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Influence of the Marine Abundance of Pink (Oncorhynchus gorbuscha) and Sockeye Salmon (O. nerka) on Growth of Ozernaya River Sockeye, 1970-1994

by

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Abstract

We used an extended data set on the size of Russian sockeye salmon (*Oncorhynchus nerka*) from 1970-94 to examine the effect of salmon abundance on sockeye growth. The length and weight of mature Ozernaya River sockeye was substantially reduced in years when the marine abundance of pink salmon (*O. gorbuscha*) from western and eastern Kamchatkan populations was high, and slightly reduced when the ocean abundance of Kamchatka sockeye populations was high. The strongest statistical relationships were found for fish from separate age-groups; measured relationships using pooled data from all age-classes combined were statistically insignificant. We estimate that in the absence of pink salmon the most strongly affected age groups would be twice the size at maturity that they would be if both the eastern and western Kamchatkan pink salmon populations were simultaneously at peak observed abundances. Trophic competition in the ocean can therefore have a significant influence on the productivity of salmon populations for the most strongly affected age-groups, and we conclude that the salmonid carrying capacity of the ocean is sufficiently limited that it should be considered in the management of salmon populations.

Key words: *sockeye salmon; pink salmon; growth; carrying capacity; density-dependence.*

Introduction

It is generally assumed that fluctuations in fish growth rate are correlated with stock abundance as well as with the abundance of their competitors (Nikolsky 1974). Birman (1985) suggested that food competition between pink and sockeye salmon at sea results in pink salmon (*Oncorhynchus gorbuscha*) abundance influencing the growth of sockeye (*O. nerka*). Krogius (1960) showed that the marine growth of sockeye returning to the Ozernaya River and Dalnee Lake was poorer in odd years, when west Kamchatkan pink salmon were abundant, than in even years, when the abundance of west Kamchatkan pink salmon was low. However, the correlation between sockeye growth rate and pink abundance was not statistically significant.

Several other studies have also reported evidence that the marine abundance of Pacific salmon may affect their growth rates, and smaller body size is associated with a number of deleterious impacts on reproductive success in salmon (review by Forbes and Peterman 1994). As most growth occurs in the ocean, if marine trophic competition reduces growth rates sufficiently the capacity of the ocean to support salmon populations may have a practical limit that should be considered in salmon management.

Rogers (1980) demonstrated that the size at maturity of Bristol Bay sockeye salmon was inversely related to their abundance. More recent studies have found statistical evidence for a reduced marine growth rate for Fraser sockeye when Bristol Bay sockeye salmon were abundant (Peterman 1984; McKinnell 1995), and in asian coho salmon (*O. kisutch*) when pink salmon abundances were high (Ogura et al. 1991). Similar evidence exists that the ocean abundance of asian chum salmon depresses their own growth in the penultimate year at sea (Ishida et al. 1993). More generally, Bigler et al. (1996) found evidence that mean size declined with time after 1976 in 45 of 47 North American and Asian salmon stocks examined, a period of generally increasing salmon abundance (Beamish 1993).

In this paper, we provide an analysis of the impact of the relative numbers of sockeye and pink from the major spawning populations in Kamchatka on length and weight characteristics of the Ozernaya River sockeye, one of the largest Asian sockeye stocks.

Materials and Methods

This study was based on data collected between 1970-1994 by the Ozernovsky Biological Station, Kamchatka, a branch of the Pacific Research Institute of Fisheries and Oceanography. The data include the number of pink salmon returning to west and east Kamchatka, the number of sockeye returning to the Ozernaya and Kamchatka rivers, and the length and weight by age-class of mature sockeye (Tables 1-3).

The size of Ozernaya sockeye was measured at the counting fence located at the entrance to Kuril Lake. Only size data for sockeye without evidence of breeding colours were used in the analysis. Age was assessed following criteria described by Selifonov (1975, 1988, 1989).

Data on pink salmon from both regions and sockeye from the Ozernaya River give partial information on the marine abundance of these populations. These estimates were supplemented using data taken from reports on Japanese fisheries in the years of spawning migrations. For Kamchatka River sockeye, population estimates were based only on their numbers counted in the outlet of the river, and do not include catches of this stock by Japanese fisheries in the year of spawning migration.

Results

Size-at-Age

The relative abundance of the main sockeye and pink salmon populations in Kamchatka fluctuated widely over the period 1970-1994 (Fig. 1). Multiple regression analysis by sex and age-class between length or weight of the most abundant age groups of fish (2.1, 2.2, 2.3, 2.4, 3.2, 3.3)[1] and the abundance of pink and sockeye salmon during 1970-1994 revealed significant differences. In general, the greatest observed effects were primarily related to the abundance of pink salmon, and only secondarily to the abundance of sockeye salmon (Tables 4-7). In most cases, the statistically significant regression coefficients are negative, indicating that an increase in the abundance of sockeye or pink salmon leads to a decrease in the body size of mature Ozernaya River sockeye.

