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ABSTRACT

Sockeye salmon *Oncorhynchus nerka* fry were reared in Auke Creek hatchery and released into Auke Lake to increase returns of a depleted salmon stock. A total of 262 female sockeye salmon were spawned and 501,000 eggs were taken from 1986 through 1989; of these eggs, 254,060 (51 percent) survived to become fry. A total of 132,470 sockeye salmon fry were released into Auke Lake, 57,067 were retained in fresh water at the hatchery, and 64,523 were retained in saltwater rearing pens for additional feeding and release as age-0. smolts.

The number of sockeye salmon smolts leaving the Auke Lake system has increased; in 1988, 1989, and 1990, 27, 61 and 44 percent of the sockeye salmon smolts emigrating from Auke Lake resulted from enhancement activities. Survivals from fry release to smolt emigration have ranged from 21 to 51 percent; lower survivals were observed after 100,000 fry were released into the lake during the spring. The true effectiveness of this enhancement technique can only be determined after returns of adult sockeye salmon from this project are complete in 1996.

KEY WORDS: Southeast Alaska, Juneau, Auke Lake, Lake Creek, sockeye salmon, *Oncorhynchus nerka*, weir, escapement, enhancement, lake stocking, IHNV

INTRODUCTION

Auke Lake (Figure 1) is approximately 17.7 km (11 mi) north of Juneau, Alaska, and at 92 hectares (227 acres), is the second largest lake located on the Juneau road system. It supports stocks of sockeye salmon *Oncorhynchus nerka*, coho salmon *O. kisutch*, pink salmon *O. gorbuscha*, and chum salmon *O. keta*, cutthroat trout *O. clarki*, and Dolly Varden *Salvelinus malma*. The Auke Lake sockeye salmon stock is one of only three that return to streams along the Juneau road system.

Auke Creek Hatchery is a research facility located on Auke Creek, midway between the lake and salt water in Auke Bay. The hatchery is operated by the National Marine Fisheries Service (NMFS) in cooperation with the Alaska Department of Fish and Game (ADF&G) and the University of Alaska. The hatchery weir is used to trap all immigrant and emigrant fish. The weir is operated from mid-March through mid-June to capture salmonids emigrating from Auke Lake, and from mid-June through October to capture adult salmon returning to Auke Lake.

The number of adult sockeye salmon escaping to Auke Lake averaged about 7,700 fish from 1963 to 1978 (Figure 2). The return supported a popular recreational fishery at the mouth of Auke Creek which harvested an estimated 2,000 to 3,000 fish annually during the early and middle 1970's (Taylor *Unpublished*). From 1979 to 1985, the escapement averaged about 2,700 fish and in 1985 the escapement dwindled to 240 fish. The sport fishery was restricted in 1976, and has been closed completely since 1980. Taylor (*Unpublished*) speculated that Auke Lake sockeye salmon smolt production had been declining since 1972, but that the trend did not become apparent until the early 1980's. He suggested that possible causes of the decline could include alteration of water flows caused by new residential construction and domestic water demands around Auke Lake, domestic waste water effluent, successive years of naturally occurring low egg-to-fry survival in Lake Creek (the major spawning tributary), superimposition of pink salmon eggs in Lake Creek, or mortality through disease. Limnologists from the ADF&G Fisheries Rehabilitation, Enhancement and Development (FRED) Division have sampled Auke Lake intermittently between 1986 and 1990. Based on an euphotic volume production model, they estimate the sockeye salmon production potential of Auke Lake to be 69,800 smolts and 7,600 adult salmon (David Bartoo, ADF&G, FRED Division, Douglas, Alaska, personal communication).

Bucaria (1968) observed that only 52-55% of the adult sockeye salmon entering Auke Lake spawnwed in tributaries of the lake, and he presumed that the remaining fish spawned in deeper waters of the lake itself. Bishop (*Unpublished*) determined that the area suitable for spawning in tributaries to Auke Lake could accomodate about half of the 3,500 to 5,000 spawning females needed to maintain the return at historic levels. He also suspected that undocumented lake-shore spawning played an important role in maintaining the Auke Lake sockeye salmon run. Bishop (*Unpublished*) believed that the quality of spawning area in Lake Creek was effected by unstable streambed materials, the absence of logs and large debris, no significant areas of spring-fed upwellings, and low to intermittant winter flows. He recommended that spawning area could be increased by removal of stumps at the mouth of the stream, placement of gabion baskets in the stream channel, and installation of instream logs, but stated that the improvements would not provide enough additional area to sustain the historic numbers of adult sockeye salmon.

