# BENTHIC RESEARCH
# IN THE FEEDING AREA OF THE WESTERN GRAY WHALE IN 2001

**FINAL REPORT**

Contract **Y 00251 Benthic Study for Whale Environmental Study**

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Feeding gray whale. Odoptu Bay area, Depth 9 m, August 2001, Photo by V. Fadeev.

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# INTRODUCTION

General information. It is known, that two independent populations of gray whales (*Eschrichtius robustus*) dwell in the Pacific ocean [81]: the eastern or California-Chukchi population, which number reach now up to 25 thousand individuals, and the West-Pacific or Okhotsk-Korean population numbering about 100 individuals.

After cessation of whaling in 40-s the eastern population of gray whale has completely recovered its number. In spite of the fact that increase of mortality, low birth rate, and impairment of physical condition of some individuals were recorded in California-Chukchi population 1999, it is at rather stable state thanks to its high number [82].

In contrast to the eastern population, the Okhotsk-Korean population of gray whale never was numerous, and, according to expert assessment, its peak number did not exceed 2-2,5 thousand individuals. The long-term whaling has put it on brink of practical extinction, and only in the beginning of 70-s the gray whales started to occur at north-east Sakhalin [83]. Nevertheless, the 40-year ban of whaling (since 60-s) has not resulted a significant recovery of the population. By optimistic assessments its number varies from 100 up to 250 individuals, however, the most of researches assessed its number as no more than 100 individuals [20, 26, 74, 78, 79, 84]. Assumptions were put that less than 50 individuals enable to reproduce remained [74]. Low rates of reproduction and low number of aggregations of the Okchotsk-Korean population of gray whale have stipulated inclusion of this species to the I category of the International List of Protected Species (IUCN) and to the Red Data Book of Russia [20, 84].

Activation of economics on the shelf of East Sakhalin in middle of 90-s and development of marine oil-and-gas industry have put task of comprehensive research of the West-Pacific population of gray whale for assessments of possible anthropogenic influence and elaboration of approaches to minimization of effect of negative factors [84, 85]. In particular, developing "Joint Statement on measures to ensure conservation of biological diversity near Sakhalin Island" of the Gore-Chernomyrdin Commission from February 7, 1997, in connection with development of oil-and-gas deposits at the island shelf, the Russian and American parties have developed the "Program of monitoring and study of the Okhotsk-Korean population of gray whales", authorized by Russian Goskomekologia and US Fish and Wildlife Service [74]. It assumed implementation of comprehensive research of the Okhotsk-Korean population during the feeding season at the east Sakhalin area:

- the number and distribution of whales,
- acoustic research,
- study of benthos as basic component in nutrition of gray whales.

The extensive material on number, spatial distribution and behavior of gray whales in costal zone of the north-east Sakhalin based on application of various techniques (air counts, observations from vessels, visual counts from the shore, photoidentification of individuals) [20, 21, 26, 74-79] was accumulated for several years In particular contributors recorded:

- high level of annual return of most of the whales for feeding in inshore waters of the north-east Sakhalin and their connection to rather local area of coast;
- the feeding area (maximum occurrences of feeding whales) comprises area, adjoining to the Piltun Bay (Appendix A, B; Fig. 39,B), feeding whales were recorded only sporadically to the south and to the north of that area;
- most of the feeding whales were recorded at depth up to 15-20 m, at greater depth the whales were recorded in isolated instances.

The feeding whales were observed within the distance up to 5 km from coast line in more than 95 % instances; at the distance exceeding 15 km from the shore the whales were observed in isolated instances.

1999-2000 researches recorded distinct changes in distribution of feeding whales (they began to penetrate more actively from traditional feeding area to the more northern sites) and in their physical condition (occurrence of whales with signs of dystrophy) [74, 84]. Most frequently as the probable causes were considered the following [84]:

- arise of diseases,
- sharp changes in metabolism under stress entailed by long-term effect of anthropogenic factors, such as underwater noise,
- decrease of feeding base resulted from natural or anthropogenic factors.

The leave of whales to more northern areas could be explained by "*natural fluctuations of distribution and availability of food. However it is possible, that these changes were caused by influence of industrial activity on biomass of benthos in the region, or by the leave of whales from areas where the strong anthropogenic noise was observed, i.e. from the south of their basic feeding area*" [84].

As we see, one of the causes of unfavorable changes implies changes in benthos, i.e. in the feeding base of West-Pacific gray whale.

The objective of the present research was study of quantitative distribution and condition of benthos in feeding area of gray whales and adjoining regions. The work was carried out within framework of "Program of monitoring and study of the Okhotsk-Korean population of gray whales", supported by Sakhalin Energy Investment Company Ltd. and Exxon Neftegas Ltd.

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1 Taking into account, that the data on distribution of a benthos in area of north-east Sakhalin and to feeding of a California-Chukchi population of a gray whale are in details analyzed and generalized in the record: *Kusakin O.G., Sobolevsky E.I., Blokhin S.A. 2001. The literary review benthic works on a shelf of north-east Sakhalin// Draft report IMB FEBRAS the Russian Academy of Science and TINRO. Vladivostok. 89 p.* We did not put in the given section a task of the review of the literature on these questions. The literary data will be attracted with us at discussion of the received results and in other necessary cases. The record [64] is accessible on a site: www.sakhalinenergy.com

Research tasks. The present report is compiled by results of SCUBA benthos survey conducted August 2001 by expedition of the Institute Marin Biology FEB RAS against the contract **Y 00251 Benthic Study for Whale Environmental Study.**

Research tasks were determined by requirements specification to the contract developed by experts of Sakhalin Energy Investment Company Ltd. and Exxon Neftegas Ltd.:

- to conduct benthos survey at 10 transects over the depth ranges from 5 up to 30 m with application of diving methods and dredge sampling. Transects should cover traditional feeding area of gray whales and areas located to the south and to the north from the feeding area,
- in the result analysis of macrobenthic samples the information on species composition and quantitative abundance (population density, biomass) of individual taxonomic groups and common species of benthos should be obtained; to assess structure and abundance of macrobenthos in the feeding area of whales and in areas beyond of the feeing zone,
- to study taxonomic structure of meiobenthos, to determine quantitative abundance of larvae of macrobenthic animals in meiobenthos, to assess the character of recruitment of communities of macrobenthos by larvae,
- to compare results of 2001 survey with data of works of 1992 expedition, to assess long-term variation of composition and of quantitative parameters of macrobenthos,
- to obtain data on granulometric structure (size distribution) of sediments and on content of oil carbohydrates and of 10 heavy metals in the sediments.

The planned pattern of allocation of diving transects was based on long-term data on distribution of gray whales in the area (Appendix A, B). In the area of intensive feeding and of the greatest number of gray whales 4 sections (P1-P4, Fig. 1) were scheduled and fulfilled. To the north from Piltun Bay 3 sections (N0-N2) were conducted. To the north of section N2 the gray whales were not registered. 3 sections were conducted to the south from Piltun Bay. Feeding gray whales were not recorded in area of sections S2-S0. Position of 4 sections (S0, P4, N2, N0) coincided with position of sections conducted 1992.

Thus, the surveyed area was located from Nyiskiy Bay at the south up to the Tront Bay at the north, completely comprising the feeding area of gray whale.

# MATERIAL AND METHODS

## 1. Material and methods of field work

Organization of work. The work related with SCUBA sampling of benthos in habitation and feeding areas of gray whale was performed by expedition group of the Institute of Marine Biology (IMB) within framework of the expedition on board of R/V "Okean" at August 2001. The expedition group consisted of 7 persons (professional divers - 2, diving hydrobiologists – 3, research officer – 1, technician – 1, SCUBA diving physiology physician – 1). The scheme of sections is shown at Fig. 1. There were 10 sections conducted in research area (4 sections correspond to sections conducted at 1992).

Terms of work. The SCUBA diving was conducted from August, 3 till August, 6 and from August, 12 till August, 20 (14 work days). The break in SCUBA work was caused by unfavorable weather conditions. Diving was performed two times a day.

Technique of work. The technique of field sampling corresponded to the methods suggested by IMB in the Technical proposals (TECHNICAL PROPOSAL, Invitation to Tender) and recommended by the Company (Letter of Intent to Award). The main methods to undertaking of underwater biological work is described earlier [1,2].

Diving activities were implemented from "Zodiac" motorboat and from specialized diving boat. The position of stations was determined by satellite navigator GPS, the depth – by echo-sounder HUMMINBIRD WIDE 150 SXM. Surface and bottom temperature, and water salinity were recorded at station by water probe MultiLine P4. Stations were allocated at standard depths: 5, 10, 15, 20, 25 and 30 m. For macrobenthos study diver took 3 assays at station by the diver tooth bottom sampler♣ (the area of capture of 0.025 $m^2$; Photo 1). Large forms of epibenthos were sampled from 5 frames with area 1 $m^2$. To study a structure and quantity of meiobenthos (animals lesser than 1 mm) 3 assays were taken by pipe sampler with area 10 $sm^2$. The meiobenthic samples were taken from 5 sections at depths 5 and 15м. All macrobenthic samples were flushed on the flushing rig (bottom sieve – 0.5 mm) and were fixed by 4 % formalin. Then all samples have been transferred into 75 % ethanol. Assays for analysis of granulometric structure (size distribution) of ground, of concentration of heavy metals and carbohydrate content in surface layer of sediment were taken by diver with teflon pipe sampler. Assays were packed into plastic packets and placed into cold storage chamber up to their transfer to the laboratory. In condition of strong bottom currents at some stations (at depths 30 м) the sampling was conducted from board of diving boat with heavy duty version of Peterson

♣ The diver's bottom sampler had a bag made of nylon with mesh size 0.1 mm, that beyond sediment sampling, it could function as epibenthos net with capture area 0.025 $m^2$ for counting of mobile forms of epibenthos (*amphipods, isopods*). Design of the bottom sampler enable its deepen even in dense sand bottoms to the depth 20-25 cm (**Photo 1**). The moments of work to expeditions see on **Photo C1 – C10** (Appendix C).


Photo 1. The diver’s bottom sampler

(capture area of 0.025 $m^2$, bag – nylon gauze with mesh size 0.1 mm)

1 – the general view, 2 - the bottom sampler in disclosed state, 3 – in the closed state, 4 – cutting blade; A – sampling, B – closure of the sampler before lifting to the surface

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dredge with capture area 0.1 m, instead of SCUBA sampling. To assess catching capacity of used instruments a simultaneous sampling of 6 assays was conducted with 3 diver bottom samplers and with 3 Petersen dredges at 4 stations.

The characteristics of the sampled material. The volume of sampled material is presented in the sampling registry (Appendix 1). There were performed during the field research: 10 Sections, 60, stations.

Number of bioassays: macrobenthos – 192, meiobenthos – 30,

Measurements: salinity – 120, temperature – 120.

Number of ground samples for granulometric analysis – 60,

For heavy metal content – 30, for oil carbohydrate content – 30.

Each assay after flashing of ground was photographed by digital camera – 192 snapshots.

The pattern of sections, their names and division of survey area to regions is displayed at Fig. 1.

## 2. Laboratory analysis of material

### 2.1. Analysis of granulometric structure of bottom sediments

Granulometric structure of bottom deposits was analyzed in the *Basic Research Laboratory of Shelf of the Far East State University* by two standard Russian techniques: the sieve and hydrometric ones. During analysis the percentage of the following ground size fractions was determined: more than 10; 10-5; 5-2; 2-1; 1-0.5; 0.5-0.25; 0.25-0.1; 0.1-0.05; 0.05-0.01; 0.01-0.005 and less than 0.005 mm. Humidity (W) and specific weight of ground assay were preliminary determined by standard Russian technique. Then ground assay was dried up and sifted through sieve series with aperture sizes 10, 5, 2, 1 mm. Ground fractions that retained on sieves and passed through the sieve with I mm apertures were weighed. The sediments that passed through the sieve with 1 mm aperture, poured in preliminary weighted porcelain cup and weighed. The ground assay was poured into retort of 1000 $sm^3$ capacity and filled with distilled water (about 300 ml). The ground filled with water was maintained for 1 day. After the day exposition 1 ml of 25 % ammonia solution was added to assay, the retort boiled during 1 hour and then chilled up to room temperature. The obtained suspension was poured into glass cylinder of 1l capacity through the sieve of 0.1 mm aperture.

Ground particles that retained on the sieve with 0.1 mm apertures were dried up, sifted through sieve series with apertures 0.5; 0.25; 0.1 mm and then were weighed separately. The suspension was stirring up during 1 min up to full roiling of upsetting from bottom of the cylinder. In 1 minute after termination of stirring the densimeter sunk and its readings were

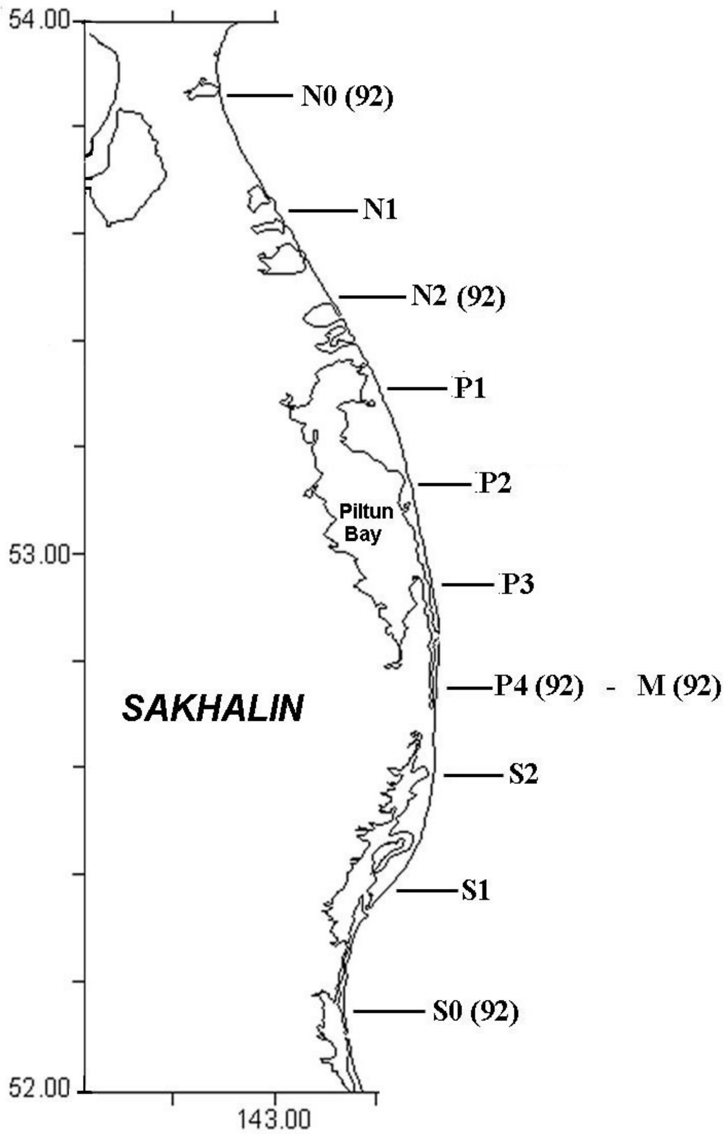



Fig. 1. The pattern of allocation of sections of 2001 and 1992.
(92) - position of 1992 sections

| Section Location | Section number | Region |
|---|---|---|
| 1. Nyiskiy Bay | S0 | **South** |
| 2. South part of Chaivo Bay | S1 | |
| 3. North part of Chaivo Bay | S2 | |
| 4. South part of Piltun Bay | P4 | **Middle** |
| 5. Beacon area of Piltun Bay | P3 | |
| 6. Central part of Piltun Bay | P2 | |
| 7. North part of Piltun Bay | P1 | |
| 8. Odoptu Bay | N2 | **North** |
| 9. Urkt Bay | N1 | |
| 10. Tront Bay | N0 | |

determined fraction less than 0.05 mm, after 30 minutes - for the fraction less than 0.01 mm, and in 3 hours - for the fraction less than 0.005 mm.

Types of grounds were defined basing on Grading of Sediments by Mechanical Composition [3,4].

Table 1

Sediment types used in determination of grain size composition [3,4]

| Groups of sediments | Types of sediments | Designation in the text | The size of prevailing particles, mm | Md, mm |
|---|---|---|---|---|
| Coarse deposits (Psephites) | Pebble | **Pb** | > 10 | |
| Coarse deposits (Psephites) | Gravel<br>large<br>medium<br>small | <br>**Grl**<br>**Grm**<br>**Grs** | <br>10-5<br>5-2<br>2-1 | |
| Sandy deposites (Psammites) | Sands<br>large<br>medium<br>small = fine | <br>**Sl**<br>**Sm**<br>**Ss** | <br>1-0.5<br>0.5-0.25<br>0.25-0.1 | <br>1-0.5<br>0.5-0.25<br>0.25-0.1 |
| Silt (Aleurites) | Aleurites large<br>Fine aleurite silts | **Al**<br>**As** | 0.1-0.05<br>0.05-0.01 | 0.1-0.05<br>0.05-0.01 |
| Clay (Pelites) | Pelite large | **Pitch** | <0.01 | 0.01-0.005 |

## 2.2. The analysis of content of heavy metals, carbohydrates, and of organochlorine pesticides in bottom sediments

The analysis of content of heavy metals, carbohydrates and pesticides in bottom sediments was conducted in special laboratories (Laboratory of Applied Ecology and Toxicology of the TINRO-CENTRE, Laboratory of Monitoring of Pollution of Sea Waters of the Primorsky Center for Monitoring of Environmental Pollution).

Heavy metals. Measurement of concentrations of iron, zinc, chromium, copper, lead was conducted with the "Nippon Jarrell Ash" atomic absorption spectrophotometer, model AA-855. As Single slot burner as sprayer and acetylene + air – as gas mixture were used. The background was corrected by deuterium burner. Sensitivity of determination in μg/ml was 2 for iron, 0.02 for zinc, 0.005 for copper, 0.02 for chromium. Concentrations of aluminium and barium were measured with gas mixture acetylene+nitrous oxide. Sensitivity of determination was 2 μg/ml for aluminium and 1 μg/ml for barium. Concentrations of cadmium, lead and arsenic were determined with "Hitachi" atomic absorption spectrophotometer, model 170-70, with graphitic cuvette as the sprayer. The background was corrected by application of Zeeman effect. Sensitivity of determination (μg/ml) was – 0.0002 for cadmium, 0.005 for lead; 0.02 for arsenic. Concentration of mercury was determined by the flameless atomic absorption method by "Hiranuma" microanalyzer Hg-1. Sensitivity of determination was 0.0001 μg/ml. Preparation of assays for atomic and absorption analyses was conducted by techniques adopted in Russia, in particular, developed by Azov Fishery Research Institute (RD-15-229-91 – Cd; RD-15-241-91 – Cu; RD-15-227-91 – As; RD-15-231-91 – Pb; RD-15-228-91 – Cr; RD-15-232-91 – Hg), as the following: assays of bottom sediments were drayed up at 105$^o$ C. 1 g batch, weighed to 0.01 g, was transferred to glass beaker, where 10 ml of concentrated $HNO_3$ was added, being maintained for 24 hours at ambient temperature, then 5 ml of twice-distilled $H_2O$ was added and beaker heated at 120$^o$ C for 3 h (the beaker was covered with watch crystal). Then 3 ml of concentrated $HClO_4$ was added to cooled solution, the mix was heated at temperature of 180$^o$ C up appearance of HCl vapor. The residual was filtered and brought up to volume 25 ml by twice distilled $H_2O$ in volumetric flask. In obtained mineralizate the acid soluble forms of heavy metals (except for mercury) were determined.

Preparation of assays for mercury determination was the following: 1 g of carefully homogenised sample of natural humidity was treated with 50 % sulfuric acid and by 6 % potassium permanganate with postreduction of mercury by stannous chloride according to the technique, developed by the Azov Fishery Research Institute "Determination of total mercury in bottom sediments by method of flameless nuclear absorption", RD-15-226-91.

The laboratory glassware used for decomposition has been preliminary washed by weak nitric acid and washed three times by twice-distilled water.

Concentration of zinc, copper, chromium, iron, barium, cadmium, lead, arsenic, aluminium (C, μg/g ) were calculated by the formula:

$$C = X*V/P,$$ where

X – content of determined element in final solution of assay, μg/ml;
P - dry weight of assay, g.
V - final volume of assay solution, ml.

Concentration of mercury in assay (C, μg/g dry weight) was calculated by formula:

$$C = X/P,$$ where

X – mercury content in assay (μg/l).
P- dry weight of assay, g

After arrival of assays of bottom sediments they were checked on probable pollution due disturbance of package, on acceptability of transfer conditions, and on adequacy of size of assay. Then labels of assays were verified with the associated documentation. Parameters of tests were recorded in the logbook. Assays were prepared for the analysis according to formerly described techniques. The standard solutions were prepared from standard samples of metals included in the State Registry of Measurement instrumentation passed the State Official Tests GSOPRM.

Each used spectrophotometer passed initial calibration according to manufacturer manual. Before implementation of analyses of samples of bottom sediments the instruments were calibrated by three points with linearity test of response factors of each of measured metal. Relative standard deviations for initial calibration and consequent calibrations were within the limits from 3 up to 5 %. Blank tests were prepared in triple replication for each test preparation for atomic absorption determination of metals.

Chlorinated pesticides. Sediments were dried at 70°C and analyzed for chlorinated hydrocarbon content (*p, p'*-DDT, *p, p'*-DDD and *p, p'*-DDE, α- and γ-isomers of HCH). The chlorinated hydrocarbons were analyzed by method of gas-liquid chromatography according to standard techniques of Russian Meteorological Service [71, 72] at gas chromatograph with glass column (1m×3 mm, stationary phase SE-30, temperature of column 220°C, temperature of the detector 250°C).

The method is grounded on extraction of chlorinated hydrocarbons by mixture of organic solvents (acetone – hexane), with isolation of extracts by sulfuric acid and water solution of sodium sulphite at presence of tetrabutil ammonium (TBA) sulfate and subsequent their determination in concentrated extract by gas-liquid chromatography technique. Identification of substances was carried out by retention time relative to DDE. Quantity of substance calculated by height of respective peak. At presence of polychlorinated biphenyls in assay they were separated from organochlorine pesticides (OCP) by alkaline dehydrochlorination (in ethanol solution).

Minimally determined quantity of DDT, DDD, DDE was 0.3-0.5 ng/g of dry ground; α-HCH, γ-HCH - 0.1 ng/g of dry ground.

Oil carbohydrates Sediments were dried up at 70°C and analyzed for the total content of oil carbohydrates (OCH). Oil carbohydrates were extracted by n-hexane, their content was determined by method of IR-spectrophotometry according to standard techniques of the Russian Meteorological Service [71, 72].

The method is grounded on extraction of OCH from assays of bottom sediments by alkaline solution of ethanol with transition of analyzed component into hexane, and on removal of interfering compounds by sorption on aluminum oxide. The method is based on extraction of OCH from assays of bottom sediments, on change of solvent by carbon tetrachloride with consequent measurement of OCH contents by IRS-method.

## 3. The analysis of benthic samples

Terminology. Benthos – the assemblage of organisms inhabiting sea floor (bottom sediments). Benthic organisms are subdivided:

1. Relative to surface of bottom sediments :
   - epifauna (epibenthos) – bottom organisms that live upon seafloor or bottom objects,
   - infauna – bottom organisms that live within sediments of the seafloor.
2. By size composition:

- macrobenthos – benthic organisms larger than 1 mm, which are dominated by polychaetae worms, pelecypods, anthozoans, echinoderms, sponges, ascidians, crustaceans,
- meiobenthos – benthic organisms between 0.1 – 1 mm in size, (they pass through the 1 mm sieve), include polychaetes, pelecypods, copepods, ostracodes, cumaceans, nematodes, turbellarians, and foraminiferans. More details concerning meiobenthos see in section 4.3,
- microbenthos – organisms smaller than 0.1 mm, include bacteria, diatoms, ciliates, amoeba, and flagellates.

Gray whale (*Eschrichtius robustus*) the is only whale, that feeds on benthic organisms. Other whales feeds on animals inhabiting water column: invertebrates (plankton) or fish (nekton).

Laboratory processing of macrobenthos comprised defining of species composition and quantitative parameters of benthos in sample (biomass and number of each species and of individual taxonomic groups, total biomass and number of macrobenthos in sample). Total sampling of animals was performed. Large organisms were counted visually, small animals - under stereo microscope MBS-10. Gross weight of large benthic organisms was determined with electronic scales VLKT-100 to 10 mg, that of small animals – with the torsion scales to 1 mg. The organisms were dried on filter paper for I min before weighing. All data were recalculated relative 1 $m^2$ area of bottom, taking in account the capture area of sampler.