[1] The first number indicates the number of years of life spent in freshwater, and the second the number of years at sea.

Discussion

In general, the observed relationships between abundance and weight or length of Ozernaya River sockeye are similar, so we focus our discussions on the growth response in terms of weight. The occasional differences in regression coefficients when length and weight characteristics of salmon are both compared with marine abundance are probably a combination of both random statistical error and variations in condition factor (i.e., fatness). In Fraser River sockeye, variations in length accounted for most of the inter-annual variation in weight and condition factor played a secondary role (Killick and Clemens 1963).

Overall, the marine growth of Ozernaya sockeye was more strongly influenced by the ocean abundance of Kamchatka pink salmon than by the abundance of either sockeye stock (Fig. 2). Based on the relative magnitude of the regression coefficients (Tables 4-7), the per-capita effect on growth of sockeye salmon was greater than that for pink salmon, although only the regression coefficients for pink salmon are statistically significant. However, the predicted overall effect on mean size is much greater for pink salmon because of the much larger size of these populations, with the predicted weight-at-maturity of Ozernaya sockeye reduced by half if both east and west pink salmon populations were simultaneously near their maximum abundance (Fig. 2). Such an effect would have a very large impact on sockeye productivity.

The best statistical relationships with body weight are achieved for age-specific data, and the level of correlation is poorer when data from all age-groups are pooled. A plausible interpretation is that feeding areas used at sea by different age groups of the Ozernaya River sockeye are dissimilar (Selifonov 1989), so that different age-groups are exposed to different levels of trophic competition. Rogers (1980) also found different correlation coefficients between abundance and size-weight characteristics of Bristol Bay sockeye of different age and sex groups. In the Gulf of Alaska, older sockeye are distributed farther at sea, and the relationship between size variations and abundance varied for different stocks and age-groups (McKinnell, 1995). There may also be complicated effects relating to the change in distributional overlap of different species over time, since the distribution of marine fish tends to change with their abundance (MacCall 1990). Ogura and Ito (1994) showed that as the abundance of Japanese chum salmon increased, their oceanic range also expanded; thus abundance may not necessarily be a stable proxy for marine density or the degree of overlap in ocean distribution.

Growth and size at maturity of Ozernaya River sockeye are determined by a combination of environmental and genetic factors. Some evidence suggests the observed differences in body size of Ozernaya River sockeye in odd- and even-years may also be controlled by genetic factors (Krogius 1960). Killick and Clemens (1963) found no direct relationship between the annual variation in body size of Fraser River sockeye and the abundance of Fraser sockeye and pink salmon populations from 1915-60, although Fraser sockeye were larger in even years, when Fraser pink salmon are virtually absent. They suggested instead that the observed differences might also have been caused by genetic factors (Killick and Clemens, 1963).

Data collected from the Kamchatka River (Konovalov, 1980; Bugaev and Ostroumov, 1990) and Kuril Lake (Krokhin and Krogius, 1937; Bugaev, 1976), which is the main spawning ground of the Ozernaya River sockeye, also support a link between genetic factors and sizes of sockeye spawners in some spawning grounds. However, our study suggests that the variations in growth rate of Ozernaya River sockeye are primarily related to the marine abundance of pink and sockeye populations. If genetic factors were to play a substantial role in the changes in mean size then we would expect to see long-term trends in mean size dominating, which is not the case. Sano (1963) also showed that both the size of sockeye and pink salmon caught in the western north Pacific ocean and the average weight of their stomach contents was smaller in odd years, when pink salmon abundance was high.

Our analysis indicates that studies of separate age groups are more informative than analyses based on pooled age-groups. Data on the age structure of the Bolshaya River sockeye population do not seem to be reliable (unpublished analysis), so it is not possible to establish the variation in growth for this population by separate age groups. However, the data suggest that the number of west Kamchatkan pink also has an effect on the body sizes of sockeye from the Bolshaya River. No statistically significant correlations between abundance of east Kamchatkan pink and the size of Bolshaya River sockeye was found for the pooled data.

