

## Survival and Early Marine Migration of Enhanced Age-0 Sockeye Salmon Smolts Raised in Freshwater and Seawater at Auke Creek, Southeast Alaska

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The adult sockeye salmon, *Oncorhynchus nerka*, population in Auke Creek in Southeast Alaska reached record low levels when 240 fish returned in 1985 and runs were less than a thousand fish for three consecutive years. To help rebuild this depressed population, a restoration project included research on hatchery production and releases of age-0 or sea-type smolts over a five year period, 1988-1992. The study included use of an experimental hatchery and two-way counting weir at the stream mouth to monitor survival and estuarine sampling of juveniles during their early marine period to examine residency in Auke Bay and migration timing.

**Table 1.** Marine survival for seven groups of age-0 sockeye salmon cultured only in freshwater and eighteen groups of age-0 sockeye salmon with additional culture in seawater released May through August, 1988 to 1992.

Release		Culture days in seawater	Size of smolts		Number of Smolts	Ocean Age of Adults				Total Adults	% Survival
Year	Date		mm	gm		1	2	3	4		
1988	21-Jun	—	75	4.4	16,400	21	14	765	73	873	5.32
1989	21-Jun	—	65	2.7	15,900	0	42	208	8	258	1.61
1990	21-Jun	—	67	2.8	12,599	0	44	659	0	703	5.58
1990	6-Jul	—	76	4.3	12,077	0	22	647	11	680	5.60
1991	5-Jun	—	49	1.2	15,527	0	0	5	0	5	0.03
1991	21-Jun	—	56	2.0	15,500	0	0	139	0	139	0.90
1991	19-Jul	—	71	3.6	15,500	0	0	81	8	89	0.57
					103,503	21	122	2,504	100	2,747	2.65
1988	21-Jun	22	84	6.2	19,888	0	16	1,168	51	1,235	6.21
1989	21-Jun	46	78	4.8	18,300	11	34	538	8	591	3.23
1990	21-Jun	28	85	6.2	13,618	0	58	1,267	4	1,329	9.76
1990	6-Jul	43	103	11.9	11,655	0	51	1,267	15	1,333	11.44
1991	28-May	6	49	1.3	10,172	0	0	19	0	19	0.19
1991	5-Jun	14	46	1.7	11,605	0	0	30	0	30	0.26
1991	21-Jun	10	62	2.6	14,069	0	0	316	8	324	2.30
1991	5-Jul	24	86	6.9	14,794	0	30	864	17	911	6.16
1991	19-Jul	43	104	11.2	15,510	0	60	836	17	913	5.89
1991	19-Jul	9	70	3.6	15,310	0	10	201	0	211	1.38
1991	8-Aug	65	125	19.4	10,020	0	124	689	13	826	8.25
1992	8-Jun	7	52	1.5	6,596	0	0	70	0	70	1.06
1992	8-Jun	16	65	2.9	5,286	0	11	117	0	128	2.42
1992	21-Jun	11	67	3.1	8,112	0	8	194	0	202	2.49
1992	21-Jun	29	88	6.2	8,370	0	23	519	1	543	6.49
1992	6-Jul	11	67	3.2	8,122	0	11	161	1	173	2.13
1992	6-Jul	26	88	6.2	8,209	0	30	384	1	415	5.06
1992	6-Jul	44	102	11.8	9,382	0	11	533	1	545	5.81
					209,018	11	477	9,173	137	9,798	4.69

Fry were initially raised in freshwater (FW) until large enough to become moderately salinity tolerant, generally from 1.0 to 1.5 g (Clark et al. 1978; Rice et al. 1994). Some were transferred to marine net pens in Auke Bay for additional growth in seawater (SW), while others were retained in freshwater rearing containers. Although not known to occur naturally in the Auke Creek population, age-0 sockeye salmon smolts are not uncommon in other nearby regional stocks (McPherson, 1987; Murphy et al. 1988; Heifetz et al. 1989). Gametes from mature Auke Lake spawners were collected from five brood years (1987-1991) from the spawning grounds in Lake Creek, the main tributary to Auke Lake, or its confluence with the lake where adults were held in net pens in the lake until ripe. Dual water sources, from Auke Creek surface water and deep lake water, for incubation and rearing in the hatchery allowed for using favorable water temperatures to accelerate embryo development and initial fry rearing. Debris filtered and ultraviolet sterilized water was used for all incubation and rearing in the hatchery to destroy bacteria and viruses (Taylor 1989; Taylor et al. 1992; Taylor and Heard 1994).

