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Variability of the pink salmon sizes in relation with abundance of Okhotsk Sea stocks

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Beginning in the mid-1970s there was an increase in abundance of all Pacific salmon species. It was shown that global climatic factors may have caused changes in salmon abundance in the North Pacific (Beamish and Bouillon 1993, Klyashtorin and Sidorenkov 1996, Radchenko and Rassadnikov 1997, Shuntov *et al*. 1997). The rise in abundance of Asian and American stocks of salmon was accompanied by a decrease in the average size of fish, by an increase in age at maturity (due to the growth rate reduction during marine period of their life cycle), and by a reduction of the fecundity of females (Ishida *et al*. 1993, Welch and Morris 1994; Bigler *at.al*. 1996). Nevertheless, there are some exceptions to the general trend of Pacific salmon productivity in relation to stock abundance. For example, a decrease in abundance was observed for the Japan/East Sea pink salmon stocks (especially for the Primorye stock) while the average size of the Primorye pink salmon decreased during the 1970-1980s (Temnykh 1998). At the same time, abundant pink salmon from Sakhalin maintained a large size (Nagasawa 1998).

The main objectives of this research were to:

- Compare growth of pink salmon from "continental" (northern coast of the Okhotsk Sea) and "island" (Sakhalin, southern Kuril islands) regions during periods of high and low pink salmon abundance; and
- Determine those factors responsible for size differences among pink salmon stocks, particularly in the northern and southern Okhotsk Sea, during periods of low and high abundance from the 1970s-1990s.

Materials and methods

Statistical data on pink salmon catches collected by TINRO-Centre, SakhTINIRO, and MoTINRO, are used in this study. These include the average size of spawners from rivers on the Okhotsk Sea coast of Sakhalin (north and south Sakhalin as well as Terpenya and Aniva bays), from Iturup Is. (southern Kuriles), and from the mainland rivers of the northern coast of the Okhotsk Sea (Gizhiga, Kukhtuy, and Tauy rivers) (Fig. 5).

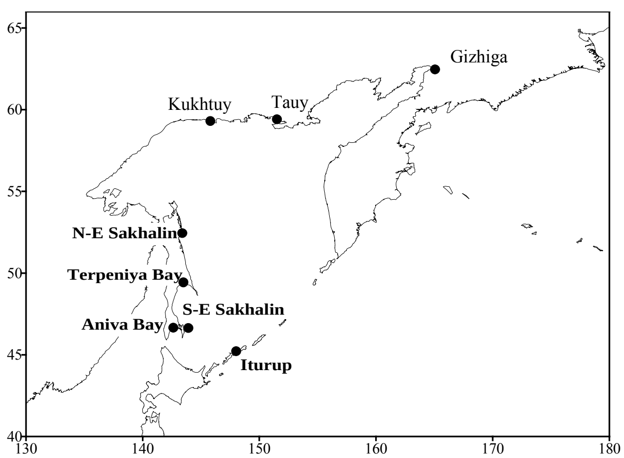

Fig. 5 Map of the location of Okhotsk Sea pink salmon regions studied.

Results

Catch dynamics for the Okhotsk Sea stocks of pink salmon

Eastern Sakhalin, western Kamchatka, southern Kurile, and northern Okhotsk Sea stocks of pink salmon are highly abundant stocks within the Okhotsk Sea. Following a period of low abundance in 1940-1960s, an increase in pink salmon number was observed in the Okhotsk Sea from the late 1970s. From the early 1990s, the total odd-year pink salmon catch increased 1.8 times when compared to the late 1970s and 1980s, and amounted to 62-133 thousand tons (Fig. 6). This was mainly due to a considerable rise of pink salmon abundance from the south-western Okhotsk Sea, particularly from eastern Sakhalin. During the last decade the share of those groups in the odd years reached 55-96% in the total number in the Okhotsk Sea.

Total even-year pink salmon catch increased 3.4 times when compared to the 1970-1980s, and amounted to 83-192 thousand tons (Fig. 6). On the Sakhalin and southern Kuriles, the number of pink salmon increased 2.2 times, while in the western Kamchatka and northern Okhotsk Sea regions it increased 4.6 and 4.3 times, respectively. Beginning in 1994, pink salmon from western Kamchatka was the most numerous among the odd-year generations (46-60% of the total number of the Okhotsk Sea stocks).