In colonial animals (*Hydroidea, Bryozoa*) individual colonies were counted, if reliable count of number of colonies was impossible (presence of fragments of several colonies, aggregation of colonies, etc.) their number was marked as “?” in the table. Taxonomic processing of samples was implemented by skilled taxonomists∗, having a decade experience of work with analyzed group of animals. At instances, when a species was presented by juvenile individuals having no distinct taxonomic traits, i.e. there was no possibility of reliable species definition, notation “sp. juv” was used in the name of taxon. In some instances it was impossible to determine species of individual due to its heavy damage, then notation “sp” was used in the name of taxon.

The quantitative samples of meiobenthos were flushed through sieves and fixed with 75 % ethanol, then they were studied under stereomicroscope in Bogorov’s chamber. Samples were stained with Bengal rose by Thiel’s [5] technique: 0.5 ml of concentrated solution of Bengal rose and 2-3 ml of concentrated phenol solution were added to 100 ml of water, the sample stained for 3-4 hours. Total sampling of animals was performed. For division of sample

∗ Employees IMB FEB of the Russian Academy of Science participated in taxonomic machining basic groups of a macrobenthos: Ph.D. L.L. Budnikova (amphipods), Ph.D. M.V. Malyutina (isopods), Ph.D. G.M. Kamenev (beach clams), Ph.D. V.V. Gulbin (gastropoda mollusks), Ph.D. E.V. Bagaveeva (polychaetes) and Ph.D. S.F. Chaplygina (hydroids). Tests meiobentos have been processed Ph.D. N.P. Fadeevoj of large volume the Chislenko's dividor [6] was used. The sample was settled for 10-15 minutes, then withdrawn contents of 2-3 sectors were examined in Bogorov's chamber, counted respective groups. Basing on that batch counting the conclusions were made respective to the entire sample. Biomass of the basic groups of meiobenthos was calculated by multiplication of average weight of the representative of each group ("Z" in the table) by number of the group. Average weight of meiobenthic animals was determined by nomographs, using the average size and weight of individuals of meiobenthic groups [7]. According to commonly adopted practice the meiobenthos is divided in two groups: proper meiobenthos and pseudomeiobenthos (larvae of macrobenthic animals).

One-factor, traditional methods (analysis of values of total biomass and number of benthos, *Shannon diversity index*) and methods of multiple statistical analysis, including discrimination and ordination [8] with use of *Statistika* System [9] were applied for description of communities.

Standard procedures of cartographical system SURFER 7* (*Surface Mapping System*) were used for construction of maps of distribution of parameters of ground sediments and water column, of concentration of pollutants and of quantitative abundance of macrobenthos. The cartographical system was used only for illustration of general pattern of distribution of parameters in surveyed water area. Therefore at calculation of isolines the method of polynomial regression in version "simple planar surface" was used. This methods method yields good results when it is necessary to reveal large-scale trends in spatial distribution of data. The ideology of the method was described in detail [73].

Tetragonal data matrix representing the list of benthic species of each sample or station with quantities parameters of species (biomass or number) was the primary base for analysis implementation. Dendrograms were constructed by method of mean correlation [10,11]. Clusters with level of similarity not less than 30 % were referred to same community.

As a whole the procedure of sampling, processing and assay analysis corresponded to Russian and foreign techniques [12 - 15].

* It is necessary to note that use of SURFER program for analysis of parameter distribution of sediments and benthos run into great problems. We surveyed the most near shore area of the sea, i.e. at the scale map all stations of sections were allocated in few millimeters from the coastline. Therefore at the use of this program all stations have been artificially allocated at equal distance from each other. The position of stations in system of new coordinates is displayed at Fig. 2.

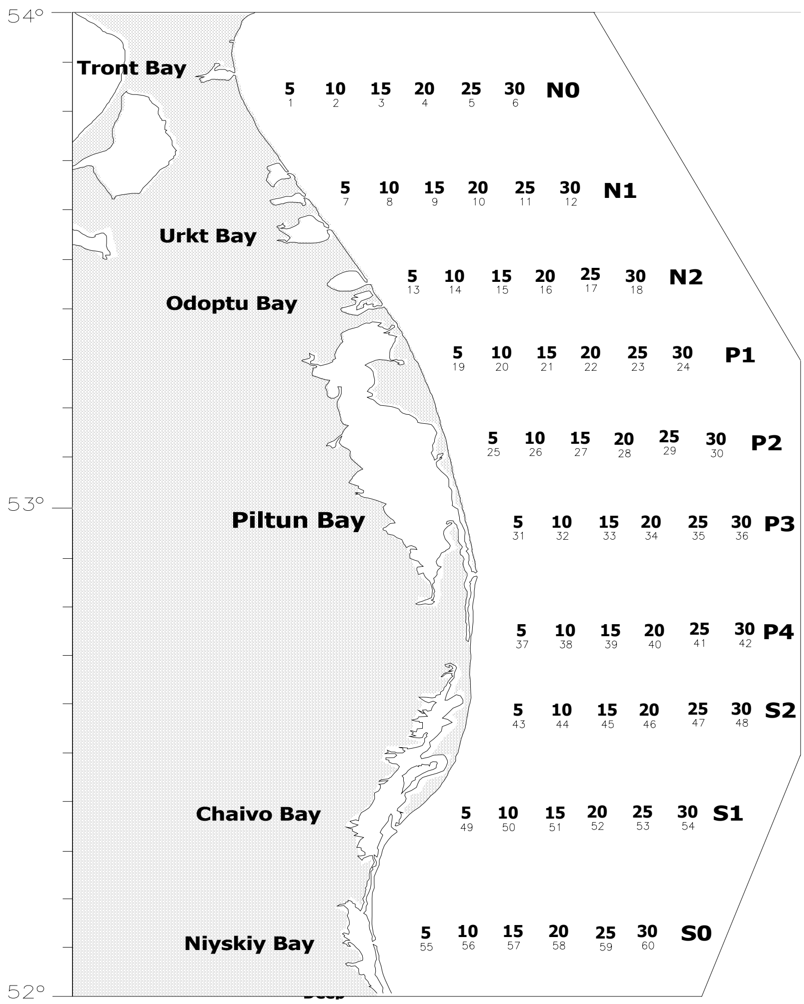



Fig. 2. Allocation of stations (1-60) at regular arrangement from coastline

Figure above stations – depth, m.

# RESULTS AND DISCUSSION

## 3. Characteristics of water column and of ground sediments

### 3.1. Distribution of water temperature and salinity during research

Measurements of oceanographic parameters of seawater in surveyed area were conducted in August 3-7 and August 12-19, 2001. Temperature and salinity of surface and bottom water layers was measured. Results of measurements are presented in the Appendix 2, distribution of parameters - at Fig. 3-6.

Temperature and salinity of water. Values of surface temperature varied within the limits 16.4° C-2.1° C. Such sharp fluctuations of water temperature could have several causes. As it follows from Fig. 3, the higher values of surface temperature were recorded in south and north parts of the area. In Piltun Bay a vast zone of colder water with upwelling of deep waters of 2.1° C temperature to surface was observed. Occurrence of colder water area might be connected as to existence of constant inflow of cooled waters, as to specifics of hydrometeorological situation during the work. During several days the area was subjected to high-power storm effect, due to passing typhoon. Similar distribution of temperature was also in the bottom water layer (Fig. 4). The minimum value 0.6° C was recorded at depth 25-30 m in Piltun Bay area. Salinity distribution of surface and bottom waters (Fig. 5-6) displayed that warmer surface water had lower salinity.

Unfortunately, the available data on temperature and salinity of water of near-shore area of Piltun Bay are fragmentary and prevent to estimate temporal sustainability of the revealed distribution patterns (Fig. 3-6). During the survey values of temperature and salinity did not differ significantly from the data of 2000 [74, Tab. 4] and well coordinated with concept of existing upwelling in coastal area of the north-east Sakhalin [80].

### 3.2. Granulometric structure of sediments

Granulometric study of bottom sediments was based on laboratory analyses of 60 assays of the ground sampled at all benthic stations. Results of laboratory analysis are adduced in Appendix 2. Distribution of basic fractions of bottom sediments (coarse aleurite, sand: fine, medium, coarse, and small gravel) in surveyed area is displayed at Fig. 7-11.

Bottom sediments of the investigated area are specified with surge dominance of sand (psammites) fractions over the most stations. Thus, the ratio of fine sand fractions at the most stations exceeds 60 % (maximum value – 96 %). Medium sands prevailed (more than 40-50 %) only at 8 stations at depths exceeding 15 m. More coarse fractions occurred only as admixture to the sand fraction.

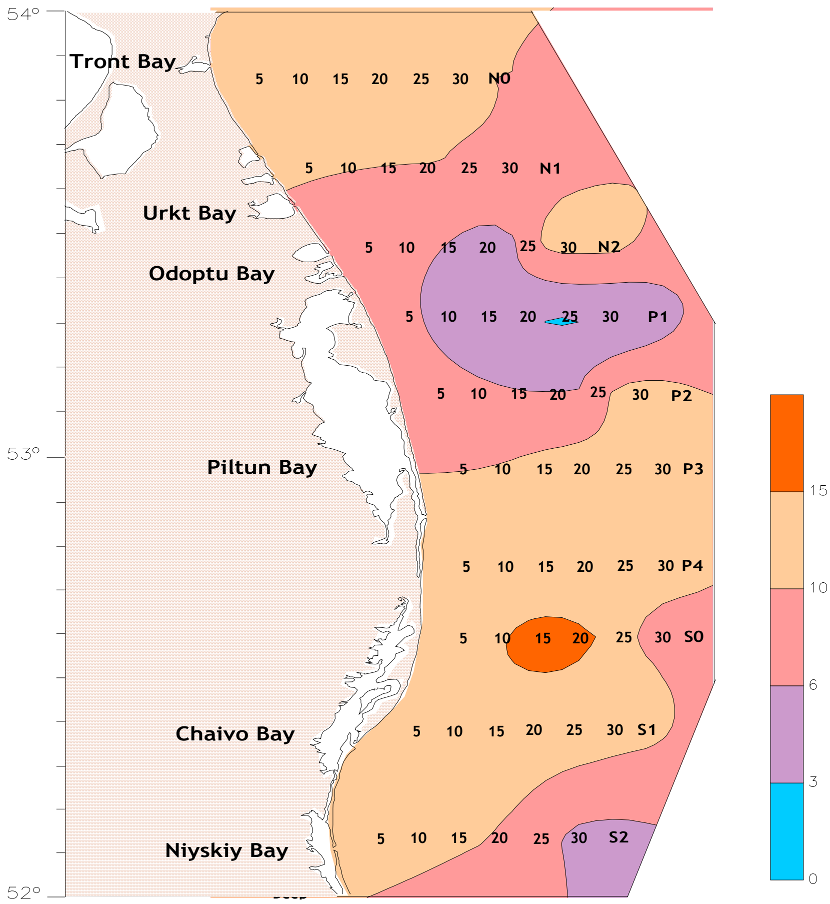



Fig. 3. Distribution of temperature of <u>surface</u> water layer ($T^{\circ}$ C)

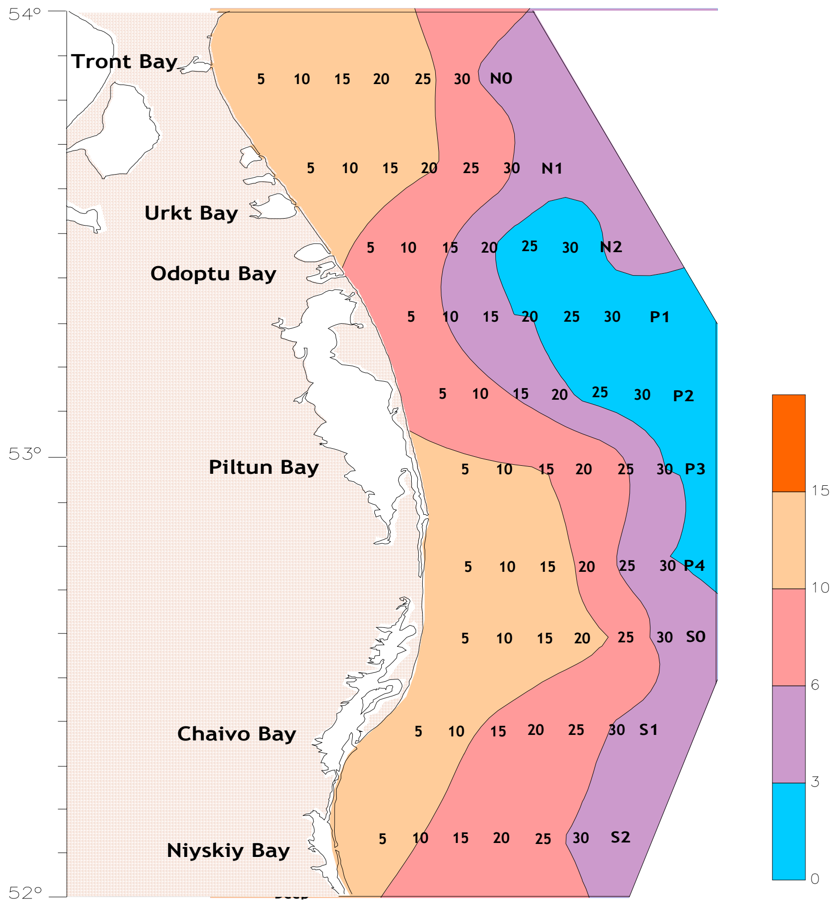



Fig. 4. Distribution of temperature of bottom water layer (T° C)

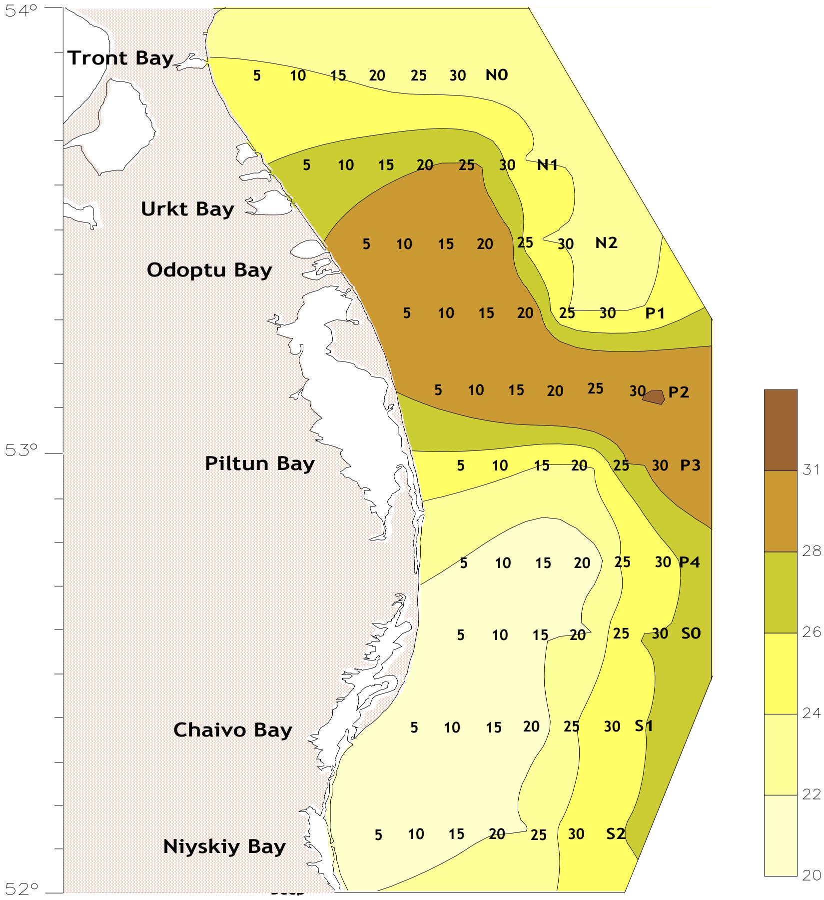



Fig. 5. Distribution of salinity of <u>surface</u> water layer (‰)

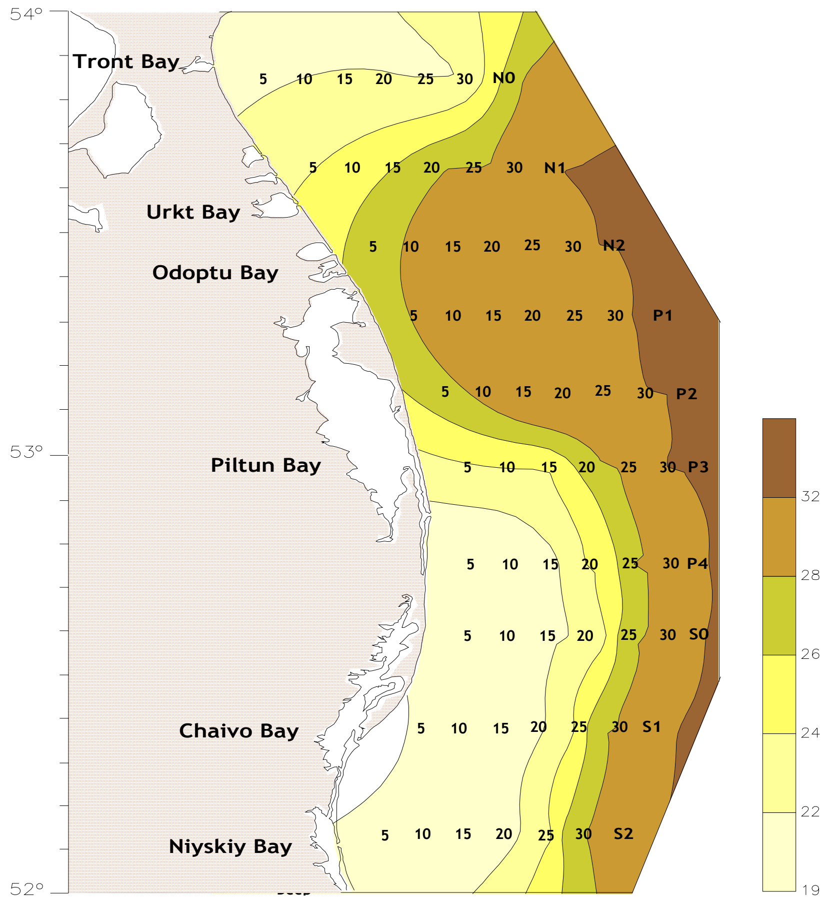



Fig. 6. Distribution of salinity of bottom water layer (‰)

Despite of considerable payload of fine-grained fractions of sediments from numerous coastal lagoons, the ratio of aleurite-pelite fractions in bottom deposits of studied area was insignificant (no more than 5 %). Probably, the active hydrodynamics of area promote transfer of fine fractions of ground to greater depths. Influence of lagoons on accumulation of coarse aleurites is tracked at Fig. 7 by two sites: to the north from Odoptu Bay and in the region Piltun Bay – Chaivo Bay. However, the ratio coarse aleurite does not exceed 5 % of weight of sediments.

The main studied bottom area was occupied by fine sands (Fig. 8). Fine sands are distributed along the survey area at depths up to 10-15 meters. Continuous decrease of fine sand ratio was observed in the ground with depth increase. Medium and coarse sands had opposite pattern of distribution. Their ratio in the ground increased with depth (Fig. 9-10).

Large gravel grounds patchy occurred at depths more than 20-25 m. At depths up to 10 m their ratio was negligible (Fig. 11). Thus, it was possible to distinguish two areas with rather high content of gravel fractions: to the north from Piltun Bay, in the region of Odoptu Bay – Tront Bay, and to the south – in region Nyiskiy Bay - Chaivo Bay at depths exceeding 20 m.

Distribution of *entropy coefficient* $N_s$♦ is displayed at Fig. 12. The most sorted sediments occurred in nearshore zone of the area at depths up to 15 m and were presented by fine sands. The least sorted sediments occurred at depths more than 15-20 m at areas of coarse sand and small gravel.

### 3.3. Classification of stations by similarity of granulometric structure

Data on 10 fraction composition of bottom sediments for on each of 60 stations have been categorized using procedures of cluster - analysis (Ward's method, Euclidean distance, matrix 10x60). The obtained dendrogram is shown at Fig. 14. All stations by similarity of their size distribution of ground can be joined into three ***groups – A, B, C***. Parameters of each sediment group are adduced in Tab. 2.

The largest ***group A*** comprises 30 stations at average depth 12.2 m with greatly prevailing fraction 0.1-0.25 mm (89.5 % of total weight of sediment).

The ***group B*** includes 19 stations at average depth 23.7 m and specifies with two dominating fractions: 0.1-0.25 mm (48.4 %) and 0.25-0.5 mm (40.8 %).

The ***group C*** includes 11 stations at depth 25.0 m without appreciable dominance on any fraction. The values of fractions 0.5-1.0 mm (18.8 %) and 1.0-2.0 (27.7 %) were the greatest.

---

♦ *Entropy coefficient of sorting* deposit calculate on base of *Index species diversity* Shannon (H): $H = -\sum p_i \times (\log_2 p_i)$, where $p_i$ - part *i*- factions of deposit.

Thus, the *group A* corresponds to well sorted fine sands, *group B* – to average sorted differently grained sands (a mix of small and medium sands), *group C* – to poorly sorted gravel ground with admixture of pebble and shell detritus. Size distribution of three groups is presented at Fig. 13.

Fine sands occurred in the nearshore zone up to depths 10-15 m along entire coast. The largest areas of bottom the fine sends sands occupied in region Chaivo Bay - Odoptu Bay. Mixed gravel - pebbly grounds occurred in patches at depths exceeding 25 m.

Table 2

Parameters of sediment groups: number of stations belonging to the group, average depth of group occurrence, fractional composition of sediments (% of total weight)

| Type of sediment | Number of stations | Depth, m | Ground fractions, mm | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | > 10.0 | 10.0-5.0 | 5.0-2.0 | 2.0-1.0 | 1.0-0.5 | 0.5-0.25 | 0.25-0.1 | 0.1-0.05 | 0.05-0.01 | <0.01 |
| Group **C** | 11 | 25.0 | 9.7 | 5.2 | 13.9 | **27.7** | **18.8** | 12.0 | 8.9 | 1.4 | 1.5 | 1.0 |
| Group **B** | 19 | 23.7 | 0.2 | 0.3 | 0.8 | 2.3 | 5.6 | **40.8** | **48.4** | 0.8 | 0.6 | 0.2 |
| Group **A** | 30 | 12.2 | 0.0 | 0.1 | 0.3 | 0.6 | 0.8 | 5.9 | **89.5** | 2.2 | 0.4 | 0.2 |

Note: The hatching notes the dominating fractions.

