Aspects of Sockeye Salmon Smolt Production in the Egegik River System of Bristol Bay, Alaska

Patrick C. Martin and Denby S. Lloyd

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ABSTRACT: In Becharof Lake a significant positive correlation was found between the total number of sockeye salmon *Oncorhynchus nerka,* primarily age 1. and age 2., produced by brood year and the proportion of older holdover parr (age 2.) produced by the subsequent brood year. This suggests possible density-dependent effects of grazing pressure by large numbers of parr that reduce the food available to fry in subsequent years, which in turn causes a higher proportion of parr from subsequent brood years to have a longer freshwater residence. Recent, large spawning escapements may affect the rearing capacity of Becharof Lake and thereby reduce the subsequent production of smolts and return of adult sockeye salmon to the Egegik River.

INTRODUCTION

Since 1979 the Egegik River system, including Becharof Lake, has had the highest rate of sockeye salmon *Oncorhynchus nerka* production, measured as returns per spawner, of any system in Bristol Bay, Alaska. Recent efforts to characterize this production using standard stock-recruitment models have not been successful because the spawner-return data do not exhibit requisite density-dependent mortality (Cross 1994). Of the 2 distinct life history phases between spawners and subsequent returns — freshwater rearing and marine growth — investigators have noted common trends in marine survival of sockeye salmon over a broad geographic area (Beamish and Bouillon 1993), whereas Brocksen et al. (1970) suggested that stock-specific density-dependent effects can be expressed within the lake-bound freshwater rearing stage. We therefore examined the freshwater phase in Becharof Lake because we were particularly concerned that very high escapements into the Egegik River, as have occurred recently, might affect overall production of sockeye salmon in this system.

METHODS

Data on spawning escapements, smolt production, and subsequent adult returns by brood year in the Egegik system of Bristol Bay (Cross 1994; Crawford and Cross 1995) were evaluated with simple linear-regression techniques in order to describe separate components of the spawner-return cycle.

RESULTS AND DISCUSSION

Cross (1994) found adult returns to be highly correlated with abundance of smolts migrating from Becharof Lake, indicating relatively consistent marine survival. A similar regression of smolt production against spawning escapement for brood years 1980–1991, however, shows almost a complete lack of correlation (Figure 1; $F = 0.00026$, $P \approx 0.99$). Thus, while magnitude of the adult return appears directly related to the number of smolts entering the marine environment, the number of original spawners does not control the production of those smolts in fresh water (Table 1).

In Becharof Lake, sockeye salmon for the most part rear for either 1 or 2 years before emigrating as smolts. It is generally believed that if parr attain a large enough size in 1 year they will emigrate, but if grazing or other conditions prevent them from attaining a large enough size, they will hold over a second year in fresh water for further growth (Burgner 1987; Koenings and Burkett 1987). One type of density-dependent effect in fresh water might involve competition between age-2. fish from a given brood year (BY) and progeny from the subsequent brood year (BY+1), causing a higher percentage of parr from BY+1 to hold

Authors: PATRICK C. MARTIN is an oceanographer currently commercial fishing along the Alaska Peninsula; DENBY S. LLOYD is chief resource analyst for the Aleutians East Borough. Correspondence may be directed to Mr. Lloyd at 1600 A Street, Suite 103, Anchorage, AK 99501.
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over a second year. A regression of these data for brood years 1980–1991, however, does not show a substantial correlation (Figure 2; $F = 1.42$, $P \approx 0.26$) in support of such a density-dependent effect.

