Influence of the Conditions in the Hairuzova and Belogolovaya Estuaries (Western Kamchatka) on Total Pacific Salmon Abundance

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INTRODUCTION

❑ According to classification, provided by V.N. Mikhailov and S.L. Gorin (2012), the estuaries of the Hairuzova and Belogolovaya Rivers should be reckoned as channel estuaries with mouth widening. Such objects occur in Kamchatka only on the northwest (on the Okhotsk sea coast), northward from the the Morozhechnaya River (Fig.1).

❑ A complex study of the Hairuzova and Belogolovaya estuaries was carried out in October 2011 and June-August 2012. The goals of this study were to determine the local hydrological and morphological conditions and to provide studying of juvenile Pacific salmon ecology during downstream migration and early marine period of life (Gorin et al., 2012; Koval et al., 2012).

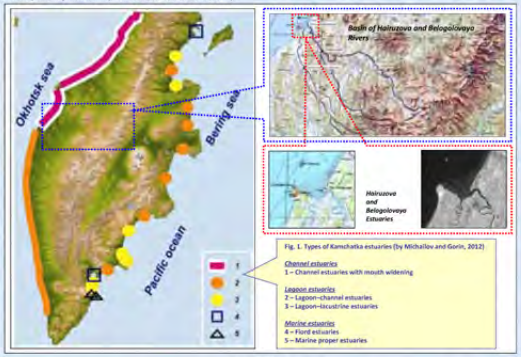


Fig. 1. Types of Kamchatka estuaries (by Mikhailov and Gorin, 2012)

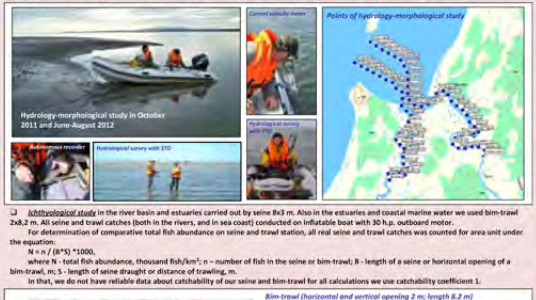
Channel estuaries
1 – Channel estuaries with mouth widening

Lagoon estuaries
2 – Lagoon–channel estuaries
3 – Lagoon–lacustrine estuaries

Marine estuaries
4 – Fiord estuaries
5 – Marine proper estuaries

MATERIALS AND METHODS

❑ *Hydrological and morphological study* carried out by standard methods accepted in the Russian hydrometeorological agency for investigation in tidal river mouth (Manual…, 1972; Hydrological investigation…, 1993). Spatio-temporal variability of a water level was investigated using 6 STD with hydrostatic sensors, placed in specific parts of estuaries. Variability of temperature and salinity of water was registered by autonomous recorders, and also during hydrological surveys and daily stations which were carried out used of STD. Speed and direction of water current was measured by electromagnetic device GRS-3M and current velocity meter. Measurements of depths were carried out by Garmin echosounder. At the analysis of the field data used of various cartographical, aerospace, geoinformation, statistical and empirical methods, and also a method of the geographical description.



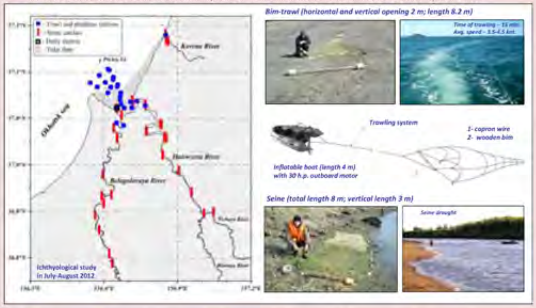
❑ *Ichthyological study* in the river basin and estuaries carried out by seine 8x3 m. Also in the estuaries and coastal marine water we used bim-trawl 2x8,2 m. All seine and trawl catches (both in the rivers, and in sea coast) conducted on inflatable boat with 30 h.p. outboard motor.

For determination of comparative total fish abundance on seine and trawl station, all real seine and trawl catches was counted for area unit under the equation:

$N = n / (B*S) * 1000$,

where N - total fish abundance, thousand fish/km²; n – number of fish in the seine or bim-trawl; B - length of a seine or horizontal opening of a bim-trawl, m; S - length of seine draught or distance of trawling, m.

In that, we do not have reliable data about catchability of our seine and bim-trawl for all calculations we use catchability coefficient 1.



