Wild and Hatchery Production and Recruitment of Autumn Chum Salmon (*Oncorhynchus keta* Walbaum) in the Tym River, Sakhalin, 1960–1998

A.A. Kovtun
Sakhalin Research Institute of Fisheries and Oceanography (SakhNIRO)
196 Komsomolskaya St., Yuzhno-Sakhalinsk, Russia, 693023

Kovtun, A.A. 2000. Wild and hatchery production and recruitment of autumn chum salmon (*Oncorhynchus keta* Walbaum) in the Tym River, Sakhalin, 1960–1998. N. Pac. Anadr. Fish Comm. Bull. No. 2: 255–261.

Keywords: Fishery, return, abundance, chum salmon, wild and hatchery production, differentiation

Abstract: The state of the Tym River chum salmon (*Oncorhynchus keta*) stock is assessed by the fishery from the number of fish returning after feeding from two to five years in the Pacific Ocean. Ocean feeding conditions probably generally determine their survival. Chum salmon returns to the Tym River greatly decreased for the recent ten years. A regular annual driftnet fishery in the Pacific Ocean may negatively affect chum salmon abundance. This is supported in part by the analysis of data on chum salmon reproduction and returns to the Tym River for the period 1960–1998. Since the level of chum salmon abundance in the Tym River is maintained by the combined wild and hatchery production, we divided a total fish return into wild and hatchery, and determined the optimal number of spawners entering the Tym River spawning grounds in order to estimate the efficiency of wild spawning and hatchery production. It appeared that chum salmon returns from wild spawning are five times more than hatchery ones. Tendencies of returns to decrease for wild and hatchery chum salmon are identical, which suggests the same factors affect the survival of both wild and hatchery fish.

INTRODUCTION

Several species of salmonids enter the Tym River to spawn, and the most abundant of them is chum salmon (*Oncorhynchus keta*). Currently chum salmon abundance is depressed (Table 1). Chum salmon returns may have decreased not only because of the regular driftnet salmon fishery in the Pacific Ocean, but also because of poor survival in the ocean due to other factors.

The objective of this work is an analysis of wild and hatchery chum salmon returns to the Tym River for the period 1960–1998 by assessing the mixed chum salmon runs to that river for spawning efficiency of wild and hatchery fish, by comparing the return coefficients (RC) of wild and hatchery chum salmon, including those in the mixed catches from Niysky Bay. Since 1993 only a control catch for research and a catch by a small number of people of the North for their needs have been allowed in Niysky Bay. The average annual capture is 17.1% of a total chum salmon abundance during a six-year fishery closure. I also wanted to determine the optimal spawning numbers for the Tym River spawning grounds using the Ricker curve in a preliminary analysis of the "spawner-recruit" relationship model.

MATERIAL AND METHODS

The Tym River is one of the largest Sakhalin rivers. Its length is 325 km, and its basin area 7,850 km^2. The Tym River can be divided into three sections: fast flowing upper river, from the river-head to the confluence of two branches near the settlement of Kirovskoye; the middle river with medium currents, from the settlement of Kirovskoye to the Nysh River falls; slow flowing lower river, from the mouth of Nysh River to Niysky Bay. During the August–October chum salmon spawning in the upper section containing 60% of total spawning grounds, current ranges from 0.05 to 1.0 m/sec. In February the rate does not exceed 0.7 m/sec, averaging 0.3 m/sec (Gritsenko et al. 1987). According to Rukhlov (1969), the Tym River spawning grounds are 37.1% gravel (0.2–2.0 cm), 40.7% pebble (2.1–10 cm) 14% sand and 8.2% cobble (more than 10 cm). The depth is 0.5–1.0 m, and the river width at low-water ranges from 20 to 30 m. In its middle section the river

All correspondence should be addressed to A.A. Kovtun.
e-mail: koval@tinro.sakhalin.ru

Table 1. Numbers of chum salmon spawners returning to and fry migrating from the Tym River, and numbers of adults caught in Niysky Bay.