A different type of effect could be impacts of heavy grazing by a large number of parr on the subsequent availability of food for parr in the next year. Kyle et al. (1988) documented such a density-dependent impact on zooplankton food supply and subsequent sockeye production in Frazer Lake. A residual grazing effect also appears likely for Kenai River sockeye salmon rearing in Skilak Lake, where data are available for sockeye parr and *Cyclops* abundance (Schmidt and Tarbox 1996). For Becharof Lake no comprehensive data for parr or zooplankton abundance are available; a surrogate indicator could be the relationship between the proportion of age-2. holdovers from a brood year against the total number of grazing fry of the previous brood year (approximated by total smolt production). Regression of these data for brood years 1980–1991 shows a significant relationship (Figure 3; $F = 5.14$, $P \approx 0.05$) in support of such a grazing effect.

Another indication of such a residual grazing effect in Becharof Lake is the low smolt production noted by Cross (1994) for brood years 1989–1991 from the largest spawning escapements on record; this low smolt production followed 2 previous brood years (1987 and 1988) that set record high escapements and high smolt production (Table 2; Figure 1). Further, the mean weight of age-2. fish for brood years 1989–1991 was apparently lower than for previous brood years back to 1982 (Table 2).

Interestingly, marine survival for age-2. fish is not better than survival of age-1. fish from the same brood year (paired $t = -0.34$, $P \approx 0.74$ for adult returns per smolt), nor for age-1. fish from BY+1 that emigrate to sea at the same time (paired $t = -0.17$, $P \approx 0.86$).

In summary, adult returns of sockeye salmon to the Egegik River show a strong, positive relationship with the number of smolts produced in Becharof Lake by brood year, yet the number of smolts produced shows no simple relationship to the original spawning escapement making up that brood year. Any future evaluation of spawning-escapement objectives for the