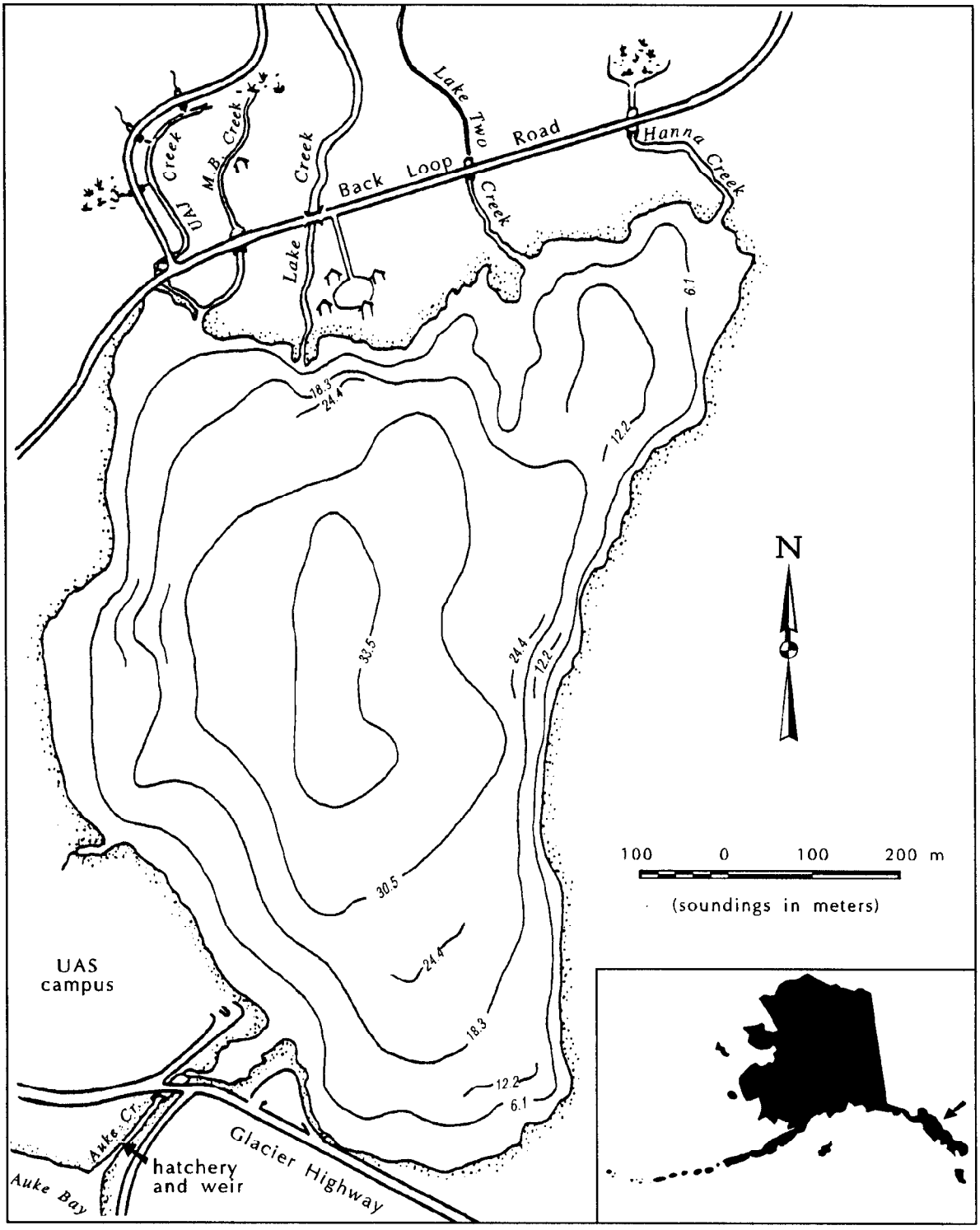

Figure 1. Auke Lake, Juneau, Alaska.

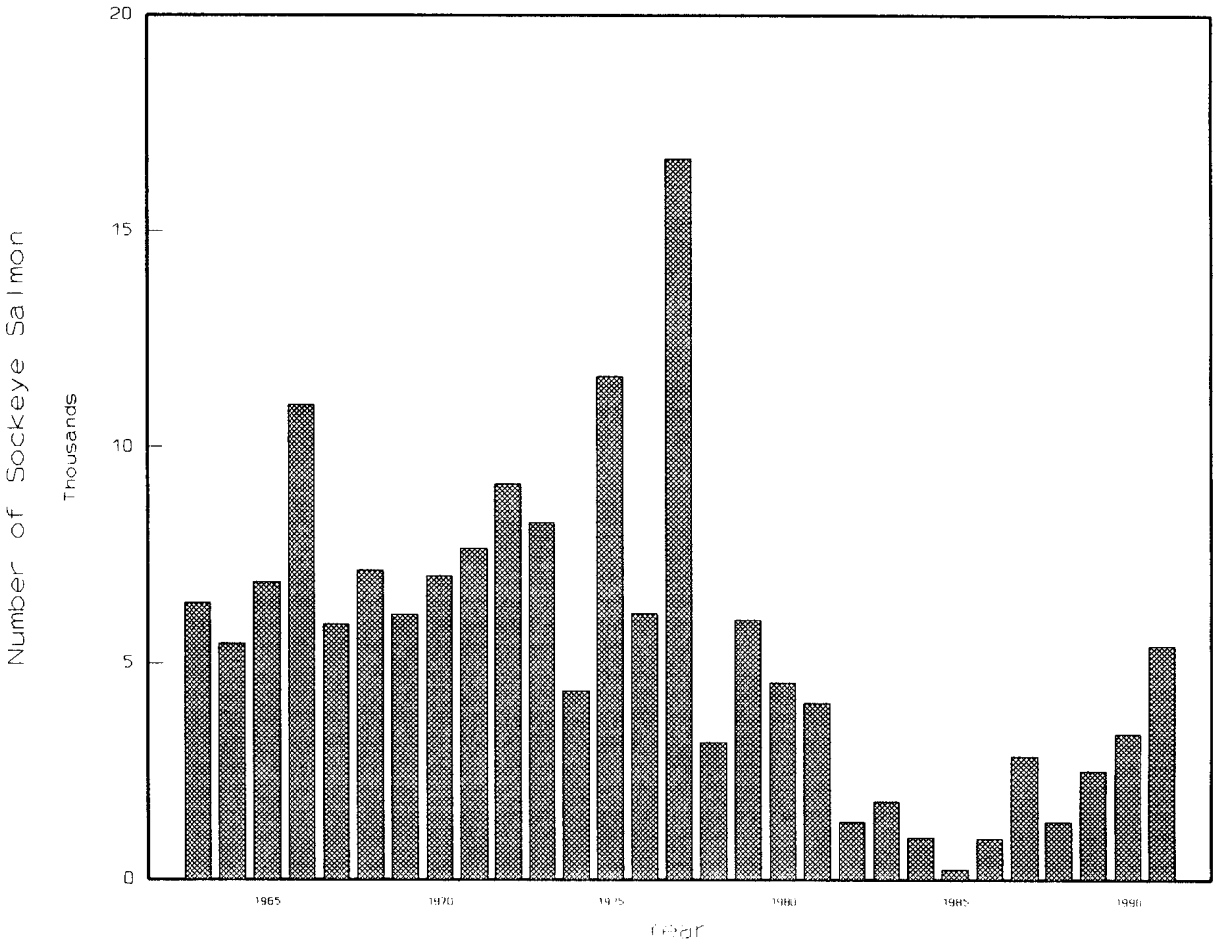

Figure 2. Escapement of sockeye salmon to Auke Lake, 1963-91.