Year	Spawners entering the river, thou. ind.		Density on the spawning grounds, ind./100 m^2	Catch		Taken by fish culturists in Rybovodny Spring	
	Near Kirovskoye	Total river basin		Tons	Thou. ind.	Tons	Thou. ind.
1987	530.5	575.6	65.5	1227.4	323.4	180.0	52.9
1988	318.0	689.5	78.3	708.7	172.9	160.0	38.8
1989	43.0	80.2	9.1	263.3	64.2	160.0	44.4
1990	62.3	135.1	15.1	347.1	102.1	260.7	75.4
1991	50.0	108.5	12.3	332.8	95.1	209.0	62.8
1992	17.7	33.5	2.0	260.0	74.3	144.0	45.0
Aver.	170.2	270.4	30.4	523.2	138.7	185.6	53.2
1993	58.8	111.4	6.5	73.2	17.9	83.1	21.5
1994	84.2	159.6	9.3	76.2	19.6	86.4	15.7+11.0*
1995	102.1	193.3	11.2	106.9	27.4	202.8	28.6+24.0*
1996	25.2	47.8	2.8	97.3	24.3	147.9	27.4+9.6*
1997	100.0	184.7	10.7	90.4	27.4	120.2	22.7+13.7*
1998	ind	10.0	0.6	76.4	21.8	88.6	18.1+7.2*
Aver.	61.7	117.8	6.9	86.7	23.1	121.5	21.9+13.1*

* Including the catch of spawners in Pilenga River

** Release of fry chum salmon from the hatchery "Pilenga Godo"

continue...

reaches 30–100 m in width. The depths in pools are up to 3 m, in reaches 15–20 cm, with sand and pebble spits often appearing near the banks, especially in the lower river. A tidal bore spreads 25–30 km up the river on spring tides, and on heap tides as far as 20 km (Gritsenko et al. 1987). Water in the Tym River system originates mainly from winter precipitation, and less from summer rains. The spring flood usually starts in the third week of April, and its peak is recorded in mid-May.

I use the term "return coefficient" (RC), which is percent survival at sea from the time chum salmon fry descend downstream to the time of return to spawn, including spawners caught in the local fishery as well as those entering spawning grounds or the hatchery. In 1993, for instance, 45 million fry migrated downstream, and 85,800 adults returned from 1995 to 1998. The percentage of returning adults to fry migrants was 0.191%, the RC. Since 1987 to 1994, the RC of wild and hatchery chum salmon varied from 0.19 to 0.42%, and averaged 0.27% (Table 2).

When estimating the proportions of hatchery and wild chum salmon returning to the Tym River spawning grounds, some assumptions were made:

1. The returns of chum salmon released from the two hatcheries located in the middle section of the Tym River (Ado-Tymovsky and Pilenga Godo) are fully accounted for by numbers recorded near the hatcheries (Rybovodny Spring, a tributary of Pilenga River).

2. The proportion of hatchery fish taken during fishing in Niysky Bay is assumed to be equal to the proportion of hatchery fish in the total of reproducing fish.

3. Only wild chum salmon arrive at the Tym River spawning grounds.

4. Age structures of chum salmon from the upper sites of spawning grounds, from hatcheries located in the middle section, and from the fishery in the lower section are assumed to be the same at every site, because it was shown earlier from an analysis of scales, that growth of chum salmon from different spawning sites is not significantly different (Kovtun 1981).

Until the early 1990s the area of chum salmon spawning ground in the Tym River was 880,000 m^2. Of this 60% (528,000 m^2) fell in the upper river near the settlement of Kirovskoye (Gritsenko et al. 1987). Over several years, after the Tym River ceased being used for timber rafting, spawning grounds began to recover. As a result, new estimates of spawning ground have risen by a factor of almost two. At present the spawning area accounts for 1,723,000 m^2.

Table 1. continued.

Total number of chum salmon, thou.ind.	Commercial catch, % of total	Number of downstream migrants, millions: Near Kirovskoye	From all river spawning grounds	Release from hatcheries	Total	Percentage migrants from hatcheries
951.1	33.9	18.0	31.0	53.4	84.4	63.2
901.2	19.2	23.4	50.4	53.7	104.1	51.6
188.8	34.0	27.0	50.5	49.2	99.1	49.3
312.6	32.7	4.8	9.0	47.0+4.3**	60.3	85.1
266.4	35.7	13.9	29.9	48.3+29.5**	107.7	72.3
152.8	48.6	8.1	13.5	40.3+18.8	72.6	59.1
462.3	34.0	15.9	30.7	48.7+17.5**	88.1	63.4
150.8	11.9	2.6	4.4	27.0+13.6**	45.0	90.2
205.9	9.5	15.4	25.7	25.6+0.17**	51.5	50.1
272.7	10.0	9.0	15.0	18.5+11.5**	45.0	66.7
109.1	22.3	14.6	24.4	36.0+14.4**	74.8	67.4
248.5	11.0	2.0	3.3	27.7+15.5**	46.5	92.9
57.1	38.2	15.7	26.2	37.2+10.8**	74.2	64.7
174.0	17.1	9.9	16.5	28.7+11.0**	56.2	72.0

...continued

Spawners entering the river and fry migrating downstream annually were counted at the upper section and estimated for the total basin.

