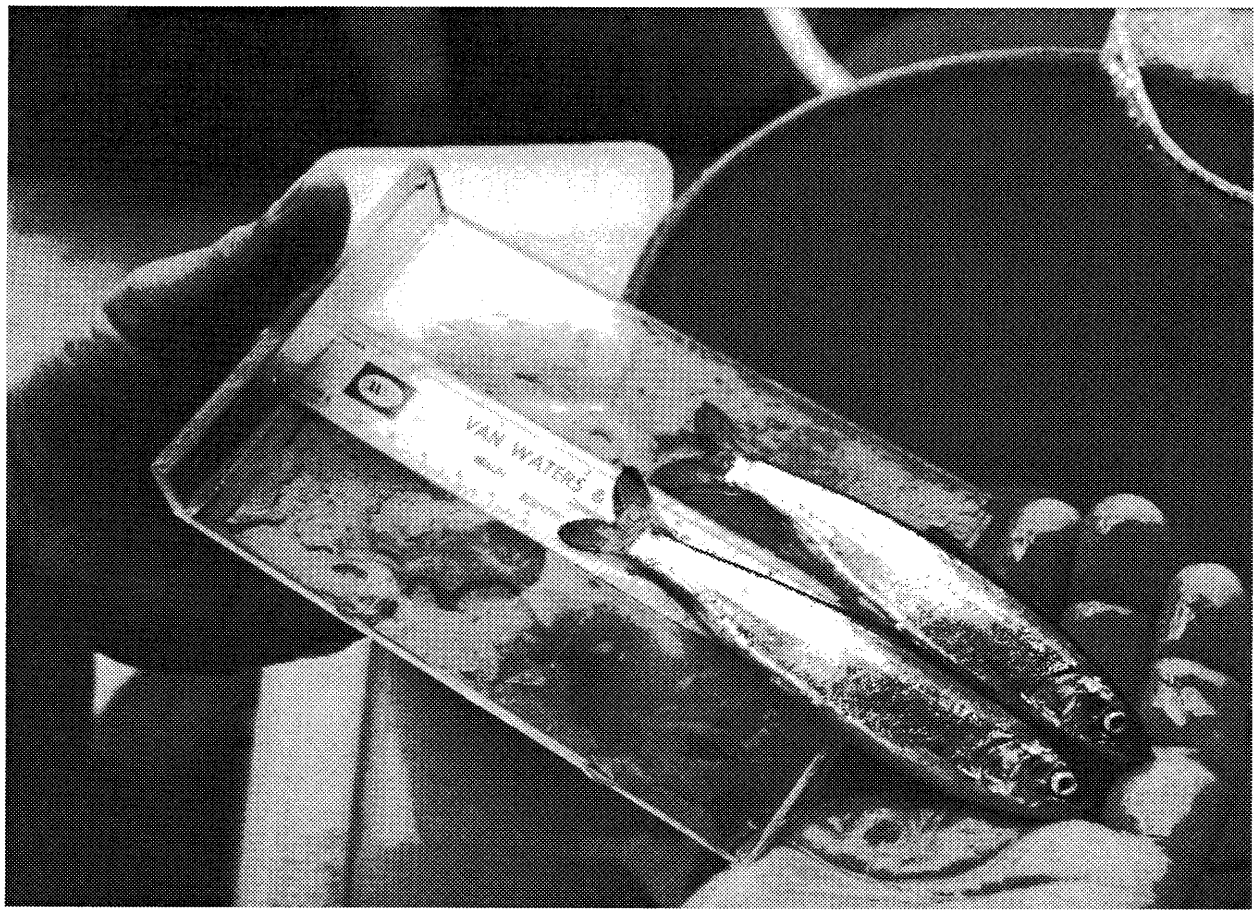

Figure 1. Age-0 sockeye salmon reared up to 2 months in net pens at Auke Bay, Alaska.

FIRST RETURNS OF ADULT SOCKEYE SALMON FROM HATCHERY-REARED AGE-0 (UNDERYEARLING) SMOLTS

The anadromous life history of Pacific salmon (*Oncorhynchus* spp.) is characterized by distinct freshwater and saltwater phases -- with some species requiring longer periods of freshwater residency than others. The sockeye salmon (*O. nerka*) typically spends one or two growing seasons in nursery lakes before the fry smolt and migrate to the ocean. However, the species is also characterized by individuals from some stocks in certain environments which migrate naturally to sea as age-0 smolts. Because of the generalized requirement for a period of freshwater residency after the initial freshwater incubation period, enhancement methods for sockeye salmon in Alaska usually follow one of two strategies.