Conclusions

Our results indicate that the final body sizes of mature sockeye in the Ozernaya River are affected more by the marine abundance of pink salmon than by the marine abundance of sockeye from the Ozernaya and Kamchatka rivers. This is probably related to the much higher abundance of pink salmon (Fig. 1) and because pink salmon feed lower down the food chain (Brodeur 1990; Pearcy et al 1988; Welch and Parsons 1993). However, on a per-capita basis the effect of sockeye on their own growth seems greater, perhaps because the trophic overlap and areas of distribution of pink salmon do not completely match that of sockeye.

The effect of pink salmon abundance should be considered when analyzing the population dynamics of Russian sockeye. The increase in abundance of the Ozernaya River sockeye, as observed from the mid-late 1980s to the early 1990s (Selifonov, 1988, and current catch statistics), may be associated not only with the fertilization of Kuril Lake and other salmon lakes in Kamchatka (Kurenkov, 1988), but also with the abrupt decrease in the marine abundance of Kamchatkan pink salmon at the same time. Significant increases in the abundance of Kamchatkan pink might therefore reduce the productivity of Ozernaya River sockeye, and future evaluations of management strategies should include not just the possibility of ocean interactions with other stocks of sockeye salmon (e.g. Peterman 1984), but also the possibility of density-dependent interactions with other species of salmon.

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Figure Legends

Figure 1. Variation in the abundance of pink and sockeye salmon stocks used in the analysis.

Figure 2. Regression planes of the estimated effect on Ozernaya river sockeye weight of the marine abundance east and west Kamchatka pink and Ozernaya and Kamchatka River sockeye populations. The abundance of populations not shown in each panel was set to their 1970-94 averages when calculating predicted body weight.

Table 1. Pink and sockeye salmon abundance, in millions of fish.

Year	East Kamchatka Pink	West Kamchatka Pink	Ozernaya River Sockeye	Kamchatka River Sockeye
1970	16.2	0.3	2.3	2.7
1971	22.9	8.8	2.4	1.2
1972	9.1	1.7	2.0	0.7
1973	15.6	7.2	1.5	0.9
1974	15.0	2.2	1.7	0.2
1975	38.3	27.8	2.3	0.7
1976	19.9	11.3	1.8	0.7
1977	51.2	56.5	1.4	1.7
1978	11.0	13.6	2.4	1.7
1979	53.6	71.3	2.4	1.4
1980	4.3	21.1	2.8	1.6
1981	57.8	41.4	2.5	1.5
1982	15.1	34.8	1.8	1.5
1983	38.7	153.2	2.8	2.3
1984	26.7	78.1	4.2	2.6
1985	22.8	8.7	5.9	1.8
1986	3.9	37.5	4.3	1.1
1987	52.8	1.6	5.7	1.6
1988	8.6	33.0	3.7	1.0
1989	65.9	1.6	5.0	0.9
1990	26.3	26.8	10.6	0.6
1991	95.3	2.8	6.7	0.6
1992	9.8	15.9	6.5	1.6
1993	66.8	0.6	5.4	2.0
1994	20.7	106.4	5.3	1.8

Table 2. Lengths-at-age of Ozernaya River sockeye salmon (cms).

	1.1	***1.2***		***1.3***		***2.1***	***2.2***		***2.3***		***2.4***	
Year	♂	♂	♀	♂	♀	♂	♂	♀	♂	♀	♂	♀
1970	-	-	-	-	-	41.1	58.0	55.2	62.5	60.2	-	63.0
1971	-	-	-	-	-	40.8	56.9	55.6	63.5	61.0	64.7	61.0
1972	-	-	-	-	-	41.8	57.9	56.4	64.2	61.7	68.0	63.0
1973	-	-	-	-	-	43.5	56.1	55.4	63.7	61.0	67.0	62.8
1974	-	-	-	-	-	42.8	58.0	56.0	63.0	61.1	62.0	60.8
1975	-	-	-	-	-	41.2	60.6	56.0	64.3	61.0	66.7	60.5
1976	-	-	-	-	-	42.7	57.7	56.6	64.0	61.0	64.5	62.8
1977	-	-	-	71.0	-	39.9	57.4	54.8	65.7	62.2	63.6	62.6
1978	40.0	54.7	53.0	-	58.0	40.2	56.8	55.9	64.6	61.2	-	-
1979	36.5	-	60.5	62.1	59.0	38.9	54.7	53.5	63.4	59.6	64.5	64.0
1980	-	57.0	53.8	62.0	-	39.8	55.7	53.9	62.4	60.6	-	62.8
1981	-	-	-	64.1	59.4	37.3	55.8	54.1	63.3	60.0	62.2	61.6
1982	-	-	-	-	-	39.2	54.7	53.3	63.6	60.3	62.4	61.8
1983	-	-	-	-	57.0	34.0	52.1	51.3	61.6	58.1	62.6	-
1984	-	-	-	-	-	37.0	53.4	53.6	62.0	58.8	62.5	-
1985	-	-	-	58.0	62.0	41.0	55.2	55.2	62.9	59.7	69.5	61.8
1986	37.8	53.3	-	57.5	62.5	40.6	56.0	55.0	63.0	59.8	62.5	60.0
1987	-	50.5	47.2	60.8	56.6	38.8	54.4	52.3	62.6	59.3	62.1	58.3
1988	-	49.5	-	62.7	58.8	37.6	55.1	54.5	62.3	59.6	62.8	-
1989	-	-	-	-	-	40.0	53.2	52.8	62.9	59.6	64.9	61.5
1990	38.5	47.5	-	-	63.6	41.3	55.6	54.3	63.8	60.8	64.8	61.9
1991	-	46.7	49.0	64.0	61.6	38.7	53.3	53.3	61.6	58.2	62.5	60.8
1992	-	52.5	-	60.4	59.5	38.9	54.1	53.2	61.5	58.3	66.5	59.5
1993	-	51.8	52.7	-	59.0	39.0	54.0	53.7	62.3	59.6	62.3	59.0
1994	-	-	-	61.6	58.6	38.0	53.3	53.0	62.4	59.1	63.2	65.5
Avg	38.2	51.5	52.7	62.2	59.7	39.8	55.6	54.4	63.1	60.1	64.2	61.7

