# HYDRODYNAMIC INFLUENCE ON MACROBENTHOS STRUCTURAL CHARACTERISTICS OF THE NORTH-EASTERN SAKHALIN SHELF

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A lot of hydrological and hydrobiological investigations have been conducted on the northeastern Sakhalin shelf in recent years caused by the industrial developing of the offshore oilfields. On the one hand, they allowed to study a macrobenthic communities distribution and indexes of their stability more detail, and on the other hand, to estimate a spatial pattern of current fields reflecting the hydrodynamic impact on environmental conditions of hydrobionts.
The anomaly strong tidal currents that can reach 100 cm/s are the main feature of hydrodynamic processes on the northeastern shelf of Sakhalin Island (in particular, in the area between 51˚ and 54˚ N) (Rabinovich, Zhukov, 1984; Tambovsky et al, 2001). Diurnal shelf waves are a cause of this phenomenon. They induce very strong currents near the coast, which velocities are decreasing rapidly with moving away from the shore. It permits to estimate the vertical limits of a wave influence. One more reason that monotony bottom which presented by a sands is permit to leave out from analysis the bottom factor.
So, we have investigated the influence of diurnal currents and wave on the spatial distribution of benthic communities and their stability indexes, and some obtained results are discussed in the present paper.

## MATERIALS AND METHODS

The materials for this paper were obtained during the complex ecological surveys in the northeastern part of Sakhalin shelf of the Okhotsk Sea. The littoral benthic samples have been collected during the on-shore survey by the staff of SakhNIRO in August 2002 and in June 2004. Dredge stations in the upper sublittoral zone have been executed during the survey at Diver boat “Aquanavt” by the staff of SakhNIRO in August 2002 and at motor boat in June 2004. Dredge

stations in the middle and lower sublittoral zones have been executed during the survey at R/V "Pavel Gordienko" by the staff of SakhNIRO in summer 2000-2002 (Fig. 1).
Benthos samples from the littoral were collected by the Levanidov benthometr (0,16 $m^2$): two samples at a station. Benthos samples from the upper sublittoral were collected using a diver method by the diver grab (0,025 $m^2$): three samples at a station. Benthos samples from the middle and lower sublittoral zones were collected by the Van-Veen grab (0,2 $m^2$): one sample at a station in 2000-2001 and tree samples at a station in 2002.
The recent structural characteristics were used in the current work: Simpson index of predominance (Gegraphy and monitoring of biodiversity, 2002) and ABS-method (Abundance Biomass Comparison) (Warwick, 1986; Warwick et all., 1987; Averintcev & Zhukov, 1987, 1992).
Simpson index of predominance by quantity:

$$I_N = \sum (\frac{n_i}{N})^2 ,$$

where $n_i$ is a quantity of the species *i*, *N* is a total quantity.
Simpson index of predominance by biomass:

$$I_B = \sum (\frac{b_i}{B})^2 ,$$

where $b_i$ is a biomass of the species *i*, *B* is a total biomass.
ABS-method use in a transcription of Mere & Dereu (cit. at Gegraphy and monitoring of biodiversity, 2002) and modified by author (Labay & Shevchenko, 2004):

$$I_{ABC} = \frac{\sum_{1}^{1W} Bc_i - \sum_{1}^{W} Nc_i}{W * 1000} ,$$

where $Bc_i$ is a cumulative biomass of the species *i* ($Bc_1$ is a comparative biomass of the dominating species (%);$Bc_2$ is a sum of comparative biomasses of the dominating species and the next by biomass species and so on), $Nc_i$ is a cumulative number of the species *i*.
Positive meanings of $I_{ABC}$ correspond to communities at the latest stages of succession (stable), negative meanings of $I_{ABC}$ correspond to communities at the early stages of succession (unstable), meanings similar to 0 correspond to communities at the state of the unstable balance.

This index permits to compare communities and areas of water. The cartographic representation is effort an opportunity to mark“crisis” areas for some reason.

Current data that were measured on the northeastern shelf of Sakhalin Island during 1987-1991 and 1996-1998 were used to describe a spatial structure of tides. A total of 30 moorings carrying out direct current measurements in the upper layer (0-10 m) with duration not less than 2 weeks were used for analysis.

In order to determine parameters of tidal currents, a least square method was used for eastward and northward components of initial vectors. Amplitudes and phases of 10 main tidal waves were calculated – for 6 diurnal (2Q1, Q1, O1, HI1, P1, K1) and 4 semidiurnal harmonics.

The main diurnal harmonics O1 and K1 determine a picture of tidal currents on the northeastern shelf of Sakhalin Island; amplitudes of their northward (longshore) components are about 45-50 cm/s near Piltun Lagoon and about 15-20 cm/s near Lunsky Lagoon. For comparison, amplitudes of the main semidiurnal harmonic $M_2$ are about 5 cm/s.