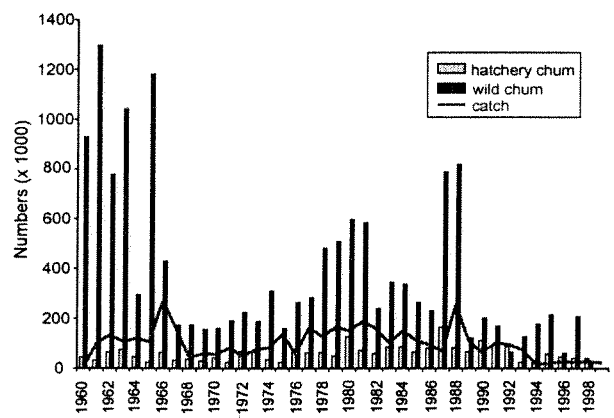
The previous measure of spawning area (880,000 m^2) was used when estimating optimal spawning escapement during the period 1960–1994, and only in the final estimation of density for optimal spawning grounds was the modern area (1,723,000 m^2) used.

RESULTS AND DISCUSSION

Except in 1992 and 1998, hatchery chum salmon returns have been less than returns of wild fish (Fig. 1). For the entire study period the number of hatchery fish returning has been low, 63,100 individuals. The number of wild spawners, 313,600 is almost five times higher. The number of downstream wild migrants from the spawning grounds is only 1.2 times that of hatchery fish, but their survival is higher (Gritsenko et al. 1987) (Table 1).

Low chum salmon returns from hatchery propagation can be explained in part by the unfortunate need to transport eggs for incubation from the upper section of Tym River to Rybovodny Spring (middle section), where the Ado-Tymovsky Hatchery is located. During years of transportation (1976–1986), only fish with mature gonads were observed returning to Rybovodny Spring. Gonad maturation rate for

Fig. 1. Numbers of hatchery and wild Tym River chum salmon and their combined catch in Niysky Bay for the period 1960–1998.



chum salmon spawning in upper section of Tym River is slower than from that in the middle section. Volovik and Landyshevskaya (1968) suggested that the maturation rate was caused by the remoteness of spawning grounds from the sea, and the duration of migrations by fry and mature fish in fresh waters. It had to be considered a hereditary feature.

Ricker (1972), analyzed the results of transport of many salmon eggs and concluded that effects were almost always negative. Returns from transported eggs may be much lower than from local eggs, even

Table 2. Numbers of chum salmon (wild and hatchery) from various brood years leaving from and returning to the Tym River, and their percent return (Return Coefficient, RC).

Year of return (new brood year)	Numbers of adults entering to spawn (thousands)	Numbers of fry migrating (millions)	Numbers of offspring returning					
			1984	1985	1986	1987	1988	1989
1987	951.9	84.4	606360	18086				
1988	901.9	104.1	295594	598397	7210			
1989	188.8	99.7		90812	92890	5098		
1990	312.6	60.3			114412	186935	11253	
1991	266.4	107.7				79121	159840	27439
1992	152.8	72.6					40645	103446
1993	150.8	45.0						48559
1994	205.8	51.5						5353
1995	272.7	45.0						
1996	109.1	74.8						
1997	248.5	46.5						
1998	57.1	74.2						
Total returns				707296	214512	271154	211738	184796
Avererage percent return:								

continue ...

if the transportation is carried out within the same river basin. Transported salmon retain the timing of runs and spawning according to their origin (Okazaki 1982). Ado-Tymovsky Hatchery is located far from natural spawning grounds, to ensure reproductive isolation from wild chum salmon. This helps avoid detrimental genetic mixing between hatchery and wild chum salmon, against which some specialists have warned (Bams 1976; Helle 1976).