RESULTS

❑ During our field study was determine, that in view of specifics of morphological and hydrological regime the Hairuzova and Belogolovaya estuaries have been separated by two parts – river and marine (Table 1, Fig. 2). The boundary between the estuary and the sea is 1–2 km seaward from the outer (marine) edge of the tidal flats, where in the case of spring ebb tide the isohaline 25‰, conventionally separating sea water from mixed water masses, gets on the surface. The boundary between the estuary and the river goes along the extreme trajectory of the isohaline 1‰; in the period of autumnal equinox ebb tides (in September–October) the boundary gets in 14–15 km from the marine edge of the tidal flats (in 5–6 km from the mouth corridor walls of the river channels). In the period of high tropic tides (in June-July) the boundary gets removed 10 km up. Thus, the total length of both estuaries can take about 15 km in September–October and 25 km in June–July.

Table 1. Hydrological particularities of Hairuzova and Belogolovaya Estuaries

Marine part of estuaries:	River part of estuaries:
in the time period closer to low water	
In the channel of estuaries (channel-tide trough) flowing a freshwater. In the marine part of estuaries freshwater mixing with marine salt water (than lower ebb tide and more river water runoff that barrier zone* closer to sea);	In the channel of estuaries flowing a freshwater (this areas becomes a river part);
in the time period closer to high water	
All area over the channel of estuaries and tidal flats covered by marine salt water (this areas becomes a sea part).	In the channel of estuaries mixing a freshwater and marine water (than higher tide and less river water runoff that barrier zone farther to sea).

*Barrier zone – zone with changing of salinity from 1 to 8 ‰ (by Mikhailov and Gorin, 2012)

Fig. 2. The scheme of Hairuzova and Belogolovaya Estuaries (by data of field researches in October 2011 and June-August 2012):

1 – marine part of the Hairuzova Estuary (length of 9.3 km);
2 – river part of the Hairuzova Estuary (a – in ebb "equinoctial" tide in October; b – in high "tropical" tide in June);
3 – marine part of the Belogolovaya Estuary (length of 9.3 km);
4 – river part of the Belogolovaya Estuary (a – in ebb "equinoctial" tide in October; b – in high "tropical" tide in June);

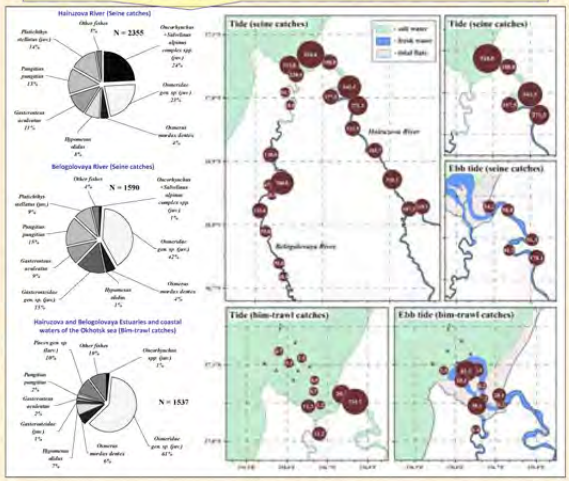
TF – tidal flats (covered by marine waters in tide; dried in ebb tide)

❑ Several key zones with specific abiotic conditions and communities of hydrobionts have been figured out as a result of studying species composition and ecology of the hydrobionts in the estuaries of Hairuzova and Belogolovaya (Fig. 3). Principal inhabitants of the pelagic and benthic zones in *the Freshwater zone (covering river channels up the zone of periodic tidal influence)* were: juvenile Pacific salmon (sockeye *Oncorhynchus nerka*, chum *O. keta*, pink *O. gorbuscha*, chinook *O. tshawytscha*, coho *O. kisutch* and masu *O. masu*), juvenile chars *Salvelinus alpinus complex* and *Salvelinus leucomaenis*, juvenile trout *Parasalmo mykiss*; ninespine stickleback *Pungitius pungitius* and threespine stickleback *Gasterosteus aculeatus*; juvenile starry flounder *Platichthys stellatus*; Asiatic brook lamprey *Lethenteron camtschaticum*.

The dominants in *the Mixing zone (within the river and marine parts of the estuaries)* were the fish species, including starry flounder and arctic flounder *Liopsetta glacialis*, pond smelt *Hypomesus olidus* and toothed smelt *Osmerus mordax dentex*, threespine and ninespine sticklebacks, juvenile salmon and chars, saffron cod *Eleginus gracilis*, sculpins *Cottidae gen. sp.*, blackline prickleback *Acantholumpenus mackayi*, tube-nosed poacher *Pallasina aix*, and the invertebrate species, including mysids *Neomysis sp.*, shrimps *Crangon sp.* and juvenile jellyfish.