The orbital and linear velocity calculation was used about the easy trochoidal wave theory (Zhukov, 1976).

$$v=wr,$$

where $v$ is a linear velocity of an orbital particle movement ; $w$ is an angular velocity of orbital movement of a particles; $r$ is a orbital radius of a particle:

$$h=2\,r,$$

$$r=r_o e^{-2\pi z/\lambda},$$

where $r_o$ is orbital radius of a particle by a surface: $r_o = h/2$; $z$ is a vertical distance down from a water surface (in our case – the depth $H$); $\lambda$ is a wave-length.

$$w=\sqrt{2\pi g/\lambda},$$

where $g$ is a gravitational acceleration.

$$\lambda/\lambda_o=\sqrt{H/H_o}$$

$$h^4/h_o^4=H_o/H$$

For a study correlation analysis between diurnal currents and results of benthic samples, the amplitudes of O1 and K1 northward components were extrapolated on the whole study area using a kriging procedure of Microsoft Surfer software (Tambovsky et al, 2001). This allowed to obtain the O1 and K1 amplitudes in the sites of benthic samples and to use them for estimating the influence of diurnal currents on the spatial distribution of benthic communities and their stability indexes. Analyses of diurnal currents and orbital particles velocity influence were used by a Microsoft Excel mathematical apparatus.

## RESULTS

To the certain combination of environmental conditions (including hydrodynamical influences) there correspond concrete macrobenthos communities. Hence, change of bottom communities reflects changes of external factors. However, on change of bottom communities it is impossible to define what of factors has caused these changes. Therefore the problem put before us is solved in two stages. On the first we describe the basic macrobenthos communities and their vertical borders. On the second we analyze correlation between $I_{ABC}$ and various types of hydrodynamical influence. Connection of both stages allows to understand what changes in bottom communities are caused by the certain factors and to determine borders of their influence.

### 1)The basic macrobenthic communities and their variability in the study area

Descriptions of the basic macrobenthos communities have been made by authors earlier (Labay, Shevchenko, 2004; Labay, 2005) therefore we shall result their brief descriptions and borders of distribution.

In a coast (littoral and upper sublittoral) 9 basic bottom communities are allocated.

The community of *Archaeomysis grebnitsky* was located near the shore line. The dominating species account 54% from a total biomass.

The community of *Eogammarus schmidti* is close by previous and was located near the shore line. The dominating species account 79% from a total biomass.

The community of *Pontoporeia affinis* + *Synidotea cinerea* was located at the Piltun-Astoch shoal at the depth 5-10 m. The dominating species account 69% & 14% from a total biomass accordingly.

The community of *Synidotea cinerea* was located north and south of previous at the depth 5-10 m. The dominating species account 60% from a total biomass.

The community of *Diastylopsis dawsoni* was located by separate parts at the depth 10-15 m. The dominating species account 90% from a total biomass.

The community of *Saduria entomon* was located by separate parts too at the depth 20-25 m. The dominating species account 94% from a total biomass.

Vagrant crustacean were prevailed in the upper listed communities.

The prepotent species in others two communities are present by surface-burer bivalvia.

The community of *Siliqua alta + Megangulus luteus* was located at the depth interval 5-15 m. The dominating species account 63% & 19% from a total biomass accordingly. The dominant of a first species give place to second with an increasing of a depth.

The community of *Megangulus luteus* was located at the same depth interval.

The flat sea-urchins which prevail in the community of *Echinarachnius parma* are at the bottom surfer. The dominating species account 79% from a total biomass.

From the above description one can see that vagile crustacea prevail in the inshore and shallow waters. Surface-burer bivalvia give place previous with an increasing of a depth. The sand dollars zone is situated deeply.

Descriptions of middle sublitoral macrobenthos communities are presented by average separately for Piltun-Astoch, Chaivo-Nyiskiy and Lunskiy water areas.

Piltun-Astoch section. The community with the dominating sand dollar *Echinarachnius parma* is observed in the middle and lower sublittoral zones from 15-20 m to 90-95 m. The groundphagan holoturians are dominated at the large depth on sandy-aleurite and aleurite deposits.

Chaivo-Nyiskiy section. The isopod *Saduria entomon* (91,1%) dominated at a depth up to 25 m. The amphipod *Ampelisca* s. str. (32,6-54,8%) forms the base of the macrobenthic biomass at a depth of 30-45 m, though in individual time periods the active migrant cumacean *Diastylis bidentata* (29-43%) prevails by biomass. The standard community of sand dollar *Echinarachnius parma* is observed deeper.

Lunskiy section. The replacement of benthic communities by depths is similar to that of Piltun-Astoch section: *Echinarachnius parma* dominated at a depth more than 15 м. Sipunculids prevail at a depth more than 95-100 m.

