

- Nagasawa, K. 1998. Long-term changes in climate, zooplankton biomass in the western North Pacific, and abundance and size of the East Sakhalin pink salmon. NPAFC Technical Report, Vancouver, Canada, pp. 35-36.
- Ogura, M. 1994. Migratory behavior of Pacific salmon (*Oncorhynchus* spp.) in the open sea. Bull. Nat. Res. Inst. Far Seas Fish. 31: 1-138.
- Radchenko, V.I., and Rassadnikov, O.A. 1997. Long-term dynamics trends of Asian stocks of Pacific salmon and factors determining it. Izv. TINRO 122: 72-94 (in Russian).
- Shuntov, V.P., Radchenko, V.I., Dulepova, E.P., and Temnykh, O.S. 1997. Biological resources of the Far Eastern Russian economic zone: structure of pelagic and bottom communities, up-to-date status, tendencies of long-term dynamics. Izv. TINRO 122: 3-15 (in Russian).
- Temnykh O.S. 1998. Primorye pink salmon growth at high and low abundance. NPAFC Technical Report, Vancouver, Canada, pp. 20-22.
- Welch, D.W., and Morris, J.F.T. 1994. Evidence for density-dependent marine growth in British Columbia pink salmon populations. NPAFC Doc. 97. 33 p.

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

**Ludmila A. Chernoiivanova**, Alexander N. Vdovin and D.V. Antonenko

Pacific Research Fisheries Center (TINRO-center), 4, Shevchenko Alley, Vladivostok, Russia, 690950.  
E-mail: tinro@tinro.ru

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, Gavrillov 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

0+, herring in Peter the Great Bay have an average body length of 110 mm and weight of 9.9 g at the end of October. The average length and weight of age 1+ fish are 220 mm and 100.1 g, respectively at the end of October. After the second year of life the growth rate quickly decreases and, after the fifth year, does not exceed 10 % of the increase in the first year.

The relative daily linear growths of herring for the first year of life vary from 0.74 to 0.76% and appear to be constant during the periods of variable abundance (Table 2). The highest growth rate of herring during ontogenesis is 1.5% per day during the first six months of life (from May to October). The decreasing growth rate after the first year of life was associated with the process of sexual maturation.

**Table 2** The relative daily linear growth (annual average, %) of Peter the Great Bay herring.

Period of observation	Age (years)							
	1	2	3	4	5	6	7	8
1999-2001	0.74	0.10	0.02	0.03	0.01	0.006	0.006	0.006
1971-1990	0.76	0.14	0.05	0.02	0.01	0.010	0.006	0.006

**Table 3** Age structure (%) of herring catches in different parts of Peter the Great Bay in 1998-2001.

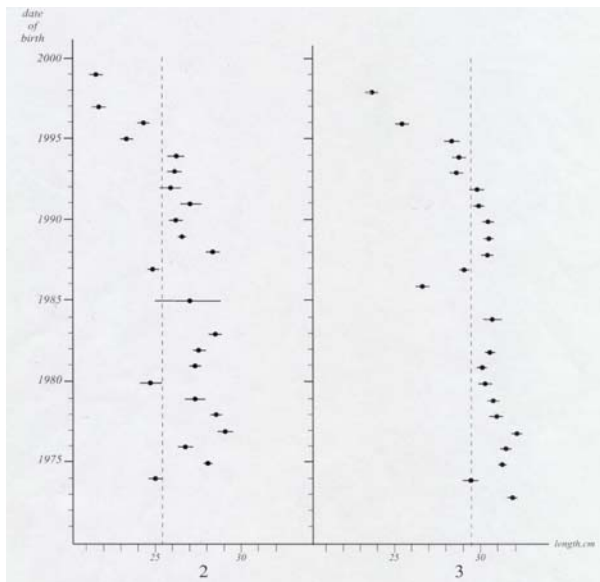
Period of observation	Age (years)										
	1	2	3	4	5	6	7	8	9	10	M
Amurskiy Bay											
1998			62.0	36.0		2.0					3.9
1999		6.4	68.3	19.1	3.5	2.2	0.5				3.8
2000		4.6	35.9	45.4	13.7	0.4					4.2
2001		8.3	20.5	27.1	35.8	7.1	0.7	0.5			4.2
Pos'et Bay											
1998			26.2	5.5	4.0	23.6	28.8	10.0	1.6	0.3	6.1
1999		1.8	14.1	14.3	27.6	29.0	11.1	2.1			5.6
2000		5.3	13.6	18.1	21.4	23.2	14.8	3.1	0.5		5.6
2001	0.7	13.8	24.8	6.9	37.2	8.3	1.4	3.4	1.4	2.1	4.9

A separate population of Pacific herring comprises 83% of genetic variability (Rybnikova 1999) which causes significant variability of the whole complex of its biological features.