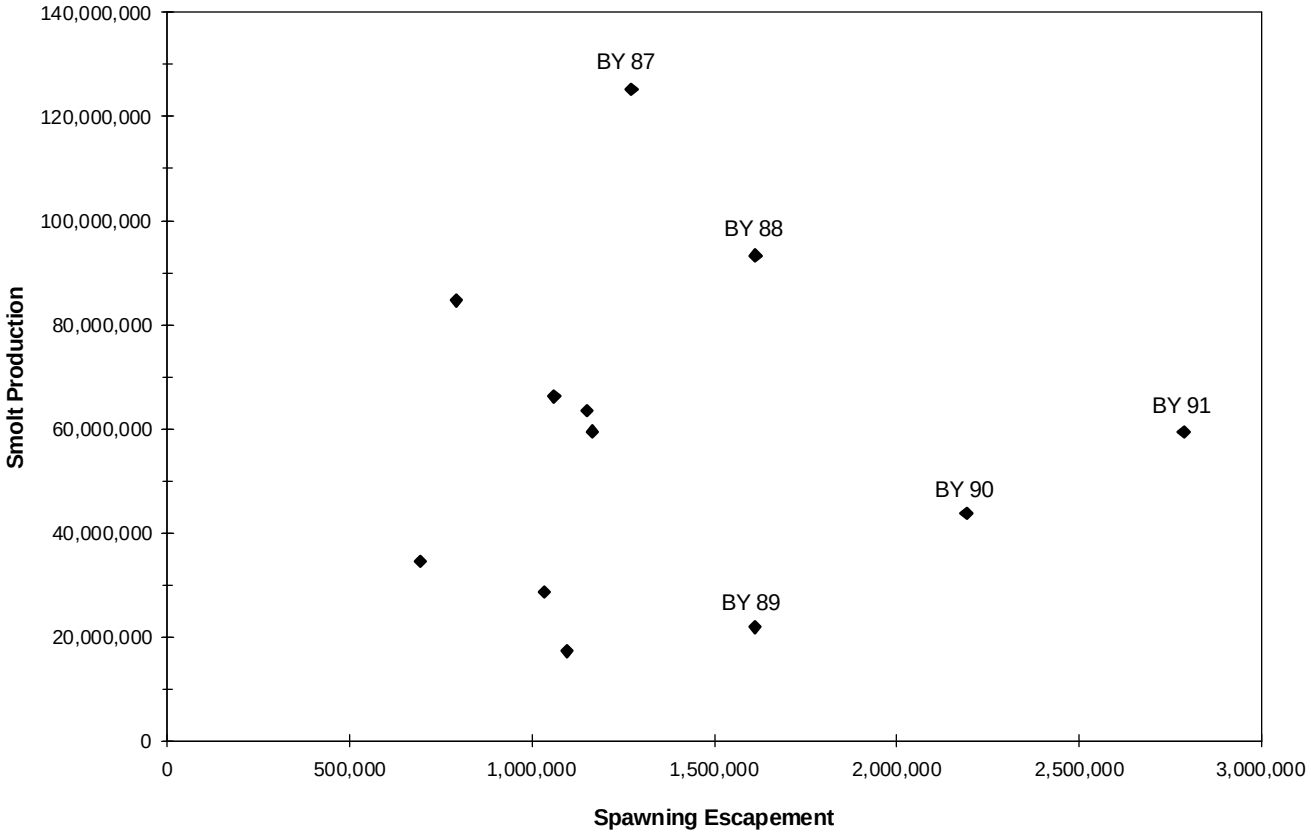

Figure 1. Number of sockeye salmon smolts produced from specific spawning escapements, brood years 1980–1991, Egegik River.

Table 1. Sockeye spawning escapement, smolt production, and adult returns per smolt for brood years 1980–1991, Egegik River (source: Crawford and Cross 1995).

		Age 1.				Age 2.				Age 3.			
Brood Year	Total Spawning Escapement	Number of Smolts	Percent of Total Smolts	Adult Returns[a]	Adult Returns per Smolt	Number of Smolts	Percent of Total Smolts	Adult Returns[a]	Adult Returns per Smolt	Number of Smolts	Percent of Total Smolts	Adult Returns[a]	Adult Returns per Smolt
1980	1,060,860	49,457,563	75	3,035,494	0.06	16,524,563	25	5,519,025	0.33	197,429	0	7,730	0.04
1981	694,680	2,242,326	6	1,508,516	0.67	32,235,734	93	4,785,803	0.15	52,852	0	16,119	0.30
1982	1,034,628	17,234,269	60	2,873,325	0.17	11,434,848	40	3,447,534	0.30	564	0	12,739	
1983	792,282	54,585,828	64	4,520,747	0.08	29,984,140	35	6,085,720	0.20	85,087	0	37,329	0.44
1984	1,165,320	14,016,441	24	1,596,859	0.11	45,386,536	76	11,482,531	0.25	80,931	0	249,131	
1985	1,095,204	4,397,087	26	1,951,334	0.44	12,758,135	74	5,558,244	0.44	81,150	0	26,295	0.32
1986	1,151,320	36,122,149	57	5,664,220	0.16	27,347,612	43	8,549,130	0.31	0	0	116,845	
1987	1,272,978	72,458,024	58	5,550,526	0.08	52,299,487	42	20,140,758	0.39	396,423	0	201,328	0.51
1988	1,612,680	3,795,739	4	1,910,599	0.50	89,162,038	96	16,777,559	0.19[b]	361,128	0	255,595	0.71[b]
1989	1,610,916	4,519,527	21	1,060,534	0.23[b]	17,338,786	79			37,254	0		
1990	2,191,362	6,048,364	14			37,719,609	86			19,196	0		
1991	2,786,880	20,203,545	34			39,158,743	66						

[a] Includes estimates of adult returns through 1994.
[b] Future adult returns will increase these values.
Note: Adult returns available only through 1994; therefore, analyses for adult returns per smolt and adult returns per spawner were restricted to brood years 1980–1988.