Table 2 (continued).

	3.1	***3.2***		***3.3***		***3.4***		***Average***	
Year	♂	♂	♀	♂	♀	♂	♀	♂	♀
1970	-	58.1	56.0	61.5	60.8	-	-	60.0	59.0
1971	-	57.2	55.6	64.8	62.0	-	-	60.4	58.5
1972	-	60.0	57.4	64.6	62.0	-	-	62.0	59.1
1973	46.4	58.3	55.8	64.2	63.0	-	-	61.8	59.9
1974	-	60.7	56.1	64.2	62.4	-	-	61.7	59.0
1975	-	58.8	57.0	65.0	61.8	-	-	61.9	59.0
1976	-	57.5	56.7	-	-	-	-	61.1	59.5
1977	-	58.5	55.1	64.2	62.6	-	-	63.3	59.8
1978	45.3	58.6	56.7	63.9	60.7	-	-	59.5	59.5
1979	40.9	57.5	54.8	63.6	60.1	-	64.5	55.2	56.8
1980	38.5	57.0	54.9	-	62.0	-	64.0	58.9	57.5
1981	-	60.0	53.6	63.0	59.6	-	-	60.0	58.0
1982	40.1	56.8	54.1	63.5	60.9	-	62.0	57.6	57.4
1983	35.9	52.7	50.7	61.0	58.6	57.0	-	58.6	57.0
1984	41.0	54.9	53.4	62.0	59.3	66.0	-	59.9	58.3
1985	-	56.1	55.1	62.4	59.5	63.8	-	60.6	58.8
1986	44.5	53.3	53.5	67.3	60.6	65.0	63.6	59.1	58.4
1987	-	55.9	53.6	60.3	57.1	-	-	58.6	57.4
1988	38.5	54.5	54.2	63.4	60.7	-	-	58.8	58.4
1989	39.0	54.4	54.6	62.8	60.2	-	-	57.8	57.8
1990	-	57.3	54.3	64.6	61.8	69.0	-	63.0	59.0
1991	44.1	54.5	52.5	62.6	58.4	62.0	-	57.4	56.0
1992	-	58.2	54.1	61.2	59.7	-	61.0	57.7	57.0
1993	-	54.7	54.6	63.3	59.6	-	-	59.7	58.6
1994	-	55.6	59.9	62.0	59.1	-	-	59.6	58.5
Avg	43.1	56.8	55.0	63.3	60.5	63.8	63.0	59.8	58.3

Table 3. Weight-at-age of Ozernaya River sockeye salmon (kgs).

