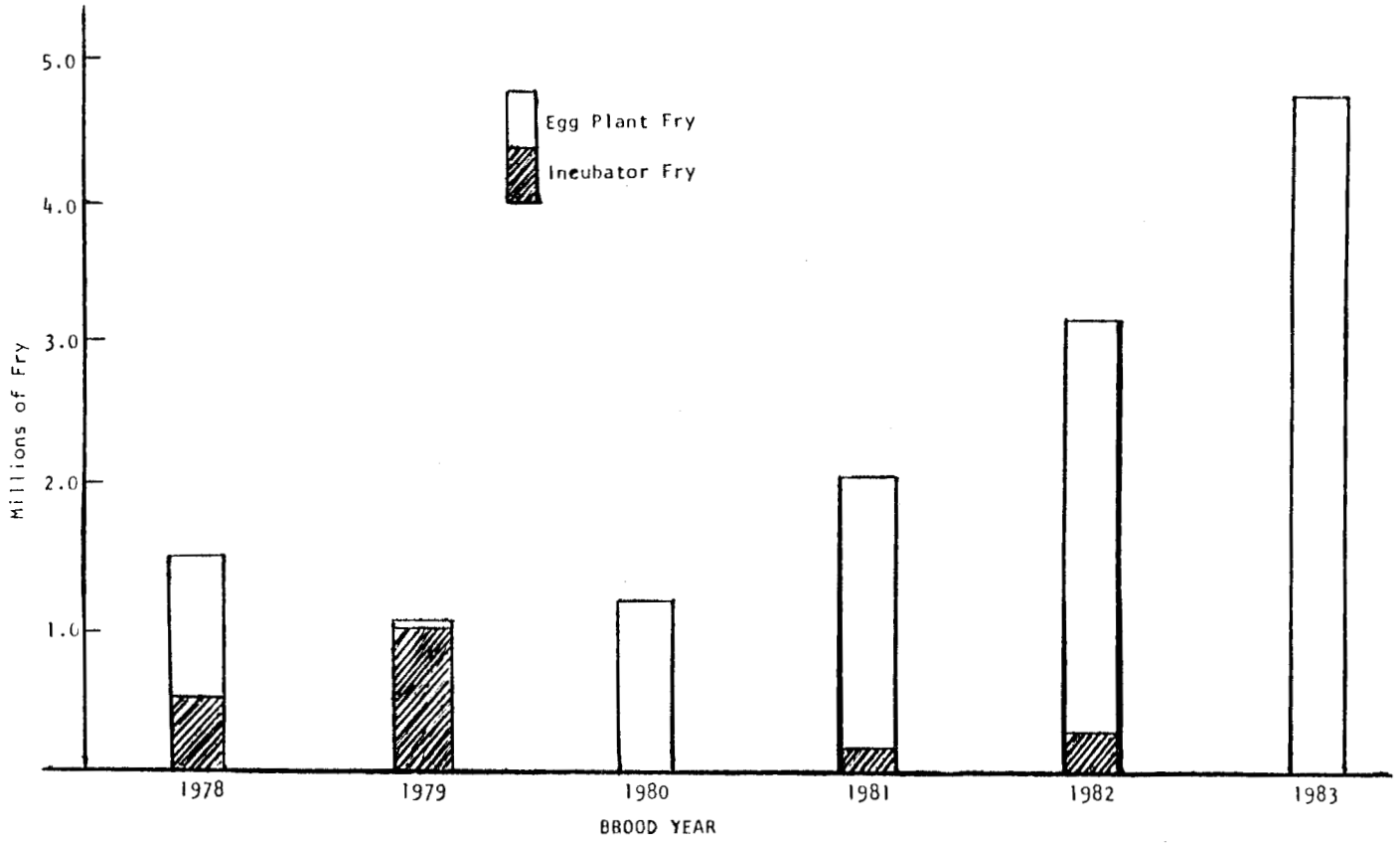

Figure 4. Fry releases at Upper Thumb River, 1978 to 1983 brood years, from eyed-egg and incubator fry plants.

Methods

The sonar smolt-counting units are described in detail by Paulus and Parker (1974). A shore-based, battery-operated electronic unit transmitted a burst of ultrasound to two arrays of upward-facing transducers located on the river bottom. Smolts that passed over the array during their migration reflected an echo back to the transducers. This echo was proportional to the biomass of the smolt school. The echoes were then electronically processed in the computer portion of the electronics unit and converted to numbers of smolts. In this manner, smolts were counted annually from May through June (1979 to 1982).

In 1983 and 1984, the USFWS operated the smolt monitoring project in cooperation with the Alaska Department of Fish and Game (ADF&G). The smolt population during these years was estimated by a mark-recapture method (Rawson 1984), utilizing a Canadian Fan Trap (Ginetz 1977) located 150 m from the lake outlet (Chatto 1983).

To obtain an age, weight, and length sample, captured smolts were anesthetized using MS-222, measured from snout to tail fork to the nearest millimeter, and weighed to the nearest 0.1 gram. Several scales were removed from individual smolts for age analysis.

Results

Since 1979 the annual smolt migration has averaged about 1.2 million; the annual estimates are given in Table 7. The age-class composition obtained from the smolts' scale samples and the population estimates is presented in Table 8. As reported by previous authors (Drucker 1970), the smolt migration has been dominated by age-2.0 smolts. The older smolts (age 3.0) are numerous in the early part of the migration but are absent later in the season. In contrast, the younger (age 1.0) smolts are

Table 7. Estimated number of sockeye salmon smolts migrating to sea in the Karluk River, 1979 to 1984.