A trophic group of gathering detritophagans occurs in the inshore and shallow waters. The large organic remains washed down by sea waves from a shore are the food for this trophic group. A trophic group of movable sestonophagans correspond to the communities of *Echinarachnius parma*, *Ampelisca* s. str., and *Diastylis bidentata*. They are observed deeper where the impact of waves is very small and the tidal current is transporting fine-dyspersated organic substances along the bottom. Groundphagans predominate at the shelf border where the nearbottom hydrodynamic is very weak.

**2) The correlation between $I_{ABC}$ and various types of hydrodynamical influence**

The average wave height is change from 1.2 m (in latitude 52º47´ North) to 1 m (in latitude 50º34´ North). Wave period to average is 4.65 sec.

Linear velocities of orbital particles near the bottom were calculated about combined equations of trochoidal wave theory. Total appropriateness of evolution linear velocity of orbital particles with a depth has the exponential character.

Examine a question the evolution $I_{ABC}$ with linear velocity of orbital particles near the bottom. $I_{ABC}$ and data scattering are decrease with increasing of a linear velocity. Thus wave is a determinative factor for the bottom community's stability with decreasing of a depth and increasing of a linear velocity of orbital particles near the bottom. Obvious logarithmic dependence of a bottom community's stability from a linear velocity is observed in the data smoothing throughout the depth interval 5 m (from shore line to depth 25 m). The equation is presents at the graph (Fig. 2).

The next step we determined the linear velocity of an orbital particles near the bottom and depth as the wave influence will prevail above the tidal currents influence. We observe variability of cumulative $I_{ABC}$ with the linear velocity from depth to shore line (the direction was chose by a predominance of a tidal constituent above a wave constituent at the depth). Results of analysis are presents at the figure 3. The considerable decreasing of a cumulative correlation is observe at the depth approximately 15 m. This depth is a breaking point at this wave influence is begun to prevail above the tidal currents influence. The linear velocity of orbital particles near the bottom at the depth is a 0.045 m/sec.

The flat sea-urchins lying on a bottom are prevailing in the benthos community at the depth more than 15 m where a tidal current without vertical constituent are prevail. Vertical burring bivalvia *Siliqua alta* & *Megangulus luteus* are prevail at the smaller depth where increasing vertical and horizontal water oscillations. Long shell is permitting them to consolidate one's grip in immovable lower layer of a ground. Thickness of mobile layer of a ground is increase with decreasing of a depth and increasing of wave oscillations. It makes impossible a being of slow-moving burring forms. Nektobenthic provisionally burring crustacea: *Diastylopsis dawsoni*, *Pontoporeia affinis*, *Synidotea cinerea*, *Eogammarus schmidti* or active swimmer myzids *Archaeomysis grebnitsky* are become a mass in the zone of an active choppiness.

The correlation $I_{ABC}$ to the base components of the tidal current waves *K1* and *Q1* showed a significant negative dependence at the Piltun-Astoch section, and a weakly expressed negative dependence at Chaivo-Nyiskiy and Lunskiy sections (Tab. 1). This fact is explained by the strongly pronounced amplitude of the tidal wave at the Piltun-Astoch section (average 74,3 cm) compared to those at Chaivo-Nyiskiy (64,3 cm) and Lunskiy sections (34,6). In addition, perhaps, the wave dynamics is weakening from south to north. However, this correlation does not give an answer to the questions.

Table 1. Correlation $I_{ABC}$ to the base components of the tidal current

| Section | Components of the tidal current | |
|---|---|---|
| | *K1* | *Q1* |
| Piltun-Astoch | -0,81739 | -0,77419 |
| Chaivo-Nyiskiy | -0,3198 | 0,11971 |
| Lunskiy | -0,33832 | -0,30495 |

At the next step we compared variabilities of the cumulative correlation $I_{ABC}$ to the base components of the tidal current waves *K1* and *Q1* from large depths to small ones (a direction of calculations was determined by dominating the tidal component in the middle and lower sublittoral zones). Results of the analysis are presented in figures 4-6.

The tidal current determines structural indices and stability of macrobenthic communities at a depth of 30-90 m by all research sections. The distinct negative correlation (-0,85 - -1) is observed at this range of depths: with the increase in the tidal wave amplitude a structural stability of macrobenthic communities decreases.

The impact of the tidal current on the community's structure decreases at a depth of less than 30 m. Perhaps, this is connected with the influence of the wave dynamics. The impact of the tidal current is absent at a depth of more than 90 m. Evidently, this is an effect of tidal current decreasing at the shelf border.

The depth range of the stable negative correlation corresponds to the trophic group of movable sestonophagans and macrobenthic communities of *Echinarachnius parma*, *Ampelisca* s. str., and *Diastylis bidentata*.