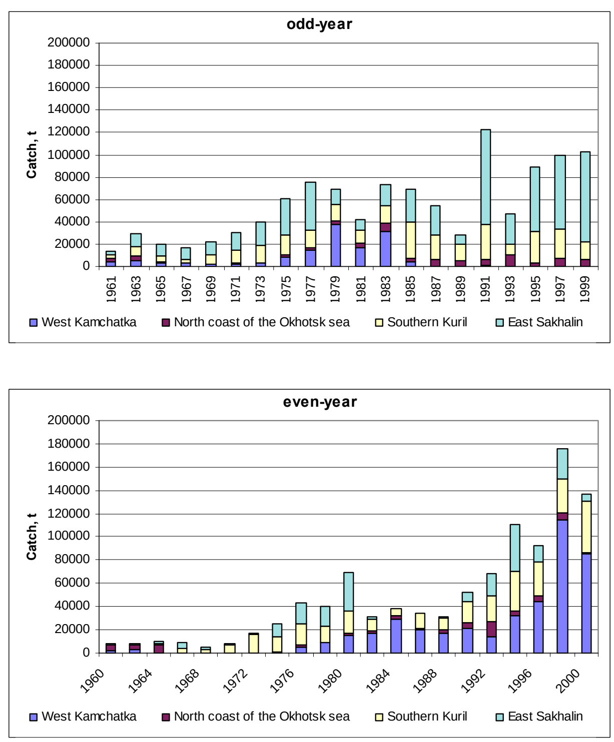

Fig. 6 Total annual catch of pink salmon in the main regions of coastal fisheries.

Changes of body weight of the Okhotsk Sea stocks of pink salmon

During the 1990s, both southern and northern pink salmon populations from the Okhotsk Sea were characterized by peculiar changes in mean size. Among the southern Okhotsk Sea stocks (eastern Sakhalin, southern Kuriles), there was a trend toward increasing body weight both in even-year, and especially in odd-year generations over the last decade (Fig. 7, Table 1).

As for the increased abundance of pink salmon from the northern Okhotsk Sea coast, the average weight was also growing in the odd-year broods, that were more abundant than even-year generations, though it was somewhat smaller in the even years. Average size changes within the "northern" and "southern" groups of pink salmon were synchronous. The increase in both abundance and average size of pink salmon from southern and northern Okhotsk Sea stocks is unequivocal evidence that favorable conditions prevailed for fish reproduction during the late 1980s - early 1990s.

Weakening of the Aleutian Low led to considerable warming of the northwestern Pacific after 1989. The carrying capacity for the Okhotsk Sea pink salmon increased. Unlike the North American pink salmon, the average size of the Okhotsk Sea pink salmon increased during a period of high abundance. We can only guess what was the main reason for that. It could be due to increased productivity as a consequence of general warming in the northwestern Pacific and/or improvements of forage reserves at the expense of significant decreases in abundance of other plankton consumers. In the 1980s, the total biomass of pelagic fishes amounted to