Research on sockeye salmon culture at Auke Creek Hatchery conducted by the NMFS during the 1970's showed that releasing hatchery fry to rear in Auke Lake increased the number of sockeye salmon smolts emigrating from the lake. The smolting success rates of two groups of sockeye salmon released into Auke Lake at 0.4 g/fish were 23% (1973 brood) and 10% (1974 brood). The smolting success of one group released at 1.0 g/fish (1973 brood) was 35% (NMFS, Auke Bay Laboratory, unpublished data).

In 1986, ADF&G and the NMFS Auke Creek Hatchery developed a program to restore the returns of Auke Lake sockeye salmon to historic levels. The objectives of the program were to:

1. release hatchery-reared juvenile sockeye salmon into Auke Lake and document their migration timing, size, and freshwater and marine survival; and

2. determine the feasibility of accelerating the development of sockeye salmon eggs and juveniles to rear age-0. smolts that were similar in size and migration timing to age-1. wild smolts.

This report summarizes the first phase of the project; i.e., the rearing and release of sockeye salmon smolts from the 1986-89 brood years. The return of adult sockeye salmon to Auke Creek from these releases will be evaluated in a later manuscript.

METHODS

Collection of Adult Sockeye Salmon

Beginning approximately August 1 in 1986, 1987, 1988, and 1989, Lake Creek was checked daily for the presence of mature sockeye salmon. In 1986, eggs were collected from adult sockeye salmon dip-netted off spawning redds in Lake Creek. In 1987 and 1988, adult sockeye salmon were: 1) collected from the weir live box, transported to Auke Lake by truck, and held in a net pen in Auke Lake for ripening; 2) beach seined at the mouth of Lake Creek and held in the pen for ripening; 3) dip-netted off spawning redds in Lake Creek and spawned immediately; and 4) gill-netted at the mouth of Lake Creek as they attempted to ascend the stream and spawned immediately. In 1989, eggs were collected from adult sockeye salmon seined off the mouth of Auke Creek or dip-netted in Lake Creek.

Adult sockeye salmon were transported to the net pen in Auke Lake in a 1.2 m x 0.6 m x 0.6 m plastic box filled with water. The net pen was 6.09 m x 6.09 m x 3.05 m, constructed of 8.1 mm knotless nylon mesh, and supported by an aluminum framework with polyform floats on each corner. The net pen was anchored off the mouth of Lake Creek, at a site providing good water circulation and close to areas where beach seines and/or gill nets could be used to collect brood stock. Sockeye salmon held in the net pen were checked for maturity every four to five days, and were usually spawned within three weeks.

Hatchery Procedures

Salmon culture techniques generally followed the procedures described by Leitriz and Lewis (1976). Eggs and sperm were collected in separate, sterile plastic bags and were transported to Auke Lake Hatchery in ice-chilled containers.

Gametes were combined in a single container at the ratio of one female to three or four males. The eggs from one female were water hardened for one hour in a 200 ppm buffered iodophor solution and placed in a Heath tray incubator. All equipment was disinfected with a 200 ppm iodophor solution after use, and water used for fertilization, hardening, and rinsing was mixed with iodophor before disposal.

Tissue samples collected from all adult salmon used as broodstock were tested for the presence of bacterial kidney disease (BKD; causative organism *Renibacterium salmoninarum*) using enzyme-linked immunosorbent assays (ELISA). Average optical density values greater than 0.10 were considered positive for the antigen *R. salmoninarum*. All female sockeye salmon spawned were also tested for the presence of hematopoietic necrosis virus (IHNV); male sockeye salmon spawned were tested for IHNV only in 1986. Samples of ovarian or seminal fluid were collected in separate sterile containers, and were tested for the presence of IHNV using plaque assay and the EPC cell line. In 1986, juvenile salmon were pooled during rearing into four groups that corresponded to the relative IHNV titers in the adults. Since fewer than 100 plaque forming units per milliliter (PFU/ml) of sample were detected in any of the fish that tested positive for IHNV in 1987 and 1988, progeny from these fish were not reared separately. Filtered, sterilized water was used for all incubation and rearing of sockeye salmon at Auke Creek. Influent water passed first through an in-line filter (200 micron, multifilament polyester mesh) that removed plankton and debris. The filtered water then passed through an ultraviolet sterilizer to destroy bacteria and viruses.

Sockeye salmon eggs at Auke Creek Hatchery were incubated in an isolated room. Personnel entering and leaving the area were required to pass through iodophor foot baths at the doors. All spawning equipment and protective clothing was disinfected with iodophor before re-use. Eggs were treated with weekly flushes of salt water to control fungus; salinity was raised to 28 to 30 ppt for about 1 hour. When the embryos reached the eyed stage of development, dead eggs were removed, substrate (a triple layer of 18 mm heavy duty plastic mesh screen) was added to each incubator, and the trays were restocked with approximately 6,000 eggs each.