	1.1	***1.2***		***1.3***		***2.1***	***2.2***		***2.3***		***2.4***	
Year	♂	♂	♀	♂	♀	♂	♂	♀	♂	♀	♂	♀
1970	-	-	-	-	-	1.02	2.57	2.24	3.22	2.82	-	3.10
1971	-	-	-	-	-	0.85	2.33	2.20	3.32	2.88	3.33	2.95
1972	-	-	-	-	-	0.98	2.56	2.30	3.50	3.04	4.10	3.30
1973	-	-	-	-	-	1.06	2.23	2.12	3.23	2.84	3.78	3.27
1974	-	-	-	-	-	1.00	2.50	2.18	3.10	2.82	2.95	3.00
1975	-	-	-	-	-	0.90	2.83	2.23	3.26	2.80	3.52	3.20
1976	-	-	-	-	-	1.00	2.57	2.40	3.22	2.97	3.40	2.98
1977	-	-	-	4.20	-	0.72	2.25	1.89	3.45	2.94	2.86	2.96
1978	0.70	2.11	1.85	-	2.45	0.85	2.35	2.18	3.62	2.96	-	-
1979	0.60	-	2.60	2.86	2.55	0.77	2.01	1.83	3.24	2.65	3.20	3.55
1980	-	2.60	2.35	3.05	-	0.83	2.33	2.09	3.29	2.82	-	3.25
1981	-	-	-	3.77	2.73	0.70	2.46	2.09	3.48	2.89	2.75	3.07
1982	-	-	-	-	-	0.80	2.24	2.03	3.54	2.93	3.34	3.15
1983	-	-	-	-	2.40	0.55	1.83	1.70	3.06	2.50	3.02	-
1984	-	-	-	-	-	0.60	2.08	2.04	3.33	2.77	3.19	-
1985	-	-	-	2.20	2.55	0.97	2.38	2.31	3.38	2.85	4.55	3.27
1986	0.75	2.08	-	2.63	3.30	1.14	2.45	2.22	3.41	2.95	3.37	3.02
1987	-	1.82	1.40	3.18	2.45	0.85	2.21	1.96	3.38	2.86	3.27	2.78
1988	-	1.70	-	3.56	2.88	0.74	2.67	2.21	3.37	2.91	3.25	-
1989	-	-	-	-	-	0.88	2.03	1.92	3.34	2.85	3.74	2.98
1990	0.75	1.15	-	-	3.34	0.98	2.30	2.15	3.58	3.02	3.78	3.29
1991	-	1.31	1.35	3.65	3.25	0.75	1.99	2.00	3.09	2.64	3.30	2.92
1992	-	1.47	-	2.84	2.84	0.70	2.10	1.89	3.05	2.64	4.08	2.55
1993	-	1.76	1.87	-	2.70	0.98	2.10	1.96	3.22	2.76	3.16	2.65
1994	-	-	-	2.98	2.63	0.59	1.90	1.82	3.23	2.71	2.98	3.50
Avg	0.7	1.78	1.90	3.17	2.77	0.85	2.29	2.08	3.32	2.83	3.41	3.08

Table 3. (Continued).

	3.1	3.2		3.3		3.4		Average	
Year	♂	♂	♀	♂	♀	♂	♀	♂	♀
1970	-	2.50	2.33	3.20	2.70	-	-	2.65	2.35
1971	-	2.44	2.17	3.51	3.10	-	-	2.58	2.57
1972	-	2.72	2.30	3.50	3.10	-	-	3.18	2.80
1973	1.20	2.46	2.21	3.25	3.27	-	-	2.99	2.74
1974	-	2.70	2.26	3.40	3.03	-	-	2.93	2.70
1975	-	2.60	2.44	3.27	2.85	-	-	3.06	2.56
1976	-	2.46	2.38	-	-	-	-	2.79	2.68
1977	-	2.33	1.92	3.21	2.92	-	-	3.08	2.60
1978	1.22	2.45	2.25	3.43	3.00	-	-	3.10	2.71
1979	0.85	2.30	2.00	3.37	2.66	-	3.40	2.25	2.27
1980	0.70	2.49	2.13	-	3.53	-	3.80	2.82	2.50
1981	-	2.85	2.08	3.35	2.75	-	-	3.15	2.72
1982	0.85	2.54	2.02	3.46	3.01	-	3.20	2.65	2.56
1983	0.64	1.86	1.59	3.10	2.54	2.30	-	2.67	2.38
1984	1.00	2.27	2.01	3.34	2.86	3.60	-	3.02	2.71
1985	-	2.51	2.27	3.39	2.84	3.32	-	3.11	2.75
1986	1.20	2.14	2.11	4.02	3.11	3.70	3.50	2.89	2.74
1987	-	2.40	1.99	3.01	2.45	-	-	2.87	2.60
1988	0.75	2.14	2.15	3.59	3.00	-	-	2.88	2.74
1989	0.75	2.11	2.01	3.24	2.81	-	-	2.66	2.60
1990	-	2.54	2.18	3.82	3.14	4.95	-	3.07	2.79
1991	1.15	2.22	1.87	3.22	2.55	3.40	-	2.50	2.44
1992	-	2.49	1.99	3.06	2.90	-	3.02	2.55	2.40
1993	-	2.20	2.12	3.40	2.70	-	-	2.87	2.62
1994	-	2.23	2.84	3.07	2.63	-	-	2.81	2.61
Avg	0.94	2.40	2.15	3.36	2.89	3.55	3.38	2.85	2.61

