Abundance Estimates of Juvenile Pacific Salmon in the Eastern Okhotsk Sea and Western Bering Sea

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KamchatNIRO initiated trawl surveys to study the biology of juvenile salmon in the coastal waters of the Bering Sea and Okhotsk Sea in 1981. In 1985, the Experimental Commercial Fisheries Base of Kamchatka designed a pelagic rope trawl (54.4/192 m; 1,600–60 mm mesh net; 24 mm mesh liner) for specialized surveys of juvenile salmon by middle-class vessels (STR 503). In this paper, we summarize information on the calibration and testing of the 54.4/192-m trawl at sea, the results fall stock assessment surveys of juvenile salmon over a period of nearly 20 years, and the use of these data to forecast adult returns for some commercial stocks.

Surface trawling at sea is the most difficult type of trawl operation, as the process depends on many ambient factors—waves, surface currents, etc. The crew must consist of highly skilled specialists with extensive practical experience in calibration of the trawl system, i.e., the vessel, warps, trawl doors, cables, and the trawl net and ropes. The spatial position of a trawl during operation and its trajectory are determined by the correlation of static and hydrodynamic forces that bring the trawl system into equilibrium, when the doors enter the water and the head rope stays at the surface, and maintain stable movement of the trawl in the desired direction. For optimal for trawling, the designed size of the trawl opening and its injection into the surface layer are achieved by adjusting the head rope and angle of incidence of the trawl doors. If the system is unadjusted, the trawl either cannot move steadily along the surface or the length of warps is not sufficient to reach the designed opening.

Tests of the 54.4/192 trawl were conducted in the Okhotsk Sea in 1989 and 2003 (Table 1). The trawl design team had to calibrate the trawl on a regular basis, as the skills of crew members were not always adequate for such work. In 1989, 69 trawl operations, using spherical 4.2 m^2 trawl doors, were conducted aboard the RV *Professor Kaganovskiy*. The total catch of juvenile salmon was 32,112 fish (57% pink, 32% chum, 9% sockeye, and 1.6% coho, and both chinook and masu < 1%). Similar work was performed in 2003 by the STR 503 *Esso*, using two types of trawl doors (standard 3.3 m^2 spherical doors and V-shaped 4.0 m^2 vertical doors). In total, there were 77 test trawl operations, which were considered valid when the trawl doors entered the water and the head rope remained steadily on the surface. Juvenile salmon were caught in 69 trawl operations (25,590 fish, averaging 42% pink, 41% chum, 13% sockeye, 1.4% chinook, 1.8% coho, and 0.8% masu). We concluded that the 54.4/192-m trawl provides acceptable results for stock assessment and distribution studies of juvenile salmon provided that gear adjustments are performed by experts.

Table 1. Examples of the results of some test operations of the 54.4/192-m trawl by the STR 503 *Esso* in the Okhotsk Sea in 200
Oper. № = trawl operation number; Vert. open. = vertical opening of the net; Distance (m) = distance between the trawl doors and wing ends; Warp dist. = warp distance. Sock = sockeye; Chin = chinook.

Trawling parameters									Juvenile salmon catches					
Oper.	Date	Speed	Vert. open.	Distance (m) Trawl doors	Distance (m) Wing ends	Warp dist. angles (·) Right	Warp dist. angles (·) Left	Warp length	Species (number of fish)					
№	(day.mo)	(knots)	(m)					(m)	Pink	Chum	Sock	Chin	Coho	Masu
1	26.9	4.5	28	50	23	12	0	200	-	1	-	-	71	-
10	29.9	4.8	27	85	39	9	10	245	229	127	-	-	-	1
20	3.10	5.2	28	67	31	0	13	260	176	116	-	-	-	1
30	8.10	5.4	30	80	37	9	12	200	1208	139	-	-	1	-
40	11.10	4.4	32	87	41	9	13	210	309	41	-	-	-	-
50	15.10	4.9	35	80	37	9	10	220	486	42	-	-	-	1
60	18.10	4.3	33	78	36	10	7	240	450	185	1	-	1	-
70	27.10	5.3	30	62	29	8	7	210	3	12	2	-	-	-

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In the eastern Okhotsk Sea, we conducted 14 trawl surveys over a period of 13 years (two surveys in 1986). A total of 993 trawl operations were made, and total catches of six species of juvenile salmon were over 186,000 fish (54.3% pink, 34.6% chum, 6.3% sockeye, 2.9% coho, 1.7% chinook, and 0.2% masu salmon). In the southwestern Bering Sea, we performed 12 trawl surveys, consisting of 614 trawl operations, and total catches of five species of juvenile salmon were over 49,000 fish (75% pink, 19% chum, 1.9% sockeye, 1.8% coho, and 2.3% chinook).