## CONCLUSION

Choppiness has not an influence upon determinacy of the bottom communities consequently at the shelf of Okhotsk Sea near northeastern Sakhalin. It have an influence on living forms of bottom hydrobionts and bottom community's stability. Defined influence of waves is noticed from 15 m depth by linear velocity of orbital particles near the bottom is 0.045 m/sec.

Tidal currents of the 24-hour range were ascertained to be the main parameter of marine environment, which determines a structural stability of macrobenthic communities on the northeastern Sakhalin shelf. Tidal waves in this region have the anomalous large amplitude caused by the shelf waves contribution. The calculated negative correlation is significant at the depth range of 30-90 m. The impact of the tidal current is absent at a depth more than 90 m.

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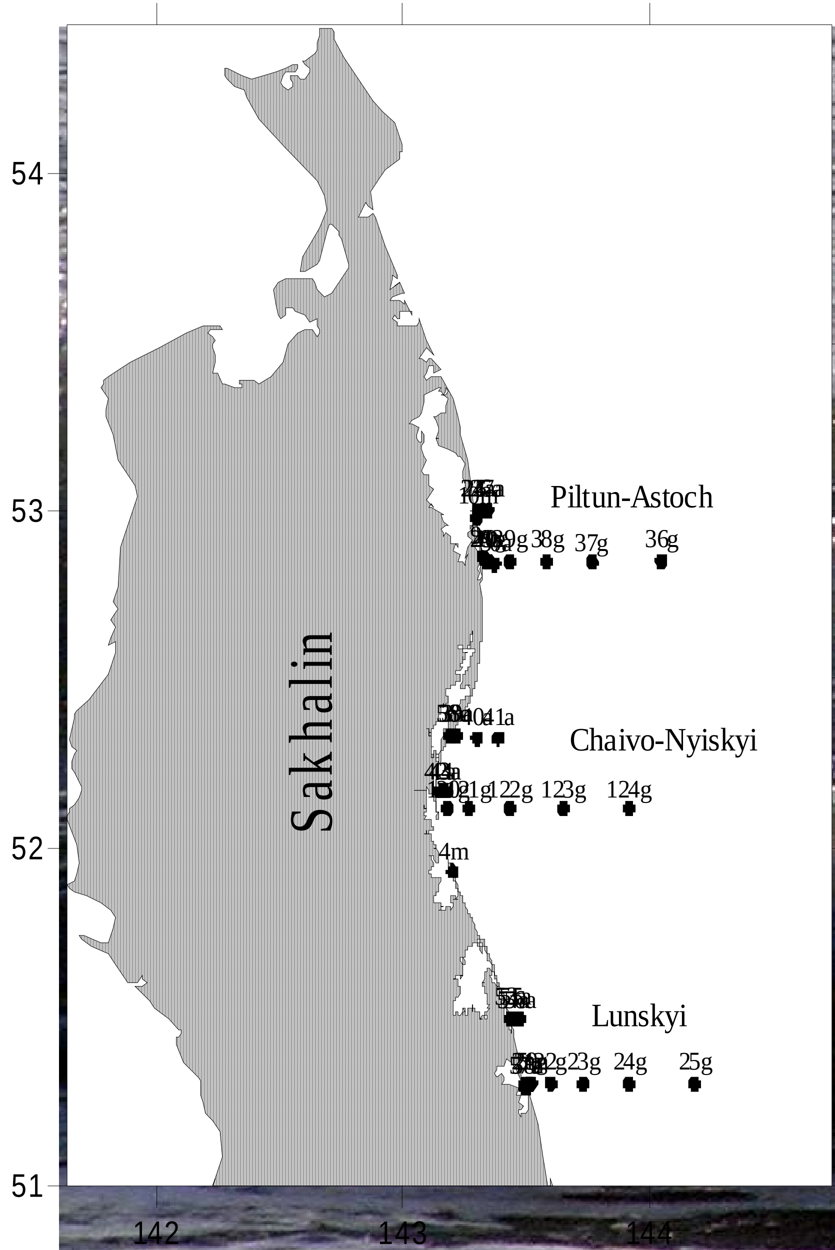