Table 4. *Summary of regression coefficients ($x10^{-3}$) of the per capita effect of sockeye and pink salmon abundance on average weight at return (kgs) of Ozernaya sockeye by sex and age. Starred values indicate statistically significant regression coefficients at the 5% (*) and 1% (**) probability level.*

	Age Group	***W. Pink***	***E. Pink***	***Ozernaya Sockeye***	***Kamchatka Sockeye***	R^2	***p value***
Male	*2.1*	*-2.6***	*-1.6*	*-1.7*	*-41.1*	*0.58*	*<0.01*
	2.2	*-2.8**	*-3.8**	*-32.2*	*-79.7*	*0.52*	*<0.01*
	2.3	*-0.7*	*-1.4*	*4.8*	*3.8*	*0.07*	*0.84*
	2.4	*-5.7**	*-7.8**	*67.8*	*92.1*	*0.46*	*0.03*
	3.2	*-2.7**	*-1.9*	*-18.4*	*-42.2*	*0.36*	*0.06*
	3.3	*-0.1*	*-4.0*	*19.7*	*-128.6*	*0.30*	*0.14*
	Pooled	*-0.6*	*-2.6*	*3.0*	*-19.4*	*0.08*	*0.78*
Female	*2.2*	*-2.5***	*-3.2***	*-8.9*	*-43.0*	*0.61*	*<0.01*
	2.3	*-1.4**	*-1.9*	*-3.2*	*-40.4*	*0.42*	*0.02*
	2.4	*-5.1**	*-2.1*	*-10.4*	*-95.2*	*0.39*	*0.08*
	3.2	*-0.8*	*-4.1*	*3.2*	*-46.7*	*0.22*	*0.27*
	3.3	*-1.2*	*-6.7***	*-11.5*	*-122.1*	*0.60*	*<0.01*
	Pooled	*-0.4*	*-2.1*	*10.5*	*-72.4*	*0.27*	*0.16*

Table 5. Estimated effect of the mean abundance of different stocks discussed in the text on Ozernaya sockeye weight (kgs). The calculations show the predicted effect on mean weight if the average abundance of each stock dropped to zero. Single and double asterisks indicate results based on regression equations statistically significant at probabilities less than 5% and 1%, respectively.