The only hatchery water source in 1986 was subsurface water from Auke Lake, and the 1986 brood eggs were incubated entirely in this water. The temperature of subsurface water averaged about 8°C during the warmest period of the year, and seldom exceeded 10°C. Surface water temperatures from Auke Creek, however, often exceed 20°C during the summer. An additional pipeline to Auke Creek was installed in 1987 that allowed water from Auke Creek to be mixed with, or used independently from, water from Auke Lake. The development of 1987-89 brood eggs and fry was accelerated by selectively drawing either surface water from the creek or subsurface water from the lake. Lake water was used throughout the winter months, but creek water was used when it became warmer than lake water. Creek water was mixed with lake water as necessary during the summer so that rearing temperatures did not exceed 14°C.

Approximately 25,000 of the resulting sockeye salmon fry were stocked in each of six 1.8 x 1.8 x 0.8 m fiberglass tanks with separate water sources and effluent drains. The floor was cleaned daily with a 100 ppm iodophor solution; disinfectant foot baths were used by all hatchery personnel and visitors. Water was not mixed between tanks of rearing sockeye salmon, separate equipment was used for each tank, and splash curtains were installed between each tank. The fish were fed several times daily and the number of feedings increased as the

natural photoperiod increased. A commercially prepared, semi-dry food was used (BioDiet); feed size and ration amount were as recommended by the manufacturer. Mortalities were removed and counted daily, and biweekly samples of 50 fish from each tank were individually weighed and measured to determine growth.

All sockeye fry reared in the hatchery were marked by feeding a diet containing the antibiotic oxytetracycline (OTC) using the method described by Weber and Ridgeway (1967). The OTC was premixed into the feed by the manufacturer at the rate of 4.5%. The 1986-brood fish were fed the OTC-treated feed for 14 days once they attained 0.43 g (37 mm). The 1987-89 brood fish were fed the OTC-treated diet for 10 days once they exceeded 0.80 g (44 mm). The presence of a mark was confirmed by examining dissected fish one day after completion of the OTC feedings, and again two weeks later. The skeleton of each fish in a sample of 200 fry was exposed by removing the flesh on one side. Vertebrae were examined using a portable, hand held, DC-powered ultraviolet light for the presence of a fluorescent yellowish spot or ring within the calcified bones.

Sockeye salmon fry released into Auke Lake were transported by truck from the hatchery in a fiberglass container, and were released into the lake at the mouth of Lake Creek. Fish were either carried a short distance in buckets and released, or were released through the outlet pipe of the tank into a floating pipeline that extended 30 m from the lake shore. The total number of sockeye salmon released into Auke Lake was determined from known inventories in each rearing tank.

Rearing of Age-0. Smolt

A portion of the fry from each brood year were retained for additional rearing in either salt water or fresh water. Beginning in late March and continuing at weekly or biweekly intervals, small lots of juvenile sockeye salmon were exposed to seawater at 24 and 30 ppt salinity for 96 hours. Mortalities were removed and recorded daily. Total mortality after 96 h was expressed as a percent of the original number of fish exposed at each concentration. Salinities were measured weekly at the net pen site, surface and at 4 meters depth, to monitor seasonal changes in Auke Bay.

When salinity tolerance tests indicated that 100% of the fish could survive the 30 ppt challenge, those fry designated the age-0. group to be reared in salt water were placed in 3.7 m x 3.7 m x 3.7 m (12 ft square) floating net pens anchored near the NMFS Auke Bay Laboratory dock in Auke Bay. The age-0. group of sockeye salmon fry to be reared in fresh water was retained in the rearing tanks at the hatchery. Diet and feeding regimen were as described for juvenile rearing.

In all years except 1986, all age-0. smolts were marked before release by removing the adipose fin and implanting a distinctive coded-wire tag (CWT). Age-0. smolts reared in salt water were released directly from the net pens. Age-0. smolts reared in fresh water were released into Auke Creek below the downstream migrant weir; the weir formed a barrier that prevented these fish from migrating upstream to Auke Lake after release. Both groups were released on the same date, generally at night. In 1986, the age-0. group was reared until late July. In subsequent years the release date was June 21. Two age-0. groups were reared for an additional two weeks in 1990.

Evaluation of Enhancement

Measures of the success of this program include: 1) the number of sockeye salmon fry that survived from the eggs taken; 2) the number of sockeye salmon juveniles released into Auke Lake; 3) the number of smolts resulting from enhancement activities that emigrated from the Auke Lake system; 4) the number of sockeye salmon juveniles released as age-0. smolts; and 5) the number of adult sockeye salmon resulting from enhancement activities that return to Auke Creek.

The total number of wild and enhanced smolts leaving Auke Lake was estimated from the proportion of OTC-marked smolts of each age class in the annual migration. All sockeye salmon smolts emigrating from Auke Lake during March through June of each year were captured and counted daily at the Auke Creek weir. Samples of the smolts were collected throughout the run at two- to eight-day intervals; samples were collected more frequently during the peak of the emigration. On sample days, approximately 50 or 100 sockeye salmon smolts were collected at random from the weir live box; a total of at least 600 smolts were collected from the annual emigration. All dead smolts found in the live box were included in the sample. Sockeye salmon smolts were individually measured to the nearest millimeter and weighed to the nearest 0.1 gram, scales were taken from the preferred area (Anas 1963) for age analysis, and vertebral bones were dissected and examined for the presence of an OTC mark. All fish with an OTC mark were considered from the enhancement program; none of the wild sockeye salmon smolts were marked or tagged during this project.