**Fig. 1. Location of benthic sampling sites in a study region**

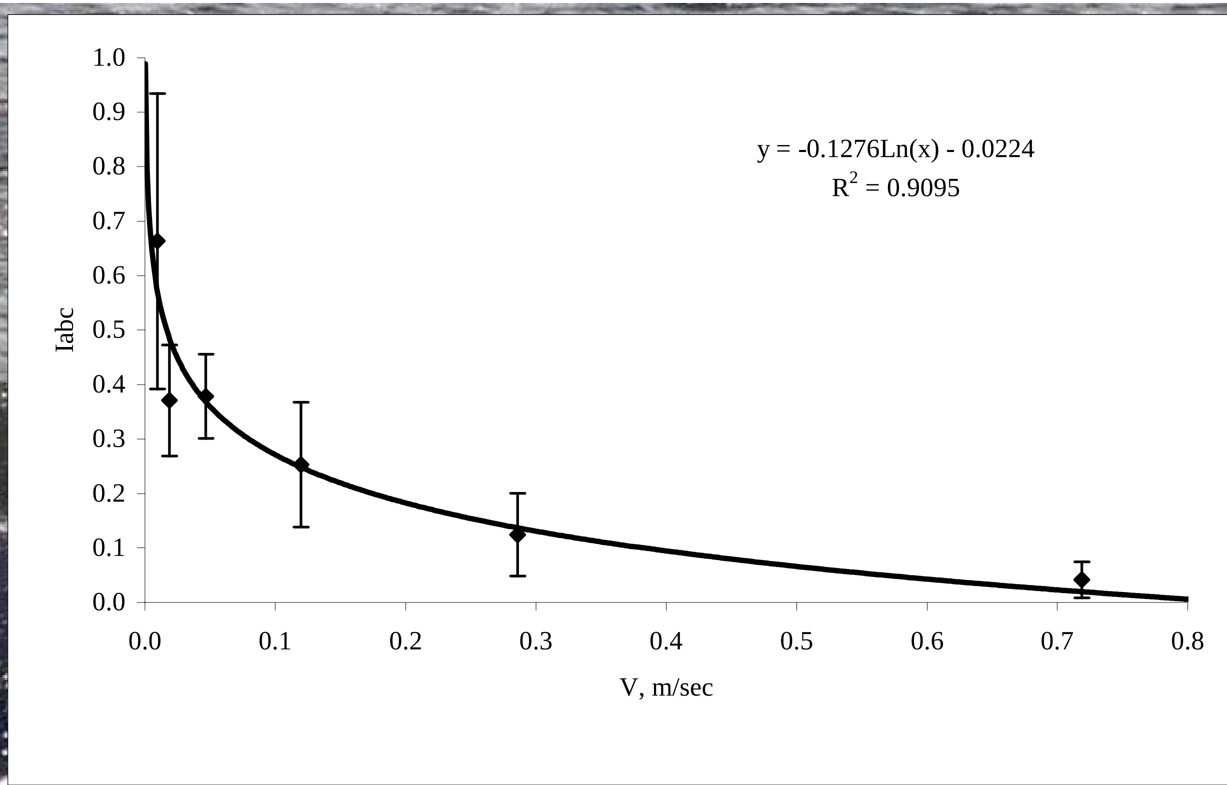
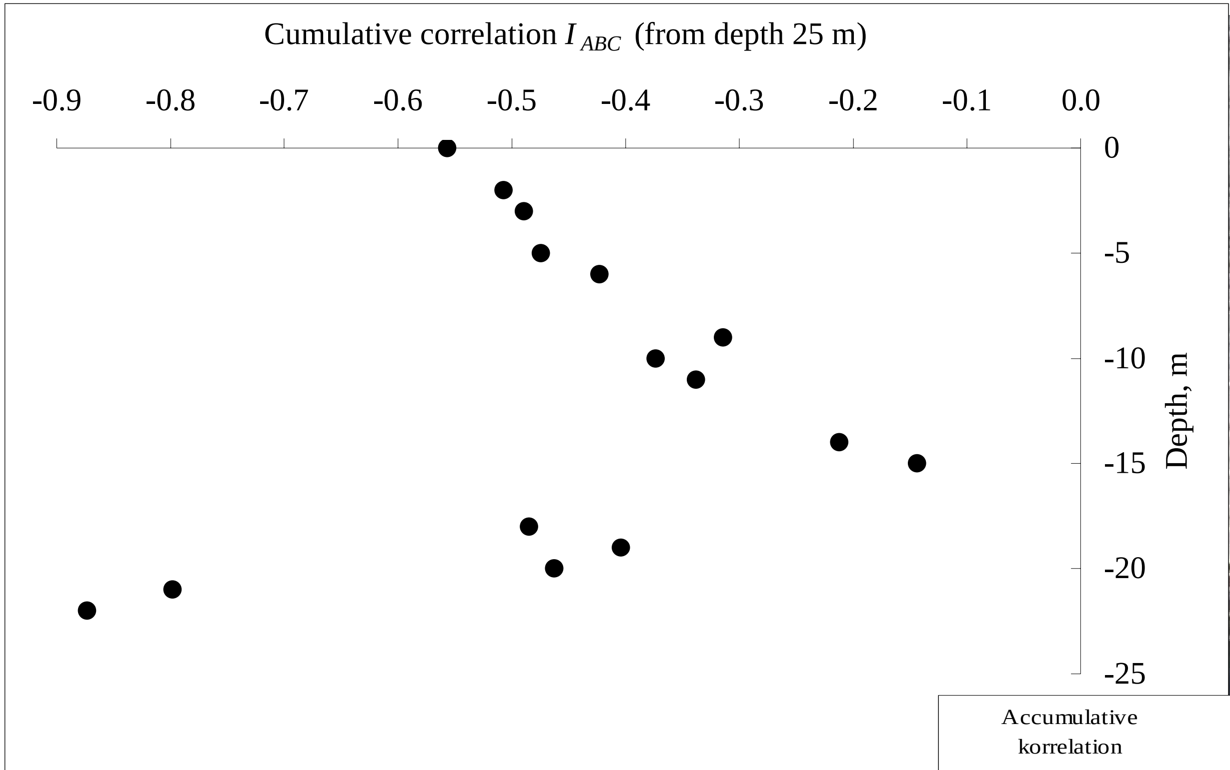