Year	Estimated number of smolts
1979	1,001,000
1980	1,686,000
1981	2,000,000
1982	821,000
1983	941,000
1984	1,074,000

Table 8. Karluk Lake sockeye salmon smolt migration, 1980 to 1984, by year, class, and age, from population estimates and scale samples.

	Year class	Age	Estimated smolts (thousands)	Annual percent of total
1980	1978	1.0	494.5	29.3
	1977	2.0	1,060.8	62.9
	1976	3.0	131.2	7.8
1981	1979	1.0	219.5	10.7
	1978	2.0	1,561.3	76.5
	1977	3.0	260.9	12.8
1982	1980	1.0	14.0	1.7
	1979	2.0	698.8	85.1
	1978	3.0	108.4	13.2
1983	1981	1.0	13.0	1.4
	1980	2.0	781.1	83.0
	1979	3.0	147.0	15.6
1984	1982	1.0	74.0	6.9
	1981	2.0	857.0	79.8
	1980	3.0	143.0	13.3

absent in the beginning of the migration and numerous in the end of the run. The predominant age-2.0 smolts are present during the entire migration.

The mean fork lengths, weights, and condition factors of the three age groups appear in Table 9. The 1979 to 1984 age-2.0 smolts averaged 115 mm and weighed 14.1 g. They were slightly smaller than the 1961 to 1968 (Drucker 1970) age-2.0 smolts, which were 118 mm long and weighed 15.0 g. A similar trend is noticed for the age-1.0 and 3.0 smolts. The smolt condition (K), which is a measure of robustness, depicts a decrease in condition with age; the age-1.0 smolts have the highest condition and the age-3.0 smolts the lowest.

Discussion

From 1922 to 1937 the age-2.0 smolts at Karluk River averaged 132 mm and weighed 20.9 g (Owen et al. 1962). The present size of 115 mm and 14.1 g for the Karluk age-2.0 smolts is a considerable decrease in growth from the earliest sampling period but only a slight decrease from the more recent 1961-1968 period.

In a marking experiment at Karluk River, Barnaby (1944) demonstrated that older and larger age-3.0 smolts had a greater return than did age-2.0 smolts. He recorded a temporary change in relationship from formerly predominant age-2.0 smolts towards age-3.0 smolts. The trend he noticed was short-lived; both the data from Drucker (1970) and our present study demonstrate that the age-2.0 smolts still predominate.

Within the total smolt population, the proportion of smolts from the rehabilitation effort is unknown. However, recent (1982-1983) increases in fry production from Upper Thumb River could theoretically contribute a total of 970,000 smolts to outmigrations in 1984-1987 if fry-to-smolt survival was 10.0% (the latter is a

Table 9. Mean lengths, weights, and condition factors of Karluk Lake sockeye salmon smolts, 1979 to 1984.

Year class	Smolt year	Mean length (mm)	Length range	Standard deviation	Sample size for length	Mean weight (g)	Weight range	Standard deviation	Sample size for weight	Condition factor (K)[1/]
					1.0 AGE GROUP					
1977	1979	112	92-150	5.1	66	14.8	8.6-24.1	2.2	66	1.0648
1978	1980	97	70-114	5.8	300	8.3	3.3-13.2	1.5	299	0.9010
1979	1981	96	48-126	13.8	77	9.4	1.7-17.0	3.5	77	1.0493
1980	1982	104	87-120	10.7	8	10.8	6.8-14.0	2.5	8	0.9601
1981	1983	101	90-117	6.2	17	9.5	7.0-13.9	1.8	15	0.9221
1982	1984	108	92-119	4.8	165	11.5	7.3-15.0	1.5	165	0.9129
Total/Avg.:		103	48-150	-	633	10.7	1.7-24.1	-	630	0.9792
					2.0 AGE GROUP					
1976	1979	120	96-160	11.6	201	18.5	9.5-40.0	4.7	201	1.0733
1977	1980	103	78-128	7.3	496	9.4	4.6-16.5	2.0	495	0.8653
1978	1981	111	78-133	8.7	600	13.4	6.0-23.8	3.0	597	0.9693
1979	1982	119	104-136	6.0	413	15.1	8.9-22.8	2.3	413	0.8961
1980	1983	117	95-135	7.1	1,014	14.2	5.7-25.7	3.1	992	0.8866
1981	1984	117	91-136	6.4	670	13.9	6.9-22.8	2.4	670	0.8711
Total/Avg.:		115	78-160	-	3,394	14.1	4.6-40.0	-	3,368	0.9393
					3.0 AGE GROUP					
1975	1979	147	138-155	4.6	11	29.1	15.9-37.5	3.5	11	0.9142
1976	1980	113	97-135	6.6	80	11.7	8.1-19.7	2.0	78	0.8007
1977	1981	119	109-145	7.1	83	16.2	11.6-28.4	3.3	83	0.9446
1978	1982	132	120-145	5.1	64	20.2	14.8-25.5	2.3	64	0.8783
1979	1983	132	119-151	5.4	149	19.9	11.9-28.8	3.2	144	0.8654
1980	1984	130	105-143	6.4	63	19.3	11.4-25.9	2.9	63	0.8785
Total/Avg.:		129	97-155	-	450	19.4	8.1-37.5	-	443	0.8991

[1/] $K = \frac{W \times 10}{L^3}$

value from FRED standard survival assumptions; other investigators believe freshwater survival in Karluk Lake to be much lower - see page 2 and Koenings and Burkett 1987).