Annual fluctuations in wild chum salmon returns ranged from 16,200 to 1,297,200, a factor of 80. The number of returning hatchery chum salmon ranged from 23,400 to 164,700, a factor of 7 (Fig. 1).

Wild chum salmon runs were highest during the early 1960s and late 1970s to early 1980s. The first maximum was about 1.3 million individuals, the second was almost half that (600,000 individuals). Chum salmon returns during 1987–1988, unexpectedly increased to 800,000. They were offspring of adults returning in 1984, that produced high numbers of four-year old chum salmon in 1987, and five-year old fish in 1988. Chum salmon returns in the 1990s decreased in numbers by almost 4 times, and did not rise above 215,000 individuals.

A comparison of the returns of hatchery chum salmon with those of wild fish shows parallel fluctuations in abundance, which suggests the influence the same survival factors during feeding migrations at sea. At present, hatchery and wild chum salmon coexist as two reproductively independent populations (Gritsenko and Kovtun 1991). Since conditions for marine survival appear to be similar, when forecasting abundance by the method of Bird (1982), the total number of wild and hatchery fry migrants is considered.

After separation of the number of wild and hatchery returns, RCs were calculated for both stocks separately for the period 1960–1992. The average long-term RC for wild chum salmon was 1.006% with a range from 0.152 to 2.864%. For hatchery chum salmon this index was 0.142% with a range from 0.063 to 0.294%. Judging from these data the survival of wild chum salmon from the Tym River basin appears to be about seven times higher than that for hatchery chum salmon (Fig. 2). Fewer hatchery migrants and lower survival at sea resulted in five times more wild fish being caught in the Niysky Bay fishery.

Earlier Gritsenko et al. reported (1987) that survival of larvae in redds increased with numbers of spawners to 450,000–500,000 individuals, then began to decrease as numbers of spawners rose further. The number of fry migrating downstream is positively

Fig. 2. Percent survival (RC) of wild (A) and hatchery (B) Tym River chum salmon from migrating fry to returning adult (+ commercial fishery catch in Niysky Bay) shown for each year as deviation from the average of all years from 1960–1995.

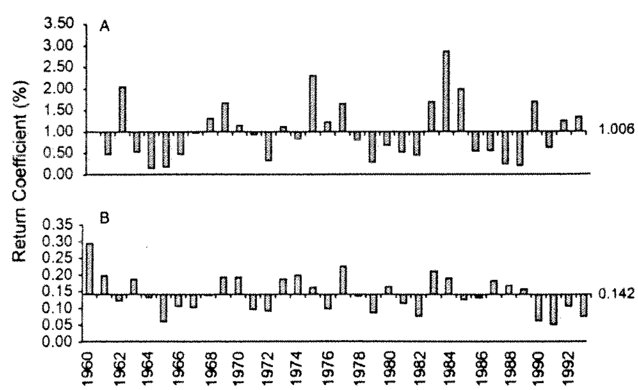


Table 2. continued.

from previous brood years							Total offspring returning, (thousands)	Percent returning (RC)
1990	1991	1992	1993	1994	1995	1996		
							271.1	0.321
							211.7	0.203
							184.8	0.186
							184.9	0.307
							228.1	0.212
8710							231.8	0.319
97718	4524						85.8	0.191
76595	120863	3089					216.5	0.420
1909	100899	167165	2727					
	1855	61532	44622	1091				
			37772	195073	15655			
			628	20328	34660	1484		
184932	228141	231786	85749	216492				
								0.270

...continued

correlated (r = 0.53) with the number of spawners entering the Tym River spawning grounds during 1960–1998. This relationship is described as follows: X = 23.751 + 0.528Y (Fig. 3).

Higher numbers of spawners were observed in the 1960s, as was the maximum number of fry migrants. In the 1990s the return of spawners decreased, and so too did the number of migrating fry. This relationship was described by a parabolic curve, as before (Gritsenko and Kovtun 1991). According to this curve, maximum numbers of spawners (900,000–950,000) result in the greatest numbers of fry migrating downstream (70–75 million).

The relationship between the number of fry per female and the number of spawning females shows, apparently, that the fewer the number of females spawning, the greater the number of downstream migrants per female (Fig. 4). In the 1990s the deviation from the mean long-term value (328.7 fry/female) is significant (150 fry/female) (Fig. 5).