**Fig. 2. Trend of evolution $I_{ABC}$ with linear velocity of orbital particles near the bottom**



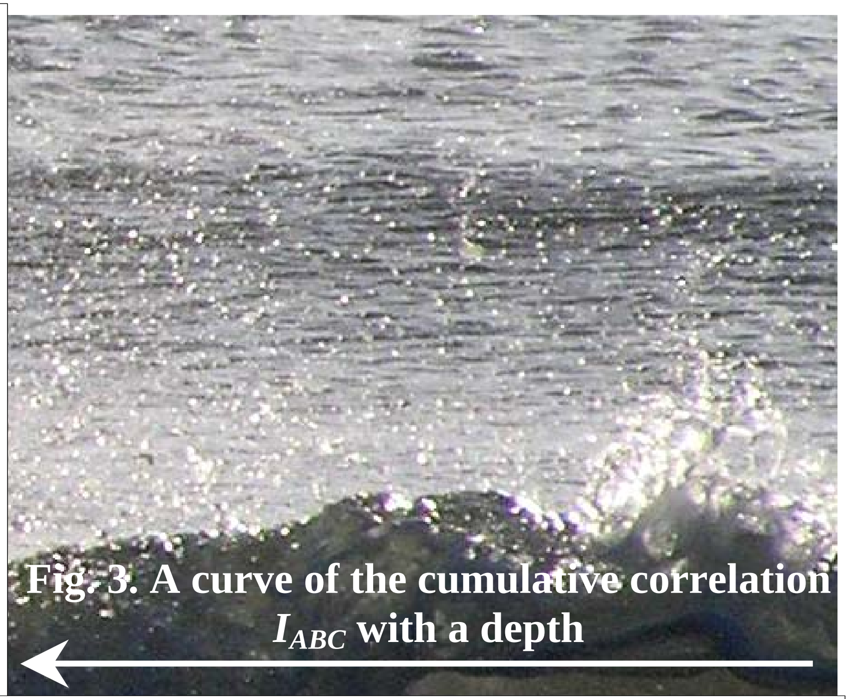
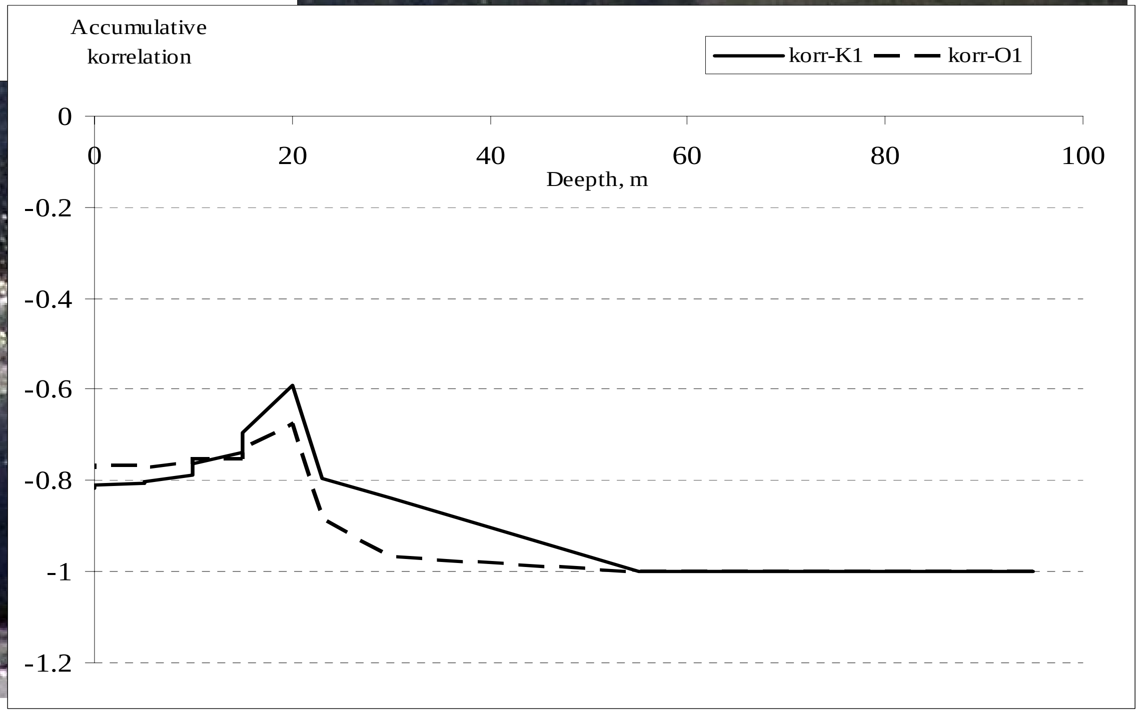