The annual emigration was partitioned into periods surrounding sample dates; the number of periods in each year ranged from 3 to 11. The proportion of fish in each mark/age class grouping in a period was estimated by:

$$\hat{p}_{hi} = \frac{n_{hi}}{n_h} \tag{1}$$

where n_{hi} was the number of fish sampled during period h with characteristic i, and n_h was the number of fish sampled during period h. The variance of $\hat{p}_{hi}$ was estimated by:

$$V[\hat{p}_{hi}] = \left(1 - \frac{n_h}{N_h}\right) \frac{\hat{p}_{hi}(1-\hat{p}_{hi})}{n_h - 1} \tag{2}$$

where N_h was the total number of fish that emigrated during period h. The total proportion of fish emigrating by characteristic in each year was estimated by:

$$\bar{p}_i = \sum_{h=1}^{L} \frac{N_h}{N} \hat{p}_{hi} \tag{3}$$

where L was the number of periods and N was the total number of fish emigrating during the year $\left(N = \sum_{h=1}^{L} N_h\right)$. The variance of $\bar{p}_i$ was estimated by:

$$V[\bar{p}_i] = \sum_{h=1}^{L} \left(\frac{N_h}{N}\right)^2 V[\hat{p}_{hi}] \tag{4}$$

The total number of fish of characteristic i that emigrated in a year was estimated by:

$$\hat{N}_i = N \bar{p}_i \quad (5)$$

and the variance of this estimate was:

$$V[\hat{N}_i] = N^2 V[\bar{p}_i] \ . \quad (6)$$

Mean length and weight and associated statistics for each grouping of fish by characteristic were estimated from the combined annual sample assuming normal distributions.

RESULTS

Sockeye salmon enhancement at Auke Lake was conducted under ADF&G Fish Transport Number 85J-1043. From 1986 through 1989, a total of 262 female sockeye salmon were taken for enhancement, 501,000 eggs were collected, and 254,060 juvenile sockeye salmon were released in various experimental groups (Table 1). A total of 132,470 juvenile sockeye salmon were released into Auke Lake, while 121,590 were retained in the hatchery and in saltwater pens for additional feeding and release as age-0. smolts.

Mature sockeye salmon were less available to capture gear in Auke Lake and Lake Creek during 1986 and 1989 due primarily to environmental conditions, and egg collection goals were not achieved in either year. The weather during those years was unusually dry, and the water level in Lake Creek was very low during most of the time in which sockeye salmon normally spawn. The fish tended to stay in deep, cooler water in Auke Lake while maturing, and either spawned there or ascended Lake Creek to spawn during brief floods while the water was high. This situation was exacerbated in 1986 due to the low escapement of adult sockeye salmon (952 fish) into Auke Lake. Maturing sockeye salmon spawners were not retained in the net pen in Auke Lake in 1989 because of exceptionally warm weather and lake water temperatures.

During 1987 and 1988, sockeye salmon milled off the mouth of Lake Creek in shallow water and were available to beach seine gear. Most of the sockeye salmon taken for enhancement, however, were captured directly off spawning redds in Lake Creek. Those salmon collected and held in the net pen did not mature as quickly as anticipated.

BKD was not detected in any of the adult sockeye salmon tested. In 1986, 89% of the male sockeye salmon and 60% of the females tested positive for IHNV. Eighty-six (86) female sockeye salmon were spawned and screened for pathogens in 1987; only two of these fish (2.3%) tested positive for IHNV. Two of 70 female sockeye salmon (2.9%) tested positive for IHNV in 1988, and none of the 44 female sockeye salmon tested in 1989 showed evidence of IHNV.

Mortalities were incurred primarily during incubation of eggs and during early life stages of sockeye salmon in the hatchery. Eighty-three percent (83%) of the eggs taken in 1986 survived to be released as fry, 71% survived in 1987, 23% survived in 1988, and 62% survived in 1989. The low survival in 1988 was presumed due to a mechanical problem in the hatchery rather than to the quality

Table 1. Numbers of adult 1986-89 brood sockeye salmon and eggs collected, and numbers of juvenile sockeye salmon released from Auke Creek hatchery.

Brood Year	Females Spawned	Number of Eggs Collected	Number of Fish Released	Number Released in Auke Lake	Number Released as Age-0. Smolts[a]	
1986	10	21,000	17,450	16,600	850	(SW)
1987	86	200,000	141,170	104,670	16,400	(FW)
					20,100	(SW)
1988	122	200,000	45,490	11,200	15,990	(FW)
					18,300	(SW)
1989	44	80,000	49,950	0	24,677	(FW)
					25,273	(SW)
Total	262	501,000	254,060	132,470	121,590	

[a] FW = reared in fresh water
SW = reared in salt water

of sockeye salmon gametes collected. The cause of the mortality is unknown, but a small group of pink salmon eggs in similar incubators also incurred a high level of mortality (Dr. William Smoker, University of Alaska, Auke Bay, Alaska, personal communication). No specific pathogens were ever detected. After hatching, approximately 50% of the fry of both species were culled due to deformities. Once fry were stocked into ponds and began to feed, they seemed very hardy and few mortalities were observed. Few of the fish held for extended rearing in salt water or fresh water died during the additional two to three months of rearing before release.

Growth rates (percentage increase in body weight per day) of juvenile sockeye salmon were closely related to water temperatures in the rearing containers. During the winter period when water temperatures ranged between 3° and 4°C, growth rates averaged approximately 1% per day. During the April through June period, freshwater temperatures ranged between 4° and 12°C, and growth rates ranged between 2% and 4% per day. Saltwater temperatures ranged from 10° to 15°C during the same period, and growth rates in salt water often exceeded 5% per day. All sockeye salmon fry sampled to confirm OTC marking since the beginning of the enhancement project have shown definite fluorescent markings on bony structures.