In the pelagic of *the Marine zone (the coastal waters of the Okhotsk Sea outside the zone of freshing)* the aquatic fauna included pond and toothed smelts, juvenile salmon and greenling *Hexagrammidae gen. sp.* and jellyfish.

Fig. 4. Species composition and distribution density (thousand fishes/km²) of total juvenile fish abundance in the rivers Hairjuzova, Belogolovaya and adjacent waters of the Okhotsk sea in various phases of a tidal cycle in July-August, 2012 (by data of seine and a bim-trawl catches; daggers - no catch).

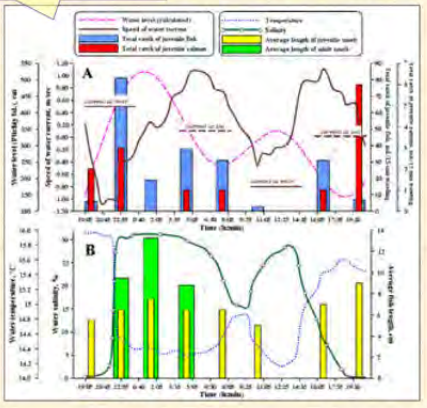


❑ Relative summary abundance of juvenile fish of mass species in the Hairuzova River was 284.0 thousand fishes/km² (Fig. 4). In the Belogolovaya River the abundance was as two times as less - 134.7 thousand fishes/km². Maximum density of the juvenile fish (over the summary abundance of 919 thousand fishes/km²) was observed in the lower part of the Hairuzova River, where majority in fish community consisted of juvenile and adult smelts, in tide.

❑ Abundance, distribution and species composition of juvenile fish in the estuaries demonstrated diurnal cycles, connected with phases of tide. Juvenile marine fish (mostly smelts) entered the estuaries and lower parts of the rivers in tides. In ebb tide the estuaries and the coastal waters received juvenile salmon and sticklebacks. In the course of the diurnal tidal cycle the estuaries first received juvenile migrants and next - elder and larger individuals (Fig. 5).

Fig. 3. Location of the several key zones with the differences of abiotic conditions and structure of hydrobiont communities in the Hairuzova and Belogolovaya Rivers and adjacent waters of the Okhotsk sea in July-August, 2012

Fig. 5. Changes of the basic hydrological characteristics, juvenile fish abundance (A) and the average body length of smelts (B) in bim-trawl catches at the daily station conducted around a mouth of the Belogolovaya River 22-23 July, 2012



DISCUSSION

❑ One of the purposes of our study was an assessment of the role, played by the rivers Hairuzova and Belogolovaya in Pacific salmon production. Making the estimation required data of field observations, basis data, collected by federal hydrometeorological agency (Resources…,1966; 1977), and published and archive data by KamchatNIRO on the production of salmon populations in Kamchatka.

It has been found as a result of the estimation that the rivers Hairuzova and Belogolovaya, having huge drainage systems (basins), are minor in the abundance of the total stock of Pacific salmon, comparing the other rivers of the region (Shevlyakov, Maslov, 2011). For the period of observations from the 1930s the summary annual catch of salmon in two mentioned systems usually did not exceed 1 thousand tons and was averagely 435.1 tons in the Hairuzova R. (1931–2011) and 101.4 tons in the Belogolovaya R. (1962–2011) (Table 2, Fig. 6). Summary abundance (from 1957) of all Pacific salmon species in spawning grounds of the Hairuzova River was averagely 221.5 thousand individuals and in the Belogolovaya River – 116.9 (Table 2, Fig. 6). Hence, the average annual abundance of Pacific salmon mature stock, spawning in two mentioned systems every year, can be estimated as 400–600 thousand individuals.

To make an insight we had to provide comparison to the Bolshaya River system (emerging to the Okhotsk Sea 4.5° southward from the Hairuzova and Belogolovaya Rivers), where only pink salmon spawning stock can reach 5.5 million individuals. The summary Pacific salmon spawning stock in this system can be 6 million individuals minimum (as 10 times as much than in two systems mentioned), although the rivers analysed, as it follows from the table (Table 1), are very similar in length and square of basin.

Table 2. General morphological and hydrological characteristics of the Hairuzova, Belogolovaya and Bolshaya River systems, Pacific salmon average annual catch (tons) and density in spawning grounds of the systems (thous. individuals).