Fig. 3. A curve of the cumulative correlation $I_{ABC}$ with a depth



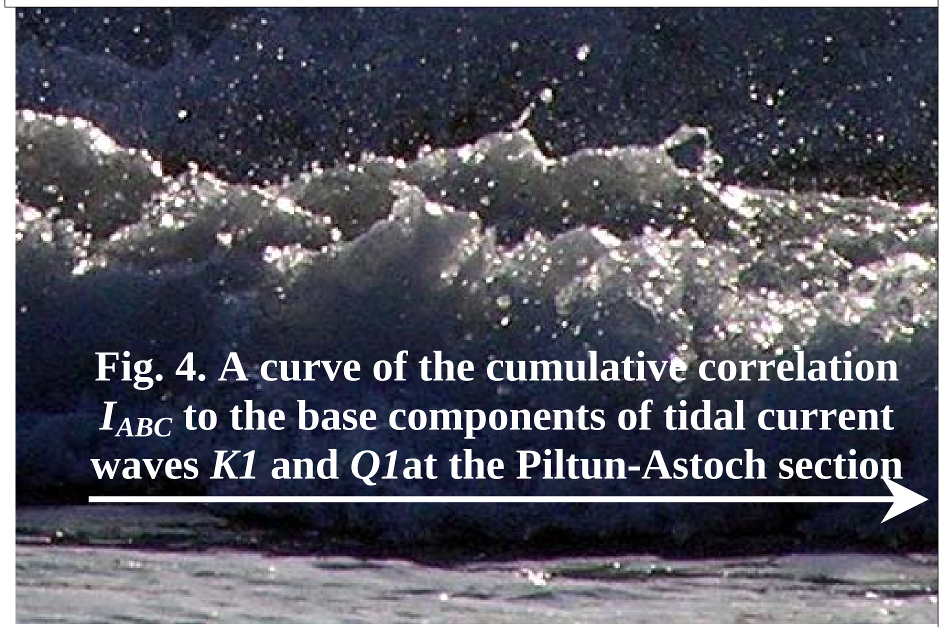
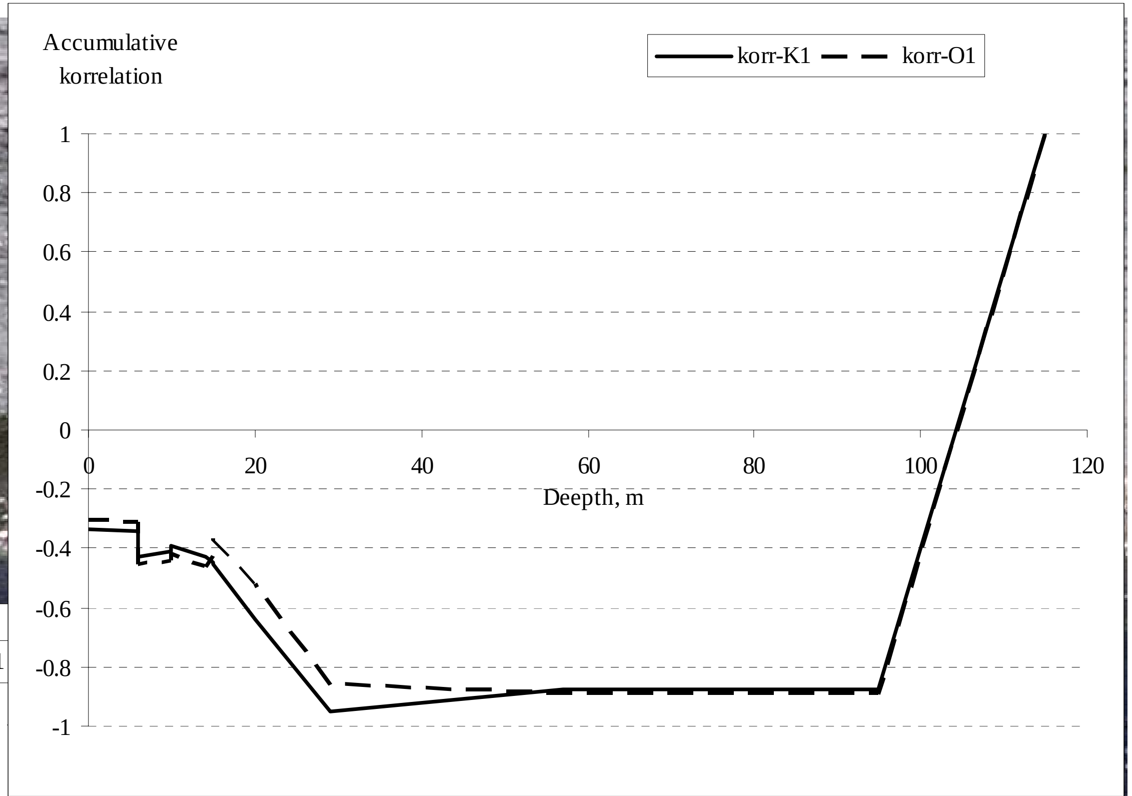