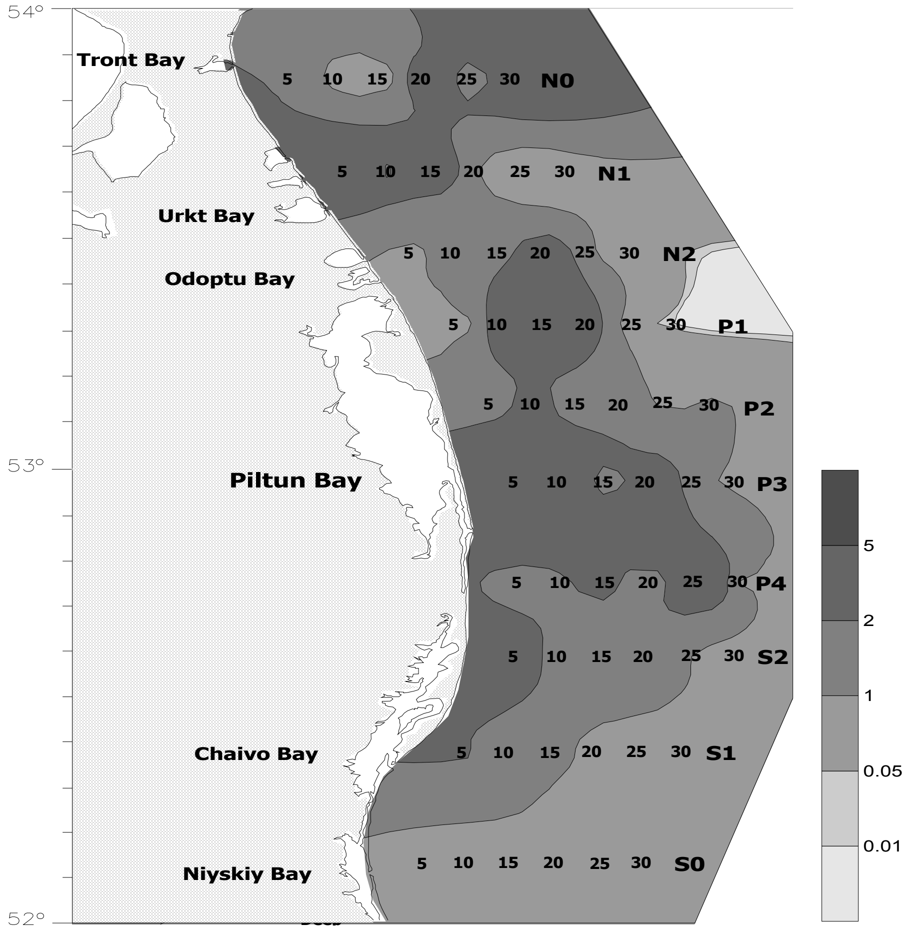



Fig. 7. Distribution of fractions of bottom sediments (% of total weight): 0.05-0.1 mm (large aleurite)

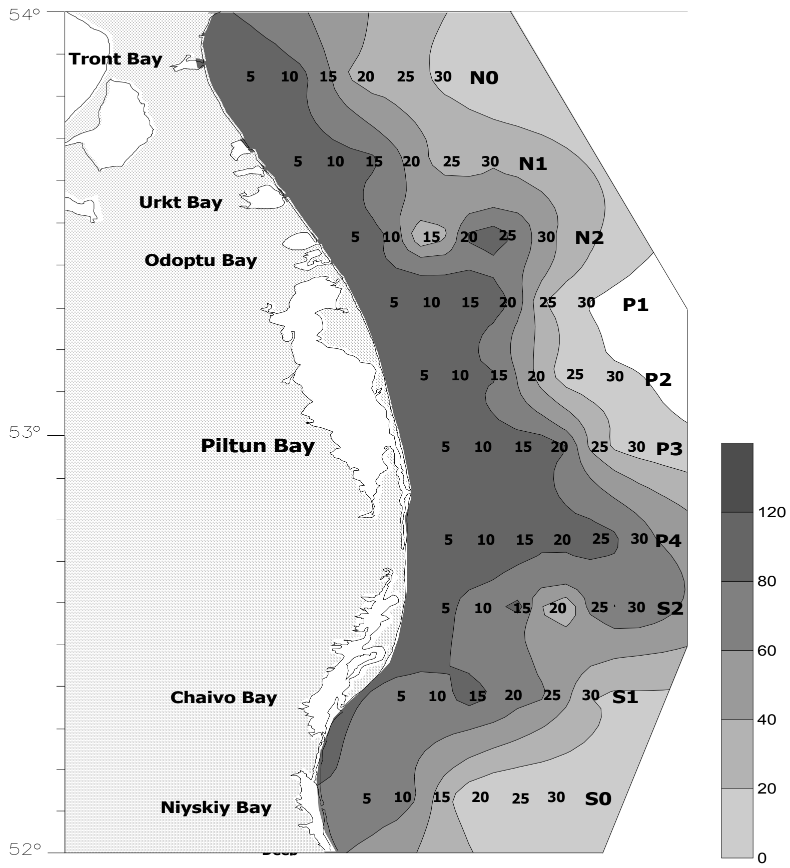



Fig. 8. Distribution of fractions of bottom sediments (% of total weight): 0.1-0.25 mm (fine sand)

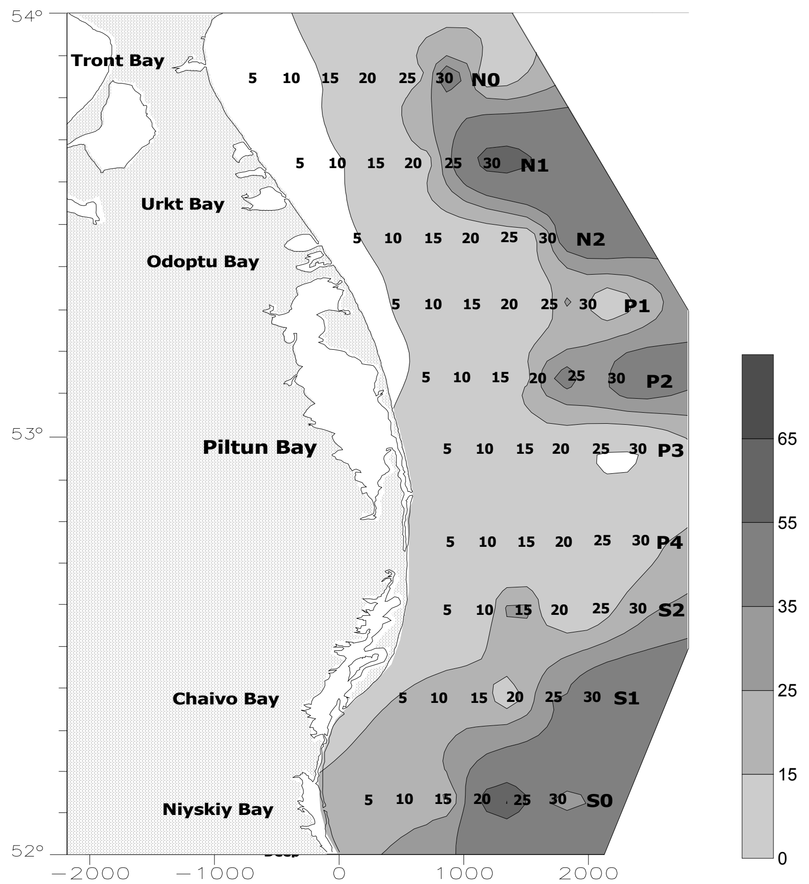



Fig. 9. Distribution of fractions of bottom sediments (% of total weight): 0.25-0.5 mm (medium sand)

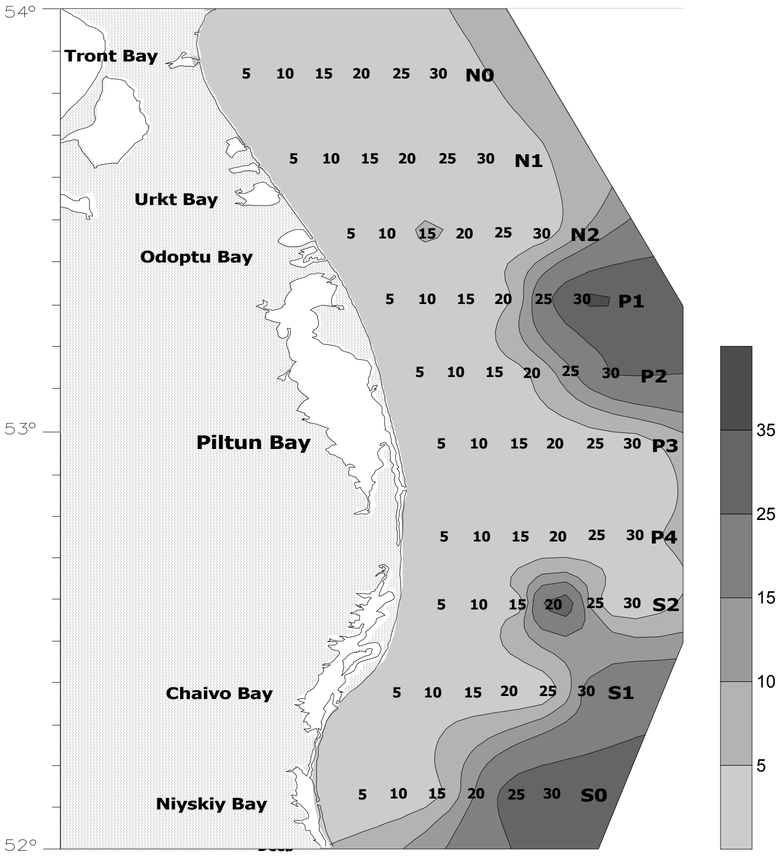



Fig. 10. Distribution of fractions of bottom sediments (% of total weight): 0.5-1.0 mm (coarse sand)

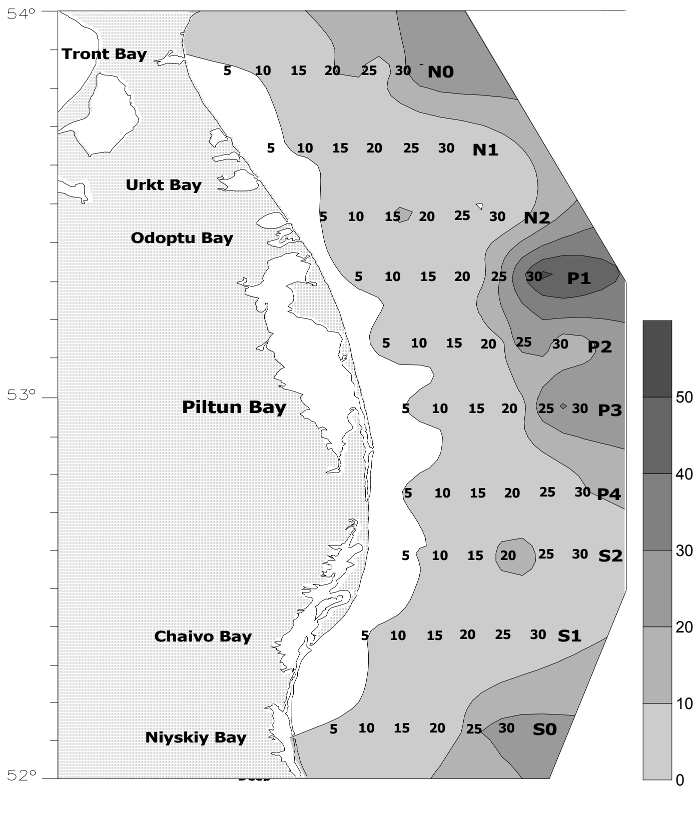



Fig. 11. Distribution of fractions of bottom sediments (% of total weight): 1-2 mm (small gravel)

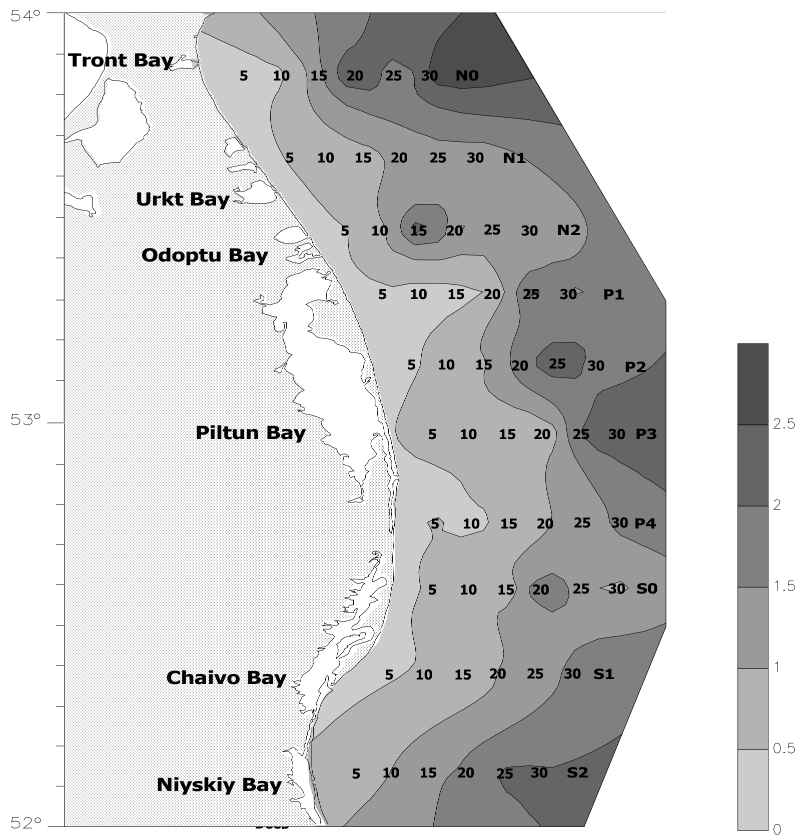



Fig. 12. Distribution of entropy coefficient of sorting (Ns) of bottom sediments

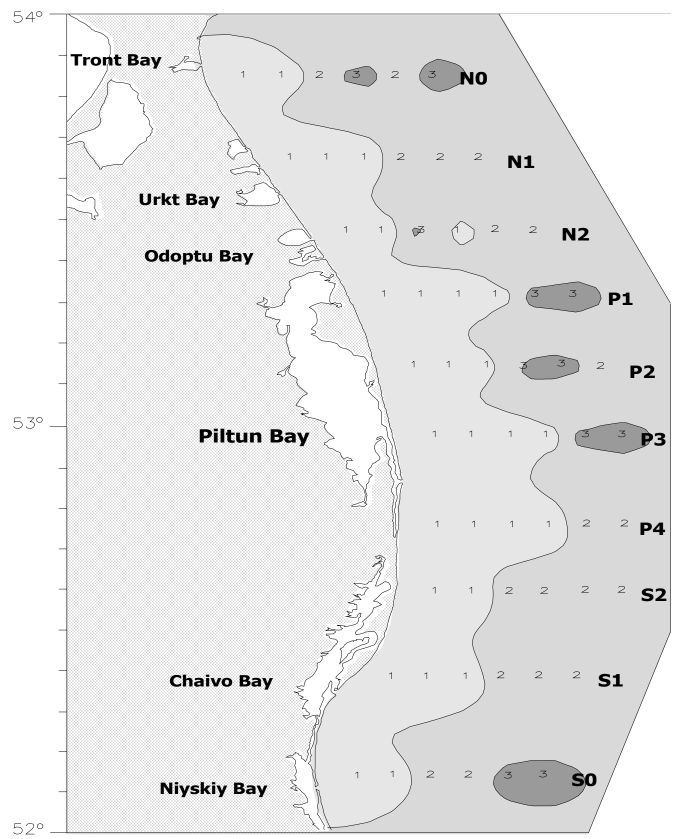



Fig. 13. Distribution of sediment groups
1 - **group A**, 2 – **group B**, 3 – **group C**

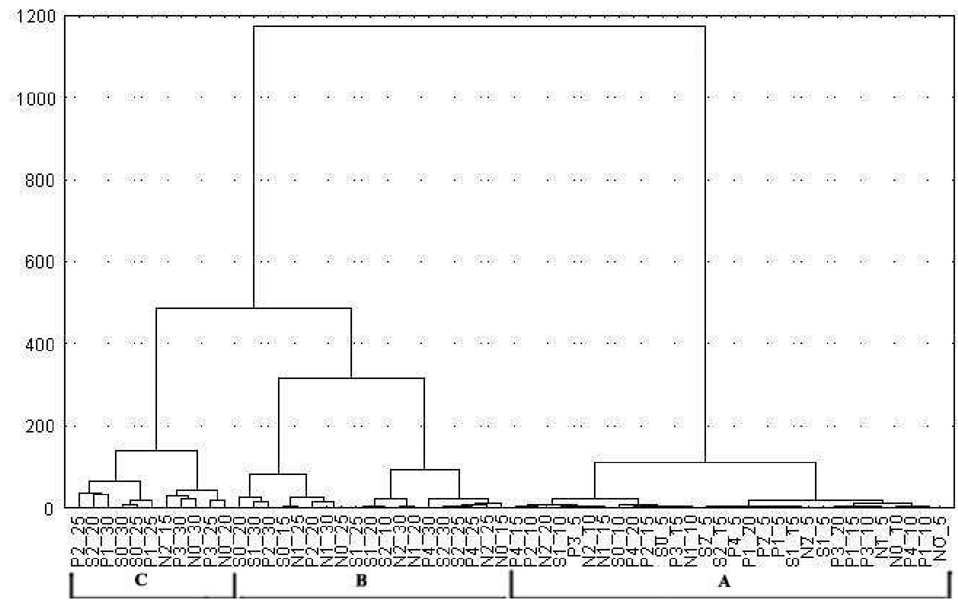



Fig. 14. Grading of 60 stations by similarity of size distribution

**A, B, C -** sediment groups

### 3.4. Granulometric structure of sediments in feeding area of gray whale

In the course of diving works we conducted incidental (not assigned to the expedition tasks) observations on feeding individuals of gray whale in the region Odoptu-Odoptu Bays. During the research there were recorded 13 actively feeding individuals in immediate proximity from place of diving works. The greater part (9 individuals) of whales was recorded at the site between sections P2 – N2, 2 individuals were recorded in vicinity of P4 section and 2 – in S2 section area. The whales fed at depths from 6 up to 13 m, 9 m on the average, traveling alongshore in south and north directions. Solitary individuals prevailed. Only in one instance, in area of Chaivo Bay (section S1) one couple of feeding whales (at depth 11 м) was recorded (Photo 1). We succeeded to make snapshot there (Photo 2) and to take samples of animals, washed out from mouth of the emerged gray whale. In most instances the whales were at considerable distance from boat, which prevented us to make quality snapshots of all the whales for lack of suitable lenses. Taking into account the significance of photo-ID of whales we have included Photos 3 and 4 to the Appendix D. In 9 feeding points of gray whales we took bottom samples with heavy-duty model of Petersen dredger. However it was apparently impossible to use these samples for thorough analysis of distribution of benthos. The were dense sands with sandy waves on surface of sediment at all sections at this range of depths. The dredger caught only a small portion of sediment. Those sediment samples were used for determination of granulometric structure of bottom sediments directly in points of feeding individuals of gray whale (Tab. 3).

Table 3

Size distribution of ground in feeding points of gray whales, August, 2001.

| Section | Depth, m | Type of ground | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pb | Grl | Grm | Grs | Sl | Sm | Ss | Al | As | Pitch |
| | | Size of prevailing fraction, mm | | | | | | | | | |
| | | > 10 | 10-5 | 5-2 | 2-1 | 1-0.5 | 0.5-0.25 | 0.25-0.1 | 0.1-0.05 | 0.05-0.01 | <0.01 |
| S2 | 6 | 0 | 0 | 0.06 | 0.05 | 0 | 0.41 | **93.63** | 5.78 | 0.07 | 0 |
| S2 | 12 | 0 | 0 | 0 | 0.29 | 1.09 | 3.71 | **94.24** | 2.34 | 0 | 0 |
| P4 | 11 | 0 | 0 | 0.32 | 1.27 | 2.43 | 6.66 | **87.19** | 1.75 | 0.38 | 0 |
| P4 | 13 | 0 | 0 | 0 | 0.11 | 0.69 | 8.87 | **89.38** | 0.95 | 0 | 0 |
| P1 | 8 | 0 | 0 | 0.21 | 0.83 | 0.76 | 3.19 | **91.95** | 2.71 | 0.24 | 0.11 |
| P1 | 9 | 0 | 0 | 0.12 | 0.18 | 0.18 | 1.15 | **94.34** | 3.88 | 0.15 | 0 |
| N2 | 6 | 0 | 0 | 0.08 | 0.97 | 1.4 | 4.57 | **92.2** | 0.72 | 0.06 | 0 |
| N2 | 10 | 0 | 0 | 0.21 | 0.48 | 2.78 | 20.47 | **73.95** | 2.11 | 0 | 0 |
| N2 | 6 | 0 | 0 | 0.06 | 0.05 | 0 | 0.41 | **83.63** | 5.78 | 0.07 | 0 |

Thus, in 9 feeding points of whales the ground has been presented by well sorted fine sands that corresponded to sediment of *Group A* (Tab. 2).

### 3.5. Concentration of oil carbohydrates (OCH), heavy metals (HM) and organochlorine pesticides (OCP)

The assessment of content of foreground pollutants, OCH, HM, OCP in the ground at feeding area of gray whales looks important as from the point of view of pollution of feeding base of gray whale, as for conditions of their habitat in feeding area. Formerly the pollutant content was not studied in shallow water feeding area. For assessment of concentrations of OCHs and 10 HM we collected in the course of field work 30 samples of bottom sediments from 10 sections (depths 5-10-20 m), i.e. in the area of the most intensive feeding of whales. There were taken 10 ground samples at 10 stations in the region Piltun Bay-Odoptu Bay for OCP content determination in the area of whale habitation.

Total oil carbohydrates. Data on OCH content in bottom sediments in the area studied are displayed in Appendix 4. Average and minimum values of the OCH content are 0.007 and 0.03 mg/g, that is even much lower than natural background values of OCH concentration at deepwater bottoms. Otis were not recorded at all at 12 stations, as well as within the limits of P4 – S2 sections. The spatial distribution of OCH is displayed at Fig. 15.

Organochlorine pesticides. Chlorinated hydrocarbons inflow at north-east Sakhalin water area with drain of Amur River and carry out of water area of coastal lagoons. The presence of pesticides in bottom deposits is a specific feature of the north-east shelf of the Sea of Knots.

Data of Tab. 4 evidence that maximum concentration of DDT proper and sum of DDT and its metabolites in bottom sediments were recorded at the south most sections – S2 and S3. We should note that even those concentrations do not exceed background values of the north-east Sakhalin area.

Table 4

Content of organochlorine pesticides (ng/g) in benthic sediments at 10 sections (depth 10 м) of the surveyed area

| Pesticide | Section | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | N0 | N1 | N2 | P1 | P2 | P3 | P4 | S2 | S1 | S0 |
| DDT | 1.5 | 0.9 | 1.1 | 1 | 1 | 1.4 | 1.4 | 1.3 | 3.3 | 3.5 |
| DDE | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.2 | 0.3 | 0.6 | 0.5 |
| DDD | 0.2 | 0.2 | 0.3 | 0.3 | 0.4 | 0.3 | 0.4 | 0.2 | 0.4 | 0.7 |
| **∑DDT** | **1.9** | **1.3** | **1.6** | **1.6** | **1.8** | **2.0** | **2.0** | **1.8** | **4.3** | **4.8** |
| α-HCH | 0.3 | 0.1 | 0 | 0 | 0.1 | 0.1 | 0.1 | 0.3 | 0.4 | 0.3 |
| γ-HCH | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 |
| **∑HCH** | **0.4** | **0.2** | **0.1** | **0.1** | **0.2** | **0.2** | **0.2** | **0.4** | **0.6** | **0.50** |

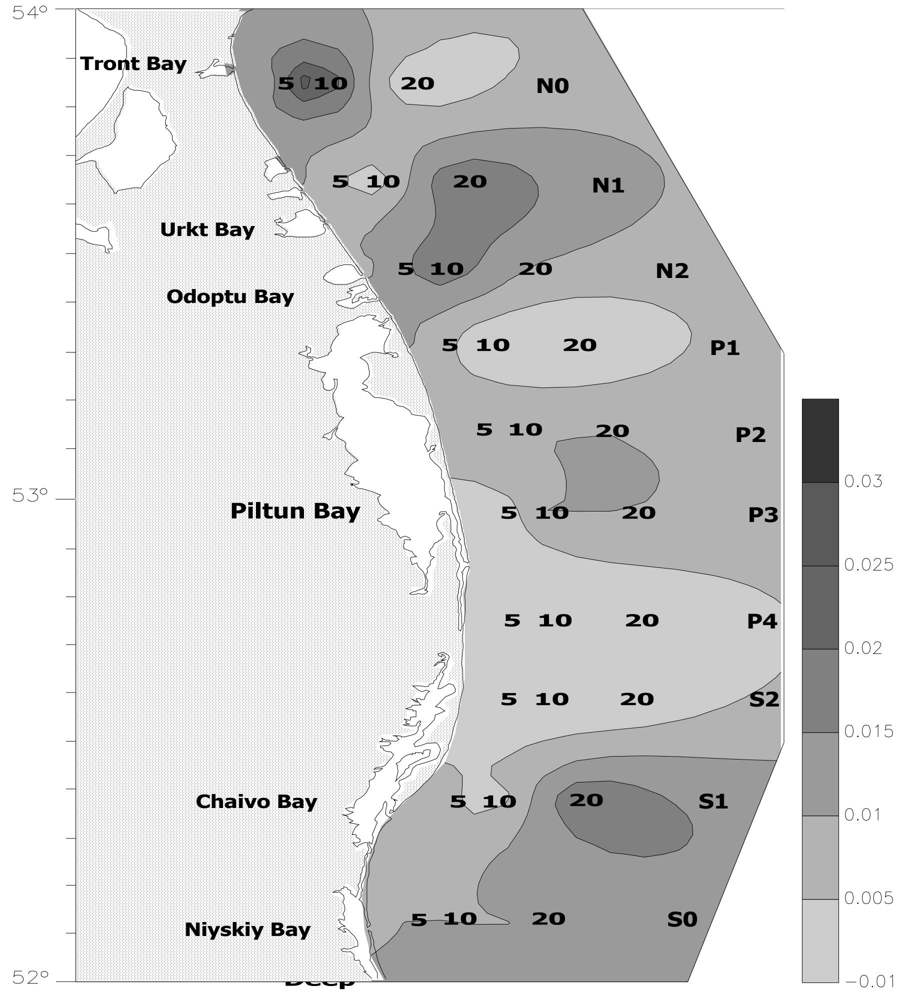



Fig. 15. Concentration of oil carbohydrates (mg/g of dry residual) in benthic sediments

Heavy metals. It is known, that HM content in bottom deposits of seas and oceans depends on great number of factors. Differences in their levels may be caused by mineralogical and granulometric composition of grounds. Thus, sandy bottoms, due to their lesser sorption nature, are specified with lesser HM content, than aleuritic-pelitic deposits. Hydrodynamics, physicochemical processes and processes of biogenic slugging affect accumulation and distribution of trace elements. All of this is displayed in continuous variation of content of many chemical elements in surface layer of bottom deposits.