A single release of juvenile sockeye salmon into Auke Lake with 1986 brood fish occurred in May 1987 (Table 2), and a total of 40% of these fish emigrated from the lake. There were two releases of 1987 brood fish, a large (100,000 fish) May 1988 release in Auke Lake and a smaller (4,670 fish) August release in Lake Creek. All fish in the August 1988 release were adipose fin-clipped and tagged with CWT's. Approximately 21% of the May 1988 release emigrated from the lake through 1991, while 50% of the August 1988 release emigrated. Fish from this latter group were larger than age-0. hatchery groups, and their release occurred after the downstream migrant weir was removed. Most of these fish were observed leaving the lake in the first year following release (1989), and these fish experienced an average 26% decrease in body weight between stocking and downstream migration, with no change in length. Some fish from this lot undoubtedly emigrated from Auke Lake undetected in the fall of 1988, because two precocious adult salmon from this group returned to Auke Lake in 1989. There was a single release of 1988 brood sockeye salmon juveniles in June 1989, and 51% of these fish have emigrated from Auke Lake through 1991. None of the 1989 brood were released into Auke Lake; all were released as age-0. smolts. Samples used to determine the age composition and origin of the emigration are described in Appendix A.

The number of wild sockeye salmon smolts emigrating from Auke Lake since 1980 has ranged between 1,700 and 25,939 smolts (Table 3). In 1989 and 1990, an equivalent number of the emigrating smolts resulted from the lake stocking phase of the enhancement project. Length, weight, and age composition of wild smolts has varied considerably since 1986 (Table 4). Age-1. wild smolts ranged from an average of 72 to 93 mm, and from an average 3.1 to 7.7 g. Age-2. wild smolts ranged from an average of 102 to 126 mm, and from an average 8.8 to 17.9 g. In 1986, 1987, 1989, and 1990 age-1. smolts comprised less than half of the wild smolt emigration from Auke Creek. In 1988, however, smolts aged 1. comprised 91% of the wild emigration. Age-0. smolts reared in fresh water or salt water and released in June were generally comparable in both length and weight to wild age-1. smolt (Table 5). The age-0. group reared in salt water and released in July 1990 was comparable in size to age-2. wild smolts.

Table 2. Estimated numbers, size, and accumulated percent survival of 1986, 1987 and 1988 brood sockeye salmon released into Auke Lake, and migrating downstream during 1988-1991 as smolts aged 0.0, 1.0, 2.0, or 3.0.

	Brood Year Release Groups			
Brood Year	1986	1987(A)	1987(B)	1988
Date Released	5/21/87	5/01/88	8/01/88	6/01/89
Number Released	16,600	100,000	4,670	11,200
CWT Code			032053	
Number Sampled	200	100	100	50
Mean Length (mm)	42	47	103	45
SE	0.2	0.4	1.1	0.1
Mean Weight (g)	0.7	1.2	12.7	1.1
SE	0.05	0.03	0.4	0.03
Smolt Aged 0.0				
Migration Year	1987	1988	1988	1989
Est. Number of Smolts	0	501	0	109[a]
SE		141		
Number Sampled		14		None
Mean Length (mm)		55		
SE		1.1		
Mean Weight (g)		1.4		
SE		0.1		
Accum. % Survival [b]		1		1
Smolt Aged 1.0				
Migration Year	1988	1989	1989	1990
Est. Number of Smolts	4,703	13,563	2,230[a]	5,540
SE	369	764		438
Number Sampled	75	260	354	125
Mean Length (mm)	86	81	103	86
SE	0.5	0.5	0.5	0.8
Mean Weight (g)	5.4	4.3	9.0	6.0
SE	0.1	0.1	0.1	0.2
Accum. % Survival	28	14	48	50
Smolt Aged 2.0				
Migration Year	1989	1990	1990	1991
Est. Number of Smolts	1,857	6,954	92[a]	48
SE	403	632		27
Number Sampled	42	115	44	3
Mean Length (mm)	106	105	111	118
SE	1.6	0.6	1.3	8.7
Mean Weight (g)	9.7	9.9	10.7	16.4
SE	0.4	0.2	0.5	3.6
Accum. % Survival	40	21	50	51

-continued-

Table 2. (Page 2 of 2).

	Brood Year Release Groups			
Brood Year	1986	1987(A)	1987(B)	1988
Smolt Aged 3.0				
Migration Year	1990	1991	1991	
Est. Number of Smolts	50	0	0	
SE	49			
Number Sampled	1			
Mean Length (mm)	111			
SE	NA			
Mean Weight (g)	12.8			
SE	NA			
Accum. % Survival	40			
Estimated Total Smolts	6,610	21,018	2,322	5,697

[a] Smolt emigration is a count rather than an estimate.

[b] Survivals are cumulative, based on the total number of smolts from each group released into Auke Lake.

Table 3. Estimated numbers of wild and enhancement sockeye salmon smolts emigrating from Auke Lake, 1980-1991.

Year	Wild	Enhancement	Total
1980	25,299	0	25,299
1981	9,183	0	9,183
1982	1,719	0	1,719
1983	3,170	0	3,170
1984	20,251	0	20,251
1985	11,747	0	11,747
1986	14,503	0	14,503
1987	17,598	0	17,598
1988	13,952	5,204	19,156
1989	11,417	17,759	29,176
1990	15,899	12,536	28,435
1991	25,939	48	25,987
1980-87 Average	12,934	0	12,934
SD[a]	8,170	0	8,170
1988-91 Average	16,802	8,887	25,689
SD[a]	6,362	7,826	4,563

[a] Sample standard deviation of the mean.

Table 4. Estimated number, percent of wild emigration, and size of wild sockeye salmon smolts, aged 1.0, 2.0, and 3.0, sampled at Auke Creek weir, 1986-91.