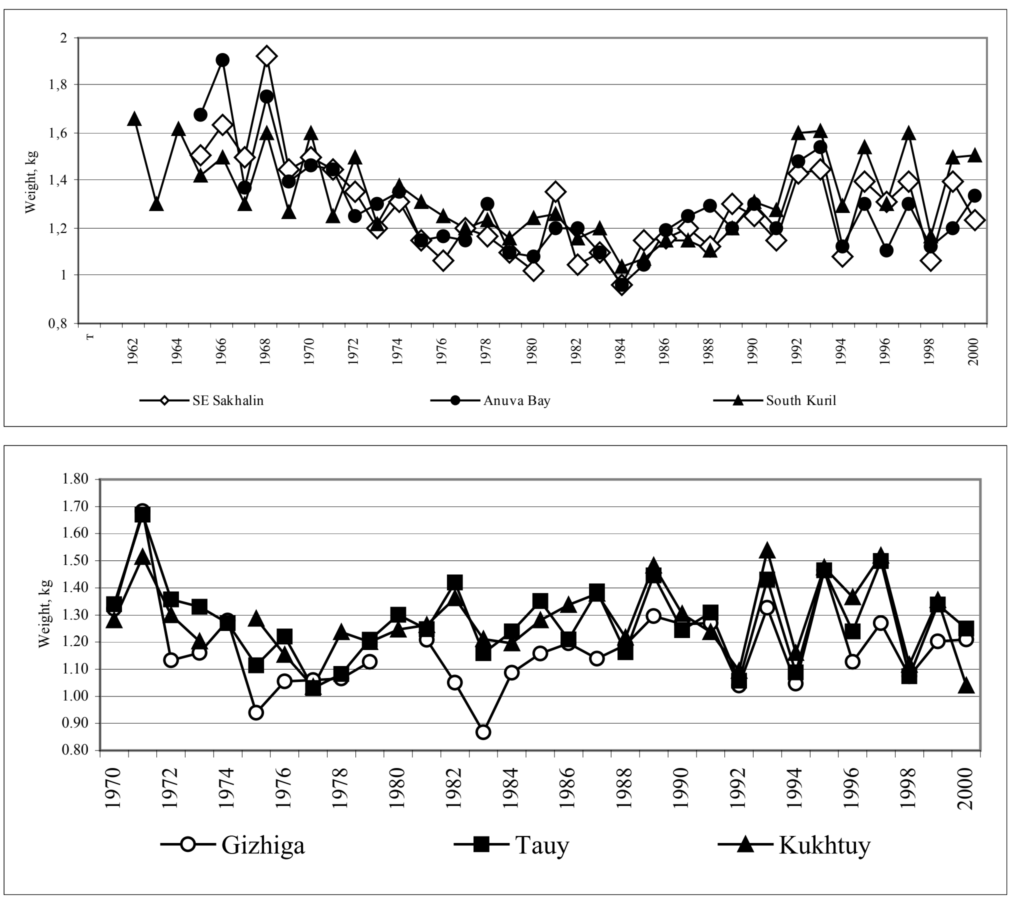

Fig. 7 Average pink salmon weight in Sakhalin-Kuril region (top panel) and northern coast of the Okhotsk Sea (bottom panel).

Table 1 Average Okhotsk Sea pink salmon catches and fish weight in the 1970-1980s and in the 1990s.

	Region		Average weight kg		Average catches ,000 t		Average total catches ,000 t	
			1978-1989	1990-2000	1978-1988	1990-2000	1978-1988	1990-2000
Even years	Northern coast of the Sea of Okhotsk	Gizhiga	1,12	1,13	1,72	5,58	43,1	123,3
		Tauy	1,12	1,13				
		Kukhtuy	1,27	1,18				
	Sakhalin Island	Aniva Bay	1,17	1,25	21,03	48,52		
		S-E Sakhalin	1,08	1,27				
		Terpeniya Bay*	1,02	1,14				
	South Kuril Islands	Iturup	1,16	1,36				
Odd years	Northern coast of the Sea of Okhotsk	Gizhiga	1,09	1,3	4,64	6,29	61,9	103,5
		Tauy	1,3	1,41				
		Kukhtuy	1,3	1,42				
	Sakhalin	Aniva Bay	1,15	1,31	39,52	85,64		
		S-E Sakhalin	1,2	1,36				
		Terpeniya Bay*	1,2	1,32				
	South Kuril Islands	Iturup	1,18	1,51				

million tons in the Kuroshio Current region. In the 1990s, the abundance of these fishes decreased by 7-8 times, mainly at the expense of Japanese sardine (Belyaev 2000). During this period, total plankton consumption by pelagic fishes decreased by up to 20 times compared to the 1980s in Pacific waters of Kuril islands (Naydenko, in press).

The increase in number and size of pink salmon from the southern Okhotsk Sea population took place together with the drop in abundance of Pacific sardine after the 1990s. The low abundance and small size of pink salmon took place together with decrease in abundance of Japanese sardine after 1989. The low abundance and small size of pink salmon were observed for stocks both in the southern Okhotsk Sea, and in Japan/East Sea during high abundance of Japanese sardine (Temnykh 1998). It is unlikely that sardine are a direct competitor with pink salmon. It appears that a high abundance of the predator results in enhanced pressure on planktonic organisms. A decrease in zooplankton abundance in the western North Pacific during the 1970 - 1980s (Odate 1994) could be due to both climate and oceanological changes, and predation of abundant nektonic species.

It is interesting to note that the average weight of pink salmon was larger in the northern Okhotsk Sea during the 1980s compared to the southern Okhotsk Sea stocks, in spite of the fact that the marine life period of northern stock fishes is 30-45 days shorter than southern Okhotsk Sea stocks. In winter, pink salmon from different Okhotsk Sea stocks dwell within the same region of the northwestern Pacific but these stocks are partly separated in time and space during migrations (Fig. 8). The range of the northern Okhotsk Sea pink salmon is less connected with feeding areas of subtropical migrants in the Subarctic Front Zone, especially at the beginning and at the end of marine period of pink salmon life.

During the last decade, there is some evidence that density-dependent factors caused the decrease in average weight of highly abundant pink salmon generations within the Okhotsk Sea. In the 1990s, a permanently high weight difference was observed between even- and odd-year generations of pink salmon from rivers of the northern Okhotsk Sea coast, Sakhalin and Iturup (Fig. 7, Table 1). In the Sakhalin-Kuril region, even-year pink salmon were 100-200 g lighter than odd-year. The average weight of eastern pink salmon is lower at low stock abundance in even years, compared to fish size observed in odd years when Sakhalin population number was twice higher. Pink salmon sizes depend on the total abundance in the Okhotsk Sea, but not abundance of each stock.

We have suggested a hypothesis explaining the dynamics of fish size and stock abundance of pink salmon. To develop our knowledge in this field, it is of primary importance to look more carefully into the basic parameters of carrying capacity for pink salmon during marine period of the life cycle.