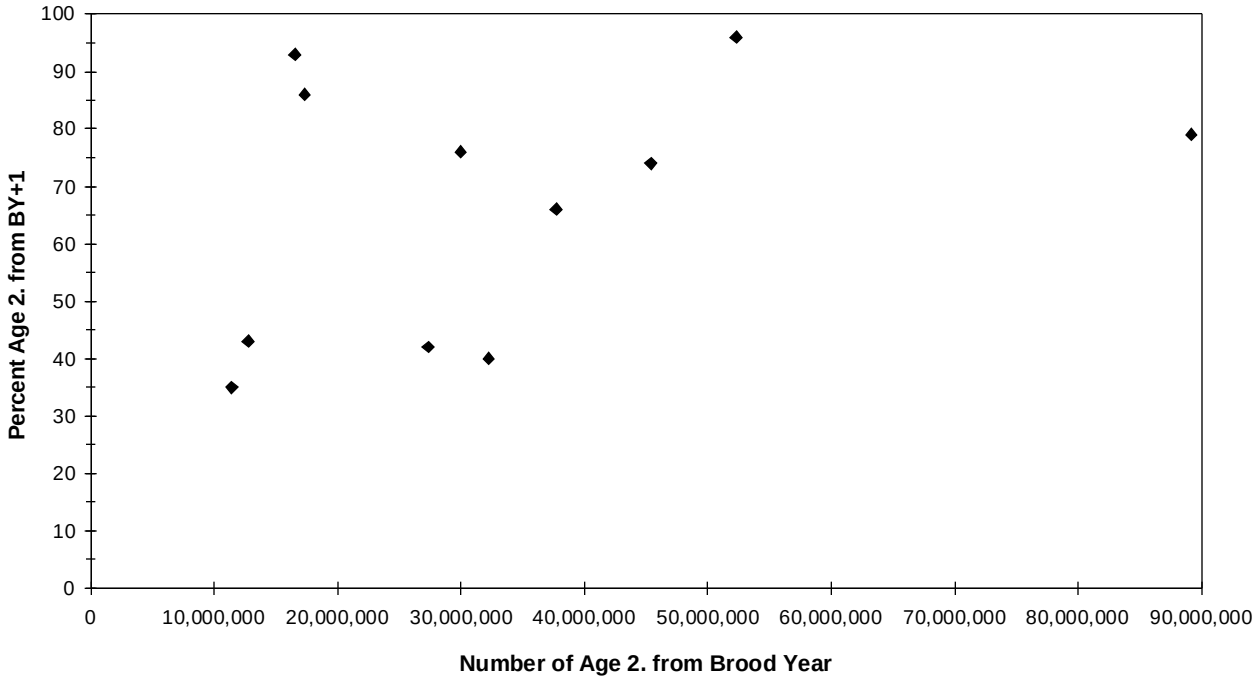

Figure 2. Test for competition effect that age-2. sockeye salmon from one brood year may have on the proportion of age-2. sockeye salmon produced by the next brood year.