In both strategies, wild sockeye salmon adults are captured and their eggs are spawned in an artificial setting. The fertilized eggs from the wild broodstock are then incubated in hatchery facilities until hatching occurs. Further enhancement of the newly hatched fry then follows one of two accepted strategies. The first enhancement technique involves stocking fry in suitable lake environments where the juveniles spend from one to two years of feeding and growing before they reach the smolt stage and migrate to the ocean. The second technique requires the rearing of sockeye fry in a hatchery for one year before release in a stream or river as yearling smolts which will migrate to the ocean.

To provide an alternative to the accepted enhancement strategies, scientists at the Auke Bay Laboratory (ABL) initiated a series of studies beginning in 1987 to investigate the feasibility of rearing age-0 sockeye smolts in a hatchery (Fig. 1). These enhancement studies were conducted at the nearby Auke Creek Hatchery (operated by the ABL) and were part of a broader enhancement effort to rehabilitate a badly depressed sockeye salmon run in the Auke Lake system. The escapement of adult sockeye salmon at Auke Creek averaged more

than 7,000 fish annually (ranging from 4,000 to 16,000 per year), before it began a rapid decline in the mid 1970s (Fig. 2). In 1985, the run reached the lowest level ever observed at Auke Creek when only 240 sockeye salmon were counted at the Auke Creek weir.

The goal of our research was to accelerate sockeye egg and juvenile development so that age-0 smolts could be released within the normal temporal window for seaward migration experienced by sockeye salmon 1 to 2 years earlier than their wild cohorts. The long-term plan was to supplement wild smolt production for several years to increase the number of returning sockeye adults to at least 5,000 fish per year. This article describes the results of our research on the first three broods of enhanced age-0 sockeye salmon that have returned to Auke Lake.

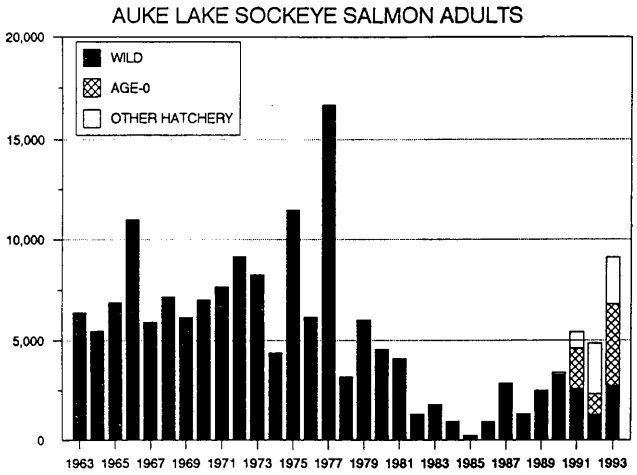

Figure 2. Escapements of sockeye salmon in the Auke Lake system, 1963-1993, depicting adults produced from wild spawners, releases of age-0 smolts, and other hatchery-produced juveniles.

Sockeye salmon eggs were collected in August from mature sockeye salmon captured in Lake Creek, the major tributary to Auke Lake, in 1987, 1988, and 1989. The Lake Creek sockeye stock is endemic to Auke Lake, and normally produces only yearling or older aged smolts. Fertilized eggs were then transferred to and incubated at the Auke Creek Hatchery located on Auke Creek. The eggs were placed in stacked, tray incubators until they reached the eyed stage of embryo development. Dead eggs were then removed and 6,000 eggs were replaced in each tray with a substrate of plastic mesh heavy duty screen with 18 mm openings. Twice weekly the incubators were flushed with salt water (28-30 ppt) for 1 hour to control fungus. Development of eggs and juvenile fish in the hatchery was accelerated by manipulating water temperature using a dual water intake system. This water collection system allowed the mixing or independent use of water from Auke Creek and subsurface water from below the thermocline in Auke Lake. Auke Creek water temperature often exceeds 20°C in August and is usually warmer than subsurface lake water through mid-November. In comparison, Auke Lake subsurface (7-m depth) water temperature seldom exceeds 8°C.