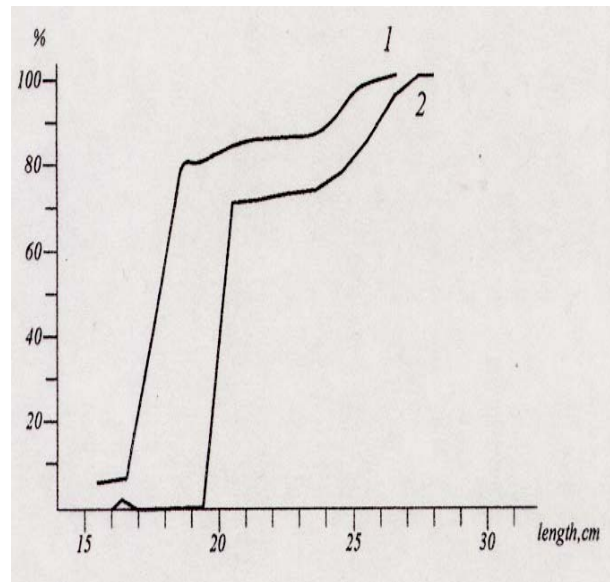
The high interannual variability in mean body length among generations in Peter the Great Bay was connected with the annual cohort strength. In the period of high abundance during the 1970s and 1980s, high yield generations (*e.g.* 1974 and 1980) were distinguished by low growth rates (Gavrilov and Posadova 1982). That tendency was not shown during the last 15 years in Peter the Great Bay. First of all, the alternation of weak and strong cohorts was disrupted (during that period there were no strong cohorts). Secondly, all generations of herring consisted of a spawning

part of the population on a background of a low reproduction level have been characterized by the low rate of growth from 1995 till now. The average body length of fish at age two and three years does not reach long-term value (Fig. 9).

Lower recruitment of Peter the Great Bay herring during the last decade has been accompanied by a reduction of the maximal age of spawners and variable age structure among sites. In the northwestern part of Peter the Great Bay (Amurskiy Bay) fish at age of 2-4 years comprised more than 80% of herring catches, whereas at the southwestern part (Pos'et Bay) the herring were from 2 to 10 years of age from 1998-2000 (Table 3).



**Fig. 9** Average length of Peter the Great Bay herring: generations at age 2 (left panel) and age 3 (right panel) years in 1974-1997. Dotted lines show long term average values (age 2: 25.2 cm, age 3: 29.5).



**Fig. 10** The rate of maturation of herring in Peter the Great Bay in 1999-2001 (1) and 1978-1990 (2).

Evidently, the distortion of a complex age structure was consequence of the deterioration of reproduction conditions of Peter the Great Bay herring. It is quite probable that the decrease of growth rate in recent years is defined not only by any negative factors but also high rates of maturity. As was stated above, the sharp decrease of growth rate was caused by the maturation process. From 1999-2001, some herring (mainly males) began to mature at 14-17 cm body length, and 80% were mature by 18-19 cm. While in 1978-1990, the bulk of the population matured at 20-21 cm body length (Fig. 10). Accumulation of slow growing and early-maturing individuals in the spawning part of Peter the Great Bay herring population during low abundance contributes to increased reproductive potential and, probably, is one of mechanisms promoting the restoration of abundance.

## References

Alimov, A.F. 1989. Introduction to the productional hydrobiology. Hydrometeoizdat, Leningrad, 152 pp.

- Gavrilov, G. M. 1998. Seasonal and interannual variability of herring distribution in waters off the northern Prymorye. *Izvestia TINRO-Centre* 124: 758-764.
- Gavrilov, G.M., and Posadova, V.P. 1982. Dynamics of Pacific herring *Clupea pallasii* Valenciennes (Clupeidae) abundance in Peter the Great Bay. *J. Ichthyology* 22(5): 760-772.
- Posadova, V.P. 1985. Interannual variability in the spawning of herring in Peter the Great Bay. *In Herring of the North Pacific Ocean*. TINRO, Vladivostok, pp. 22-29.
- Posadova, V.P. 1988. Stock assessment of herring in Peter the Great Bay. *In Variability of ichthyofauna composition, yield year classes and forecasting techniques of fishes in the western Pacific*. TINRO, Vladivostok, pp. 64-69.
- Rybnikova, I.G. 1999. Population structure of Pacific herring *Clupea pallasii* (Valenciennes) in the Japan and Okhotsk seas. Abstract of the Ph.D thesis (marine biology). Vladivostok, 23 pp.