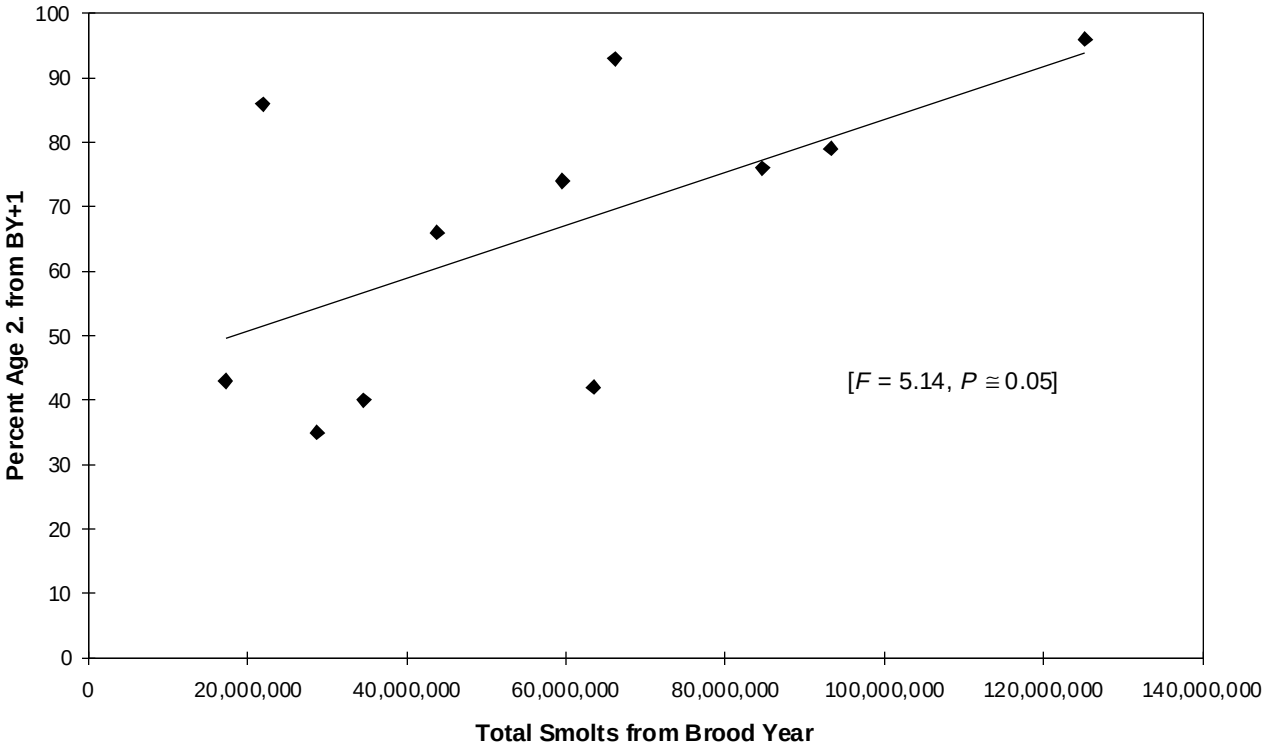

Figure 3. Indication of residual grazing effect that total smolts produced in one brood year may have on the proportion of age-2. sockeye salmon produced by the next brood year.

Table 2. Sockeye smolt production and adult returns for brood years 1980–1991, Egegik River (calculated from data in Crawford and Cross 1995).

Brood Year	Total Smolts Produced	Smolts Produced per Spawner	Mean Weight Age 2. (g)	Total Adult Returns[a]	Adult Return per Smolt	Adult Return per Spawner
1980	66,179,555	62.38	13.6	8,562,249	0.13	8.07
1981	34,530,912	49.71	12.2	6,310,438	0.18	9.08
1982	28,669,681	27.71	16.8	6,333,598	0.22	6.12
1983	84,655,055	106.85	15.7	10,643,796	0.13	13.43
1984	59,483,908	51.05	14.1	13,328,521	0.22	11.44
1985	17,236,372	15.74	14.3	7,535,873	0.44	6.88
1986	63,469,761	55.13	15.4	14,330,195	0.23	12.45
1987	125,153,934	98.32	14.5	25,892,612	0.21	20.34
1988	93,318,905	57.87	15.6	18,943,753	0.20	11.75
1989	21,895,567	13.59	12.4			
1990	43,787,169	19.98	12.2			
1991	59,362,288	21.30	13.7			

[a] Includes estimates of age-1., -2., and -3. returns through 1994.

Egegik system should therefore closely consider the dynamics of freshwater production and fry survival. To that end, ongoing limnological and zooplankton studies initially reported by Mathisen and Farley (1995) and Mathisen et al. (1996) may become particularly helpful. If, as suggested here, there are density-dependent effects in the freshwater rearing of sockeye salmon in Becharof Lake, then recent, high levels of spawning escapements to the Egegik River (well above established escapement objectives) may not only constitute wasted harvestable surpluses of adult salmon, but they may also promote increased fry loading that could cause potential detriments to salmon production in subsequent years.

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