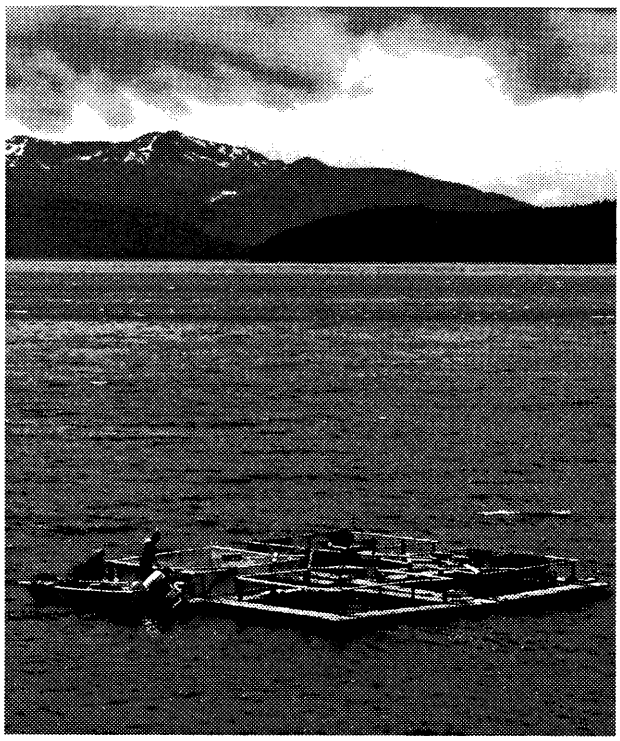

Figure. 3 Age-0 sockeye salmon were cultured in net pens in sea water at Auke Bay, Alaska, to produce age-0 smolts.

Sockeye salmon eggs were initially incubated in a mixture of stream and subsurface waters with water temperature maintained not to exceed 14°C. As water temperatures in Auke Creek declined, eggs were then incubated using stream water until the fall temperature inversion occurred in Auke Lake at approximately mid-November of each year. Subsurface water was used throughout the winter and early spring until water temperatures in Auke Creek again exceeded the Auke Lake subsurface water temperatures.

All water used for incubation and rearing in the hatchery passed through an in-line filter (200 micron, multi-filament polyester mesh) that removed plankton and debris. Filtered water was also exposed to ultraviolet-light in a disinfection unit before passing to the incubation and rearing tanks.

Table 1. Data relating to release and return of 1987, 1988, and 1989 brood year sockeye salmon reared at Auke Creek Hatchery as age-0 smolts. Release data includes release group (designated by brood year and rearing treatment in fresh, fw, or sea water, sw), release data and number and size of smolts. Adult returns include total number of all age groups, proportion of each release group that returned after 3 years in the ocean (3-oc.), average length of 3-ocean adults (cm) and marine survival (%) determined at Auke Creek weir.

		Smolt release			Adult return			
group	date	no.	mm	gm	no.	3-oc.	cm	%
87-fw	6/21/88	16,432	75	4.4	873	0.88	51.9	5.3
87-sw	6/21/88	19,888	84	6.2	1,235	0.95	53.2	6.2
88-fw	6/21/89	15,991	65	2.7	239	0.79	51.3	1.5
88-sw	6/21/89	18,369	78	4.8	599	0.92	50.0	3.3
89-fw	6/21/90	12,599	67	2.8	703	0.94	53.6	5.6
89-sw	6/21/90	13,618	85	6.2	1,325	0.96	54.0	9.7
89-fw	7/06/90	12,077	76	4.3	669	0.97	54.1	5.5
89-sw	7/06/90	11,655	103	11.9	1,318	0.96	53.3	11.3

The sockeye salmon eggs began hatching 60 days after spawning, by which time the eggs had accumulated 650° C temperature units (TU = the average number of degrees above 0° C during a 24-hour period). Within 5 months after spawning, the fry were fully developed after accumulating 1,100° C TUs, and transferred to freshwater rearing tanks where they were fed several times each day. No comparable temperature data are available for wild sockeye from the Auke Lake system, however, emergent wild fry are not observed until late May, approximately 10 months after spawning. All groups of fish were fed a prepared semi-dry food; feed size was that recommended by the manufacturer. Daily feed ration, expressed as a percentage of fish biomass, was adjusted daily to account for fish growth.

In our study, we used two different culture approaches to produce age-0 sockeye salmon smolts. One group of fish was reared entirely in fresh water, while a second group was reared in fresh water until they could osmoregulate and survive in salt water -- this occurred at approximately 2 g in weight. This latter group was then transferred to seawater net pens in Auke Bay near the mouth of Auke Creek (Fig. 3). Fish placed in seawater net pens were cultured for 4-6 weeks. The freshwater and seawater groups were fed the same diet, experienced the same feeding frequency, and were cultured for the same period and released on the same day.