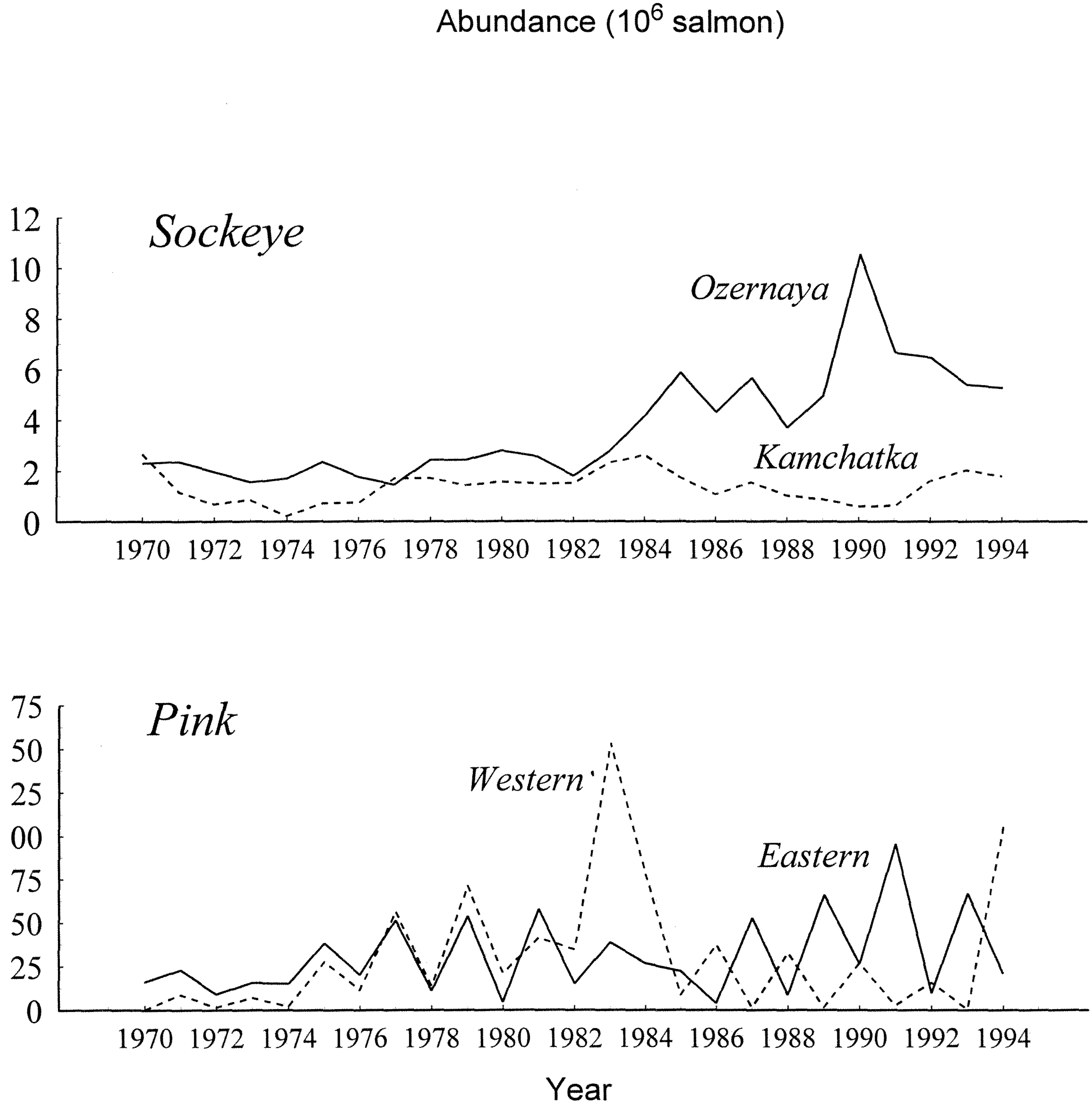
Sex	*Age Group*	*W. Pink*	*E. Pink*	*Ozernaya Sockeye*	*Kamchatka Sockeye*	*Net Effect (kgs)*
Male	2.1	-0.08	-0.05	-0.01	-0.05	-0.19**
	2.2	-0.09	-0.12	-0.12	-0.10	-0.43**
	2.3	-0.02	-0.04	0.02	0.00	-0.04
	2.4	-0.17	-0.24	0.25	0.12	-0.04*
	3.2	-0.08	-0.06	-0.07	-0.06	-0.26
	3.3	0.00	-0.12	0.07	-0.17	-0.22
	Pooled	-0.02	-0.08	0.01	-0.03	-0.11
Female	2.2	-0.08	-0.10	-0.03	-0.06	-0.26**
	2.3	-0.04	-0.06	-0.01	-0.05	-0.17*
	2.4	-0.16	-0.06	-0.04	-0.13	-0.38
	3.2	-0.02	-0.13	0.01	-0.06	-0.20
	3.3	-0.04	-0.21	-0.04	-0.16	-0.45**
	Pooled	-0.01	-0.06	0.04	-0.10	-0.13

Table 6. *Summary of regression coefficients of sockeye and pink salmon abundance on average length at return (cms) of Ozernaya sockeye by sex and age.*