ZOOPLANKTON INVESTIGATIONS

Background

One of the major concerns of earlier investigators was the loss of lake productivity. These investigators (Juday et al. 1932; Barnaby 1944; Nelson and Edmondson 1955) implied that the decline of the Karluk sockeye salmon run may have been related to a decrease in nutrients because of a decline in the number of salmon carcasses from that of earlier years when the escapements were large. This condition may have subsequently led to less zooplankton, less feed, and a lower survival of young sockeye salmon.

Zooplankton is monitored to estimate composition and abundance over time and by location. An analysis of the zooplankton might indicate, among other things, an underutilization or overutilization by the sockeye salmon fry or competitor fish species. This is particularly important, considering the increase of fry in the Thumb River area.

Methods

Vertical plankton hauls were made at an approximate velocity of 1 m/s using a 0.5- to 0.2-m-diameter, 130-μm to 153-μm mesh conical zooplankton net. The contents from each replicated haul were emptied into separate 125-ml bottles containing a 10% solution of formalin. Three subsamples were taken, and zooplankters were categorically identified by the FRED Division Limnology Laboratory, Soldotna, Alaska: cladocerans, copepods, and

rotifers expressed as mean number per cubic meter. There were three sampling stations on Karluk Lake and one in each of O'Malley and Thumb lakes.

Results

The vertical hauls were made from 30 to 50 m deep at Karluk Lake. The results (Table 10) demonstrate a twofold increase in cladocerans and copepods in the September and October period over the July to August period of 1983 and 1984. Also, there was a two to threefold increase in these organisms after 1980. Rotifers dominated the samples in July and August but were less numerous in September and October.

In the more shallow Thumb Lake, the vertical hauls were from a depth of 8 to 9 m. The plankton in Thumb Lake (Table 11) has been characterized by a high percentage of rotifers over the last 6 years of sampling. Unlike Karluk Lake, the numbers of cladocerans and copepods was highest in the July to August sampling period. The month-to-month and year-to-year variation in density of these organisms is extreme. While the 1983 sample showed one of the lowest counts of zooplankters on record, the 1984 season was the highest.

In O'Malley Lake the vertical hauls were from a depth of 8 to 10 m. The results (Table 12) indicate a predominance of rotifers and an increase in cladocerans and copepods in July and August, similar to Thumb Lake.

Discussion

An increase in zooplankter abundance, particularly cladocerans and copepods, is evident after 1980. In 1980 a 2,359,160 pink salmon escapement occurred in the Karluk system. This large escapement caused an unknown percentage of the fish to be pushed into the lakes and the traditional sockeye salmon spawning

Table 10. Karluk Lake zooplankton composition and density per cubic meter, 1978 to 1984.

Year	Total Number Zooplankters	Cladocerans & Copepods		Rotifers	
		Percent	Number	Percent	Number
		MAY - JUNE			
1978	17,678	5.4	957	94.6	16,721
1979	4,014	38.9	1,563	61.1	2,451
1980	4,314	79.0	3,409	21.0	905
1981	11,894	86.9	10,339	13.1	1,555
1982	1,415	75.4	10,670	24.6	3,480
1983	49,010	26.6	13,060	73.4	35,950
1984	25,498	43.5	11,079	56.5	14,419
Average:	16,260	33.7	7,297	66.3	10,783
		JULY - AUGUST			
1978	14,308	2.1	300	97.9	14,008
1979	9,493	9.4	895	90.6	8,598
1980	10,221	24.0	2,457	76.0	7,764
1981	25,057	93.5	23,433	6.5	1,624
1982	86,027	17.4	14,975	82.6	71,070
1983	36,980	18.4	6,790	81.6	30,190
1984	21,643	41.8	9,050	58.2	12,593
Average:	29,104	28.4	8,271	71.6	20,835
		SEPTEMBER - OCTOBER			
1978	14,906	7.5	1,121	92.5	13,785
1979	3,041	31.3	952	68.7	2,089
1980	14,869	80.4	11,951	19.6	2,918
1981	23,839	98.0	23,368	2.0	471
1982	34,910	84.1	29,350	15.9	5,560
1983	45,150	78.6	35,490	21.4	9,660
1984	27,020	73.2	19,792	26.8	7,228
Average:	23,391	74.5	17,432	25.5	5,959

Table 11. Thumb Lake zooplankton composition and density per cubic meter, 1978 to 1984.

Year	Total number zooplankters	Cladocerans & Copepods		Rotifers	
		Percent	Number	Percent	Number
		MAY - JUNE			
1978	28,919	0	0	100.0	28,919
1979	2,149	0	0	100.0	2,149
1980	1,147	60.2	691	39.8	456
1982	3,645	2.6	95	97.4	3,550
1983	631	14.4	91	85.6	540
1984	10,900	59.2	6,449	40.8	4,451
Average:	7,898	15.5	1,222	84.5	6,677
		JULY - AUGUST			
1978	47,020	1.3	619	98.7	46,401
1979	49,677	6.2	3,071	93.8	46,606
1980	16,215	36.7	5,943	63.3	10,272
1982	76,550	10.9	8,320	89.1	68,230
1983	17,547	8.6	1,506	91.4	16,041
1984	122,578	36.3	44,469	63.7	78,109
Average:	54,931	19.4	10,655	80.6	44,276
		SEPTEMBER - OCTOBER			
1978	20,884	2.2	464	97.8	20,420
1979	15,616	22.3	3,477	77.7	12,139
1980	25,171	9.5	2,397	90.5	22,774
1982	830	27.7	230	72.3	600
1983	3,568	6.9	245	93.1	3,323
1984	30,285	36.5	11,047	63.5	19,238
Average:	16,059	18.5	2,977	81.5	13,082

Table 12. O'Malley Lake zooplankton composition and density per cubic meter, 1979 to 1983.