Fig. 3. Relation between the number of fry migrating downstream and the number of spawners entering the Tym River for the period 1960–1998.

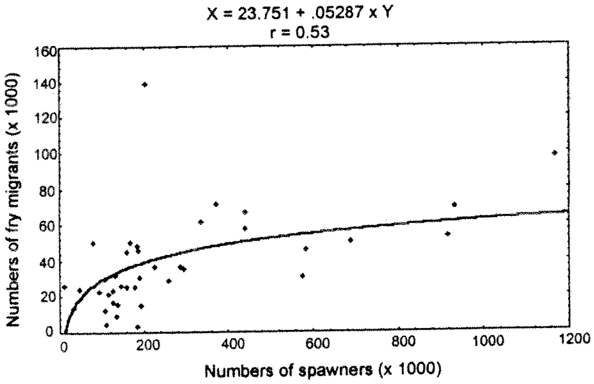


Fig. 4. Relation between numbers of the chum salmon fry migrants per female and numbers of spawning females in Tym River for the period 1960–1998.

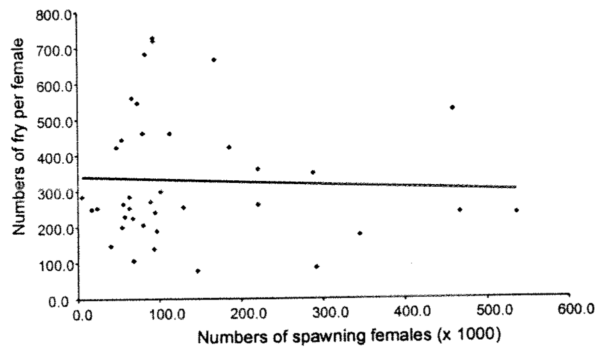
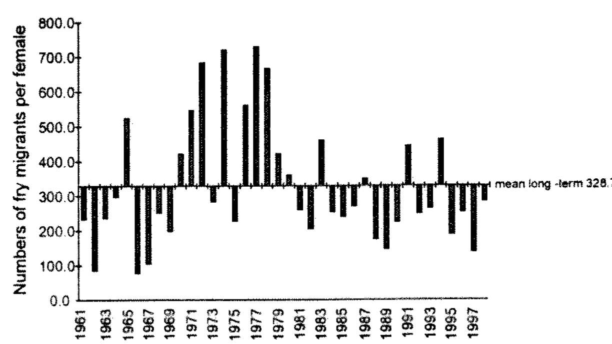


Fig. 5. Numbers of chum fry migrants per female shown as the deviation from the average for the years 1961–1998.



The second form of the Ricker "spawner-recruit" model was chosen for estimation of the optimal number of spawners when parents (P) and recruits (R) were measured in the same units (Ricker 1979). The Ricker model reflects the relationship between the number of spawners entering to spawn (parents) and the number of their offspring returning (recruits), expressed in thousands of individuals. The second form of this relationship is:

$$R = Pe^{a(1-P/Pe)} \quad (1)$$

where R is the number of recruits; P is the number of parents; a is a dimensionless parameter.

Data from 33 years were used to construct the Ricker curves, and two curves were produced:

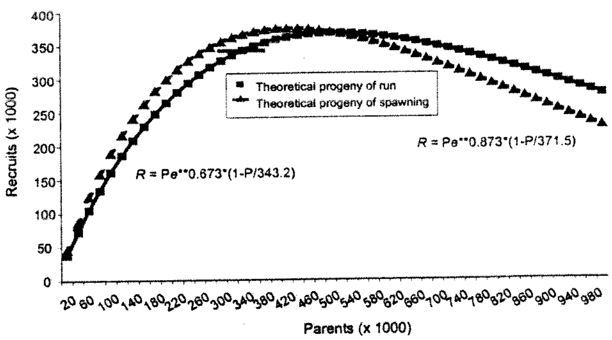
1. Return from the spawners' entrance;

2. Return from the total number of chum salmon in the year of spawning (the curve data are not analyzed) (Fig. 6).

The equation for return from the spawners' entrance was:

$$(1) \quad R = Pe^{0,873(1-P/371,5)} \quad (2)$$

Fig. 6. Ricker curves showing numbers of recruits returning to spawn as a function of the numbers of parents in the preceding generation, derived from data from the Tym River chum salmon for the period 1960–1998.