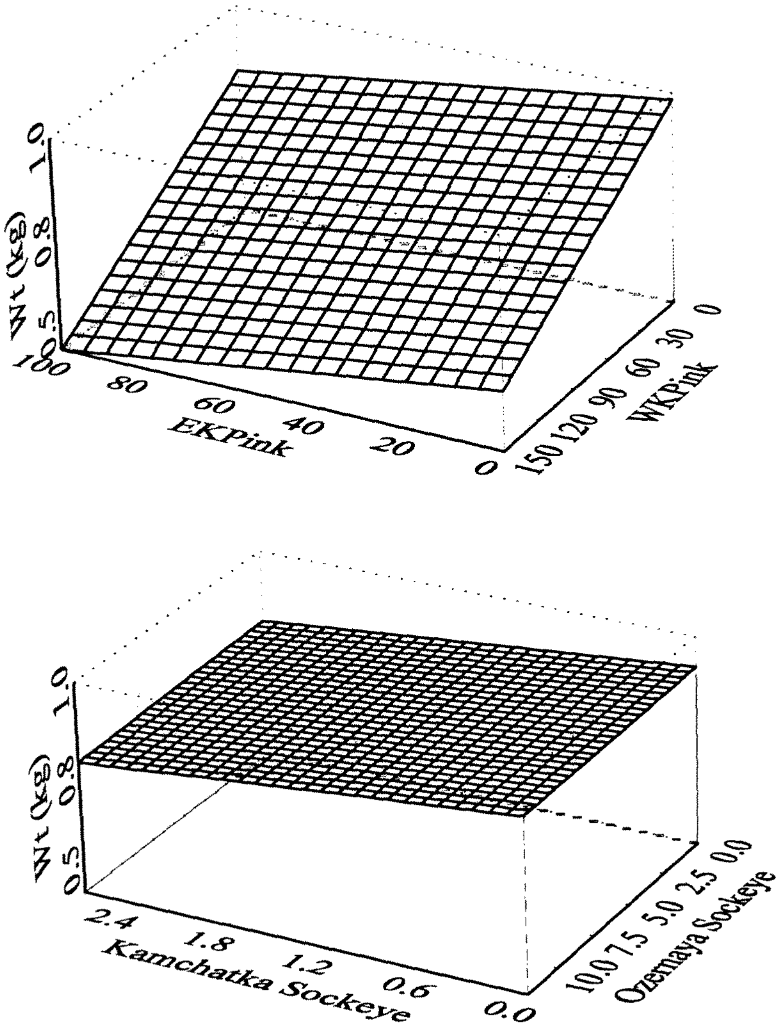
		Regression Coefficient					
Sex	***Age Group***	***W. Pink***	***E. Pink***	***Ozernaya Sockeye***	***Kamchatka Sockeye***	R^2	***p value***
Male	***2.1***	*-0.032***	*-0.025**	*-0.141*	*-1.087**	*0.71*	*<0.01*
	2.2	*-0.019**	*-0.020*	*-0.411***	*-0.749*	*0.54*	*<0.01*
	2.3	*-0.002*	*-0.001*	*-0.197**	*-0.491*	*0.29*	*0.13*
	2.4	*-0.018*	*-0.029*	*0.046*	*0.057*	*0.19*	*0.43*
	3.2	*-0.018*	*-0.013*	*-0.380**	*-0.608*	*0.37*	*0.05*
	3.3	*0.001*	*-0.015*	*-0.147*	*-1.450***	*0.44*	*0.03*
	Pooled	*-0.004*	*-0.020*	*-0.040*	*-0.640*	*0.13*	*0.56*
Female	***2.2***	*-0.015**	*-0.020**	*-0.222**	*-0.563*	*0.63*	*<0.01*
	2.3	*-0.008*	*-0.010*	*-0.227**	*-0.480*	*0.51*	*<0.01*
	2.4	*0.035***	*-0.012*	*-0.167*	*-0.107*	*0.43*	*0.05*
	3.2	*-0.008*	*-0.025*	*-0.151*	*-0.415*	*0.23*	*0.25*
	3.3	*-0.005*	*-0.024**	*-0.266**	*-0.980**	*0.57*	*<0.01*
	Pooled	*-0.006*	*-0.016*	*-0.103*	*-0.061*	*0.29*	*0.13*

Table 7. Estimated effect of mean abundance on Ozernaya Sockeye Lengths (cm)

Sex	*Age Group*	*W. Pink*	*E. Pink*	*Ozernaya Sockeye*	*Kamchatka Sockeye*	*Net Effect (kg)*
Male	*2.1*	*-0.98*	*-0.76*	*-0.53*	*-1.49*	*-3.76***
	2.2	*-0.57*	*-0.60*	*-1.53*	*-1.03*	*-3.74***
	2.3	*-0.07*	*-0.03*	*-0.74*	*-0.67*	*-1.51*
	2.4	*-0.54*	*-0.90*	*0.17*	*0.08*	*-1.19*
	3.2	*-0.56*	*-0.40*	*-1.42*	*-0.83*	*-3.21**
	3.3	*0.02*	*-0.46*	*-0.55*	*-1.99*	*-2.98**
	Pooled	*-0.13*	*-0.61*	*-0.15*	*-0.88*	*-1.76*
Female	*2.2*	*-0.47*	*-0.62*	*-0.83*	*-0.77*	*-2.69***
	2.3	*-0.26*	*-0.30*	*-0.85*	*-0.66*	*-2.07***
	2.4	*1.06*	*-0.36*	*-0.62*	*-0.15*	*-0.07**
	3.2	*-0.24*	*-0.76*	*-0.56*	*-0.57*	*-2.13*
	3.3	*-0.16*	*-0.73*	*-0.99*	*-1.34*	*-3.23***
	Pooled	*-0.19*	*-0.48*	*-0.38*	*-0.08*	*-1.14*


Abundance (10^6 salmon)
Sockeye
Ozernaya
Kamchatka
12
10
8
6
4
2
0
1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994
Pink
Western
Eastern
75
50
25
00
75
50
25
0
1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994
Year

Age 2.1 Male Sockeye



Age 2.2 Female Sockeye