Results of analysis of 30 assays of sediment on the content of 10 HM (copper, aluminium, arsenic, barium, cadmium, chromium, iron, mercury, lead, zinc) are adduced in Appendix 4. Distribution of HM concentration at water area is shown at Figs. P12-P21. The sediment samples collected from all 10 sections at depths 5-10-20 m (30 assays) were specified with low content of toxic HM, which corresponded to natural geochemical background of the surveyed area. Close concentration values of heavy metals have been determined in bottom deposits for various areas of north-east shelf of the Sea of Okhotsk. Beyond, the distribution practically of all HM was specified by minimum concentrations at depths up to 15-20 m, i.e. in feeding zone of gray whales.

Data available in literature [16, 17] on HM content in deposits in region of Piltun-Astokhsky oilfield confirm in full our conclusion about low concentration of HM in surveyed area (Tab. 5).

Table 5.

Concentration of heavy metals in region of Piltun-Astohsky oilfield (by literature data)

| Elements | Concentration |
|---|---|
| Al (%) | 1.10-5.15 |
| As (μg/g) | 2.5-14.8 |
| Ba (μg/g) | 268-763 |
| Cd (μg/g) | <0.01-0.13 |
| Cr (μg/g) | 0.6-121 |
| Cu (μg/g) | 0.6-6.7 |
| Fe (%) | 0.12-1.50 |
| Hg (μg/g) | 0.001-0.047 |
| Pb (μg/g) | 5.1-19.5 |
| Zn (μg/g) | 3.1-29.1 |

Comparison of concentrations of OCHs and HCHs in the surveyed area with literature data and the most studied areas of Far East seas (Tab. 6) is not less indicative.

Table 6.

Concentration of DDT, its metabolites ($\sum$DDT), $\alpha$- and $\gamma$-isomers of hexachlorocyclohexane ($\sum$HCH) and of oil carbohydrates in bottom sediments of various areas of the Peter the Great Bay (Sea of Japan) and the surveyed area

| AREA | OIL CARBOHYDRATE, mg/g of dry mass* | $\sum$HCH, ng/g of dry mass** | $\sum$DDT ng/g of dry mass ** |
|---|---|---|---|
| GOLDEN HORN BAY AND EASTER BOSPORUS STRAIT | 5.4-16.7 | <0.2-5.5 (1.66) | 0.8-22.7(9.01) |
| AMURSKY BAY | 0.03-2.72 | <0.2-1.3 (0.58) | 4.4-14.8(7.59) |
| USSURIISKY BAY | 0.03-0.25 | <0.2-1.1 (0.32) | 4.4-9.1(6.01) |
| SURVEYED AREA *** | 0-0.03 (0.007) | <0.1-0.6 (0.29) | 1.3-4.8(2.31) |

* [18] - data 1986-1989 up to 1994, range of concentrations displayed.
** [19] - data 1994, range of concentrations and average values (in brackets)
*** - our data

As it follows from the table, the maximum concentrations of considered pollutants in the surveyed area correspond to maximum concentrations in the Peter the Great Bay (Sea of Japan).

Thus, the analysis of the content and distribution of the foreground pollutants, OCH, HM, OCP, in bottom sediments of the surveyed area enables to conclude that no significant impact on benthos was observed there at present.

# 4. Benthos composition and quantitative distribution

## 4.1. Taxonomic composition and species of macrobenthos

The benthos of the coastal zone of the northeastern Sakhalin at a depth of less 20 m has been studied quite poorly, which is due to the impossibility for the majority of research vessels to work at small depth. The diving works in that region were done quite sporadically and did not make any significant contribution to the studies of coastal biota. Only in recent years the diving works in Piltun Bay have been started, which allowed to find 34 amphipod species in the whale fattening area and to identify mass benthos species [21, 64].

As a result of the taxonomic treatment of the material collected by diving in 2001 in the area of Nyiskiy Bay – Tront Bay, 171 benthos and nektobenthos species were registered in the quantitative samples. The list of  taxa is given in Appendix 5.

By species number, 5 animal groups are dominant: amphipods (53 species or 31 % total species number), polychaetes (41 species, 25 %), bivalve mollusks (27 species, 16 %), hydroids (15 species, 9 %) and gastropods (11 species, 7 %). Other 10 taxonomic groups of benthos are represented by 1-3 species. Out of 171 species included into the list, 20 species (hydroids, sponges and barnacles) inhabit only hard substrates– rocks or dense gravel-pebbles bottom. Other animal species (151) inhabit sandy bottom and can be found in the zone of gray whales fattening.

For the evaluation of species occurrence in the area of sandy bottom an indicator «species occurrence frequency» (P,%) – the relation of the number of quantitative samples in which the species was found to the total number of quantitative samples expressed as a percentage. This indicator is important, first of all, for the characteristics of food organisms because it characterizes their availability to predators. The analysis of the occurrence frequency of all species (151) shows that the majority of the species - 87 occurs rarely. Only 64 species (43 % of total species number) have an occurrence frequency over 10%. The list of these species is given in Table 5. The occurrence frequency over 10 % is observed for 23 amphipod species, 22 polychaete species, 14 bivalve species, 3 isopod species, one species of cumaceans and a nectobenthic fish species Ammodytes hexapteris. All these species inhabit the zones of fine and medium sands (groups of ground A,B in Fig. 13). In that range of depths there is a surge increase of biomass of sand dollars and reduction of biomass of bivalves and crustaceans as a whole. All the stated above reflects only general trends in distribution of biomass of macrobenthos in the entire surveyed area.

Table 5

Species occurrence frequency (P> 10%) of macrobenthos in the area studied

(based on quantitative samples data)

| № | Species | Code* | Species occurrence frequency (P, %) | | | |
|---|---|---|---|---|---|---|
| | | | In the area of: | | | avarage P,% in the whole area |
| | | | Nyiskiy Bay – Chaivo Bay | Piltun Bay | Odoptu Bay - Tront Bay | |
| 1 | ***Synidotea cinerea*** | Is | 96 | 75 | 87 | 86 |
| 2 | ***Pontharpinia longirostris*** | Am | 78 | 75 | 69 | 74 |
| 3 | ***Eohaustorius eous eous*** | Am | 75 | 81 | 60 | 72 |
| 4 | ***Pontoporeia affinis*** | Am | 42 | 71 | 51 | 55 |
| 5 | ***Megangulus luteus*** | Bi | 42 | 46 | 62 | 50 |
| 6 | *Siliqua alta* | Bi | 69 | 31 | 42 | 47 |
| 7 | *Eogammarus schmidti* | Am | 48 | 61 | 28 | 46 |
| 8 | *Macoma lama* | Bi | 36 | 45 | 55 | 45 |
| 9 | *Onuphis shirikishinainensis* | Po | 33 | 51 | 46 | 43 |
| 10 | *Echinarachnius parma* | Ech | 36 | 31 | 51 | 39 |
| 11 | *Atylus collingi* | Am | 42 | 25 | 37 | 35 |
| 12 | *Westwoodilla sp.* | Am | 45 | 38 | 19 | 34 |
| 13 | *Pontharpinia robusta* | Am | 33 | 41 | 28 | 34 |
| 14 | *Synchelidium gurjanovae* | Am | 39 | 28 | 33 | 33 |
| 15 | *Protomedeia popovi* | Am | 33 | 18 | 42 | 31 |
| 16 | *Spisula voyi* | Bi | 30 | 21 | 42 | 31 |
| 17 | *Anisogammarus pugettensis* | Am | 18 | 38 | 33 | 30 |
| 18 | *Scoloplos armiger* | Po | 24 | 35 | 28 | 29 |
| 19 | *Diastilis bidentata* | Cu | 33 | 25 | 19 | 26 |
| 20 | *Boeckosimus derjugini* | Am | 24 | 21 | 28 | 24 |
| 21 | *Saduria entomon* | Is | 18 | 25 | 24 | 22 |
| 22 | *Nephtys caeca* | Po | 24 | 21 | 19 | 21 |
| 23 | *Magelona sachalinensis* | Po | 24 | 18 | 19 | 20 |
| 24 | *Orchomenella gurjanovae* | Am | 30 | 21 | 19 | 19 |
| 25 | *Eteone longa* | Po | 18 | 18 | 19 | 18 |
| 26 | *Travisia forbesii* | Po | 18 | 18 | 19 | 18 |
| 27 | *Capitella capitata* | Po | 18 | 12 | 24 | 18 |
| 28 | *Metopa majuscula* | Am | 24 | 0 | 24 | 16 |
| 29 | *Anonyx nugax pacificus* | Am | 21 | 25 | 0 | 15 |
| 30 | *Ophelia limacina* | Po | 0 | 25 | 19 | 15 |
| 31 | *Eumida sanguinea* | Po | 21 | 0 | 19 | 13 |
| 32 | *Ammodytes hexapteris* | Pi | 21 | 0 | 19 | 13 |
| 33 | *Ampharete goesi* | Po | 21 | 0 | 19 | 13 |
| 34 | *Monoculodes crassirostris* | Am | 39 | 0 | 0 | 13 |
| 35 | *Protomedeia macrocarpa* | Am | 21 | 18 | 0 | 13 |
| 36 | *Synidotea bicuspida* | Is | 0 | 18 | 19 | 12 |
| 37 | *Ampelisca eschrichti* | Am | 18 | 0 | 19 | 12 |

| № | Species | Code* | Species occurrence frequency (P, %) | | | |
|---|---|---|---|---|---|---|
| | | | In the area of: | | | avarage P,% in the whole area |
| | | | Nyiskiy Bay – Chaivo Bay | Piltun Bay | Odoptu Bay - Tront Bay | |
| 38 | *Photis reinchardi* | Am | 18 | 0 | 19 | 12 |
| 39 | *Protomedeia microdactila* | Am | 18 | 0 | 19 | 12 |
| 40 | *Orchomenella japonica* | Am | 18 | 0 | 19 | 12 |
| 41 | *Orchomenella pinguis* | Am | 18 | 0 | 19 | 12 |
| 42 | *Tridonta borealis* | Bi | 18 | 0 | 19 | 12 |
| 43 | *Metopa layi* | Am | 18 | 0 | 19 | 12 |
| 44 | *Nephtys longosetosa* | Po | 18 | 18 | 0 | 12 |
| 45 | *Pectinaria sp.* | Po | 18 | 18 | 0 | 12 |
| 46 | *Serripes groenlandicus* | Bi | 18 | 18 | 0 | 12 |
| 47 | *Nephtys ciliata* | Po | 18 | 18 | 0 | 12 |
| 48 | *Crenella dec. decussata* | Bi | 0 | 18 | 17 | 12 |
| 49 | *Mysella gurjanovae* | Bi | 0 | 0 | 33 | 11 |
| 50 | *Glycinde armigera* | Po | 21 | 12 | 0 | 11 |
| 51 | *Lumbrineris japonica* | Po | 21 | 12 | 0 | 11 |
| 52 | *Chaetozone setosa* | Po | 21 | 12 | 0 | 11 |
| 53 | *Spiophanes bombyx* | Po | 15 | 18 | 0 | 11 |
| 54 | *Macoma balthica* | Bi | 15 | 18 | 0 | 11 |
| 55 | *Mysella kurilensis* | Bi | 15 | 18 | 0 | 11 |
| 56 | *Liocyma fluctuosa* | Bi | 15 | 18 | 0 | 11 |
| 57 | *Ischyrocerus elongatus* | Am | 15 | 18 | 0 | 11 |
| 58 | *Macoma calcarea* | Bi | 15 | 18 | 0 | 11 |
| 59 | *Tridonta rollandi* | Bi | 15 | 18 | 0 | 11 |
| 60 | *Demonax fullo* | Po | 15 | 18 | 0 | 11 |
| 61 | *Phyllodoce groenlandica* | Po | 18 | 12 | 0 | 10 |
| 62 | *Glycera capitata* | Po | 18 | 12 | 0 | 10 |
| 63 | *Lumbrineris bifurcata* | Po | 18 | 12 | 0 | 10 |
| 64 | *Lumbrineris minuta* | Po | 18 | 12 | 0 | 10 |

Note: * - For group code see the list of species composition of benthos and nekthobenthos (Appendix 5).
In the Table the species are ranged by the occurrence frequency in the whole area of studies.
Species with P> 50% are given in bold type.

The number of the species with the occurrence frequency over 10% changes from south to north. In the southern part, the number of such species is 60, in the intermediate one – 51, in the northern part – 41. However, this tendency is not observed in the number of frequently occurring species (P> 50%). In all the areas, the number of such species varies from 5 species in the southern part to 7 in the northern part. In total, 10 species out of 151 species found on sandy bottom have an occurrence frequency over 50%. Out of them: 4 species are amphipods, 3 – bivalves, one species each - isopods, polychaetes and an echinoderm - the sand dollar *Echinarachnius parma*. In all three areas, the isopoda *Synidotea cinerea* and the amphipods *Pontharpinia longirostris* and *Eohaustorius eous eous* have an occurrence frequency over 50%. Some species are found only in two areas. In the southern and intermediate area, P>50% is observed for the amphipod *Eogammarus schmidti*, in the intermediate and northern areas – for the amphipod *Pontoporeia affinis* and the polychaete *Onuphis shirikishinainensis*. Other 4 species (bivalves *Siliqua alta, Megangulus luteus, Macoma lama* and the sand dollar *Echinarachnius parma*) have P> 50% only in one area. The last three species have P> 50% only in the northern area.

All the above-mentioned amphipod and isopod species have been mentioned in the literature only in connection with the feeding of gray whales in Piltun Bay [20, 21]. Known, that of three amphipod species, playing the dominant role in the feeding of gray whales off the southeastern coast of Chukotka – *Pontoporeia femorata femorata*, *Ampelisca macrocephala, A. eschrichti* [22]. In the area studied, the first two species have never been found, and the occurrence frequency of A. eschrichti does not exceed 12% for the whole of the area. In the intermediate part, individual specimens of this species have been observed and in the southern and northern parts P = 18-19%.

### 4.2. The quantitative abundance and distribution of macrobenthos

#### 4.2.1. Distribution of total biomass of benthos over the entire water area

In the surveyed area the total biomass of macrobenthos varied within considerable limits, from 12.1 g/m$^2$ on fine sands in coastal zone, up to 2780 g/m$^2$ in the zone of mass development of sand dollars, averaging 595.3 ± 89.2 g/m$^2$ (n = 56 stations). Data only on 56 stations fulfilled on sandy bottoms (sediments groups A and B), i.e. in the zone potentially fit for feeding of gray whales, was used for calculations of total biomass (Tab. 8).

The quantitative samples were also taken at 4 stations, where substrate was presented by dense gravel - pebbly grounds and outcomes of bedrock, but their values were not taken into account at filling of Tab. 8. In condition of strong bottom currents a “fouling fauna", formed by sponges, bryozoans, hydroids, sestonophages, and mollusks, developed on bedrock outcomes. There the total biomass of attached epibenthos exceeded 3500 g/m$^2$, and it was more than 1800 g/m$^2$on gravel - pebbly grounds (grounds of group S). The diversity of grounds reflected in distribution of biomass of macrobenthos over the water area, creating belt-patched pattern of arrangement of contours of biomasses.

The density of benthos settlements varied even more greater: hooded shrimps *Diastilis bidentata* had the maximum values, up to 92000 ind/$m^2$, small beach clams *Mysella kurilensis kurilensis* - up to 9000 ind/$m^2$. High population density, up to 7000 ind/$m^2$, was recorded at some stations in polychaete *Onuphis shirikishinaiensis* living in tubes, and in concomitant to their settlements isopods *Synidotea cinerea*, amphipods *Pontoporeia affinis* and *Eohaustorius eous eous,* up to 2000-5000 ind/$m^2$.

The tendency to increase of total biomass of benthos with increase of depth (Tab. 8, Fig. 16-17) is characteristic for considered water area. However, this trend was mostly caused by increase of biomass of sand dollars and, to a lesser extent, of hooded shrimps with depth increase. The biomass of other groups either decreases (bivalves, crustaceans) with depth increase, or remains approximately at the same level (polychaetes, decapods). It is distinctly tracked at Fig. 17, that the most essential changes in biomass of individual groups of benthos occurs in range of depth 15 m.

In that range of depths there is a surge increase of biomass of sand dollars and reduction of biomass of bivalves and crustaceans as a whole. All the stated above reflects only general trends in distribution of biomass of macrobenthos in the entire surveyed area.

4.2.2. Distribution of benthic biomass in the individuals regions.

Data on biomasses of basic groups of benthos and of total biomass in each of three regions are displayed at Tab. 9-11. With progress from south to north region the average total biomass varied: in **the south** region it was 322.3±51.8 g/$m^2$, **in the middle** – 790.8±114.3 g/$m^2$, **in the north** – 671.2±134.9 g/$m^2$. The variation of total biomass and of biomasses of 4 basic benthic groups by 6 ranges of depth (5m-10m-15m - 20m – 25m – 30m) in each of the three studied regions is displayed at Fig.18.

<u>In the south region</u> (Nyiskiy Bay – Chaivo Bay) the general trend for entire surveyed water area was observed: total biomass of benthos increased with depth from 159.8 g/$m^2$ at 5m up to 558.8 g/$m^2$ at 30 m (Tab. 9, Fig. 18), the average total biomass was 322.3±51.8 g/$m^2$. This trend was determined, first of all, by distribution of flat sea urchins *E. parma*. Their ratio in total biomass reached 54.4 %. The biomass of bivalves was 21 % of the total, at 30 m depth it decreased to 23.7 g/$m^2$. Crustaceans were at the third place, their ratio was 15.7 % of the total biomass of benthos. The crustacean biomass decreased about average depths (15 m) and then insignificantly increased by 30 m. The biomass the polychaetes was negligible (3 % of the total) and practically did not vary with depth.

<u>In the middle region</u> (Piltun Bay area) the total biomass also increased with depth even with greater quantities parameters (Tab. 10, Fig. 18). The total biomass increased from 321.1 g/$m^2$ at 5 m up to 1153 g/$m^2$ at 30 m, averaging 790.8±114.3 g/$m^2$. As well as in the south region, the increase of total biomass with depth was determined by course of variation of

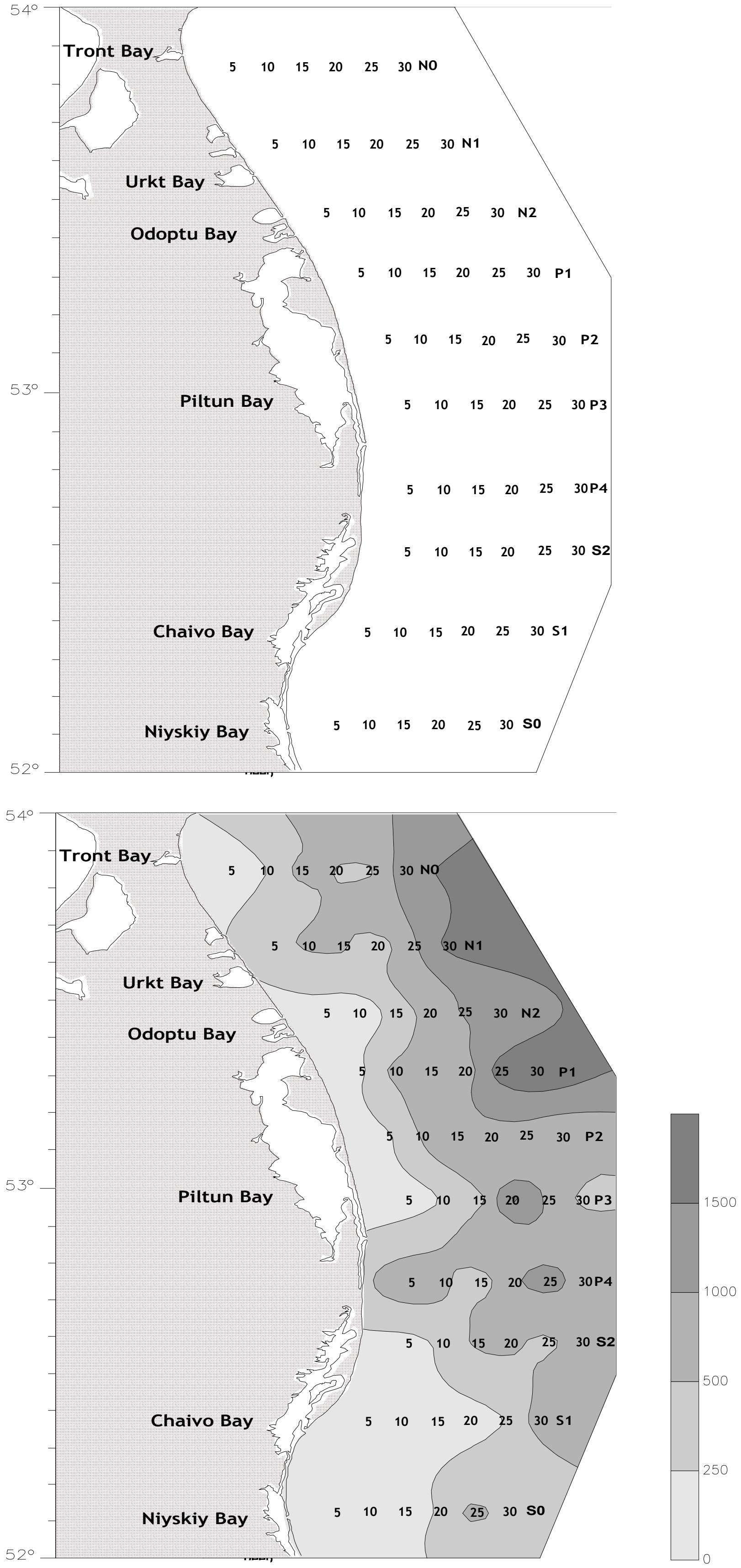



Fig. 16 . Locations of sampling stations (upper) and distribution of total macrobenthic biomass ($g/m^2$) (down).

biomass of sand dollars, their ratio in total biomass of the region reached 61.1 %. The biomass of the rest groups decreased with depth. Ratios of biomass of basic groups compounded to the total: crustaceans – 17.2 %, bivalves: 13 %. The ratio of polychaetes did not exceed 4 % of total biomass for the entire region and persisted with depths.

The north region (Odoptu Bay – Tront Bay) remained the trend, common for the entire water area, of increase of a total biomass with depth (Tab. 11, Fig. 18). The total biomass increased from 327.8 g/m$^2$ at 5 m up to 1360.1 g/m$^2$ at 30 m, averaging 671.2±134.9 g/m$^2$. Sand dollars, which biomass determined the general course of total biomass variation, took 54 % of the total biomass of macrobenthos of the region, the ratio of bivalves was 16 %, that of crustaceans – 12 %. The ratio the polychaetes as well as in more south regions did not exceed 3 %, remaining stable at all depths. The crustacean biomass decreased by range of depths of 15-20 m to 45.8 g/m$^2$ and then increased up to 139.8 g/m$^2$ at depth 30 m. Such substantial growth of biomass of crustaceans occurred for the account of hooded shrimps, which biomass increased with growth of depth.

Thus, the analysis of variation of total biomass of macrobenthos displays that the trend of total biomass increase with depth was common, as for the entire surveyed area, as for the each distinguished region. Peak values of biomass were observed in all the regions at depths 25-30 m. The high values of total biomass were caused by mass development of flat sea urchins. With northward progress the average total biomass of macrobenthos varied from 322.3±51.8 g/m$^2$ in the **south** region up to 790.8±114.3 g/m2 in the **middle** region, being 671.2±134.9 g/m$^2$ in the north region. The average total biomass for the entire area studied was 595.3±89.2 g/m$^2$ (n = 56 stations).

### 4.2.3. Distribution of biomass of main taxonomic groups and mass benthic species in the regions.

In the previous section the common trends of variation of total biomass of basic groups of benthos with depths increase were revealed, both for the entire water area, and for each distinguished region. Biomass of flat sea urchins *E. parma* and of hooded shrimps distinctly increased with depth growth. The rest common groups of benthos were specified either by reduction of biomass with depth increase (bivalves, amphipods, isopods, and decapods), or by its retaining about the same level (polychaetes). These trends are clearly tracked at Fig. 17-18. The most part of total biomass falls on sand dollars (from 40 up to 60 %) in all the regions. It is known, that echinoderms have a low calorie content and gray whales do not use them as food object.

We consider below the distribution of biomass of basic groups and mass species of benthos, disregarding biomasses of sand dollars. That concerns, first of all, to the range of depths from 5 up to 15 m, where send dollars were absent, and intensive feeding of gray whales occurred. Relative ratio (%) of biomasses of 6 groups in total biomass of benthos, disregarding biomasses sand dollars, is displayed at Fig. 19 for the three regions. Bivalves took considerable part (from 35 up to 49 %) of total benthic biomass in all the three regions. The ratio of crustaceans in the total biomass was comparable to that of mollusks - from 35 up to 45 %. From 7 up to 13 % of total biomass fell to polychaetes.