The growth rate of sockeye salmon in the seawater net pens was greater than that for fish reared in fresh water, and at the time of release, the seawater-reared fish were larger than those reared in fresh water. The seawater groups probably grew faster because of a combination of the hypoosmotic environment in the net pens, exposure to the natural photoperiod, and slightly higher water temperature. The average size of sockeye reared in seawater ranged from 78 to 103 mm, while freshwater reared sockeye averaged from 65 to 76 mm at release (Table 1).

Eight groups of age-0 sockeye salmon smolts were released in this study; two groups of fish (freshwater- and seawater-reared) were released on 21 June 1988, 1989, and 1990 and on 6 July 1990 (Table 1). Freshwater-reared smolts were released directly into Auke Creek and emigrated about 50 m downstream to Auke Bay. Seawater smolts were released directly into Auke Bay at the net pen site. Two months before release, all fish were marked by clipping of the adipose fin and tagged with a half-length coded wire tag; a different tag code identified each culture group. A final size inventory and count was made for each test group the day before release.

Marine survival of smolts and age and size at maturity of adults were determined for the sockeye salmon that returned to Auke Creek. From 1989 through 1993, every sockeye salmon that entered the fish counting weir

at the mouth of Auke Creek was examined for a missing adipose fin. A subsample of marked fish were sacrificed to recover tags, and the remainder of the fish were released to spawn. Among the groups of underyearling smolts released on the same dates, those that had received some rearing in seawater net pens (from 4 to 6 weeks) had significantly ($P = 0.05$) higher survival rates than those reared entirely in freshwater.

The smolt-to-adult survival rate ranged between 3.3% and 11.3% for seawater-reared sockeye, and between 1.5% and 5.6% for those reared in freshwater (Table 1). These percentages represent minimal survival rate estimates because no adjustments were made for undetermined levels of fishery harvest. While no systematic fishery sampling for tagged adult sockeye salmon was possible in the region, several tagged Auke Creek sockeye were recovered in each of the adult return years coincidental to sampling programs for other species and purposes.

Based on linear regression, there was a positive relationship between smolt length at release and marine survival. Most sockeye that returned from this study spent 3 years at sea (Fig. 4), exactly like the wild cohorts from Auke Lake. There were no significant differences in individual length between groups released in the same year, and in each year adults from hatchery-reared smolts were indistinguishable in size from their wild counterparts.

The sockeye salmon cultured as age-0 smolts at Auke Creek hatchery have contributed significantly to the escapement of sockeye salmon to Auke Lake since 1990. The adult sockeye salmon returns at Auke Creek in 1991 and 1992 were the first evidence that age-0 smolt culture was feasible. Age-0 releases resulted in the return of more than 2,000 adults in 1991 and 1,100 in 1992, comprising 37% and 23%, respectively, of the total return. The escapement of 9,113 sockeye salmon in Auke Creek in 1993 was one of the highest ever recorded and exceeded any observed spawning escapement for more than a decade. More than 4,000 of the adults that returned in 1993 originated from releases of age-0 smolts and accounted for 44% of the total return.

This project has demonstrated that the culture of underyearling age-0 sockeye salmon is a feasible enhancement method and that underyearling smolts can be successfully reared from a stock that naturally produces only yearling or older-aged smolts.

By SIDNEY TAYLOR and WILLIAM HEARD

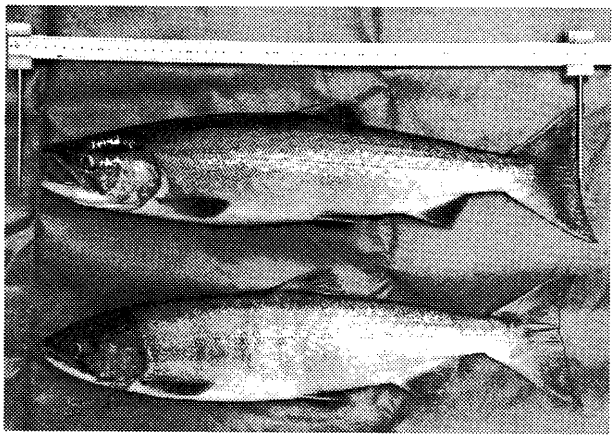

Figure 4. Most sockeye salmon adults resulting from production of age-0 smolts returned after spending 3 years in the ocean, exactly the same as wild fish from Auke Lake. The missing adipose fin identified the fish as hatchery-produced age-0 fish that had been tagged with coded wire tags before release.