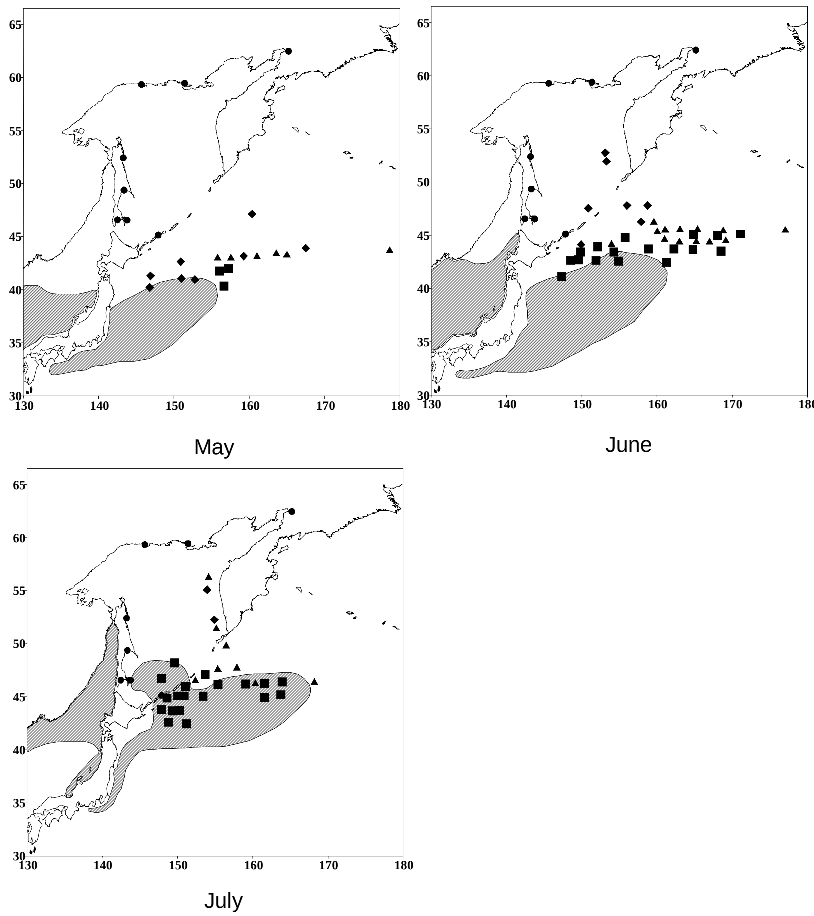

Fig. 8 Seasonal distribution of the Okhotsk Sea pink salmon and Japanese sardine in the northwestern Pacific. (■) pink salmon from Sakhalin-Kuril stocks, (▲) pink salmon from the northern Okhotsk Sea, (✡) pink salmon from western Kamchatka stocks (tagging data from Ogura 1994). The shaded area indicates Japanese sardine distribution during the period of high abundance in the 1970-1980s.

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The characteristic growth rate of herring in Peter the Great Bay (Japan/East Sea)

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Pacific herring are subarctic species forming several local populations within its extensive natural habitat. The Peter the Great Bay herring form one of most southerly groups, and are typically characterized by a high growth rate. There is no uniform opinion about the hierarchical status of this group, but it has the highest biopotential among other herring groups of the Japan/East Sea (Posadova 1988, Gavrilov 1998, Rybnikova 1999).

The life cycle of Peter the Great Bay herring occurs within the Bay and in adjacent waters in the northwestern part of the Japan/East Sea. Considering its restricted distribution and spawning grounds, the potential level of biomass of this population does not exceed 150 thousand tons. From 1910 till now, three peaks of high abundance have been observed: in the mid 1920s, the mid 1950s, and the late 1970s/early 1980s. Each rise was associated with one or several dominant generations (Posadova 1988). In the 1990s, the abundance and productivity of Peter the Great Bay herring have come near to the historical minimum, and its biomass during these years varied from 5 - 10 thousand tons.

It is necessary to determine how the size-age characteristics and population structure changed in connection with the present depressed condition of Peter the Great Bay herring stocks. The biostatistical data from annual monitoring of the Peter the Great Bay herring stocks from 1971 to 2001 were analyzed. The data were collected from control catches by gill nets, seines and traps exposed directly on the spawning grounds. The data were processed using standard ichthyological techniques. The scales from a middle part of fish body under a dorsal fin were used for age interpretation. The following formula (Alimov 1989) was used for growth rate:

$$C_l = \frac{\lg(l_1) - \lg(l_0)}{0.4343(t_1 - t_0)} \times 100\%$$

where C_l is the average speed of linear growth, l_0 is length at the initial time, t_0, and l_1 is length at a later time, t_1.

The Peter the Great Bay herring are the fastest growing of all herring populations in the western Pacific (Posadova 1985). Growth is most rapid during the first and second years of life. At age