Table 8

Distribution of total biomass of a macrobenthos (g/m$^2$) and of biomasses of taxonomic groups relative to depths over the entire surveyed area

| Taxonomic group | Entire water area (Nyiskiy Bay – Tront Bay) sections S0 – N0 | | | | | | Average biomass | Error in mean |
|---|---|---|---|---|---|---|---|---|
| | 5 m | 10 m | 15 m | 20 m | 25 m | 30 m | N=56 | % |
| Bivalvia | 85.1 | 168.1 | 182.4 | 68.7 | 54.8 | 28.9 | 98.0 | 17.5 |
| Crustacea: | 124.6 | 117 | 87.2 | 48.7 | 86.8 | 97.1 | 93.7 | 16.2 |
| *Isopoda* | *28.9* | *54.7* | *27.3* | *8.8* | *10.5* | *7.0* | *22.9* | *27.6* |
| *Amphipoda* | *78.4* | *55.8* | *48.7* | *18.0* | *11.0* | *9.4* | *36.9* | *25.2* |
| *Cumacea* | *14.6* | *4.1* | *6.3* | *17.6* | *54.7* | *69.1* | *27.8* | *26.7* |
| *Decapoda* | *2.7* | *2.4* | *4.9* | *4.3* | *10.6* | *11.6* | *6.1* | *23.9* |
| Polychaeta | 33.5 | 17.5 | 21.2 | 22.3 | 27.6 | 21.6 | 23.9 | 19.8 |
| Echinodermata | 0.0 | 0.0 | 145.2 | 439.8 | 634.1 | 850.6 | 345.0 | 27.0 |
| Rest | 3.4 | 5.1 | 10.2 | 24.7 | 18.9 | 19.1 | 13.6 | 20.9 |
| **Biomass Total** | **246.6** | **307.7** | **446.2** | **604.2** | **822.2** | **1017.3** | **574.2** | **15.0** |
| **Ratio of feed benthos, %** | **43.5** | **35.9** | **17** | **4.4** | **2.6** | **1.6** | **10.4** | |

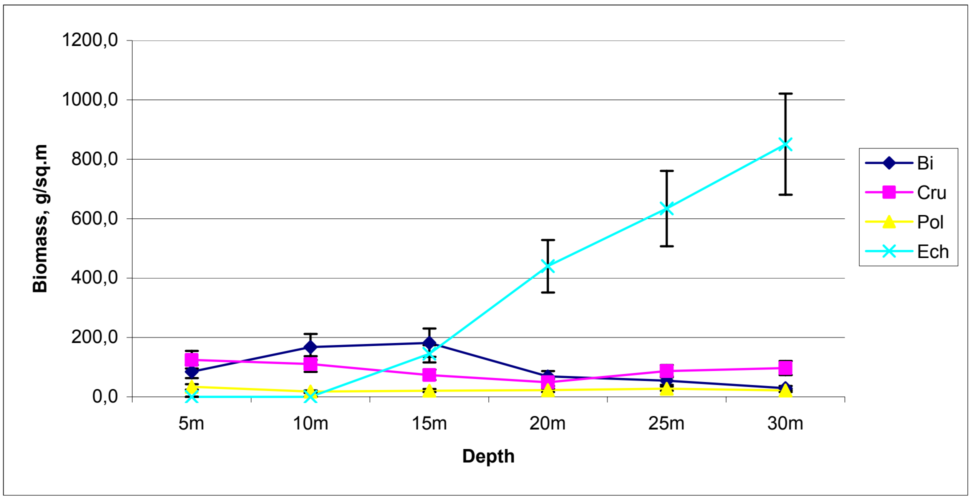



Fig. 17. Variation of biomass of 4 taxonomic groups of macrobenthos with depth

In this drawing and further the verticals notes error in mean

Table 9

Distribution of total biomass of macrobenthos (g/m$^2$) and of biomasses of taxonomic groups relative to depth in the south region

| Taxonomic group | Nyiskiy Bay – Chaivo Bay sections S0 - S2 | | | | | | Average biomass | Error in mean |
|---|---|---|---|---|---|---|---|---|
| | 5 m | 10 m | 15 m | 20 m | 25 m | 30 m | N=18 | % |
| Bivalvia | 63.1 | 88.1 | 116.2 | 79.3 | 36.2 | 23.7 | 67.8 | 16.8 |
| Crustacea: | 93.7 | 50 | 49.1 | 23.5 | 61.9 | 84.8 | 60.5 | 23.0 |
| *Isopoda* | *11.6* | *17.4* | *1.6* | *5.2* | *10.4* | *7.8* | *9.0* | *20.3* |
| *Amphipoda* | *58.5* | *30.7* | *44.4* | *5.4* | *5.3* | *3.4* | *24.6* | *31.9* |
| *Cumacea* | *19.7* | *1.7* | *3* | *12.9* | *42.5* | *67.8* | *24.6* | *35.0* |
| *Decapoda* | *3.9* | *0.2* | *0.1* | *0* | *3.7* | *5.8* | *2.3* | *36.5* |
| Polychaeta | 1.3 | 6.6 | 6.8 | 11.4 | 14.5 | 20.3 | 10.2 | 22.1 |
| Echinodermata | 0 | 0 | 133.5 | 192.8 | 302.5 | 423 | 175.3 | 31.9 |
| Rest | 1.7 | 8.1 | 4.4 | 22.4 | 8.1 | 7.7 | 8.6 | 27.9 |
| **Biomass total** | **159.8** | **152.8** | **310.2** | **329.4** | **423.1** | **558.8** | **322.3** | **16.1** |
| **Ratio of feed benthos, %** | **43.9** | **31.5** | **14.8** | **3.2** | **3.7** | **2** | **10.4** | |

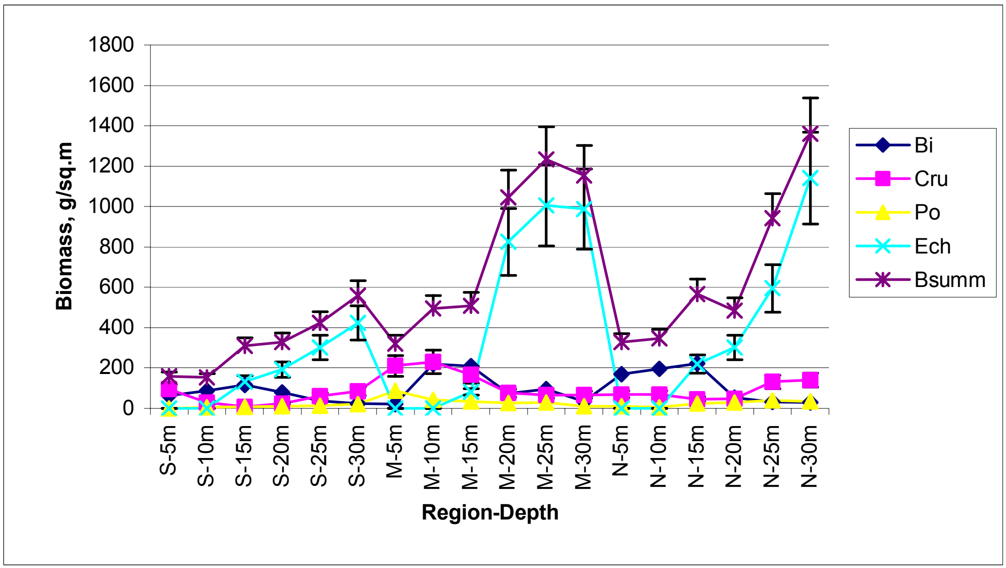



Fig. 18. Variation of total biomass ($B_{summ}$) and of biomasses of basic groups of macrobenthos at 6 ranges of depth (5-10-15-20-25-30m) in the three regions.

Regions: S – South, M – Middle, N – North.

Table 10

Distribution of total biomass of macrobenthos (g/m$^2$) and of biomasses of taxonomic groups relative to depths in the **middle** region

| Taxonomic group | Piltun Bay area sections P1-P4 | | | | | | Average biomass | Error in mean |
|---|---|---|---|---|---|---|---|---|
| | 5 m | 10 m | 15 m | 20 m | 25 m | 30 m | N=24 | % |
| Bivalvia | 22.5 | 219.8 | 207.8 | 74.6 | 95.6 | 34.7 | 107.5 | 23.4 |
| Crustacea: | 210.7 | 231.1 | 166.9 | 75.6 | 67.3 | 66.8 | 136.4 | 16.0 |
| *Isopoda* | *52.1* | *103.5* | *65.2* | *17.7* | *9.8* | *7.4* | *42.6* | *25.8* |
| *Amphipoda* | *138.7* | *118* | *85.4* | *26.2* | *16.1* | *16* | *66.7* | *23.6* |
| *Cumacea* | *17.8* | *3.8* | *2.2* | *18.9* | *31.1* | *28.9* | *17.1* | *20.5* |
| *Decapoda* | *2.1* | *5.8* | *14.1* | *12.8* | *10.3* | *14.5* | *9.9* | *14.5* |
| Polychaeta | 87.7 | 41.2 | 33.4 | 27.2 | 29.3 | 11.3 | 38.4 | 19.6 |
| Echinodermata | 0 | 0 | 82.2 | 825.3 | 1005.5 | 987.5 | 483.4 | 30.1 |
| Rest | 0.4 | 2.5 | 17.1 | 42.2 | 35.8 | 22.8 | 20.1 | 24.4 |
| **Biomass total** | **321.1** | **494.6** | **507.4** | **1044.9** | **1233.5** | **1153.1** | **790.8** | **14.5** |
| **Ratio of feed benthos, %** | **59.4** | **44.8** | **29.7** | **4.2** | **2.1** | **2** | **13.8** | |

Table 11

Distribution of total biomass of macrobenthos (g/m$^2$) and of biomasses of taxonomic groups relative to depths in the **north** region

| Taxonomic group | Odoptu Bay – Tront Bay sections N0 - N2 | | | | | | Average biomass | Error in mean |
|---|---|---|---|---|---|---|---|---|
| | 5 m | 10 m | 15 m | 20 m | 25 m | 30 m | N=18 | % |
| Bivalvia | 169.6 | 196.4 | 223.2 | 52.1 | 32.6 | 28.3 | 117.0 | 25.3 |
| Crustacea: | 69.3 | 69.9 | 45.8 | 47.1 | 131.3 | 139.8 | 83.9 | 16.5 |
| *Isopoda* | *23.1* | *43.2* | *15.1* | *3.4* | *11.3* | *5.7* | *17.0* | *28.8* |
| *Amphipoda* | *37.9* | *18.6* | *16.4* | *22.5* | *11.6* | *8.8* | *19.3* | *17.9* |
| *Cumacea* | *6.2* | *6.9* | *13.7* | *21.1* | *90.6* | *110.7* | *41.5* | *37.4* |
| *Decapoda* | *2.1* | *1.2* | *0.6* | *0.1* | *17.8* | *14.6* | *6.1* | *43.6* |
| Polychaeta | 11.5 | 4.8 | 23.4 | 28.2 | 38.9 | 33.2 | 23.3 | 18.6 |
| Echinodermata | 0 | 0 | 220 | 301.2 | 594.4 | 1141.2 | 376.1 | 38.5 |
| Rest | 8.1 | 4.6 | 9.1 | 9.4 | 12.8 | 27.5 | 11.9 | 22.6 |
| **Biomass total** | **258.5** | **275.7** | **521.5** | **438** | **810** | **1370** | **612.2** | **20.1** |
| **Ratio of feed benthos, %** | **23.6** | **22.4** | **6** | **5.9** | **2.8** | **1.1** | **5.9** | |

#### 4.2.3.1. Biomass of bivalves (*Bivalvia*).

It was recorded in section 4.1 that only three species of mollusks had frequency of occurrence in the regions more than 50 %, of 27 species found in the quantitative samples. All those species prevailed by their biomass in the studied regions: *Siliqua alta, Macoma lama, Megangulus luteus* (= *Peronidia lutea*, the mollusk is more widely known under this name). Beyond those species the mollusk *Mactromeris polynyma* (= *Spisula voyi* – this name has a more widespread circulation) had high values of biomass. That species had frequency of occurrence 31 % over the entire surveyed area, and from 21 up to 42 % in the regions.

In the entire area studied the biomass of Bivalvia somewhat increased from 5 m to 10-15 m, and consequently decreased at depths exceeding 20 m (Fig. 20,21).. The average value of biomass of bivalves over the entire water area was 98.0±17.1 g/m$^2$. With progress from the south region to the north, the trend of molluskan biomass to increase was recorded: in the south region it was 67.8 g/m$^2$, in the middle – 107. 5 g/m$^2$, in the north – 117.0 g/m$^2$. The greatest average biomass of Bivalvia was recorded in the middle region at the depth 10-15 m (more than 200 g/m$^2$) and in the north one, at the same depth 5-15 m (from 170 up to 220 g/m$^2$).

The distribution of 4 mass species of mollusks relative to depths is shown at Fig. 20. By pattern of distribution it is possible to distinguish the group of species, which the greatest biomass was recorded in the depth range 5-15 m. They are - *Siliqua alta* and *Megangulus luteus*. Mollusk *Macoma lama* had approximately the same biomass in entire range of depths. One species – *Spisula voyi (Mactromeris polynyma)* had the minimum biomass in the depth range 5-15 m, but deeper the biomass sharply increased.

One of the important parameters of benthic animals is the pattern of spatial distribution (*regular, random or aggregated*). The representative ness of the quantitative sample (n = 192) sufficed to evaluate pattern of spatial distribution of common species of macrozoobenthos∗. The following values of dispersion index were obtained in bivalves: *Siliqua alta* – 10.2; *Macoma lama* – 12.3; *Megangulus luteus* – 8.1; *Spisula voyi* – 22.3. In all instances we have deal with the aggregated distribution of individuals of 4 mass species of Bivalvia. Ecological consequences of that will be considered below.

#### 4.2.3.2. Biomass of polychaetes (*Polychaeta*)

As it was noted above, only one species, *Onuphis shirikishinaiensis*, had frequency of occurrence emceeing 50 % of 41 polychaete species having P> 10 %. Another species, *Scoloplos armiger*, was recorded in 30 % of samples. The average biomass of polychaetes was 23.9±4.7 g/m$^2$ over the entire water area. The ratio of polychaetes in the total biomass of macrobenthos in all the three regions was rather stable, from 6.9 % up to 12.2 %. As follows

∗ From many **indexes of aggregation** used now we applied one of the most simple, but interpretable reliably enough – the dispersion index (Elliott, 1977), $I_\partial = s^2 / _{xm}$, where $s^2$ – sampling variance, $_{xm}$ – sample average. At I = 0 a species has the maximum regular distribution; at I = 1 – the random, the maximum degree of aggregation will be observed at I = ∑x. We should note, that overwhelming number of bottom animals has the aggregated distribution, the random, and furthermore, the regular distribution of individuals is rare exception to the rule.

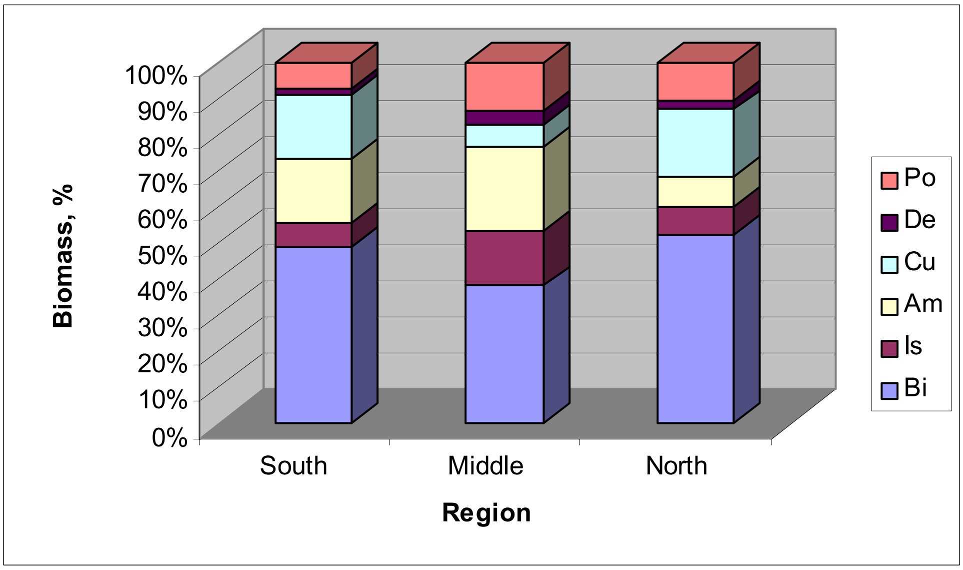



Fig. 19. Ratios of biomass of basic groups of benthos in the three regions
(% of total biomass of benthos, disregarding biomasses of flat sea urchins)

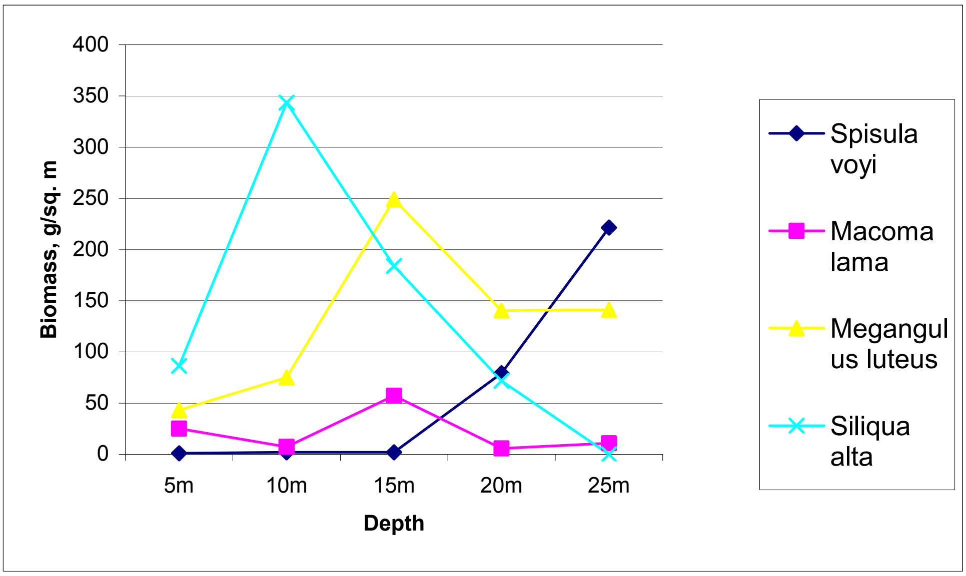
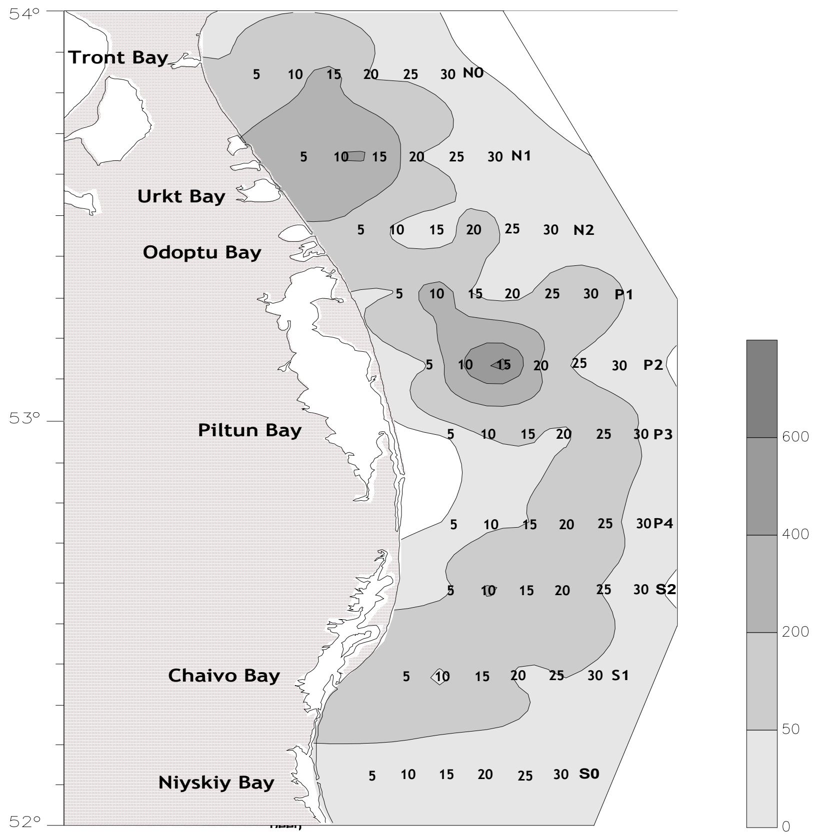



Fig. 20. Distribution of biomass of 4 mass species of bivalves relative to depths



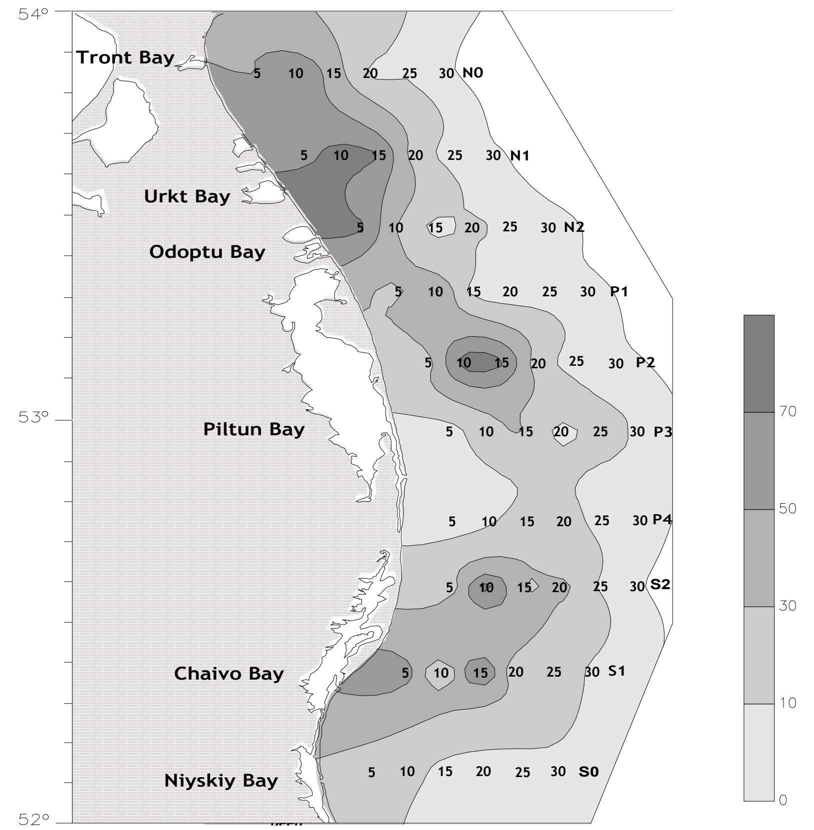




Fig. 21. Distribution of biomass ($g/m^2$) of bivalves (upper) and their ratio (%) in the total macrobenthic biomass (down).

from Figs. 16 and 17, the polychaetes had close values of biomass at all the depths studied in all the three regions, as well as over entire surveyed area. In the south region their biomass was 10.2 g/m$^2$, in middle region – 38.4 g/m$^2$, in the north – 23.3 g/m$^2$ (the error in mean was 22.1 %, 19.6 % and 18.6 % respectively).