Year	Total number zooplankters	Cladocerans & Copepods		Rotifers	
		Percent	Number	Percent	Number
		MAY - JUNE			
1979	-	-	-	-	-
1980	34,445	19.9	6,861	80.1	27,584
1982	71,700	16.4	11,765	83.6	59,935
1983	39,273	46.7	18,327	53.3	20,945
Average:	48,473	25.4	12,318	74.6	36,155
		JULY - AUGUST			
1979	12,343	44.3	5,463	55.7	6,880
1980	16,671	40.5	6,751	59.5	9,920
1982	207,880	42.2	87,500	57.9	120,380
1983	46,069	70.7	32,566	29.3	13,503
Average:	70,741	46.8	33,070	53.2	37,671
		SEPTEMBER - OCTOBER			
1979	8,092	32.0	2,592	68.0	5,500
1980	52,601	22.6	11,866	77.4	40,735
1982	108,580	3.3	3,580	96.7	105,000
1983	51,254	11.6	5,938	88.4	45,316
Average:	55,132	10.9	5,994	89.1	49,138

grounds. In 1982 another 2,326,674 pink salmon escapement occurred. Koenings (1980) reanalyzed the data of Juday et al. (1932) and found that "up to 60% of the annual phosphorus input to the lake comes from decaying salmon carcasses. At an average escapement of one million sockeye salmon, the fertilizing potential of the fish is such as to maintain the nitrogen to phosphorus (N:P) ratio in the lake at 17:1." Koenings further notes that it is the "excess nutrients brought in by the fish annually which determine the increase in lake fertility." Accordingly, the increase in zooplankton in Karluk Lake after 1980 could be due to the nutrients that were contributed by the excess pink salmon carcasses in 1980 and 1982.

The extreme oscillations of the numbers of cladocerans and copepods in Thumb Lake may be a reflection of grazing of these organisms by young fish. Migrant and rearing sockeye salmon fry; coho salmon, *Oncorhynchus kisutch*; pink salmon; rainbow trout, *Salmo gairdneri*; Dolly Varden char, *Salvelinus malma*, fry; and three-spine stickleback, *Gasterosteus aculeatus*, are present in the lake. Stickleback are known to migrate from Karluk Lake into Thumb Lake (Blackett 1973), and sockeye salmon fry are known to reside in Thumb Lake for a variable period before migrating out into Karluk Lake. Changes in abundance of these two species, along with the other species mentioned, as well as flushing rate and other abiotic factors come together to strongly affect the number of zooplankters in this lake.

ADULT SALMON INVESTIGATIONS

Background

Since 1921 a weir has been used to count the daily escapement of salmon into the Karluk system. To achieve the minimal escapement goals, daily sockeye salmon escapement goals for the June and early July portions of the run have been developed. These daily goals were based on average timing of the run (Manthey 1983). In

late July and August (even-numbered years), sockeye salmon escapement goals are difficult to achieve because of the mixed-stock pink salmon fishery in Karluk and Uyak districts. The harvest of September sockeye salmon, however, is again based primarily on weir counts. Coho salmon fisheries in September frequently also result in an incidental catch of late-run Karluk sockeye salmon.

Methods

While the migration is in progress, adult sockeye salmon are enumerated as they pass through the weir in Karluk Lagoon. Scale samples are taken from a small number of adult sockeye salmon and are placed on gummed, numbered cards. After the field season, ages are determined by reading the light-projected scales.

The lake shore and tributaries of Karluk Lake were surveyed during the peak of spawning by boat and foot from July until October. Counts of live and dead sockeye salmon were recorded to indicate relative abundance and utilization of spawning areas. These counts, compared to previous years, suggest changes in utilization and abundance.

Results

From 1978 to 1984, the Karluk Lagoon weir was installed in mid-May and operated until the end of September or early October. The monthly escapement for sockeye salmon and the annual escapement for other salmon species are given in Table 13. Escapements have ranged from 146,000 to 513,000 sockeye salmon (mean of 323,000). The escapements in 1979 and 1983 were not only the largest for this period, but they were also well distributed by escapement period; i.e., both the early and late portions of the run were relatively strong for these years.

Table 13. Karluk Lake sockeye salmon escapement, catch, and return and other salmon species enumerated, 1978 to 1984.

Sockeye Salmon	1978	1979	1980	1981	1982	1983	1984
May	80	395	106	2,908	201	19	173
June	230,372	186,145	117,478	91,328	98,836	188,066	231,894
July	21,529	28,261	20,577	4,104	26,854	33,983	61,571
August	48,853	79,503	6,579	54,762	8,927	94,453	11,702
September	58,445	167,476	1,883	69,604	29,589	119,624	114,928
October	1,656	51,357	-	-	-	-	-
Total Escapement:	360,935	513,137	146,623	222,706	164,407	436,145	420,268
Total Catch (%)	251,335 (41.0)	93,479 (15.4)	244,741 (62.5)	95,143 (29.9)	146,755 (47.2)	140,950 (24.4)	258,375 (38.1)
Total Return	612,270	606,886	391,363	317,849	311,162	577,095	678,643
Other Salmon							
Pink Salmon	1,380,792	81,473	2,359,160	51,248	2,326,674	38,902	1,672,386
Chinook Salmon	9,795	9,555	4,810	7,575	7,490	11,747	7,747
Coho Salmon	12,089	45,262	5,739	24,792	14,902	34,778	12,365
Chum Salmon	32	85	262	286	104	67	138

From 1978 to 1984, the catch of Karluk sockeye salmon on the west-side districts ranged from 93,000 to 258,000 (mean of 176,000). The overall interception rate was 35.2%; the majority of these fish came from the late run and were taken in the west-side pink salmon fishery. Interception of early run fish also occurred, but few of these were caught.