A total of 25 age-0 smolt groups were released: 7 FW groups and 18 SW groups (Table 1). All groups were adipose fin clipped and tagged with half-length coded-wire tags (CWT). From 1989-1996 all sockeye salmon adults entering Auke Creek weir were examined for fin clips and were subsampled to recover wire tags. Other tags were recovered from spawning ground carcasses in Lake Creek. Estimated numbers of adult returns from age-0 sockeye salmon smolts made important contributions to Auke Creek weir counts over a five year period, 1991-1995 (Fig. 1).

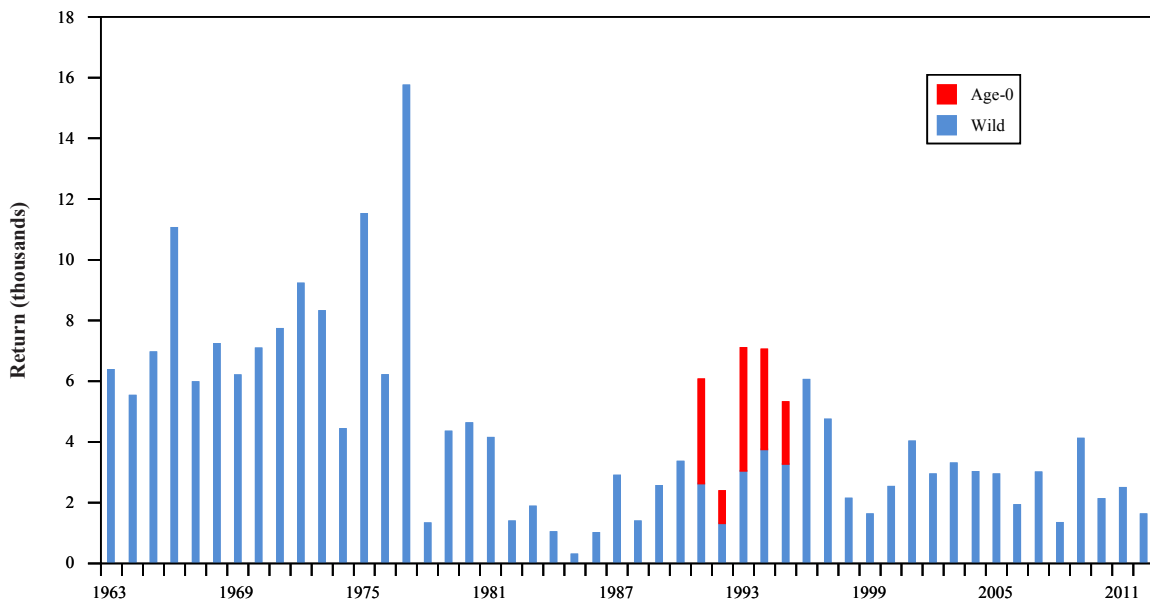


Fig. 1. Adult sockeye salmon returns to Auke Creek from wild and age-0 hatchery smolts, 1963-2012.

