Estimation of Pink and Sockeye Salmon Adult Returns to Western Kamchatka Based on the Data of Juvenile Salmon Trawl Catches in the Okhotsk Sea

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The data of trawl catches obtained by KamchatNIRO in 1982–2003 was used to forecast adult returns of pink and sockeye salmon in western Kamchatka. Methods of forecast for each species were demonstrated. Forecast effectiveness was analyzed. In the forecast of highly abundant returns of western Kamchatka pink salmon (over 25 million samples) deviations from the actual number did not exceed +25% in 75% of cases. In the forecast of sockeye salmon returns the accuracy was in 65% of cases.

The method of estimation of pink adult returns was based on the data of juvenile trawl catches by KamchatNIRO in the Okhotsk Sea, and it was applied successfully in the Bering Sea in 1986–1991 (Karpenko et al. 1998; Erokhin 2002; Erokhin 2006). In 2005 the analogous method was applied for estimation of adult returns of sockeye salmon in Kurilskoye Lake (the largest sockeye stock in Asia) in 2006. The basis for using similar methods to forecast sockeye and pink salmon was the following:) spawning stocks of Kamchatka juvenile of both species were completely covered by trawl surveys during their maximum distribution in the western part of the Okhotsk Sea; 2) size similarity of sockeye and pink juveniles in their aggregations in the sea gave an opportunity to use the integrated coefficient of catch capacity for fishing gear for both species (Erokhin 1998, 2002); 3) juvenile sockeye salmon along the western coast of Kamchatka were primarily from Kurilskoye Lake (Bugaev 1995); and 4) biostatistics and statistics of sockeye returns to Kurilskoye Lake were the fullest.

The work was based on the data of trawl surveys conducted by KamchatNIRO in September and October, 1981–2005 in the Okhotsk Sea on board of middle-tonnage vessels. Since 1985 catches were conducted by the special pelagic rope trawl 54.4/192 m with a vertical opening of 25–30 m and with a horizon opening of about 40 m (Anon. 1997; Kim et al. 2005). Early catches by other types of trawls were recounted by the trawl 54.4/192 m, working in standard regime. The coefficient of trawl catch capacity (k = 0.6) was used to calculate juvenile abundance (Erokhin 2002, 2006). Absolute juvenile abundance (N_a) was calculated by the area method according to the formula: $N_a = ns / vdtk$, where n, average catch per trawling (samples); s, area of surveyed territory (km^2); v, trawling speed (km/hour); d, horizon opening of trawl mouth (km); t, trawling time (hr).

Expected number of pink salmon spawners was estimated by the equation: $N = aN_a^2 + bN_a + c$, where N, forecasted abundance of spawners in million; a, b, c, empirical coefficients. The results of estimation of pink adult returns of western Kamchatka were given in Table 1. Deviation from the actual number did not exceed ±25% in 75% of cases.

Returns of sockeye salmon were estimated simultaneously with pink salmon in the sea; consequently, there was an opportunity to check accuracy of calculations of estimated sockeye salmon juvenile abundance and to correct it

Table 1. Abundance of calculated juvenile pink salmon in the Okhotsk Sea and return of adult pink salmon to the rivers of western Kamchatka (millions of fish). The majority of estimated juveniles was immigrants.

Year	forecast (N)	actual return (N_F)	Repetition factor related to forecast (N_F / N)	Forecast deviation from fact (%) $(N – N_F) / N_F$
1981	39.5	37.3	0.94	+5.9
1982	160.7	141.1	0.88	+13.9
1985	32.9	26.0	0.79	+26.7
1995	84.9	79.6	0.94	+6.7
1997	151.2	126.6	0.84	+19.4
1999	85.0	87.0	1.02	-2.3
2001	57.0	82.7	1.45	-31.1
2003	108.5	103.5	0.95	+4.9

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promptly based on next years pink salmon returns. The index of repetition factor of actual pink salmon was used as a correcting coefficient for estimated sockeye.

Applying correcting coefficients for particular years, it was possible to correct estimated indexes of sockeye salmon juvenile abundance of the western coast of Kamchatka for the same years (Table 1). On the basis of correlation of the main and secondary stocks (9:1), abundance of the Kurilskaya juvenile stock was determined out of the total sockeye salmon juvenile abundance, estimated in the sea (Erokhin 2006). Respectively, abundance of the Kurilskaya juvenile stock (N'_a, million fish), presented in Table 2 was multiplication of constant coefficient 0.9 (a portion in the total feeding stock), varying in the years of correcting coefficient and total estimated abundance in the sea: $N'_a = 0.9\ k'\ N_a$.