Eight age groups of adult sockeye salmon were recognized in the escapement between 1978 and 1984 (Table 14). Barnaby (1944) reported 20 age groups from 1921 to 1936. Overall, the age-2.2 group (5-year-old fish) was dominant, and the age-2.3 and 3.2 group (6-year-old fish) was next in abundance. This pattern is similar to the age structures reported by Barnaby (1944) and Drucker (1970).

The incidence of the principal age-2.2 group ranged from 24.8% to 67.3% and that of the age-2.3 group ranged from 15.6% to 55.2%. These fluctuations have been observed in the past and can be expected to continue. Because the runs are composed of fish from different brood years, the escapement and survival levels will always vary.

The escapement distribution from 1978 to 1984 is shown in Appendix Table 5. The peak spawning-area survey counts represent the highest number of live and dead sockeye salmon observed at one time. These figures are conservative, as they do not take into account those fish that may have spawned between survey periods or taken by predators. The June escapements in 1978, 1979, 1983, and 1984 were well dispersed to the tributaries.

The return of 20,000 and 22,000 sockeye salmon to Upper Thumb River in 1983 and 1984, respectively, was the largest recorded since 1926 (Gilbert and Rich 1927). The total return to Lower Thumb River was at optimal levels in 1978, 1979, and 1984 and above optimal levels in 1983. The overall stream escapements in 1980, 1981, and 1982 were below the minimal levels desired (*see* Appendix Table 5).

Table 14. Projected number of Karluk Lake sockeye salmon by age group and escapement from scales collected at Karluk Lagoon, 1980 to 1984.

Sample year	Adults enumerated	Projected numbers by age group (%)							
		1.2	1.3	2.1	2.2	2.3	3.1	3.2	3.3
1980	146,623	8,064 (5.5)	16,128 (11.0)	2,199 (1.5)	36,363 (24/8)	80,937 (55.2)	0 (0.0)	0 (0.0)	2.932 (2.0)
1981	222,706	3,236 (1.8)	18,856 (7.8)	0 (0.0)	104,511 (47.8)	52,460 (24.0)	1,813 (0.9)	28,522 (12.2)	13,308 (5.5)
1982	164,407	4,603 (2.8)	5,261 (3.2)	0 (0.0)	65,598 (39.9)	80,231 (48.8)	658 (0.4)	1,973 (1.2)	6,083 (3.7)
1983	436,145	5,670 (1.3)	12,212 (2.8)	28,786 (6.6)	293,526 (67.3)	91,590 (21.0)	436 (0.1)	3,489 (0.8)	436 (0.1)
1984	420,268	6,925 (1.6)	9,088 (2.2)	30,710 (7.3)	228,160 (54.3)	65,520 (15.6)	4,263 (1.0)	69,513 (16.5)	6,089 (1.5)
Total:	1,390,149	28,498 (2.0)	61,545 (4.4)	61,695 (4.4)	728,158 (52.4)	370,738 (26.7)	7,170 (0.5)	103,497 (7.4)	28,848 (2.1)

1 - ocean age = 68,865 (4.9)
2 - ocean age = 860,153 (61.9)
3 - ocean age = 461,131 (33.2)

4 year old = 90,193 (6.5)
5 year old = 796,873 (57.3)
6 year old = 474,235 (34.1)

7 year old = 28,848 (2.1)

Discussion

During even years, the pink salmon escapement into Karluk River has averaged 1.9 million fish (range 1.3 to 2.4 million). Over 6 million pink salmon have been harvested during the intense July and August fishing periods in the Karluk and Uyak fishing districts. Regardless of their run strength, the smaller runs of sockeye salmon are harvested incidentally. This incidental catch has resulted in an exploitation rate of 47.2% (range 38.1% to 62.5%) on the even years; this rate exceeds that which occurred from 1920 to 1940. It is the late-run sockeye salmon that are providing the greatest harvests. Since 1921 the escapement data (*see* Table 1) depict a long-term decline of the overall run.

FRY MARKING INVESTIGATIONS

Background

In the spring of 1979, 1980, 1981, and 1984, sockeye salmon fry produced by the project in Upper Thumb River were marked so that adult returns could be evaluated. From 1979 to 1981, sockeye salmon fry were marked by removing the adipose fin (Ad) and one other fin. In 1984 fish were marked with a "half length" 0.5-mm coded-wire tag (HLCWT).

Methods

Fry from the planted eggs and hatchery were marked by fin removal in the manner described by Bams (1972) and Moberly et al. (1977). A quality-control program was conducted during the entire project to ensure that only valid marks were recorded for each marked group. Hatchery-produced fry marked at Kitoi Bay in 1979 and 1980 were transported back to Upper Thumb River for imprinting and release. Fry marked at Upper Thumb River were released in the evening or at night when the natural migration occurred.