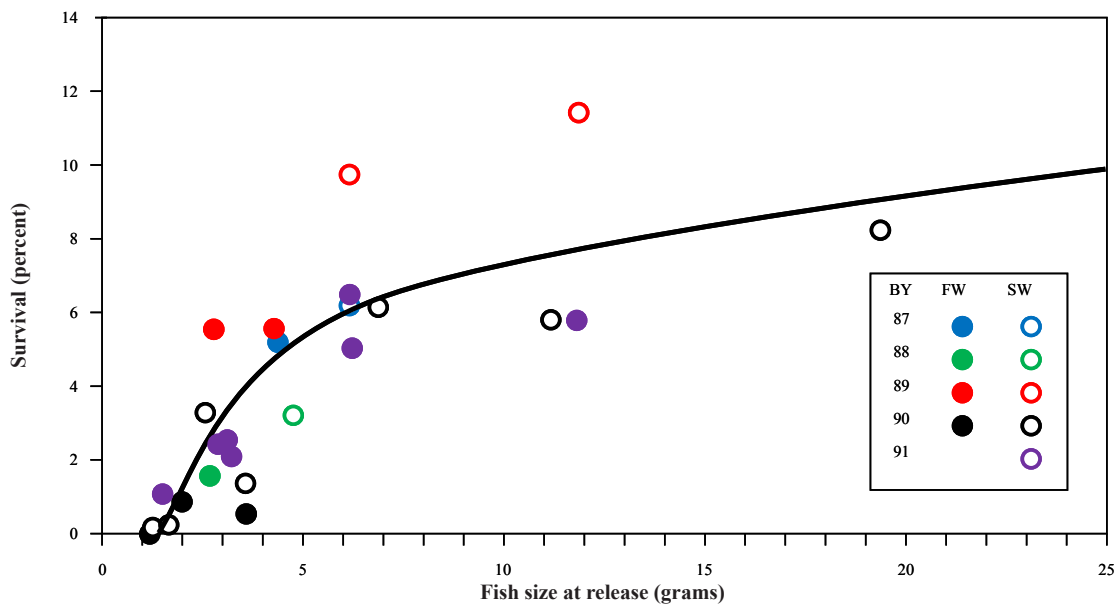
Age-0 smolts were released as early as May 28 and as late as August 2 (Table 1). Nine groups including both FW and SW groups were released on the summer solstice (~ 21 June) over a five year period (Table 2) to examine any temporal significance of this photoperiod event compared with other release dates. Sizes of age-0 smolts ranged from 49 mm and 1.3 g to 125 mm and 19 g. Growth rates in FW during the April through June period ranged from 2% to 4% per day while SW growth rates in May and June often exceeded 5% per day (Taylor et al. 1992; Taylor and Heard 1994).

Marine survival of SW age-0 smolts averaged 4.7% (range 0.2-11.4%) and was significantly greater ( $p = 0.05$ ) than FW-raised smolts (average 2.7%, range 0.03-5.6%; Table 1). Higher SW group survival (Fig. 2) likely was due to larger smolts and greater growth rates in SW (5-7%/day) than in FW (2-4%/day) for juveniles reared during the same time periods. Higher growth rates in SW was the result of warmer temperatures and possibly because sockeye salmon smolts may experience more rapid growth in seawater even if temperatures are similar.

Adult sockeye salmon from age-0 SW smolts returned mostly at ocean age-3 (93.6%). While age-0 FW smolts also returned primarily as ocean age-3 adults, they returned at a slightly lower rate (91.2%, Table 1). This age at return is consistent with wild FW age-1 and age-2 sockeye salmon smolts from Auke Creek that also return mostly as ocean age-3 adults.

**Table 2.** Marine survival for nine groups of age-0 sockeye salmon smolts all released on June 21, 1988 to 1992, including groups cultured only in freshwater and groups cultured with additional days in seawater (SW).