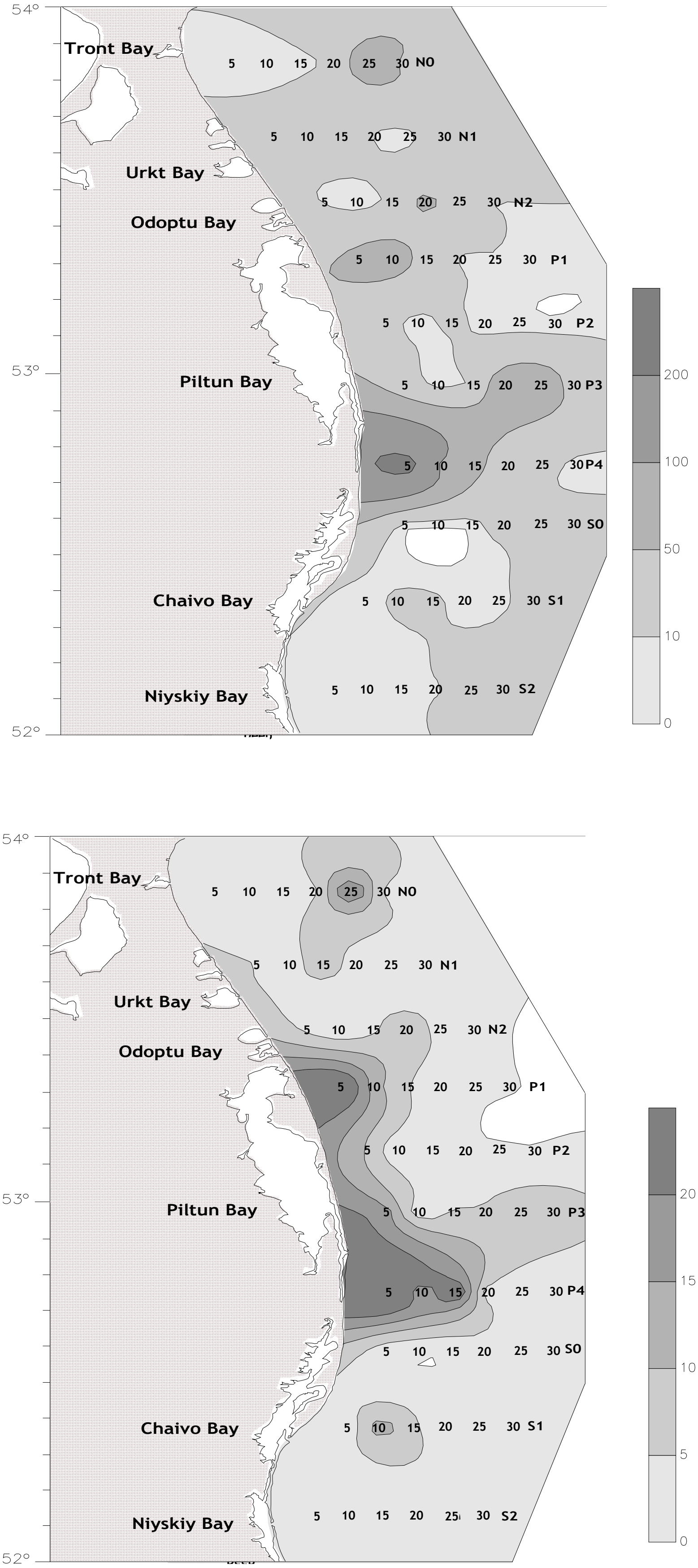
Distribution of the most common species of polychaete, *O. shirikishinaiensis*, relative to depths is adduced at Fig. 22. The biomass of this species sharply decrease with the depth. In the Piltun Bay area its biomass on the average reached 107 g/m$^2$ at 5m depth, and was less than 13 g/m$^2$ at 20 m. In the south and north regions that species occurred in much lesser biomasses, up to 40 g/m$^2$.

Results of diving works unambiguously evidenced, that that species is a potent environment edificator in the Piltun Bay area. At some stations, within the depth range from to 5 to 10 m, there were recorded patches, by visual assessment of divers the patch area was on the average 3-5 m$^2$, with population density from several hundreds to several thousands individuals per square meter of bottom.

The maximum population density, 7000 ind/m$^2$, with biomass 960 g/m$^2$ was recorded in section P3 at depth 5 – 6 m. *Onuphis shirikishinaiensis* (fam. *Onuphiidae*) lives in tubes, in contrast to other species of polychaetes living in tubes, that species, if necessary it can abandon old tubes and build new ones [24]. By the way of feeding that species belongs to sedimentators, i.e. inhabits sites of active hydrodynamics [25]. Probably, exactly that ability enabled that species to occupy hydrodinamically active areas of instable fine sand bottoms at shallow depths. Tubes of this species were up to 5-6 mm in diameter, the length of tubes was up to 20 sm. Average weight of individuals of that species was 0.137±0.06 g. The tubes 3-4 sm protrude from a ground, i.e. a peculiar tube “wood” arises from the ground surface.

High population density settlements of isopods and amphipods were recorded among the tubes, i.e. crustaceans intensively use the polychaete settlements as shelters[♥]. Thus, polychaetes stabilize their environment, creating condition for habitation in hydrodinamically active areas to other animals, in particular, to crustaceans and to other species of polychaetes. Of the other polychaetes recorded in dense settlements of *O. shirikishinaiensis*, we should note *Scoloplos armiger* (P = 29 %), *Nephtys caeca* (P = 21 %), *Eteone longa* (P = 18 %), *Travisia forbesii* (P = 18 %). The dispersion index of *Onuphis shirikishinaiensis* reached 128.6, displaying a high level of aggregation in distribution of this species.

[♥] Design of the diver’s bottom sampler makes it possible to take samples even in dense sandy grounds up to depth of 20-25 sm from their surface, which enabled count of biomass and number of polychaetes. Quite the opposite occurred with use of dredges on dense grounds (**Photo. 2**). There was a plenty of empty tubes of polychaetes of lengths 3-4 sm (that was the height the tubes protruded from the ground) but no polychaete individuals were recorded in the samples. On dense grounds the dredger simply cuts protrusions of tubes. At that, animals associated to tube mats of polychaetes (amphipods and isopods), were counted quite satisfactorily **(Photo 3**). Thus, the poor overall efficiency of bottom dredges on dense sandy grounds of shallow water zone results in distinguishing of communities consisting only of crustaceans, amphipods and isopods, over there.




)

Fig.22.Distribution of biomass (g/m$^2$) of <u>polychaetes</u> (upper) and their ratio (%) in the total macrobenthic biomass (down).

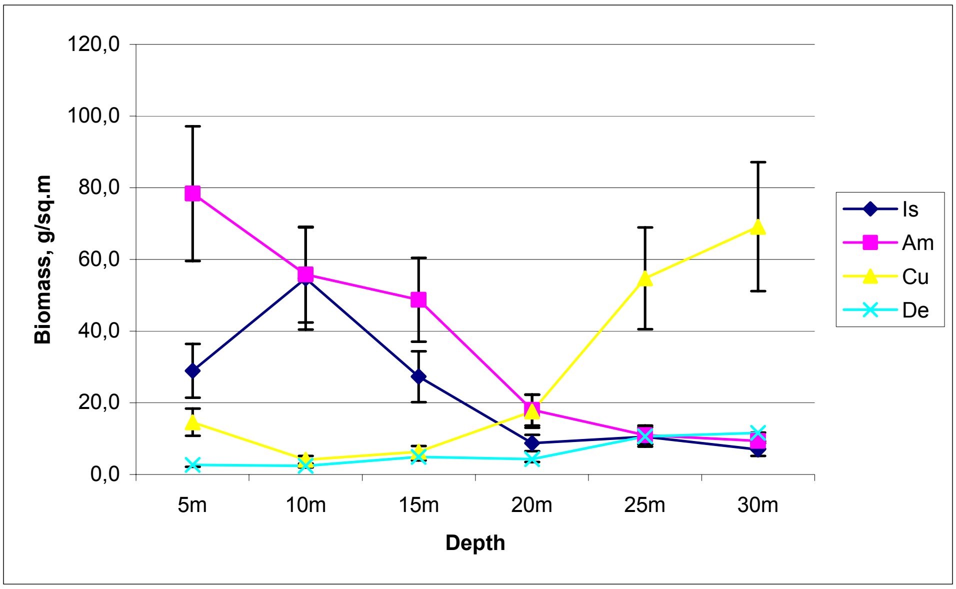



Fig. 23. Variation of biomass of 4 crustacean groups with depths

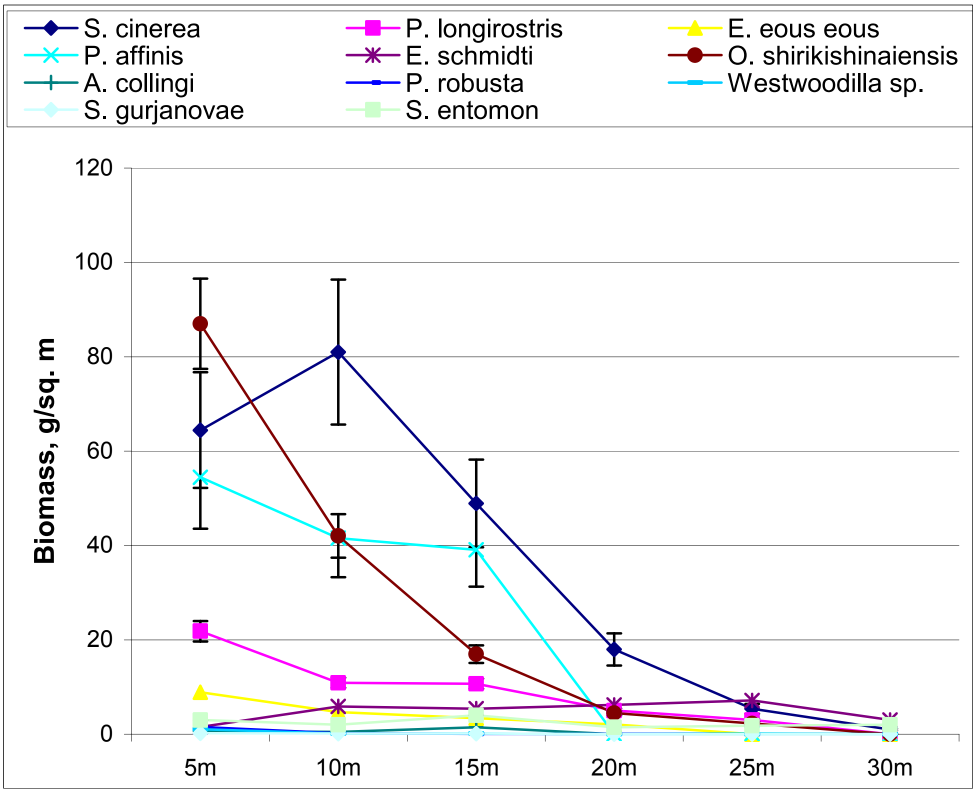



Fig. 24. Distribution of biomass of mass species of macrobenthos by depths

Abbreviations of names: 8 species of amphipods - *Pontoporeia affinis, Atylus collingi, Synchelidium gurjanovae, Pontharpinia longirostris, P. robusta, Eogammarus schmidti, Eohaustorius eous eous, Westwoodilla sp.*; 2 species of isopods – *Synidotea cinerea, Saduria entomon*; 1 polychaete species – *Onuphis shirikishinaiensis*.

Photo 2. Empty tubes of polychaete *Onuphis shirikishinaiensis.* Length of tubes 3-4 sm.
(heavy duty model of the Petersen dredge; transect P 3; depth 10 m; dense fine sand with sandy waves on surface)

Photo 3. The fauna associated to tub mats of *Onuphis shirikishinaiensis*
(amphipods – 12 species), dominated - *Pontoporeia affinis, Eohaustorius eous eous, Pontharpinia longirostris, Eogammarus schmidti, Atylus collingi, Pontharpinia robusta, Synchelidium gurjanovae and Westwoodilla sp.;* isopods *Synidotea cinerea*; juveniles of beach clam *Siliqua alta*)

### 4.2.3.3. Biomass of crustaceans (*Crustacea*).

Crustaceans, isopods, amphipods, decapods and hooded shrimps, spur the greatest interest from the point of view of study of the gray whale feeding in surveyed area. The significance of these groups in feeding of California-Chukchi population of gray whales was repeatedly discussed [64]. Data on crustacean distribution in feeding area of the Okhotsk-Korean population of gray whales are absent, except for fragmentary observations [26].

The total ratio of crustacean in total biomass of macrobenthos was 41.2 % in the south region, 45.1 % - in the middle region, and 35.5 % - in the north region. (Fig. 19, 25). Distribution of biomass of 4 groups of crustaceans over the entire surveyed area is displayed at Fig. 23. Three types of biomass variation with depth were observed. Amphipods and isopods had maximum biomass within the range 5-15 m, its drastic reduction was recorded at depth exceeding 20 m. The biomass of hooded shrimps varied in the opposite way. It was minimum at depths less than 20 m, and surge increased with increase of depth. The biomass of decapods was approximately equal at all depths. The biomass of crustaceans over the entire water area was on the average 90.3±14.6 g/m$^2$ (in the **south** region – 50.6 g/m$^2$, in the **middle** region – 136.4 g/m$^2$, in the **north** one – 83.9 g/m$^2$).

Decapodes (*Decapoda*) (Fig. 26). We should note that quantitative assessment of decapods was considerably difficult. In total, 4 decapods species were recorded in quantitative samples – 2 species of hermit crab, juveniles of crab *Hyas coarctatus* and shrimp *Crangon septemspinosa*. At implementation of diving works the first three species were counted concurrently with sampling of large epibenthos from 5 m$^2$ count area.

The diver’s bottom sampler had a bag made of nylon with mesh size 0.5 mm, that beyond sediment sampling, it could function as epibenthos net with capture area 0.025 m$^2$. In the most instances Crangon shrimps, that were on the bottom surface or in the surface ground layer, were seized by the bottom sampler. Naturally, that species richness decapods of considered water area should be much greater, than we succeeded to reveal.

Shrimps *Crangon septemspinosa* were recorded in all the three regions on sandy bottoms, practically at all depths studied. But in no area their frequency of occurrence exceeded 15 % from the total number of samples. The juveniles of crabs were observed in the greatest number on gravel - pebbly grounds among sponges, bryozoans, and hydroids. No aggregations of crab juveniles were recorded in any of the three regions studied.

Isopods (*Isopoda*). The relative ratios of isopods in the total biomass of macrobenthos in the south and north regions were close – 6.1 % and 7.1 %, their ratio was a little bit higher in the middle region – 14.1 % (Fig. 19, 27). The average biomass over the entire surveyed area was 22.9±6.3 g/m$^2$. The greatest average biomass of isopods was in the middle region, 42.6 g/m$^2$, in the south and north regions – 9.0 g/m$^2$ and 28.8 g/m$^2$ respectively. The

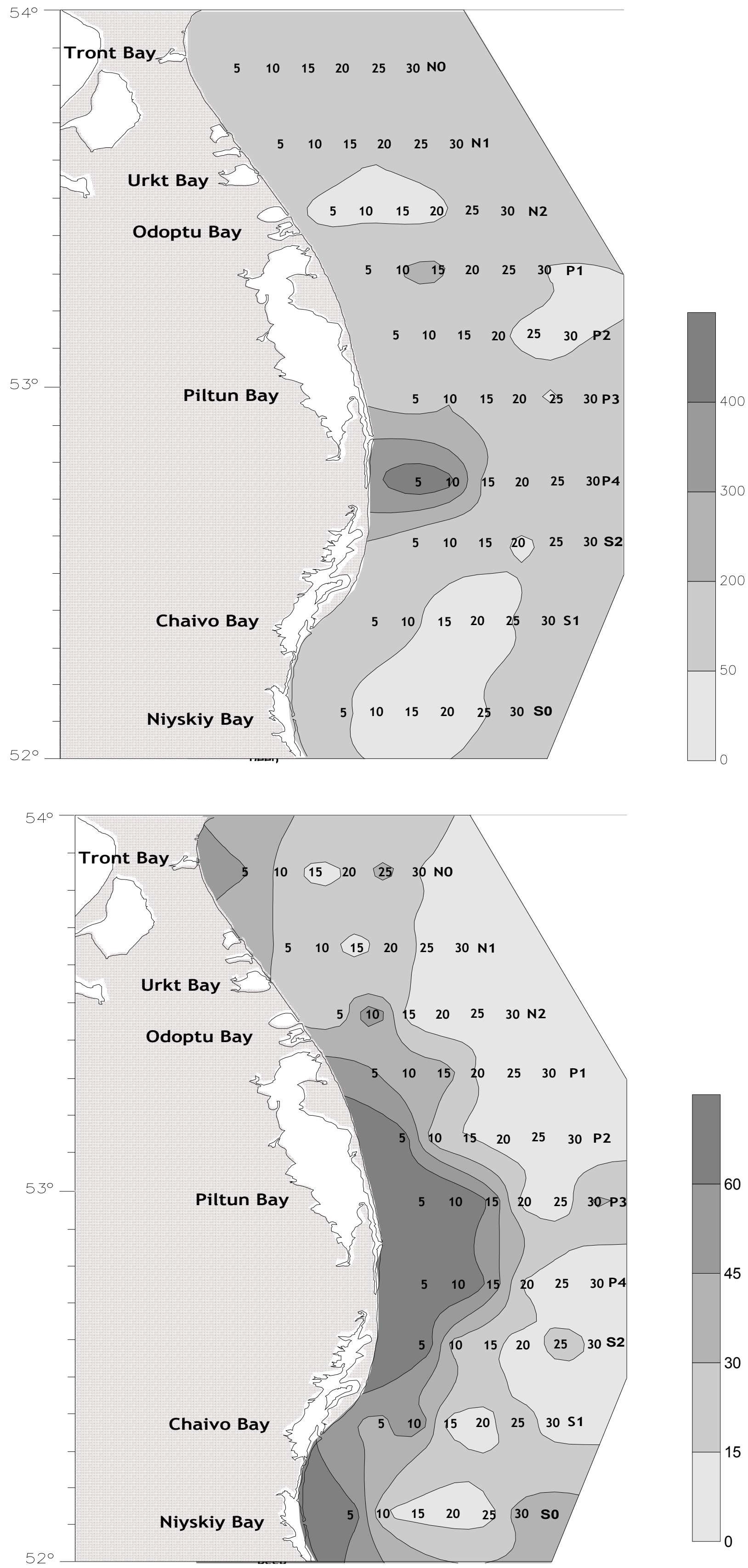



Fig.25. Distribution of biomass (g/m$^2$) of crustaceans (upper) and relative part (%) of total macrobenthic biomass (down).

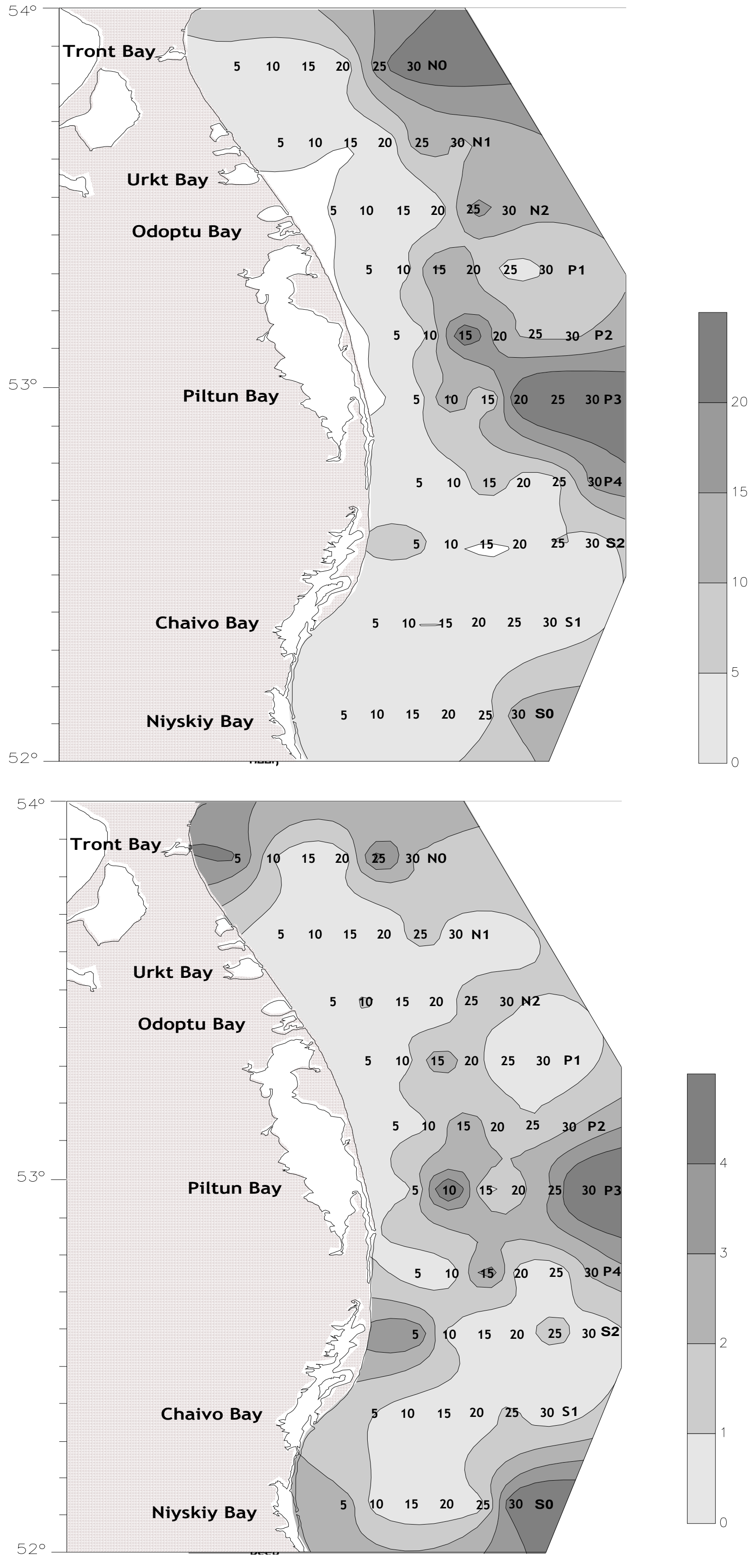



Fig.26. Distribution of biomass (g/m$^2$) of decapods (upper) and their ratio (%) in the total macrobenthic biomass (down).

greatest values of biomass of isopods were recorded at depths 5 – 15 m (27.3 - 54.7 g/m$^2$), in the range of 20-30 m the biomass sharply decreased and being 7.0 - 10.5 g/m$^2$ (Fig. 23).

Of three isopods species found in our samples one species – *Synidotea bicuspida* (P = 12 %) was presented by single individuals, the quantitative samples and had no essential part (12 %) in isopod abundance. Large isopod *Saduria entomon* (the average weight of individuals was 2.09 g –Tab. 12) had 22 % frequency of occurrence (in middle region – 25 %). The biomass of that species varied insignificantly in the entire range of depths 5 - 30 m, from 1.5 g/m$^2$ up to 4 g/m$^2$. That isopod species belongs to predators by its type of feeding.

The most significant part in isopod biomass isopods took *Synidotea cinerea*. That isopod had the maximum frequency of occurrence among all species of macrobenthos over the entire water area studied - 86 %. That species had the greatest values of biomass at depths up to 15 m, with greater depth its biomass sharply decreased. Only singular individuals occurred at the depth exceeding 25 m (Fig. 24). *S. cinerea* belongs to detritophages by its type of feeding, the greatest population density was associated with tubular mats of polychaete *O. shirikishinaiensis,* which accumulated detritus. In mats the maximum population density of *S. cinerea* was more than 5000 ind/m$^2$, the biomass was more than 90 g/m$^2$. The value of aggregation index (I = 156) evidenced for a high degree of aggregation.

<u>Amphipods (*Amphipoda*)</u>. In the studied area amphipods had a greatest species richness of all groups of benthos - 53 species. 10 species of them had frequency of occurrence more than 25 %, 3 species – more than 50 %. The average biomass of amphipods over the entire surveyed area was 36.9±9.7 g/m$^2$. The greatest average biomass of amphipods was observed in Piltun Bay region – 66.7±15.7 g/m$^2$, in the south and north regions - 24.6 and 17.9 g/m$^2$ respectively. The relative biomass of amphipods (Fig. 19, 28) varied from 8.2 % in the north region up to 16.7 % in the south region. The maximum ratio of amphipods in the total biomass of benthos (22.1 %) was recorded in the middle region.

The biomass of amphipods over the entire surveyed area gradually decreased from 78.4 g/m$^2$ at 5 m to 9.4 g/m$^2$ at 30 m depth. That trend was also recorded within the limits of each distinguished region. However, there were recorded significant differences in quantitative abundance of amphipods at depths up to 15 m. Thus, the average biomass in the Piltun Bay area reached 114.1 g/m$^2$, while in the south region it was 44.5 g/m$^2$, and in the north - 24.3 g/m$^2$. The amphipod biomass was the same at depths 20 – 30 m in all the regions, being less than 10 g/m$^2$. Among amphipod species, which frequency of occurrence exceeded 25 %, 6 species had the greatest values of biomass: *Pontharpinia longirostris, Eohaustorius eous eous, Pontoporeia affinis, Eogammarus schmidti, Atylus collingi, Pontharpinia robusta, Synchelidium gurjanovae* and *Anonyx nugax pacificus*.