Returning adult sockeye salmon were inspected for missing fins in the commercial catch in June 1983 and in July and August 1984. At Upper Thumb River all of the brood fish were inspected for missing fins, in conjunction with the spawning operations in 1983 and 1984. In September 1983 fish were also inspected at Lower Thumb River because straying can occur when transplanted stocks are nearby.

Because there are multiple age groups of sockeye salmon with the same mark, each one that is inspected has to be aged to determine brood year. The age of brood fish was determined from otolith samples.

Results

Table 15 summarizes the fry marking and release programs from 1978 to 1983. A total of 25,930 adult sockeye salmon brood fish and catch were inspected for marks in 1983 and 1984. This sample contained 60 marked fish with missing ventral, pectoral, or adipose fins (Table 16); a total of 53 marks were from the 1978 brood year, three were from the 1979 brood year, and four were from the 1980 brood year. Several age classes of marked sockeye salmon have yet to return: age-3.3 fish from the 1978 brood; age-2.3, 3.2, and 3.3 fish from the 1979 brood; and age-2.2, 3.2, and 3.3 fish from the 1980 brood.

Discussion

There is insufficient information regarding mark recovery and fin regeneration to discuss the findings in detail; however, there appear to be problems in both areas. At times it is an arbitrary judgement whether or not a fish has been actually marked or has simply had a close encounter with a predator. Funding limitations precluded an adequate recovery of marked fish in the commercial fishery that, in turn, compromised analysis.

Table 15. Summary of fry marked at Thumb River, Karluk Lake, 1979 to 1984.

Brood stock	Brood year	Run timing	Origin	Mark type	Number fry marked	Number unmarked fry released
Upper Thumb	1978	Early	Egg plant	AdLV	27,700	691,000
Lower Thumb	1978	Late	Egg plant	AdRV,AdRP	24,600	186,000
Lower Thumb	1978	Late	Fry plant	AdLP	36,100	485,000
Lower Thumb	1979	Late	Fry plant	AdLV	102,000	968,000
Upper Thumb	1980	Early	Egg plant	AdLV	70,600	942,400
Lower Thumb	1980	Late	Egg plant	AdRV	32,200	504,800
Upper Thumb	1983	Early	Egg plant	HLCWT	117,000	4,683,000

Table 16. Recovery of marked Karluk sockeye salmon by fishing area, time, and mark type, 1983 to 1984.

Recovery year	Run timing	Fishing/Inspection location	Number sockeye inspected	Total marks found	Type of marks		
					AdLV or LV	AdRV or RV	AdLP or LP
1983	Early	Uyak District	900	0	0	0	0
1983	Late	Uyak District	Not surveyed				
1983	Early	Upper Thumb River	7,300	4	4	0	0
1983	Late	Upper Thumb River	400	5	1	2	2
1983	Late	Lower Thumb River	2,700	2	0	1	1
1984	Early	Uyak District	Not surveyed				
1984	Late	Uyak District	2,000	8	3	4	1
1984	Early	Upper Thumb River	12,600	41	27	12	2
1984	Late	Upper Thumb River	30	0	0	0	0
1984	Late	Lower Thumb River	Not surveyed				
TOTAL:			25,930	60	35	19	6

The half-length coded-wire tagging of young sockeye salmon in 1984 was done to avoid the problems of fin regeneration and to obtain a life-time tag that would assist in monitoring the fish through all life stages. This is the first time that sockeye salmon fry have been tagged without the removal of an adipose fin for external identification. Adults and smolts will have to be inspected electronically for tag detection.

Using the same method employed at Upper Thumb River, the rehabilitation of all segments of Karluk system early run sockeye stocks appears feasible. The early run component is also manageable in a way that should allow for restoration of these fish. The rehabilitation work should continue at Upper Thumb River and possibly at other lateral tributaries which support early run stocks. Eggs taken should be incubated at Upper Thumb River or other streamside incubator sites around the lake and then planted in their parent stream as eyed eggs each fall.

The decrease in smolt size (weight and length) over the past 60 years indicates a change in the lake's productivity (Koenings and Burkett, 1987). USFWS researchers (cooperating with FRED Division on this project) believe that threespine stickleback competition may be limiting survival and growth of young sockeye salmon. To increase smolt size and fry survival, ADF&G limnologists have been investigating Karluk Lake as a potential candidate for lake fertilization. These programs are compatible because both objectives (decreasing stickleback numbers and fertilizing the lake) would probably improve the rearing environment for the young sockeye salmon and allow an increase in smolt size and survival.

SUMMARY

The Karluk Lake sockeye salmon rehabilitation project is in the 7th year of production; its objective is to increase the returns of adult salmon by planting massive numbers of eyed sockeye salmon eggs in the underutilized streambed of Upper Thumb River. During the first 4 years, production was low because of weak natural returns to Upper Thumb River and because of disease and logistical problems. After these problems were overcome, the project has been successful in respect to the numbers of eggs annually planted, the egg-to-fry survivals that have greatly exceeded the values commonly obtained in production from naturally spawning fish, and the resulting return of 20,000 and 22,000 adult sockeye salmon to Upper Thumb River in 1983 and 1984, respectively. The 1984 return was the best recorded in that system since 1926. The Karluk project has become the largest single rehabilitation effort in the state and the largest egg-planting effort in any Pacific Rim country.