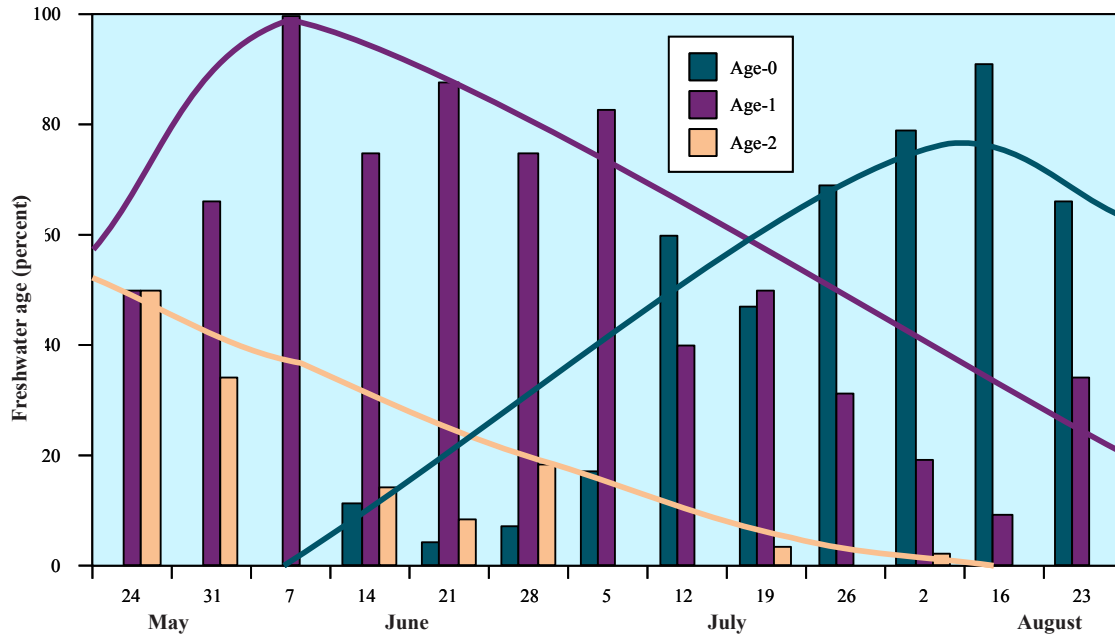
Release year	Freshwater or seawater culture	SW days	Size		Number of smolts	Ocean age of adults				Total adults	% Survival
			mm	g		1	2	3	4		
1988	FW		75	4.4	16,400	21	14	765	73	873	5.32
1988	SW	22	84	6.2	19,888	0	16	1,168	51	1,235	6.21
1989	FW		65	2.7	15,990	0	42	208	8	258	1.61
1989	SW	46	78	4.8	18,300	11	34	538	8	591	3.23
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1990	SW	28	85	6.2	13,618	0	58	1,267	4	1,329	9.76
1991	FW		56	2	15,500	0	0	139	0	139	0.90
1991	SW	11	67	3.1	8,112	0	8	194	0	202	2.49
1992	FW				0						
1992	SW	29	88	6.2	8,370	0	23	519	1	543	6.49
					128,777					5,873	4.56



**Fig. 2.** Marine survival of Auke Creek age-0 sockeye salmon smolts raised only in freshwater (FW) and with additional culture in seawater (SW) net pens in Auke Bay, brood years 1987-1991.

The early marine life history of sockeye salmon smolts in Auke Bay was studied from May to September in 1990 and 1991 by weekly samples of littoral and pelagic habitats with beach seines and surface trawls (Orsi 1991). Up to 10 beach seine sets were made diurnally at five sites and nine surface trawl tows were made nocturnally at three stations. Sockeye salmon smolts were present from late May to late August with peak abundance in June and July. In both years combined, 1,393 sockeye salmon smolts that were sampled for age, size, and collection of the CWT comprised less than 2% of the fish abundance caught. Pacific herring and capelin constituted over 80% and 95% of the catch in littoral and pelagic zones, respectively. Age composition of sockeye salmon smolts changed seasonally with FW age-2 and age-1 fish prevalent from late May to early July while age-0 fish were most abundant from early July to mid-August (Fig. 3). A total of 307 CWT

recoveries of age-0 smolts in both years revealed smaller fish utilized littoral habitats first and then move offshore as they grew larger. In 1990 the 557 sockeye salmon smolts with readable scales revealed the following age structures: 54% age-0 (including 28% hatchery reared with CWT and 26% wild), 40% age-1, and 6% age-2. The longest residency of age-0 hatchery smolts was 41 and 59 days in 1990 and 1991, respectively. Few CWT fish over 100 mm fork length were recovered, suggesting most migrate out of Auke Bay before reaching this size.



**Fig. 3.** Smoothed temporal distribution of freshwater age composition of juvenile sockeye salmon caught in Auke Bay with seines and trawls, May 24-August 23, 1990. N = 403 fish

In conclusion, this study demonstrated that sockeye salmon can be successfully cultured and released as age-0 smolts with marine survival averaging 4.7% and 2.7%, respectively, for SW- and FW- raised smolts. Littoral and offshore migration was size dependent with most smolts migrating out of Auke Bay before reaching 100 mm fork length.

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