Variation of biomass of those species with depth is displayed at Figs. 23, 24, 28. Their biomass decreased with increase of depth. The most considerable variation of amphipod biomass occurred at depths 15-20 m. Thus, the average biomass of *P. affinis* was 42.5 g/m$^2$ at

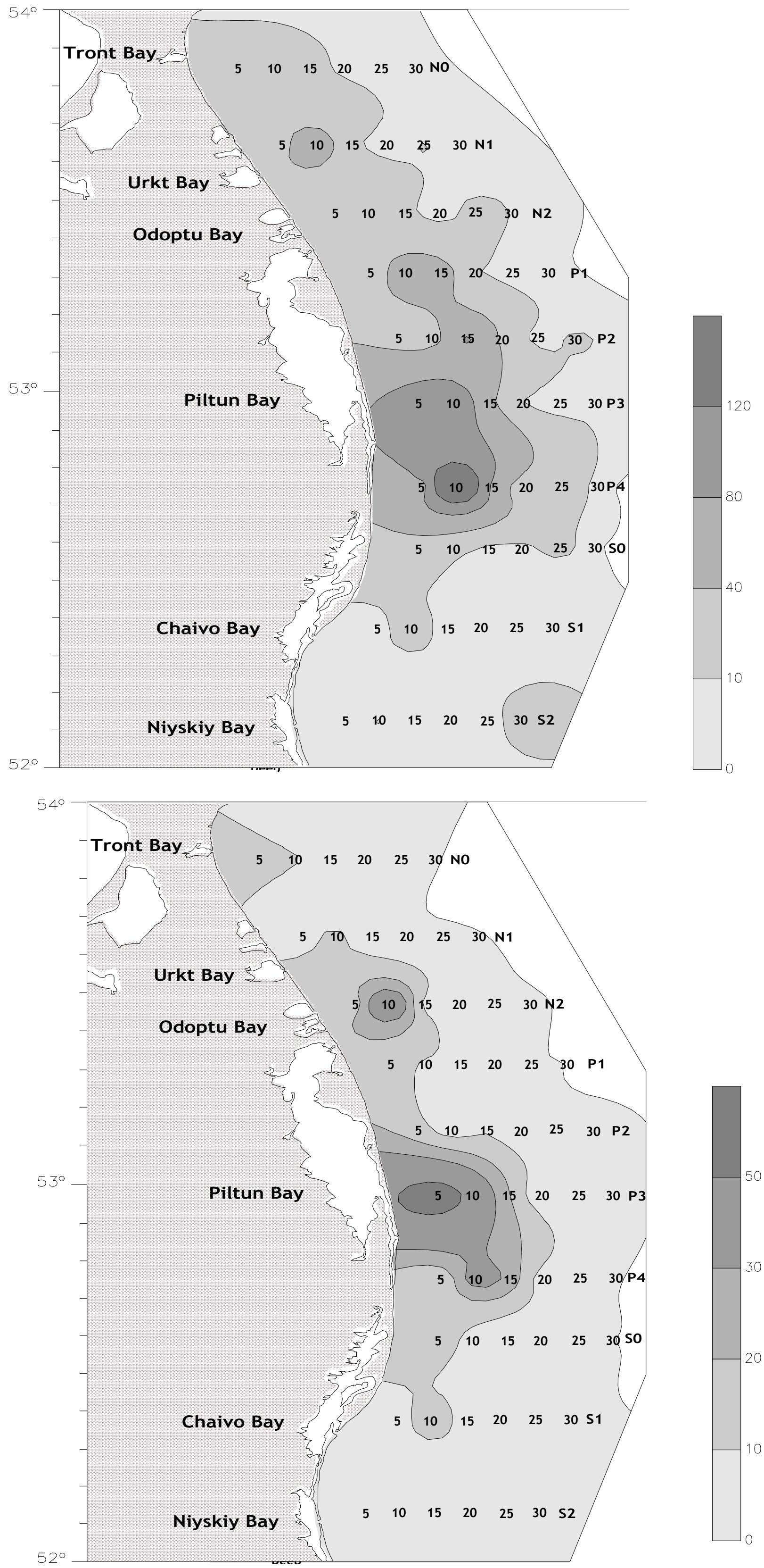



Fig.27. Distribution of biomass (g/m$^2$) of <u>isopods</u> (upper) and their ratio (%) in the total macrobenthic biomass (down).

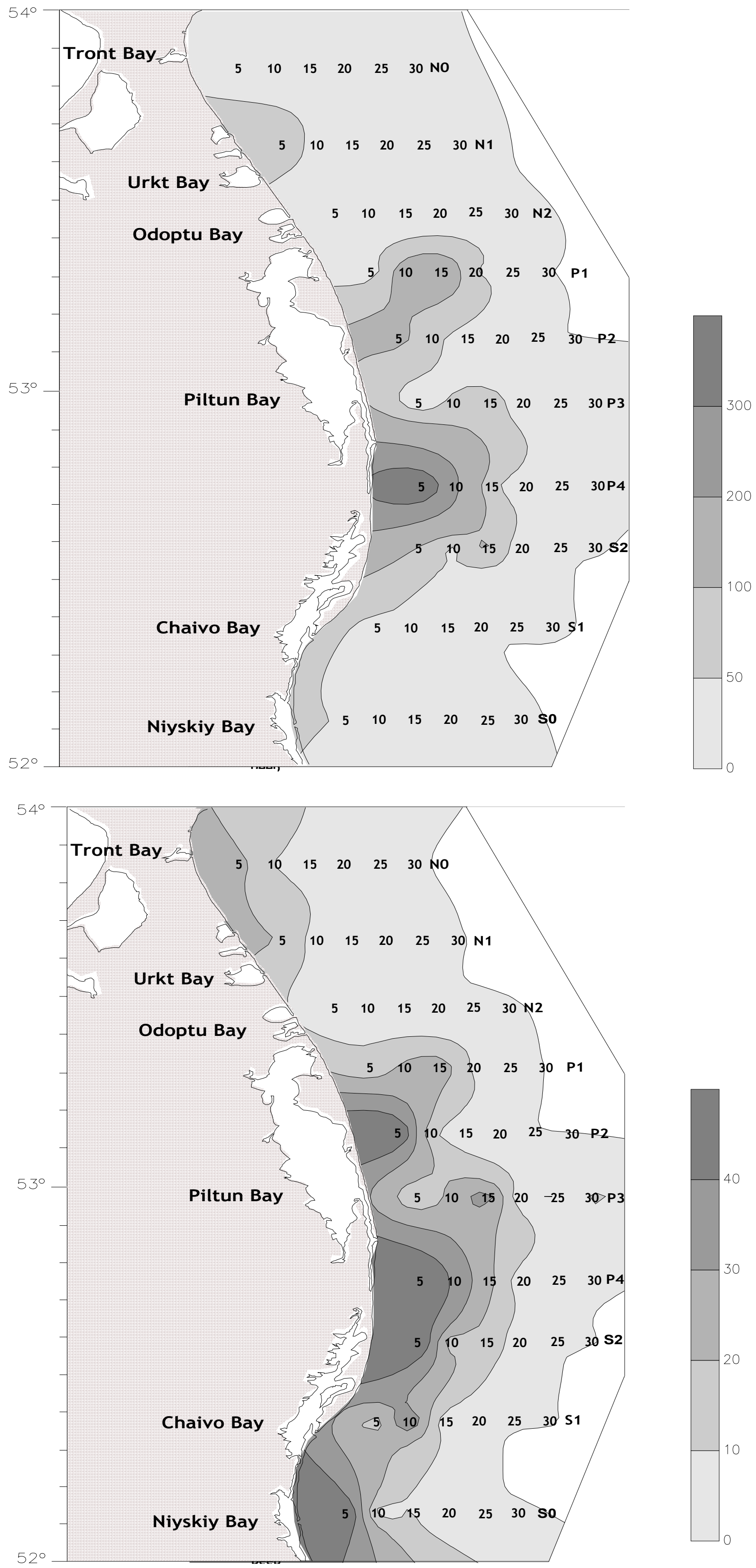



Fig.28. Distribution of biomass (g/m$^2$) of amphipods (upper) and their ratio (%) of total macrobenthic biomass (down).

depths 5-15 m and sharply decreased to 0.12 g/m$^2$ at depth of 20-25 m. Other mass species, *P. longirostris, E. eous eous,* had the similar pattern of biomass variation with depth.

Values of dispersion index evidenced for an aggregated character of distribution of common amphipod species. Thus, it was equal to 231.4 in *Pontoporeia affinis* and 218.6 in *E. eous eous*. The most part of common amphipod species had the greatest values of populations density and biomass in tube mats of *O. shirikishinaiensis*.

Size structure of amphipods. Amphipods are the major component of gray whale nutrition. Analysis of size structure of 6 mass species was carried out to estimate recruitment of amphipod settlements by juveniles. Statistic parameters of size structure (Appendix 8, Tabl. A8.1) and histograms of length distribution of amphipod body were estimated (Appendix 8; Fig. A8.1 and Fig. A8.2). From 200 up to 400 individuals were measured in each amphipod species. Analysis of histograms displayed that significant ratio of young individuals was typical to all species, which evidenced for absence of negative effect on amphipod settlements and for normal recruitment of soft bottom communities in feeding area of gray whales.

Hooded shrimps (*Cumacea*). The average biomass of hooded shrimps was 27.8±7.9 g/m$^2$over the entire surveyed area, with frequency of occurrence 26 % (Fig. 30). In the distinguished regions the average biomass varied from 17 up to 37 g/m$^2$ (Tab. 9-11). With depth increase more significant variations of biomass of hooded shrimps were recorded, both over the entire area and in the individual regions (Fig. 29). It is indicative, that biomasses of amphipods and of hooded shrimps varied antiphase – the mean biomass of amphipods decreased, while that of hooded shrimps increased with depth. The most crucial changes were observed at depth 20 m (Fig. 29). The maximum population density of hooded shrimps was recorded in zone of mass development of sand dollars within the range 25-30 m, up to 32000 ind/m$^2$ (maximum – 92000 ind/m$^2$; Photo 4) . We noted that there were no regular correlation recorded between biomass values of samples of flat sea urchins and those of hood shrimps. At the most stations sand dollars and hooded shrimps occurred.

Hence, at the same station sand dollars + hooded shrimps occurred in some samples, either only sand dollars or only hood shrimps – in the other. The relative number of samples with hooded shrimps and without flat sea urchins did not exceed 5 % of the total number of samples in the range 25-20 m (n = 56 tests), which evidenced for aggregation distribution of flat sea urchins and hooded shrimps. The dispersion index of hooded shrimps was 298.7.

Over the entire surveyed area 3 hooded shrimp species were recorded: *Diastylis bidentata, Diastylopsis dowsoni,* and *Lamprops quadriplicata*. The two latter species occurred up to depth of 15-20 m with P <10 % and had no great significance in the total biomass of hooded shrimps.

Table 12

Average weight of individuals of amphipods (Am), isopods (Is) and of hooded shrimps (Cu)

| Group | Species | N | Average weight of individual, g | Group | Species | N | Average weight of individual, g |
|---|---|---|---|---|---|---|---|
| Is | *Saduria entomon* | 111 | 2.087 | Am | *Pontharpinia longirostris* | 272 | 0.009 |
| Am | *Ampelisca eschrichti* | 98 | 0.134 | Cu | *Diastilis bidentata* | 5870 | 0.008 |
| Am | *Anonyx pacificus.* | 35 | 0.103 | Am | *Eohaustorius eous eous* | 1082 | 0.007 |
| Am | *Eogammarus schmidti* | 131 | 0.101 | Am | *Atylus collingi* | 327 | 0.006 |
| Am | *Boeckosimus derjugini* | 49 | 0.097 | Am | *Orchomenella japonica* | 56 | 0.006 |
| Is | *Synidotea bicuspida* | 67 | 0.092 | Am | *Protomedeia microdactila* | 32 | 0.004 |
| Is | *Synidotea cinerea* | 2198 | 0.020 | Am | *Orchomenella pinguis* | 12 | 0.004 |
| Am | *Anisogammarus pugettensis* | 212 | 0.018 | Am | *Orchomenella gurjanovae* | 46 | 0.003 |
| Am | *Pontoporeia affinis* | 3745 | 0.014 | Am | *Protomedeia macrocarpa* | 37 | 0.003 |
| Am | *Pontharpinia robusta* | 122 | 0.014 | Am | *Synchelidium gurjanovae* | 51 | 0.002 |
| Am | *Monoculodes crassirostris* | 154 | 0.009 | Am | | | |

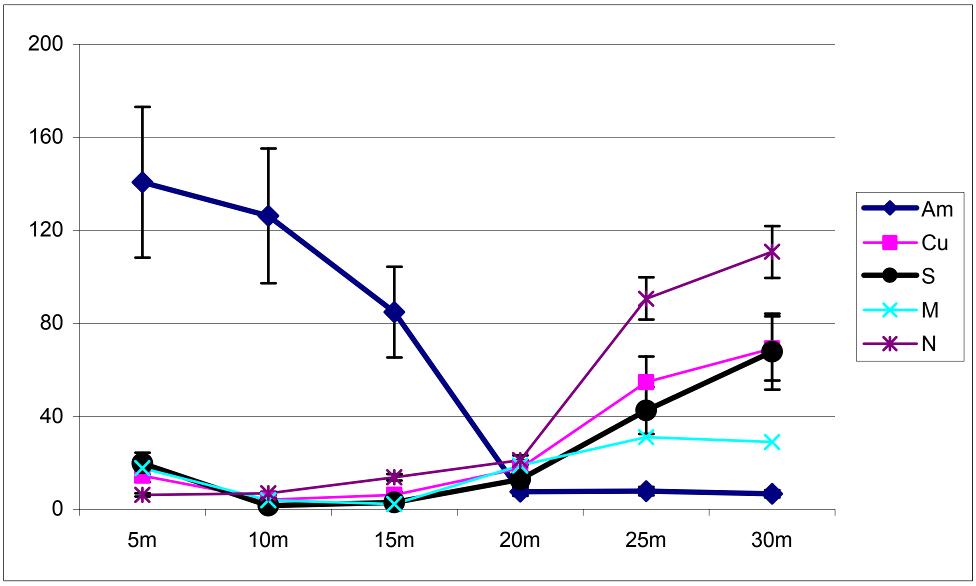



Fig. 29. Variation of biomass (g/m$^2$) of amphipods and of hooded shrimps with depth

Am – average biomass of amphipods in the entire area, Cu – average biomass of hooded shrimps in the entire area. Biomass of hooded shrimps in the regions: S – south, M – middle, N – north.

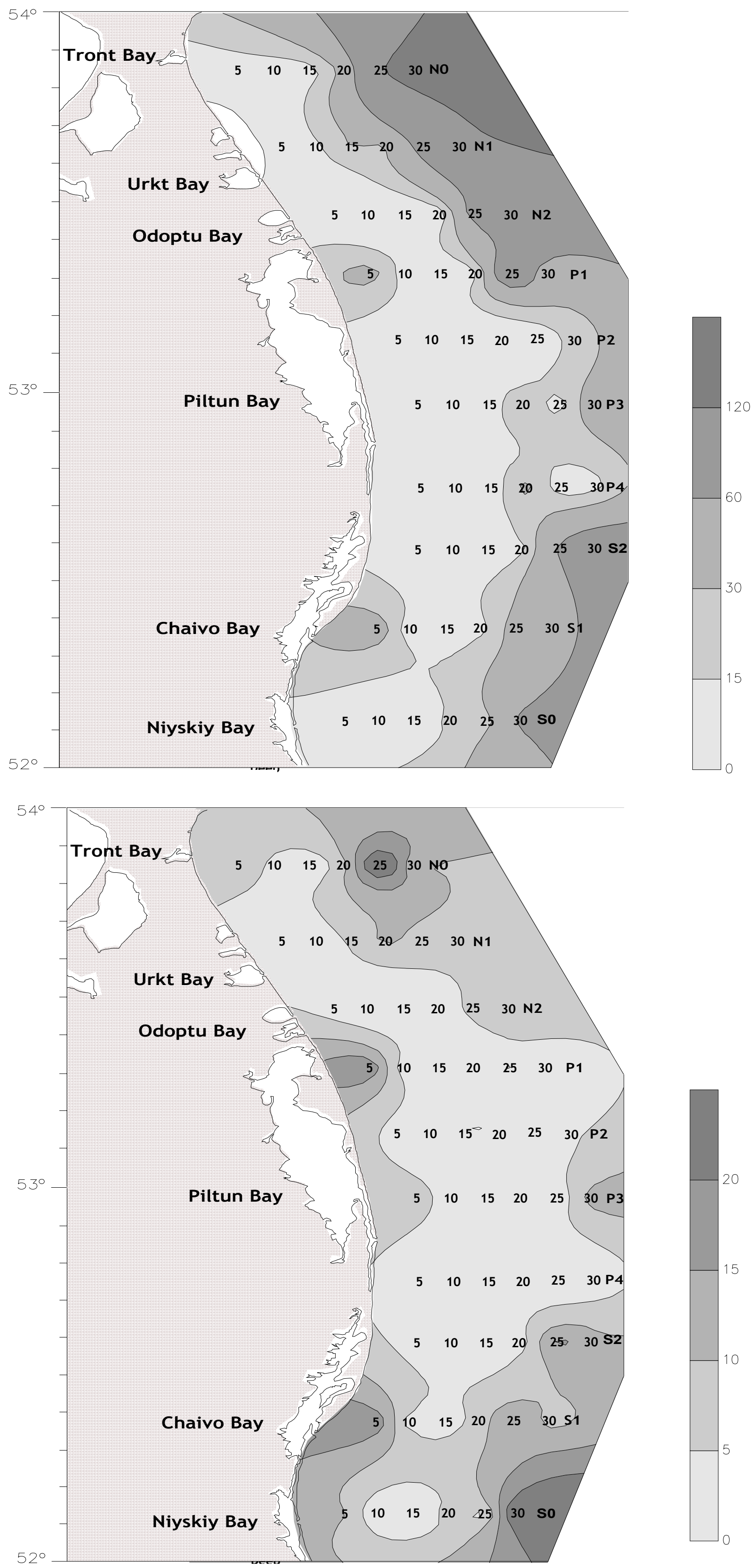



Fig.30.Distribution of biomass (g/m$^2$) of <u>hooded shrimps</u> (upper) and their ratio (%) in the total macrobenthic biomass (down).

Photo 4. Hooded shrimps *Diastylis bidentata*
(diver's bottom sampler; transect N1, depth 25 m, medium sand + gravel)

Photo 5. Larvae of flat sea urchins in the sample from 5 m depth
(Sand dollars were collected from count area 1 $m^2$, the rest animals –
by diver's bottom sampler, transect P1, depth 5 m, fine sand)

### 4.2.3.4. Biomass of echinoderms (*Echinodermata*).

In the surveyed area only 3 echinoderm species were recoded: 2 species of brittle star and sand dollar *Echinarachnius parma* (Appendix 5). The brittle stars were not recorded in quantitative samples. *E. parma* was dominating species in the surveyed area at depths over 15-20 m (Tab. 9-11, Fig. 16-17, 31). The ratio of that species was up to 97 % of the total biomass. Community of flat sea urchins is widespread in all the Far East seas.

According to Averintsev [27], there is a huge wide-boreal association of flat sea urchin *E. parma* at depths 15-120 m, occupying about 13 thousand km$^2$ at coast of the East Sakhalin, i.e. 40 % of the shelf area. *E. parma* community is associated to fine sand and silt-covered sand bottoms, subjected to bottom currents of high enough speeds [28]. With slowing speed of current to the south along the shelf of East Sakhalin and increasing silting of grounds, the sand dollar is substituted by other species. As A.P. Kuznetsov [29], recorded the mobile sestonophages (flat sea urchin, some amphipods and bivalves) settle mostly on sands – coars aleurites with the organic content 0.5-1.0 % and with concentration of suspended matter about 20 mg/l in the bottom layer. By observations conducted 1995-1996, the content of suspended matter in water varied from 0.93 up to 11.8 mg/l, with suspended matter of biological origin prevailed [16,17].

The considerable bottom areas occupied by *E. parma* community were found at West Kamchatka shelf [30], and, as explorers noted, the north boundary of range of E. parma was advanced northward more than 20 miles. The cause of such changes connects to indirect anthropogenic influence, overfishing of red king crab and flounder (feeding on sea urchins), which entailed disturbance of balance in “pray–predator” system.

Sand dollar community on the shelf of the Sea of Japan (the Peter the Great Bay) was recorded at depths from 50 up to 200 m. K.M. Deryugin [31] stated by materials of 30-s research about grouping of sea urchins on sandy plateau at the depth 67 m included in biocoenosis *Liocyma fluctuosa* + *Ampelisca macrocephala*. *E. parma* community is widespread on the shelf Japan Sea coast of Sakhalin [31] The statistical analysis of distribution of *E. parma* had shown, that this species associated to depths exceeding 15 m and preferred stable medium -and fine-grained bottoms with minor silting [32].

Considering distribution of *E. parma* relative to depth in the studied area, it is necessary to note, that within the depths range 15-20 m there is a boundary of zone of mass development of sea urchins. Starting from that depths the sand dollars dominate by biomass over other species of macrobenthos. *E. parma* was repeatedly recorded in minor numbers or individually at SCUBA counting at 5-meter transect (the count area = 5 m$^2$) at depths 5 and 10 m in all the three regions (Photo 5). Population density of sand dollars varied from 1 up to 4 ind. on count site (0.1 – 0.8 ind/m$^2$). The probability of sand dollar catching by bottom sampler at such population density was extremely low.

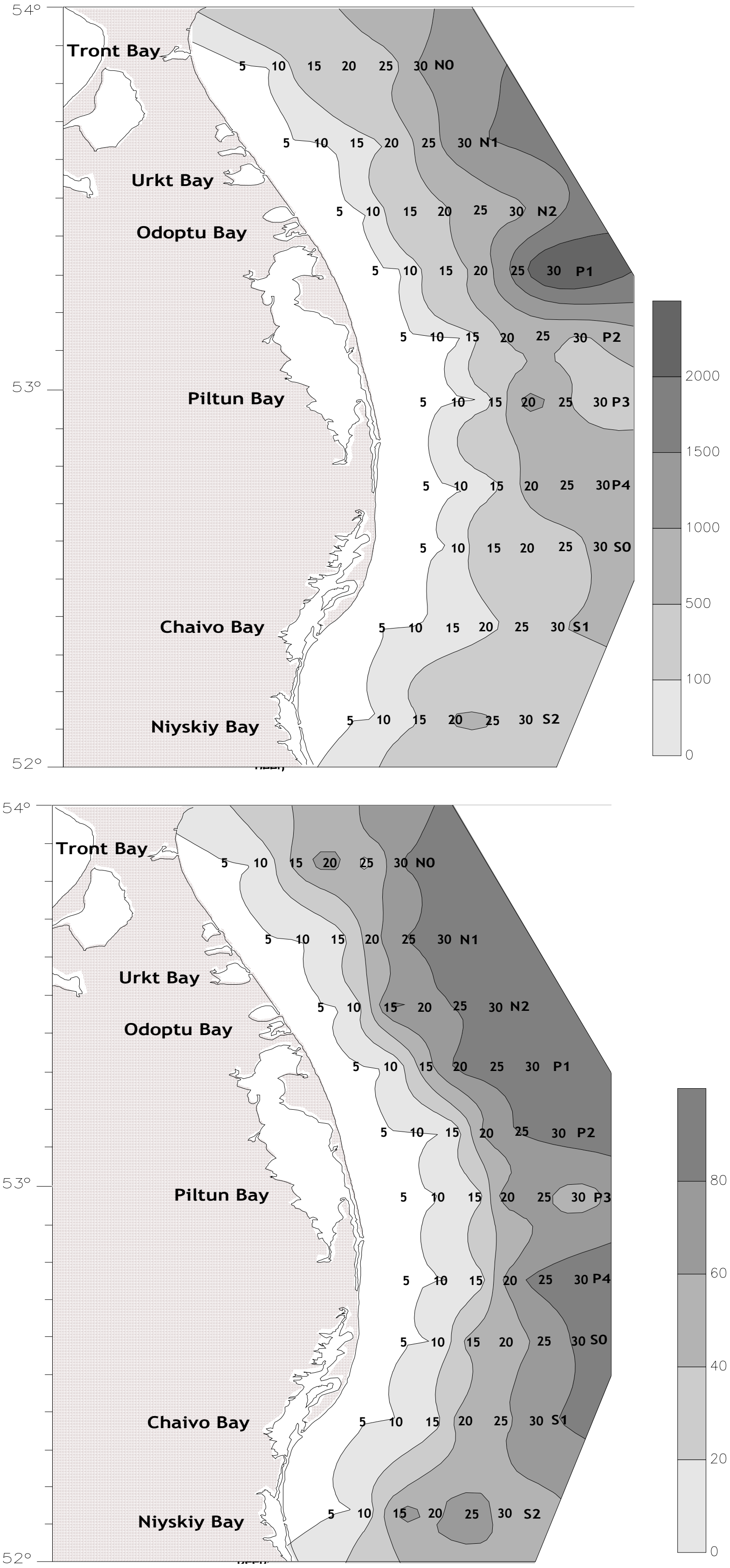



Fig.31. Distribution of biomass (g/m$^2$ ) of <u>sand dollars *Echinarachnius parma*</u> (left) and their ratio (%) in the total macrobenthic biomass (right)

Thus, the pattern of distribution of sand dollars was more likely continuous, than discrete. Rather distinct boundary in range of depth 15-20 m was caused by greater catchments probability of sand dollars by bottom sampler thanks to their higher population density at those depths, i.e. the boundary is of statistical nature to a greater extent. That implies, that simple presence or absence of sand dollars in an area is not a proof of unfitness of the area for gray whale feeding. It is possible to assume, that major factor-defining boundary of mass development of sand dollars in water area is stability of sediments, which in its turn, is determined by hydrodynamics of the area and by speed of bottom currents [26].