Fig. 4. A curve of the cumulative correlation $I_{ABC}$ to the base components of tidal current waves *K1* and *Q1*at the Piltun-Astoch section

**Fig. 6. A curve of the cumulative correlation $I_{ABC}$ to the base components of tidal current waves *K1* and *Q1*at the Lunskiy section**



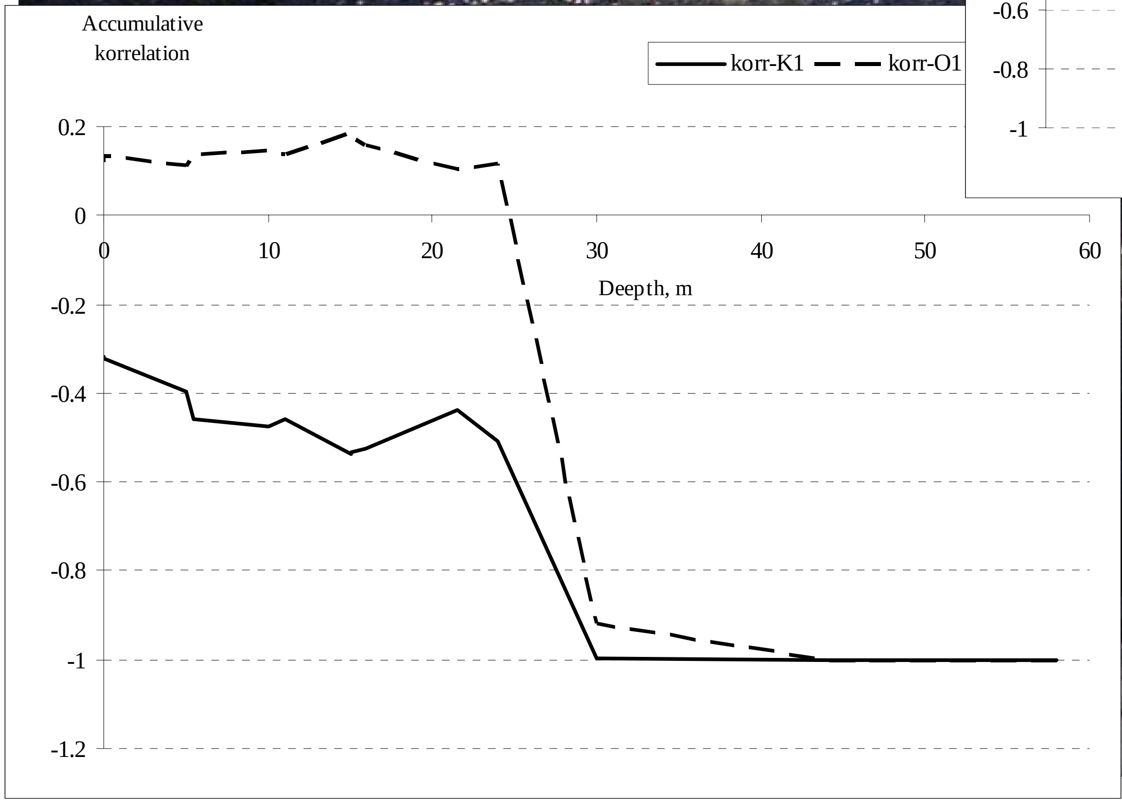




**Fig. 5. A curve of the cumulative correlation $I_{ABC}$ to the base components of tidal current waves *K1* and *Q1*at the Chaivo-Nyiskiy section**