The main age groups of 14 groups returning to Kurilskoye Lake were 2.2, 2.3, 3.2, and 3.3 (Bugaev 1995). Estimations of average portions in return at the age were presented by three age combinations 2.2–3.2; 2.3–3.3, 2.2–3.2–2.3, and 3.3. Over two last decades in spawning stocks of Kurilskaya sockeye the total portion of fish at the age of 2.2 and 3.2 increased from 21% (in 1984–1985) to 30% (1986–2000) and decreased to 22% in 2001–2004. At the same periods the total portion of fish at the age of 2.3 and 3.3 was 77, 64 and 69%, and the total portion of all four age groups was 98, 94 and 91%, respectively.

Table 2. Forecast of return of separate age groups of western Kamchatka sockeye salmon based on the data of juvenile trawl catches.

Estimated juvenile abundance (N'_a) in million fish			Forecasted abundance of return ($k_{sp}\ N'_a$) in million fish					
Year of estimation	2+	3+	Year of return	2.2	3.2	Year of return	2.3	3.3
1982	5.93	0.88	1984	0.83	0.26	1985	2.19	0.26
1985	3.42	0.38	1987	0.48	0.11	1988	1.26	0.11
1986	8.12	0.39	1988	1.14	0.11	1989	3.00	0.11
1987	13.26	0.56	1989	1.86	0.16	1990	4.91	0.16
1989	16.54	0.74	1991	2.32	0.21	1992	6.12	0.21
1990	17.56	2.00	1992	2.46	0.58	1993	6.50	0.58
1991	7.24	0.95	1993	1.01	0.27	1994	2.68	0.27
1997	9.35	2.95	1999	1.31	0.85	2000	3.46	0.85
1999	13.61	0.19	2001	1.91	0.06	2002	5.04	0.06
2001	10.35	1.51	2003	1.45	0.44	2004	3.83	0.44
2002	9.49	1.05	2004	1.33	0.30	2005	3.51	0.30
2003	25.09	2.01	2005	3.51	0.58	2006	9.28	0.58
Average coefficient of specific return (k_{sp})				0.14	0.29		0.37	0.29

Table 3. Retrospective and perspective forecast (2006) of return of Kurilskoye Lake sockeye salmon based on the data of trawl catches.

Year of return	1984	1985	1987	1988	1989	1990	1991	1992	1993	1994	1999	2000	2001	2002	2003	2004	2005	2006
Forecasted age groups	2.2 3.2	2.3 3.3	2.2 3.2	2.2 2.3 3.2 3.3	2.2 2.3 3.2 3.3	2.3 3.3	2.2 3.2	2.2 2.3 3.2 3.3	2.2 2.3 3.2 3.3	2.3 3.3	2.2 3.2	2.3 3.3	2.2 3.2	2.3 3.3	2.2 3.2	2.2 2.3 3.2 3.3	2.2 2.3 3.2 3.3	2.3 3.3
Average of total portion of given age groups in return (%)	21	77	30	94	94	64	30	94	94	64	30	64	22	69	22	91	91	69
Forecast of total return of age groups (million fish)	1.086	2.45	0.59	2.62	5.14	5.07	2.53	9.37	8.37	2.95	2.16	4.31	1.96	5.09	1.89	5.90	7.91	9.87
Forecast of whole stock return (million fish)	5.17	3.18	1.96	2.79	5.47	7.92	8.43	9.97	8.90	4.62	7.21	6.74	8.92	7.38	8.58	6.48	8.69	14.30
Deviation of forecast From fact, %	+24	–46	–65	–25	+10	–25	+21	+52	+46	–13	+45	+7	+11	–30	+14	–3	–2	-

Based on the data of abundance of juvenile age groups in the sea and statistics on adult return and abundance of return actual abundance indexes (N_{sp}) and return coefficients of sockeye age groups ($k_{sp} = N_{sp} / N'_a$) were determined. Averaging the data, return coefficients for main age groups for many years were obtained (Table 2). Theoretical indexes of adult returns according to the age were obtained by multiplication of coefficients and abundance of juvenile age groups ($k_{sp}N'_a$).

Total abundance of return of forecasted age groups was multiplied by the coefficient of their portion in the spawning run. Thus, theoretical indexes of the whole stock were obtained (Table 3). Owing to intervals between trawl surveys, expected return of sockeye of kurilskoye stock based on four main age groups of spawners was calculated only for six years (1988, 1989, 1992, 1993, 2004, and 2005). For the other years calculations were based on two age groups in combinations 2.2–3.2 and 2.3–3.3.

In retrospect, estimated deviations of forecasted indexes from actual ones varied from -65 to ±52%, and for 11 out of 17 years they did not exceed the limits of 25% range. Spawning sockeye salmon returns estimated on the basis of trawl catch data of late years showed the least range of index fluctuations. Synchronism in fluctuations of calculated and actual indexes of return was more apparent during this period except failure in 2002 (Table 3).

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