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APPENDIX

LIST OF APPENDIX TABLES

Appendix Table 1. Summary of the spawning operation records for the rehabilitation effort at Upper Thumb River, Karluk Lake, 1978 to 1984.[1/]

Brood year	Brood source	Number of eggs taken	Females spawned	Males spawned	Egg take fecundity	% survival eyed eggs	Number live eggs	Incubation location
1978	Early Upper Thumb	3,071,000	1,030	525	2,982	84.1	2,583,000	Devil's Creek
1978	Late Lower Thumb	2,638,000	860	473	3,067	79.1	2,087,000	Kitoi Bay
1979	Early Upper Thumb	4,816,000	1,491	489	3,298	81.9	3,945,000	Devil's Creek
1979	Late Lower Thumb	2,386,000	678	274	3,502	83.2	1,984,000	Kitoi Bay
1980	Early Upper & Lower Thumb	4,115,000	1,563	925	2,679	73.8	3,038,000	Upper Thumb
1980	Late Lower Thumb	1,340,000	475	292	2,821	87.2	1,168,000	Upper Thumb
1981	Early Upper & Lower Thumb	2,902,000	1,241	701	2,338	81.0	2,343,000	Upper Thumb
1981	Late Lower Thumb	1,274,000	396	294	3,216	82.8	1,055,000	Upper Thumb
1982	Early Upper Thumb	11,190,000	4,888	1,404	2,282	82.0	9,206,000	Upper Thumb
1982	Late Lower Thumb	2,659,000	1,030	236	2,582	78.0	2,075,000	Upper Thumb
1983	Early Upper & Lower Thumb	15,256,000	6,353	2,138	2,401	80.0	12,284,000	Upper Thumb
1984	Early Upper Thumb	15,475,000	6,452	3,324	2,399	85.8	13,207,000	Upper Thumb
Total or Average:		67,122,000	26,457	11,075	2,537	81.9	54,975,000	

[1/] Early run fish are those spawned in July to mid-August and late run are those fish spawned from mid-August to October.

Appendix Table 2. Summary of early and late egg plantings in Upper Thumb River, Karluk Lake, from 1978 to 1984.

Brood year	Stock	Number of eggs planted	Area planted (m^2)	Mean density (eggs/m^2)	Rate of planting[1/] eggs/man hour
1978	Early	2,583,000	1,779	1,452	-
1978	Late	1,207,000	832	1,451	-
1979	Early	1,449,000	680	2,121	-
1980	Early	3,038,000	1,566	1,940	10,060
1980	Late	1,168,000	428	2,729	28,485
1981	Early	2,344,000	1,037	2,260	13,000
1981	Late	655,000	223	2,938	42,000
1982	Early	9,206,000	2,489	3,691	38,206
1982	Late	792,000	132	5,997	27,298
1983	Early	12,284,000	5,017	2,448	18,869
1984	Early	13,207,000	4,926[2/]	2,681[2/]	26,796
Total or Average:		47,933,000	19,109	2,508	25,589

1/ Man hours does not include packing time.

2/ Estimated from 1983 data.

Appendix Table 3. Age composition of adult sockeye salmon spawned from 1978 to 1984 at Lower and Upper Thumb River, Karluk Lake.

Brood year	Brood source	Sample number	Age Composition (%) 2.1	3.1	1.2	1.3	2.2	2.3	3.2	3.3	4.2
1978	Early Upper	54	0 ( )	0 ( )	0 ( )	1 (1.8)	39 (72.2)	9 (16.7)	3 (5.5)	2 (3.7)	0 ( )
1978	Late Lower	115	0 ( )	0 ( )	0 ( )	4 (3.5)	73 (63.5)	21 (18.3)	14 (12.2)	3 (2.6)	0 ( )
1979	Early Upper	75	0 ( )	0 ( )	0 ( )	1 (1.3)	18 (24.0)	49 (65.3)	5 (6.7)	2 (2.6)	0 ( )
1979	Late Lower	76	0 ( )	0 ( )	0 ( )	0 ( )	14 (18.4)	10 (13.2)	36 (47.4)	15 (19.7)	1 (1.3)
1980	Early Up&Lwr	158	12 (7.6)	1 (0.6)	16 (10.1)	14 (8.9)	67 (42.4)	45 (28.5)	2 (1.3)	1 (0.6)	0 ( )
1980	Late Lower	80	4 (5.0)	0 ( )	18 (22.5)	13 (16.2)	26 (32.5)	18 (22.5)	1 (1.3)	0 ( )	0 ( )
1981	Early Up&Lwr	154	3 (2.0)	0 ( )	3 (2.0)	1 (0.6)	73 (47.3)	31 (20.1)	34 (22.1)	9 (5.8)	0 ( )
1981	Late Lower	79	1 (1.3)	0 ( )	0 ( )	3 (3.8)	19 (24.0)	44 (55.7)	8 (10.1)	4 (5.1)	0 ( )
1982	Early Upper	80	1 (1.3)	0 ( )	0 ( )	5 (6.2)	38 (47.5)	28 (35.0)	6 (7.5)	2 (2.5)	0 ( )
1982	Late Lower	77	2 (2.6)	0 ( )	11 (14.3)	3 (3.9)	33 (42.9)	22 (28.6)	4 (5.2)	2 (2.6)	0 ( )
1983	Early Upper	308	0 ( )	0 ( )	22 (7.1)	36 (11.7)	168 (54.5)	76 (24.7)	6 (2.0)	0 ( )	0 ( )
1984	Early Upper	200	6 (3.0)	0 ( )	5 (2.5)	12 (6.0)	62 (31.0)	99 (49.5)	6 (3.0)	10 (5.0)	0 ( )
Subtotal, Early:		1,029	22 (2.1)	1 (0.1)	46 (4.5)	70 (6.8)	465 (45.3)	337 (32.7)	62 (6.0)	26 (2.5)	0 ( )
Subtotal, Late:		427	7 (1.7)	0 ( )	29 (6.8)	23 (5.4)	165 (38.6)	115 (26.9)	63 (14.8)	24 (5.6)	1 (0.2)
Total:		1,456	29 (2.0)	1 (0.1)	75 (5.2)	93 (6.4)	630 (43.3)	452 (31.0)	125 (8.6)	50 (3.4)	1 (0.1)