The actual number of spawners entering the spawning grounds (in thousands of individuals) in the following years was introduced into formula (1), and the expected number of recruits was calculated. The optimal number of spawners was calculated for the new area of spawning grounds (1,723,000 m^2). It was 727,000 individuals. Higher numbers of spawners are not effective, because chum salmon returns decrease above this optimum. Optimum density on spawning grounds is 42 individuals per 100 m^2. The optimum density is assumed to be constant over a given time, and is used as a reference standard to regulate the Tym River chum salmon stock.

CONCLUSION

Long-term observations on the status of autumn chum salmon in the Tym River permitted a comparative analysis of reproduction of hatchery and wild chum stocks for the period 1960–1998, and a calculation of RC, the percent survival of the number of fry migrating downstream that returned to spawn or be caught in the local fishery. The average percent survival within the whole period 1960–1994 was 1.006% for wild, and 0.142% for hatchery chum salmon. The smaller number of hatchery fry migrating downstream and their lower survival at sea mean that during the fishery in Niysky Bay five times fewer hatchery chum salmon were caught than wild ones.

Numbers of wild and hatchery chum salmon returns varied in parallel, suggesting that the same factors were affecting survival during ocean life. The decrease in all reproductive indices occurred in the last decade, when the driftnet fishery was operating in the Pacific Ocean. The closure in 1993 of the Niysky Bay fishery did not promote the restoration of stocks. A historically minimal chum salmon return was recorded in 1998 (57,100).

Wild chum salmon are more important for maintaining stock abundance, and based on the Ricker "spawner-recruit" model, 727,000 spawners at an average density of 42 fish per 100 m^2 are necessary for optimal use of the spawning grounds of Tym River (1,723,000 m^2). In the last decade a significant deficit of spawners on the spawning grounds (16.4% of standard), has caused the decrease in returns.

REFERENCES

Bams, R.A. 1976. Reflections on salmonid enhancement. *In* Proceedings of the Conference on salmon aquaculture and the Alaskan fishing community. Cordova, Alaska. pp. 191–196.

Bird, F. 1982. Preliminary forecast model for Kotzebue sound, Alaska chum salmon (*Oncorhynchus keta*). Alaska Department of Fish and Game. Inform. Leaflet. No. 203.

Gritsenko, O.F., A.A Kovtun, and V.K. Kostkin. 1987. Ecology and reproduction of chum and pink salmon. Agropromizdat, Moscow.

Gritsenko, O.F., and A.A. Kovtun. 1991. Interaction between wild and hatchery-reared chum salmon (*Oncorhynchus keta*) from the Tym River. *In* Proceedings of the International Fishery Symposium on Biological Interactions of Enhanced and Wild Salmonids. Nanaimo, British Columbia, Canada. pp. 26–27.

Helle, J.H. 1976. Genetic considerations for salmonid aquaculture: biological uncertainties. Proc. Conference on Salmon Aquaculture and the Alaskan Fishing Community. Cordova, Alaska. pp. 171–190.

Kovtun, A.A. 1981. Return and linear growth of the Sakhalin autumn chum salmon (*Oncorhynchus keta* Walbaum). Vopr. Ichthiologii 21: 1030–1038.

Okazaki, T. 1982. Geographical distribution of allelic variations enzymes in chum salmon *Oncorhynchus keta*, river population of Japan and effects of transplantation. Bull. Jap. Soc. Sci. Fish. 48: 1525–1535.

Ricker, W.E. 1972. Heredity and environmental factors affecting certain salmonid populations. Stock Concept in Pacific Salmon. MacMillan lectures in fisheries. Univ. Brit. Columbia, Vancouver. pp. 19–160.

Ricker, W.E. 1979. Computation and interpretation of biological statistics of fish populations. Pistchepromizdat, Moscow.

Rukhlov, F.N. 1969. Materials on soil composition from spawning grounds and redds of pink salmon (*Oncorhynchus gorbuscha* Walbaum) and chum salmon (*Oncorhynchus keta* Walbaum) at Sakhalin Island. Vopr. Ichthiologii 9: 839–849.

Volovik, S.P., and A.E. Landyshevskaya. 1968. Some questions on biology of Sakhalin autumn chum salmon. Izv. TINRO. 65: 108–118.