	1986	1987	1988	1989	1990	1991
Smolt Aged 1.0						
Est. Number of Smolts	5,994	2,045	12,825	2,298	480	16,866
SE	567	364	397	395	161	591
Percent of Wild Smolts	41	12	92	20	3	65
Sample Size	73	35	259	71	20	389
Mean Length (mm)	77	93	84	72	92	76
SE	0.4	0.7	0.3	0.6	2.1	0.2
Mean Weight (g)	3.9	6.9	5.0	3.1	7.7	3.9
SE	0.1	0.2	0.1	0.1	0.5	0.1
Smolt Aged 2.0						
Est. Number of Smolts	8,509	15,553	1,110	9,052	15,310	9,073
SE	567	364	164	704	678	591
Percent of Wild Smolts	59	88	8	79	96	35
Sample Size	126	115	50	193	250	201
Mean Length (mm)	105	105	126	102	103	124
SE	1.2	0.4	1.7	0.9	0.4	0.8
Mean Weight (g)	9.6	9.5	17.9	8.8	9.4	16.4
SE	0.3	0.1	0.6	0.2	0.1	0.2
Smolt Aged 3.0						
Est. Number of Smolts			17	67	109	
SE			16	50	70	
Percent of Wild Smolts			<1	1	1	
Sample Size			1	3	3	
Mean Length (mm)			138	141	120	
SE				16.7	8.2	
Mean Weight (g)			23.0	25.9	15.7	
SE				7.4	3.4	
Total Smolts	14,503	17,598	13,952	11,417	15,899	25,939

Table 5. Number, size, release date, and coded-wire tag (CWT) code of age-0. sockeye salmon (1986-89 broods) reared in saltwater net pens and in fresh water at Auke Creek Hatchery.

Brood Year	Number Released	Fish Size					Date Released	CWT Code
		Number Sampled	Length (mm)		Weight (g)			
			Mean	SD	Mean	SD		
Salt water								
1986	850	50	84	3.9	6.0	0.7	7/24/87	None
1987	20,100	100	84	4.1	6.2	0.8	6/21/88	032125R3
1988	18,300	100	78	5.3	4.8	0.8	6/21/89	0301010111
1989	13,618	100	85	4.5	6.2	0.9	6/21/90	0301010503
1989	11,655	100	103	3.1	11.9	1.1	7/06/90	0301010505
Fresh water								
1987	16,400	100	75	3.9	4.4	0.8	6/21/88	032126R3
1988	15,990	100	65	5.0	2.7	0.6	6/21/89	0301010112
1989	12,600	100	67	3.2	2.8	0.4	6/21/90	0301010504
1989	12,077	100	76	3.6	4.3	0.7	7/06/90	0301010110

DISCUSSION

Since sockeye salmon normally emigrate as smolts from Auke Lake after one, two, or three years of rearing in the lake, the total smolt surviving from the first two (1986 and 1987) broods of fry released into Auke Lake can be estimated at this time and a preliminary estimate of the 1988 brood survival can be made. Survival of the 1986 brood was 40% from fry to smolt; survivals from the two 1987 releases were 21% and 50%. Survival of the 1988 brood release will be at least 51%. These survival rates suggest that the release of 100,000 hatchery fry into Auke Lake in 1987 was too high a stocking density and resulted in a reduced survival rate. In 1989, both wild and hatchery age-1.0 smolts were also smaller in length and weight than in any other year of this study (1986-1991). Methods described by Koenings and Burkett (1987) suggest that about 75,000 fry would be an optimum number of juvenile sockeye salmon for Auke Lake. The late (August 1, 1988) release of 1987 brood fingerlings was not as affected by the high rearing densities in Auke Lake; these fish entered the lake at a greater initial length and weight, and some undoubtedly left the lake within a few months of release. Those that remained in Auke Lake lost weight during the winter, but survived to leave the lake as age-1.0 smolts.

Sufficient eggs have been taken and sufficient fry and smolt have been released to permit evaluation of both lake stocking and age-0. smolt rearing as sockeye salmon enhancement techniques. The project has not, however, met its original fry and smolt release objectives. Nevertheless, the numbers of adult sockeye salmon returning from the fry and smolt that have been released could be substantial. Assuming marine survival rates of approximately 10 percent, the total return from the 1989 release of 49,950 age-0. sockeye salmon smolts alone could be about 5,000 adult sockeye salmon. The initial returns of precocious adult sockeye salmon are encouraging, but are too few to allow projections of future returns.

The reason why the numbers of sockeye salmon returning to Auke Lake declined in the early 1980's is still unknown. Nothing has been done since the beginning of this project in 1986 to improve the quality of spawning habitat in Lake Creek. Independent of enhancement activities, however, the numbers of adult sockeye salmon returning to Auke Lake in recent years, as well as the numbers of wild juvenile smolts leaving the lake, have been higher. The 1991 escapement of 5,424 sockeye salmon approached the 1963-78 average, while the wild smolt emigration in 1991 was the highest since 1980. The ADF&G does not plan to participate in sockeye salmon enhancement at Auke Lake after the fry and smolt releases in 1990, and the NMFS currently plans to discontinue fry or smolt releases after the 1991 brood.

Adult sockeye salmon resulting from these enhancement activities are expected to return to Auke Lake from 1990 through 1996; that phase of the project will be evaluated in a subsequent report. The true effectiveness of this enhancement technique can only be determined after adult returns are complete in 1996. The number of adult sockeye salmon resulting from enhancement will be based on: 1) a subsample of adipose fin-clipped adults returning to the Auke Creek weir; 2) scale samples from fish that do not have clipped adipose fins; 3) carcasses obtained during hatchery egg collection; and 4) from carcasses of naturally spawned fish in Auke Lake and Lake Creek. Heads from fin-clipped fish will be examined for the presence of a CWT, and the vertebrae from the carcasses will be examined for the presence of an OTC mark. The estimate of enhancement contribution will be based on the ratio of OTC marked to unmarked carcasses in

the sample, expanded by the total weir count of sockeye salmon immigrants to Auke Lake that are not fin-clipped. Age-0. smolt contribution will be based on the number of sockeye salmon immigrants that are missing adipose fins, and on the numbers of fish from each tag lot that are identified in the sample.