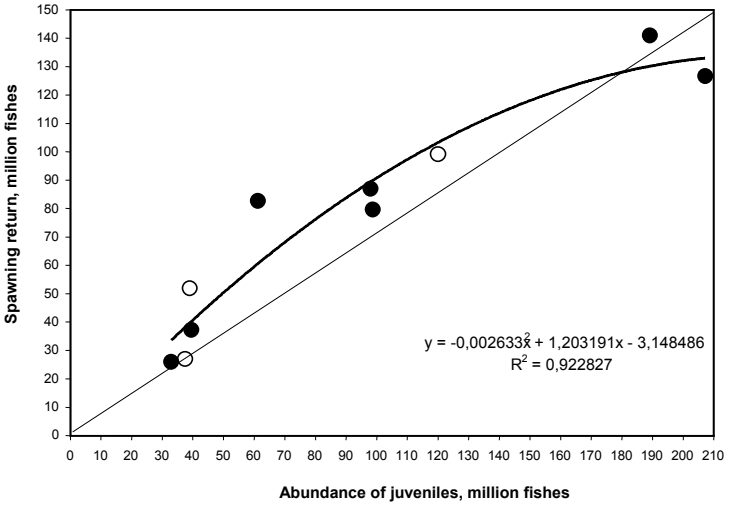
Because of differences in the timing of downstream migrations, stock assessment surveys are usually performed 10–15 days earlier in Bering Sea (late August) than in the Okhotsk Sea (mid September). Seaward migration of salmon juveniles begins on both coasts of Kamchatka at almost the same time. However, sizes of some species in the Bering Sea and Okhotsk are not identical, as conditions for foraging in coastal waters and survey times are different. Usually, juvenile pink, chum and coho in the Okhotsk Sea are bigger (especially in weight) than in Bering Sea. However, sockeye and chinook are bigger in the Bering Sea than the Okhotsk Sea. In general, variation in body size is higher in the Okhotsk Sea than the Bering Sea.

Distribution of stocks during survey operations also plays an important role in stock assessment surveys. The 54.4/192-m trawl was designed for species, such as pink and chum salmon that migrate from coast to the ocean as an entire stock rather than in separate groups. Downstream migration of pink salmon begins earlier, and hence their seaward migration begins earlier as well. As a rule, species with a long freshwater life period (sockeye, coho, chinook) migrate to the ocean in echelons, and fish of different ages may migrate at different times. Older fish abandon the coast earlier than younger fish. Freshwater age 0+ fish migrate later than older fish.

Because the timing of downstream migration and foraging in coastal waters differs for various species and age groups, duplicate surveys are needed to assess different cohorts. In recent years, duplicate surveys were performed in the Bering Sea (2000, 2002) and the Okhotsk Sea (2001, 2003), which enabled more accurate assessment of the abundance, direction of migration, and natural mortality of different cohorts.

Ocean stock assessment of juveniles in fall is the final stage for calculating the return ratio for mature fish and estimating the allowable catch. At present, these data are used only for pink salmon. In some areas, however, they can also be used for other species—only sockeye, chum and coho salmon, as biomass of chinook and masu salmon is too low. Trawl survey data on juvenile stock biomass are the foundation for preparation of a spawning run forecast for Kamchatka pink salmon. The following empirical formula is used to estimate spawning runs of West Kamchatka pink salmon (Fig. 1): $Y = ax^2 + bx + c$, where Y is the commercial (total) return (millions of fish), and x is the abundance of juveniles in fall season (millions of fish). The most regular and accurate results have been achieved for West Kamchatka stocks, where the deviation of actual return ratios from forecasted has rarely been higher than 30%. Such similarity between actual and forecasted data was also achieved for the northeastern Kamchatka stock in 1980s and 1990s, when ocean stock assessment surveys of juvenile salmon were performed on a regular basis.

Fig 1. Dependence of abundance of pink salmon in total spawning runs on abundance of juveniles in fall season (September-October). Closed circle—Western Kamchatka; Open circle—northeastern Kamchatka.



In conclusion, the trawling methods described herein fulfill many theoretical and practical tasks associated with management of salmon stocks, including the collection of data on abundance and biological characteristics, annual assessment of distribution, migration, and foraging conditions, forecast information for commercial runs of certain stocks, and assessment of the role of juvenile salmon in coastal ecosystems.