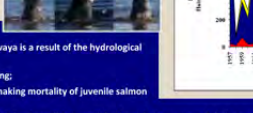
River	General characteristics*			Pacific salmon species**					
	Length, km	Square of basin, km²	Average discharge, m³/s	Pink	Chum	Sockeye	Coho	Chinook	Totally
Hairuzova	265	11 600	181***	72.7	263.3	24.2	72.6	2.4	435.1
				151.0	51.5	4.3	9.9	4.7	*221.5*
Belogolovaya	226	4 000	63***	21.2	55.7	6.6	17.6	0.2	*101.4*
				91.1	15.8	1.8	6.3	1.9	*116.9*
Bolshaya	275	10 800	317***	4877.3	398.4	240.2	292.1	93.8	5901.8
				2773.5	42.8	90.2	53.6	18.9	2978.9

Notes: * – on the reference database (Resources…,1966; 1977);
** – on the archive data by KamchatNIRO (above – the catch on the average annual data; below – the average annual density in spawning grounds);
*** – authors' calculations.

What might be the reason of such poor level of the Pacific salmon production in the systems of the Hairuzova and Belogolovaya rivers?

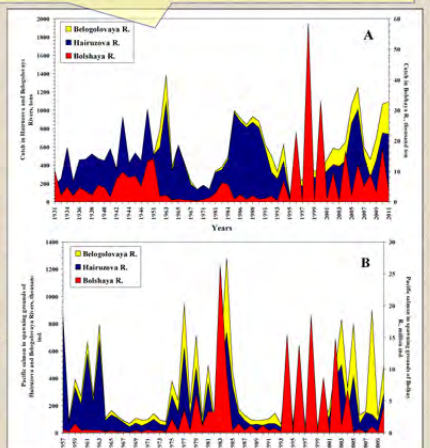
According to our observations, the grounds in the estuaries of these rivers (and lower parts of channels) are silty and unfavorable for salmon to spawn on. That is well known for river mouths affected by tides and can be explained by avalanche-type sedimentation of particles from the river in the zone of mixing river and sea waters and regular stagnating water currents, when changing phases of the tide. As a result the total square of nice spawning grounds in the rivers Hairuzova and Belogolovaya is sensibly less than in the Bolshaya River (Sevlyakov, Maslov, 2011; Ostroumov, unpublished data).

Our field observation also has demonstrated permanent sliding the zone of mixing river and sea waters in both estuaries during 24 hours: from the sea edge to the top and back. In summer the range of the move can get up to 15–30 km within the estuary channel, and maximum speed of water current there can reach 1.0–1.5 m/sec (see Fig. 5). Juvenile Pacific salmon are required to cross the zone in the course of their strive for the Okhotsk Sea. The juvenile migrants (especially pink and chum salmon, migrating as underyearlings) cannot actively resist strong currents and get extremely vulnerable for piscine, avian and mammal predators (Karpenko, 1998). Moreover, the occurrence of the silt grounds in the lower parts and estuaries of the rivers reduces developing benthic attaching organisms, playing (like drift and zooplankton) not the last role in feeding by juvenile salmon in the estuary (Maximenkov, 2007). It can be suggested in this way, that juvenile salmon mortality (from the complex of limiting factors) in the estuaries of Hairuzova and Belogolovaya is higher than in the other rivers of West Kamchatka.



At one more important factor of poor natural salmon production in the Hairuzova and Belogolovaya river systems is press of predators during anadromous migrations. The principal active predators are marine mammals, first of all killer whale *Delphinapterus leucas* and large seal *Phoca largha*. During the intense run of pink salmon for spawning (normally observed in mentioned area in early August) the number of killer whales and large seals within the estuaries in tide can reachseveral hundred heads. In tide the mammals sometimes can pursue salmon for many kilometers up the river to feed on (Shuleshko et al., 2011). We believe that the factor of aggregating the marine mammals in the estuaries of the Hairuzova and Belogolovaya rivers in summer is morphology of the estuaries. Whales don't afraid to enter estuaries with wide and deep entrance to the sea. Extensive sandbanks (raising parts of the bottom, visible in tide) can help effective hunting by whales and seals in such sites.

Fig. 6. Total commercial catch (A) and Pacific salmon in spawning grounds (B) in the Hairuzova and Belogolovaya Rivers, 1931-2011 (by archival data of KamchatNIRO).



CONCLUSIONS

Poor abundance of Pacific salmon in the rivers Hairuzova and Belogolovaya is a result of the hydrological and morphological specifics of the estuaries, including:

1) silt bottom, making the lower parts of both rivers useless for spawning;

2) huge extension of the estuaries and extremely hard effects of tide, making mortality of juvenile salmon in the course of downstream migration high;

3) aggregating predators (esp. marine mammals), rising mortality of adult (and possibly juvenile) salmon in the course of their transit migrations in the estuaries.

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