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APPENDIX A

Appendix A. Sample periods, number of smolts counted (excluding those marked with CWT's), composition of aged samples, and estimated total emigration at age of wild and hatchery produced sockeye salmon smolts, Auke Creek weir, 1986-91.

Period	Smolts Counted	Sample Date	Wild Smolt Aged			Hatchery Smolt Aged				Total Smolts Aged
			1.0	2.0	3.0	0.0	1.0	2.0	3.0	
					1986					
May 5-25	5,091	May 22	0	99	0					99
May 26-June 1	8,078	May 29	30	20	0					50
June 2-18	1,334	June 05	43	7	0					50
Total	14,503									199
	Proportion		0.41	0.59	0					
	Estimate		5,994	8,509	0					
	Variance		321,842	321,842	0					
	Standard Error		567	567	0					
					1987					
April 29-May 22	9,627	May 19	1	49	0					50
May 23-27	5,934	May 26	6	44	0					50
May 28-June 28	2,037	May 28	28	22	0					50
Total	17,598									150
	Proportion		0.12	0.88	0					
	Estimate		2,045	15,553	0					
	Variance		132,479	132,479	0					
	Standard Error		364	364	0					
					1988					
May 1-11	334	May 10	1	18	1	0	0	0	0	20
May 12-14	483	May 12	10	16	0	0	4	0	0	30
May 15-16	3,687	May 16	50	4	0	2	19	0	0	75
May 17-18	962	May 17	95	5	0	0	67	0	0	167
May 19-21	5,451	May 19	56	5	0	0	39	0	0	100
May 22-23	1,334	May 22	43	2	0	0	5	0	0	50
May 24	649	May 24	36	0	0	0	14	0	0	50
May 25	1,290	May 25	16	0	0	2	2	0	0	20
May 26-28	1,690	May 27	40	0	0	3	7	0	0	50
May 29-31	1,033	May 29	26	0	0	2	3	0	0	31
June 1-4	1,232	June 02	40	0	0	1	9	0	0	50
June 5-28	1,011	June 07	38	0	0	4	8	0	0	50
Total	19,156									693
	Proportion		0.67	0.06	0.00	0.03	0.25	0.00	0.00	
	Estimate		12,826	1,110	17	501	4,703	0	0	
	Variance		157,742	26,932	262	19,746	136,050	0	0	
	Standard Error		397	164	16	141	369	0	0	

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Appendix A. (Page 2 of 2).

Period	Smolts Counted	Sample Date	Wild Smolt Aged			Hatchery Smolt Aged				Total Smolts Aged
			1.0	2.0	3.0	0.0	1.0	2.0	3.0	
					1988					
May 1-9	379	May 08	0	36	2	0	0	4	0	42
May 10-13	411	May 11	0	45	0	0	0	5	0	50
May 14-18	1,866	May 17	0	35	0	0	18	1	0	54
May 19-20	1,066	May 19	0	29	0	0	11	10	0	50
May 21-23	7,680	May 22	1	38	0	0	58	2	0	99
May 24-27	9,603	May 25	5	17	0	0	33	6	0	61
May 28-31	2,603	May 30	8	12	0	0	73	15	0	108
June 1-4	2,471	June 01	20	11	1	0	17	1	0	50
June 5-10	489	June 07	8	4	0	0	17	1	0	30
June 11-16	120	June 12	14	0	0	0	11	1	0	26
June 17-28	149	June 19	15	2	0	0	22	0	0	39
Total	26,837									609
	Proportion		0.09	0.34	0.00	0.00	0.51	0.07	0.00	
	Estimate		2,298	9,052	67	0	13,562	1,857	0	
	Variance		156,052	495,956	2,534	0	584,159	162,356	0	
	Standard Error		395	704	50	0	764	403	0	
					1990					
May 1-19	2,492	May 19	0	41	2	0	0	7	0	50
May 20	1,906	May 20	0	33	0	0	1	16	0	50
May 21	4,978	May 21	0	65	0	0	3	31	1	100
May 22-23	9,075	May 22	1	45	0	0	4	20	0	70
May 24-27	5,100	May 27	2	36	0	0	46	16	0	100
May 28-29	938	May 29	1	11	0	0	11	7	0	30
May 30- June 2	1,660	May 31	0	7	0	0	17	5	0	29
June 3-13	1,254	June 05	0	3	0	0	10	7	0	20
June 14-22	484	June 21	13	5	1	0	27	4	0	50
June 23-July 1	456	June 25	3	4	0	0	6	2	0	15
Total	28,343									514
	Proportion		0.02	0.54	0.00	0.00	0.19	0.25	0.00	
	Estimate		480	15,310	109	0	5,440	6,954	50	
	Variance		25,795	459,701	4,853	0	191,493	399,005	2,428	
	Standard Error		161	678	70	0	438	632	49	
					1991					
May 7-21	1,199	May 21	48	0	0	0	0	0	0	48
May 22-26	5,961	May 23	90	10	0	0	0	0	0	100
May 27-28	1,909	May 28	63	37	0	0	0	0	0	100
May 29	1,605	May 29	53	44	0	0	0	3	0	100
May 30-June 1	6,033	May 30	26	24	0	0	0	0	0	50
June 2-3	1,750	June 03	38	12	0	0	0	0	0	50
June 4-11	6,174	June 06	49	46	0	0	0	0	0	95
June 12-28	1,356	June 17	22	28	0	0	0	0	0	50
Total	25,987									593
	Proportion		0.65	0.35	0.00	0.00	0.00	0.00	0.00	
	Estimate		16,866	9,073	0	0	0	48	0	
	Variance		349,535	349,469	0	0	0	710	0	
	Standard Error		591	591	0	0	0	27	0	