		Early	%	Late	%	Total	%
(2.1, 3.1)	one ocean =	23	(2.2)	7	(1.6)	30	(2.1)
(1.2, 2.2, 3.2, 4.2)	two ocean =	573	(55.7)	258	(60.4)	831	(57.0)
(1.3, 2.3, 3.3)	three ocean =	433	(42.1)	162	(38.0)	595	(40.9)
	Total:	1,029	(100.0)	427	(100.0)	1,459	(100.0)

Appendix Table 4. Ocean age, freshwater age, and years of life composition of adult sockeye salmon spawned at Upper and Lower Thumb River from 1978 to 1984.

Ages	Ocean, fresh water or years of life - age	Sample Size	Percent
2.1, 3.1	One - ocean	30	2.1
1.2, 2.2, 3.2, 4.2	Two - ocean	831	57.0
1.3, 2.3, 3.3	Three - ocean	595	40.9
	Total	1,456	100.0
1.2, 1.3	I - fresh water	168	11.5
2.1, 2.2, 2.3	II - fresh water	1,111	76.3
3.1, 3.2, 3.3	III - fresh water	176	12.1
4.2	IV - fresh water	1	0.1
	Total	1,456	100.0
2.1, 1.2	4-year old	104	7.1
1.3, 2.2, 3.1	5-year old	724	49.8
2.3, 3.2	6-year old	577	39.6
3.3, 4.2	7-year old	51	3.5
	Total	1,456	100.0

Appendix Table 5. Peak spawning-area surveys of adult sockeye salmon at Karluk Lake, 1978 to 1984.[1/]

	UPPER THUMB RIVER				LOWER THUMB RIVER			
Year	Total early run enumerated	Total brood fish	Total late run enumerated	Total return	Total early run enumerated	Total brood fish	Total late run enumerated	Total return
1978	10,120	1,555	7	11,682	6,394	1,333	515	8,240
1979	5,343	1,980	54	7,377	4,409	1,034	4,500	9,943
1980	2,429	1,916	28	4,373	1,536	1,339	1,910	4,785
1981	2,226	1,942	35	4,203	1,866	690	3,077	5,633
1982	6,687	6,292	55	13,034	1,335	1,268	2,500	5,103
1983	10,355	9,261	125	19,741	5,711	305	11,900	17,916
1984	11,361	10,415	438	22,214	6,528	0	3,766	10,294
Mean	6,932	4,766	105	11,803	3,968	853	4,024	8,845

-Continued-

Appendix Table 5 (continued). Peak spawning-area surveys of adult sockeye salmon at Karluk Lake, 1978 to 1984.

Year	O'MALLEY RIVER			Canyon Creek	Fall Creek	Cascade Creek
	Total early run enumerated	Total late run enumerated	Total run			
1978	3,149	3,162	6,311	28,261	3,472	4,106
1979	3,074	3,050	6,124	19,490	884	2,227
1980	5,138	2,200	7,338	7,781	710	317
1981	1,615	1,101	2,716	5,530	335	380
1982	550	229	779	4,350	384	214
1983	3,394	2,300	5,694	17,678	293	2,729
1984	1,000	3,957	4,957	25,883	882	5,161
Mean:	2,560	2,286	4,846	15,568	994	2,162

- Continued -

Appendix Table 5 (continued). Peak spawning-area surveys of adult sockeye salmon at Karluk Lake, 1978 to 1984.

Year	Meadow Creek	Halfway Creek	Grassy Point Creek	Spring Creek	Moraine Creek	Cottonwood Creek	Big Bear Creek
1978	7,926	1,475	2,448	335	864	2,117	80
1979	2,830	1,148	1,474	454	1,956	1,759	140
1980	2,125	200	1,164	28	75	703	31
1981	771	174	900	64	1,758	321	29
1982	617	488	1,106	472	1,972	2,051	11
1983	3,118	835	1,079	652	726	3,855	192
1984	4,139	2,025	2,281	965	3,449	1,692	22
Mean:	3,075	906	1,493	424	1,543	1,785	72

- Continued -

Appendix Table 5 (concluded). Peak spawning-area surveys of adult sockeye salmon at Karluk Lake, 1978 to 1984.

Year	Alder Creek	Lagoon Creek	Salmon Creek	Karluk River	Karluk Lake shore	O'Malley Lake shore	Thumb Lake shore
1978	210	38	3,886	31,000	15,236	-	-
1979	409	0	1,152	17,000	30,064	2,532	38
1980	7	7	117	10,000	16,287	6,350	129
1981	9	0	289	-	19,709	8,351	252
1982	55	35	1,132	-	-	-	196
1983	210	136	1,817	45,000	18,790	-	3,000
1984	108	58	1,116	-	-	-	86
Mean:	144	39	1,358	25,750	20,017	5,744	616

1/ Peak survey counts underestimate actual return. Total run exceeded the counts given in this table.