Microdistribution of flat sea urchins has a high degree of aggregation (the dispersion index I = 312.8). Some variations in distribution of sand dollars, occurred for 1992-2001 decade are considered in section 4.4.

#### 4.2.4. Assessment of similarity of the regions and of depths by total biomass and by caloricity of benthos

##### 4.2.4.1. Biomass

Distribution of biomass of individual taxonomic groups over the entire surveyed area and in individual distinguished regions has been considered above. It is of interest to evaluate similarity of the regions by ratio of biomasses of taxonomic groups at particular depths. The following matrix was analyzed: Biomass of 7 taxonomic groups (*Bivalvia, Isopoda, Amphipoda, Decapoda, Cumacea, Polychaeta, Echinodermata*) x 6 ranges of depths (5-10-15-20-25-30 м) x 3 areas (the south, middle and north regions). The hierarchic cluster analysis was used (dendrogram was constructed by Ward method, the measure of similarity was the normalized Pearson correlation coefficient). Resulting dendrogram is adduced at Fig. 32.

All ranges of depths in the regions by similarity of quantitative abundance of taxonomic groups of benthos were combined in two major clusters. The first cluster comprised all areas of the three regions with depths more than 20 m and areas with 15 m depth in the north and south regions. Areas with depths 5-10 m from all the regions and area with 15 m depths of the middle region were combined in the second cluster. Thus, over the surveyed area two ranges of depths are distinguished rather distinctly by similarity of biomasses of taxonomic groups: range of depths 20-30 m and that of 5-10 m. In all the regions benthos had a transient character at depth 15 m, at that, in the middle region the benthos at 15 m was more similar to areas of 10 m depth, and in the south and north regions – to depths exceeding 20 m.

##### 4.2.4.2. Caloricity.

It is known, that bottom invertebrates of various taxonomic groups significantly differ by their energetic value. That is related, first of all, with differences in biochemical structure of organisms. To the present a lot of information on *caloricity* of marine benthos was accumulated, including data on species found in the considered water area [34 – 40]. Analysis of literature data enabled us to estimate averaged energy equivalents (kcal/g of dry weight) of biomass of basic groups: *Amphipoda* - 0.98±0.04 kcal/g, *Isopoda* – 0.95±0.04 kcal/g, *Polychaeta* – 0.87±0.06 kcal/g, *Decapoda* – 0.86±0.04 kcal/g, *Cumacea* – 0.6±0.05 kcal/g, *Bivalvia* – 0.55±0.06 kcal/g, *Echinodermata* – 0.24±0.05 kcal/g. Based on these data the caloricity of each taxonomic group in the total biomass of benthos was calculated for the regions studied.

The ratios of 7 taxonomic groups of macrobenthos from sandy bottoms (depth 5 - 15 м) in all three regions, i.e. in area zone of possible feeding of gray whales, relative to the total biomass and caloricity are displayed at Fig 19.

A trend to decrease of bivalve ratio in the total caloricity of macrobenthos, comparing with the ratio in total biomass was observed in all the regions. For high energy groups of the benthos (*Crustacea*) the ratio in total caloricity was higher, than that in the total biomass. Thus in the south region the crustacean ratio in total caloricity of benthos was 51,7 %, in the middle – 65.8 %, in the north region – 43.8 %, the ratio of crustacean groups of the highest energy content, amphipods and isopods, was the highest (58. 3 %) in the middle region (Piltun Bay area). In the south (Nyiskiy Bay – Chaivo Bay) and north (Odoptu Bay – Tront Bay) regions the ratios of amphipods and of isopods in total caloricity of benthos were only 34.2 and 23.3 % respectively.

That result was also ascertained by variation of total caloricity of taxonomic groups in the three regions (Fig. 33). In the middle region the absolute values of total caloricity of isopods and of amphipods were much higher than in the south and north regions.

Above we estimated similarity of the regions by biomass ratios of taxonomic groups of macrobenthos that enabled to distinguish two depth horizons with different structure of benthic biomass and transient horizon between them. We use the analogous approach for the analysis of similarity of the regions by ratio of benthos caloricity (Fig.33-34). The depth depths were distinguished in two groups. One group included areas of the middle region with depths 5-15 m, the second – areas of the south and north regions with same depth range. This result ascertains the former conclusion that the middle region is most specific by the total caloricity of macrobenthos. As it was noted above the Piltun Bay area was specified by predominance by biomass of high energy groups of macrobenthos, first of all, amphipods and isopods.

Analyzing variation of total biomass and caloricity of macrobenthos with depth (Fig. 34) one could notice that despite of low caloricity of sand dollars, their total caloricity had rather high values at depths 20-30 m. That was caused by high values of biomass of sand dollars at that range of depths – more than 1000 g/m$^2$. However, it is clear, that to obtain the same amount energy, e.g. 100 kcal, different quantities of biomass of sand dollars and of crustaceans should be consumed. Let us adduce the concept of "energy efficiency of biomass", as ratio of total caloricity of benthos of an area to its total biomass. The less is this value, the more

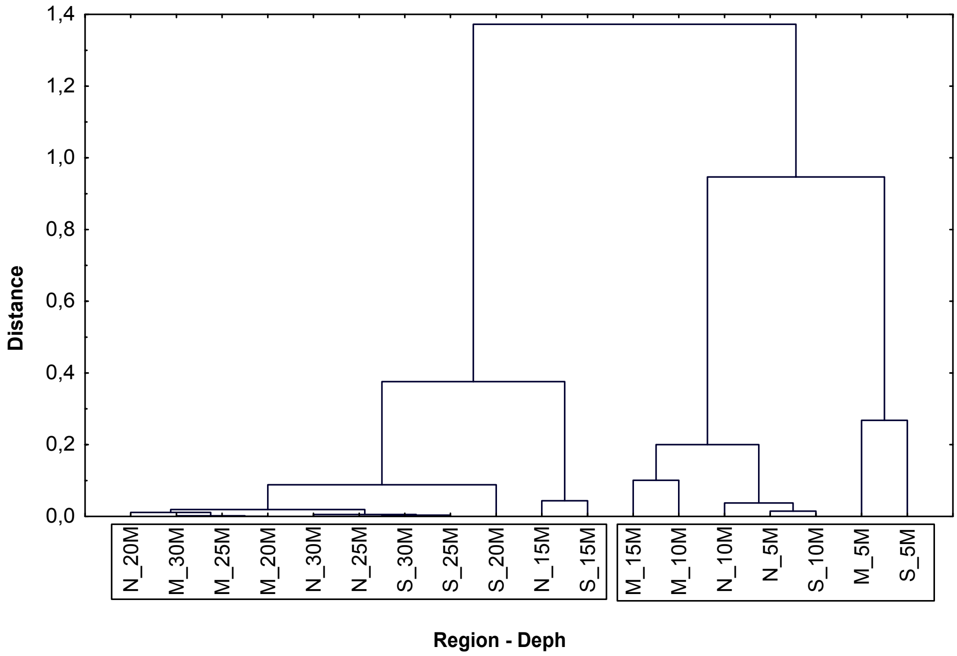



Fig. 32. Dendrogram of similarity by biomass of taxonomic groups of benthos at 6 depths ranges in the distinguished regions

Regions: S – south, M – middle, N – north.

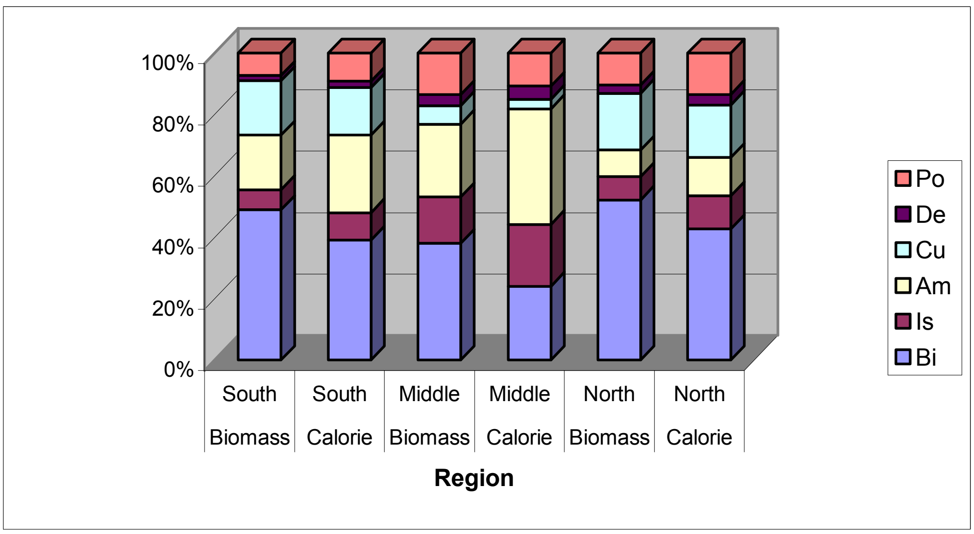



Fig. 33. Ratio (%) of biomasses (g/m$^2$) and of caloricity (kcal/m$^2$) of taxonomic groups in the three regions in zone of sandy bottoms at depths 5-15 m

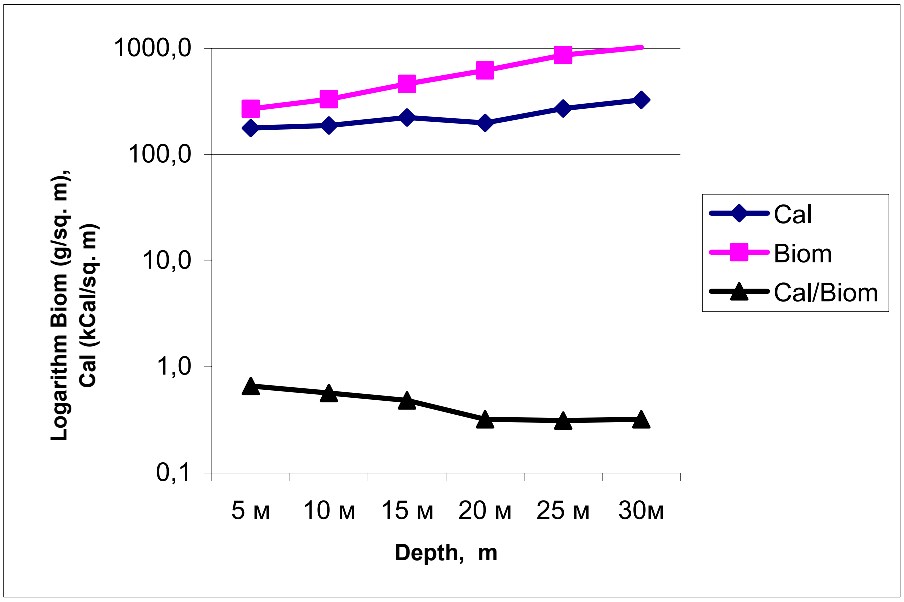



Fig. 34. Variation of the total biomass (Biom, g/m$^2$) and caloricity of benthos (Cal, kcal/m2) with depth and ratios of their "energy efficiency" of biomasses (Cal/Biom)

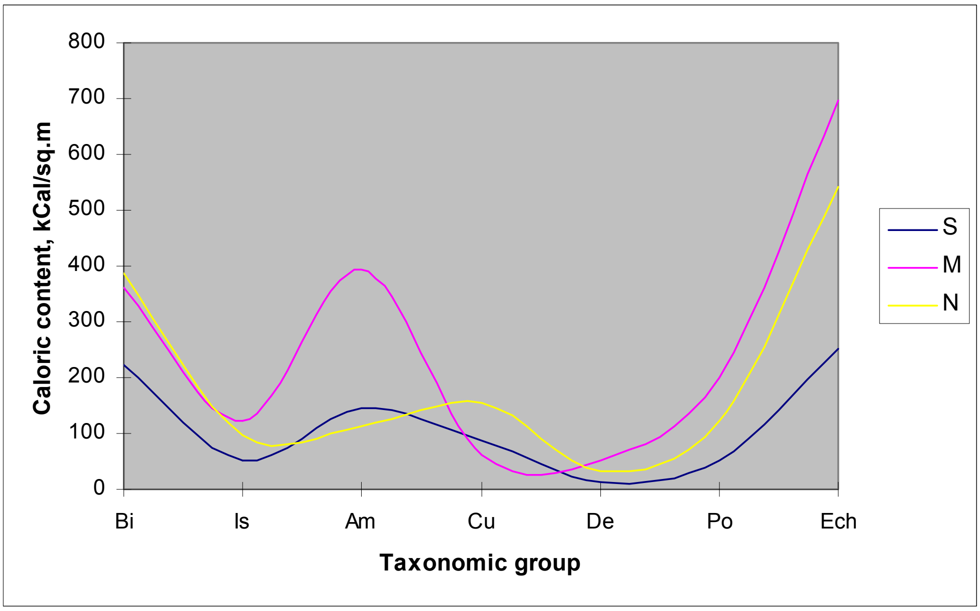



Fig. 35. Variation of total caloricity of 7 taxonomic groups in the regions Regions: S – south, M – middle, N – north.

biomass is necessary to consume to obtain the same amount of energy. The ratio of "energy efficiency of biomass" (Cal/Biom) decreased over the range from 5m up to 20 m, then stabilized (Fig. 20). It is related with to the similar set of benthic groups (dominance of flat sea urchins) with a high total biomass at depths 20-30 m. Thus, to obtain 100 kcal at 5 m depth is necessary to consume from 125 up to 150 g of biomass, at depth 20-30 m - from 320 up to 410 g.

Thus, the gray whales from Piltun Bay area have to main feeding alternatives available:

1. To dive to depth from 20 up to 30 m and to consume more than 400 g of flat sea urchin *Echinarachnius parma* for obtaining of 100 kcal,

2. To dive to depth from 5 to 10-15 m and to receive the same of 100 kcal consuming 150 g *of amphipods and isopods*.

*It is not necessary to be cleverer than the gray whale to chose of two alternatives the more efficient and savory* (Photo 6).

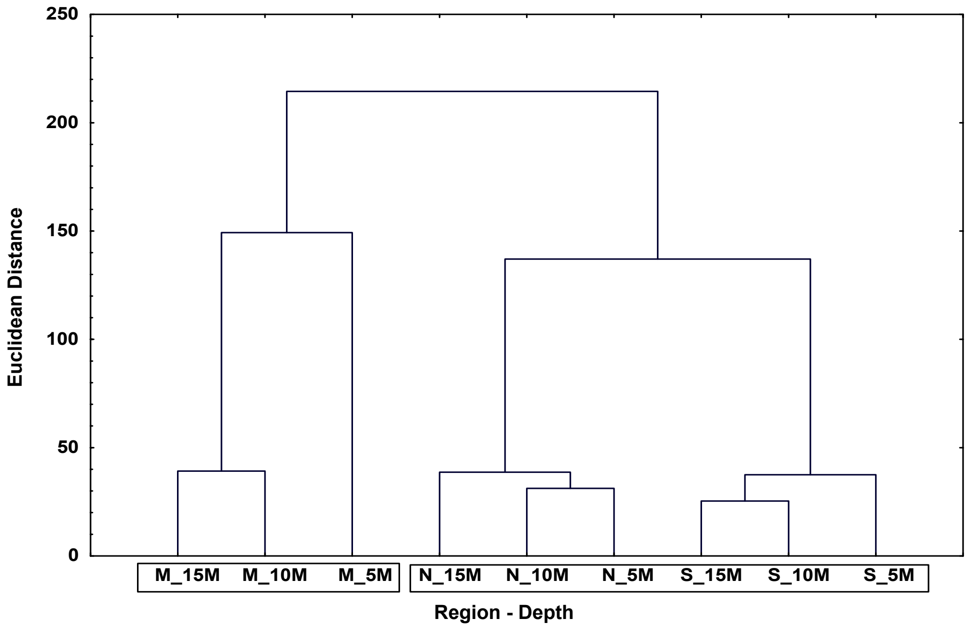



Fig. 36. Dendrogram of similarity by total caloricity of taxonomic groups of benthos at 6 depth ranges in the regions

Regions: S – south, M – middle, N – north.

Table 13

Importance of index of dispersion (aggregation) for mass types macrobenthos

| Species | index dispersion | Species | index dispersion |
|---|---|---|---|
| *Echinarachnius parma* | 312.8 | *Scoloplos armiger* | 48.5 |
| *Diastilis bidentata* | 298.7 | *Anisogammarus pugettensis* | 25.6 |
| *Eohaustorius eous eous* | 218.6 | *Eogammarus schmidti* | 21.8 |
| *Pontoporeia affinis* | 213.4 | *Orchomenella gurjanovae* | 15.5 |
| *Onuphis shirikishinaiensis* | 188.6 | *Anonyx sp.* | 7.9 |
| *Synidotea cinerea* | 156.0 | *Atylus collingi* | 7.8 |
| *Siliqua alta* | 82.4 | *Boeckosimus derjugini* | 6.4 |
| *Spisula voyi* | 62.3 | *Synchelidium gurjanovae* | 5.0 |
| *Macoma lama* | 52.7 | *Pontharpinia longirostris* | 2.2 |
| *Megangulus luteus* | 49.4 | *Monoculodes crassirostris* | 1.1 |

**Depth 20-30 m;        450 g = 100 kCal**

**Depth  5 – 10(15) m;  150 g = 100 kCal**

Photo 6.  Ratio of masses of flat sea urchins and crustaceans (isopods, amphipods) equivalent to 100 kcal

### 4.2.5. Some notes on spatial microdistribution of macrobenthos and feeding of the gray whale

#### 4.2.5.1.Aggregation of macrobenthos

In the Table 13 there are values of dispersion index of mass species of macrobenthos. The greater values of dispersion index differ from 1, the greater the degree of aggregation (patchiness) of microdistribution of species. Practically all species had the aggregated distribution. The low degree of aggregation is specific for rare species having low-level parameters of quantitative abundance. The maximum degree of aggregation have the most widespread species with high abundance.

Some mechanisms resulting in aggregation of macrobenthos were considered above. For example, the patch distribution of tube mats of polychaete *Onuphis shirikishinaiensis* (their area was a few square meters) entailed aggregation of crustacean and polychaetes inhabiting the mats. The active hydrodynamics of water area also promoted irregularity of distribution of benthos. In conditions of active hydrodynamics on surface of sandy grounds a periodic forms of microrelief – sandy waves arised. In hollows between crests of sandy waves detritus accumulated. Higher abundance of detritophagous animals was observed in those sites.

Some kind of corroboration of aggregation of benthos could be revealed in feeding behavior of gray whales. At Photo D1 (Appendix D) the whale performing vertical dives for food is snapped. Within the limits of small area the whale performed 4-6 vertical dives. Then it passed to a new area.

The aggregated distribution of food resource plays important role for an animal consuming this resource. It is known that feeding in conditions of patch distribution of food is energetically more expedient to a resource consumer [66]. We should note, that adduced values of species aggregation index in Tab. 13 are averaged for the entire water area. In the middle and north regions, the mass species of crustaceans and polychaetes with retained aggregated distribution had lower values of dispersion index, than in the south region, i.e. the degree aggregation of these groups was higher in the south.

The feeding behavior of gray whales could be related exactly with macroaggregation of feed benthos, when they “remained at the same place (sometimes for several days) at the area less than 500 $m^2$” [74].

#### 4.2.5.2. Possible additional food objects

Recently, the information on more wide spectrum of food of gray whales accumulates, than it was traditionally considered [67]. It was displayed, that in different time periods, concurrently with the traditional food object, amphipods of fam. *Ampeliscidae*, other animals might take an essential part in nutriment of gray whales. In particular, opossum shrimps, larvae of crabs, shrimps. The probable role of bivalves in nutrition of gray whales was discussed also. Presence in nutriment of gray whales of diverse taxonomic groups of benthos was noted already for a long time [68, table II].

We already noted above, that there are no amphipods inhabiting tubes (fam. *Ampeliscidae*, etc.) in considered water area at all, or they have negligible abundance. Species associated to tubular mats of polychaete *Onuphis shirikishinaiensis* had high biomass. Thus, the biomass of the polychaetes is comparable to biomass of concomitant crustacean species. Naturally that whales at feeding seize sediment together with polychaetes and amphipods. It is complicated to assume a way or mechanism which enable the whale to sort out polychaetes and amphipods hereinafter, since the average weight of amphipods (Tab. 12) is comparable to that of polychaetes (section 4.2.3.2).

In result of processing of sample of animals, washed out of the mouth the emerged whale (section 3.3 and Photo D3, Appendix D), a plenty of empty tubes of polychaetes was found (Photo D3 designated as “POL”). Morphologically they are similar to tubes of *O. shirikishinaiensis*. If to take into account, that there were no other polychaetes building tubes in that area, it is possible to assume, that in the sample there were tubes of that species. Fragments of polychaetes *Scoloplos armige*r and insignificantly damaged individual of *Travisia forbesii* were found also. Intact isopods *S. cinerea* (Photo D3 – IS), and, in lesser quantity, – fragments of amphipods *P. affinis* and *Anonyx sp*. prevailed among crustaceans. As it was already recorded, all those species had a high frequency of occurrence and quantitative abundance in areas.

<u>Opossum shrimps</u>∗ Conducting diving works at depths 5-15 m (August, 13-16) in area of the Piltun Bay – the north part of Chaivo Bay (sections P3 – S2) we have recorded a dense benthic layer of opossum shrimps (mysidae) *Tenagomysis orientalis* (98 % of number) and krill species *Thysanoessa raschii*. We should note, that those species were not recorded in lagoon of Piltun Bay [69]. The thickness of layer was from 5 up to 10 sm. Opossum shrimps were recorded practically in all samples at depth 5 - 10 m and in 40 % of samples at the depth 10-15 m. To the north of section P3 and to the south of S2 the opossum shrimps occurred individually. The nylon bag of diver’s bottom sampler functioned as epibenthic net at sampling. Naturally, we do not speak here about a precise quantitative assessment of opossum shrimps, but only about general trends of their distribution. In five points the diviner’s bottom sampler was used only to plough up opossum shrimps. The bottom sampler in the open state was sharply

∗ *In the Information report by results of forwarding activities of 2001* (Fadeev*, 2001*), the planktons organisms met en masse in Piltun region there were are wrongly determined to *chaetognats*. The analysis of materials experts planktonologists, has shown, that in a 5-10 cm benthic layer dominate *mysidae*, much less *euphasiidae* is cancerous, and *chaetognatae* practically miss.

dropped on button surface, then closed without taking ground. That way the quantity of opossum shrimps was counted with capture area 0.025 $m^2$ in bottom layer of 10 cm above the surface. Number of opossum shrimps varied in samples from 4 up to 130 ind., being on the average 27 ind/0.025 $m^2$ (about 1000 ind/$m^2$) in 10 cm benthic layer. Weight of individuals varied in samples from 0.02 up to 0.05 g, averaging 0.03 g. If to accept all these preliminary data - the biomass in 10 cm layer of dense clump of krill was up to 30 g/$m^2$. There is no sense to recalculate that value per $m^3$, as it is adopted in planktonology, since the dense layer of krill does not spread higher than 10 cm from bottom surface. The obtained preliminary value is one order higher than in the other regions [67].

In this instance we only record the availability of a dense benthic layer of krill in the period of survey conduction in local area. Problem of recurrence of that phenomenon, as well as its causes, still remain open. We only could notice, that the works have been conducted after pass of the powerful tropical cyclone accompanied with a heavy rainfall and storm surge. Naturally, that entailed freshening of the coastal water and considerable carry out of practically fresh water from Odoptu and Piltun lagoons.

Crab juveniles. At conduction of diving works juveniles of crab *Hyas coarctatus* were recorded practically over the entire survey area, mostly at the depth exceeding 10 m. Their greatest quantities were recorded on mixed grounds (group C, Tab. 2). The “fouling fauna” presented by sponges, bryozoans, hydroids, and so on filtered develops on those grounds in condition of strong bottom currents. We should notice that there is still no method of correct count of juveniles of large crustaceans. In some instances we succeeded to receive rough assessments (Photo 7). The photograph fixed results of count of large isopods and juveniles of crabs from 1 $m^2$ in zone of sandy waves. The juveniles of crabs were concentrated there in hollows between crests of sandy waves, i.e. formed aggregations in zone of detritus and of *Zostera* eelgrass accumulation that were brought from lagoons. The total biomass of crustaceans on that site was 18 g/$m^2$.

Pacific stout sand lace *Ammodytes hexapterus*. The sand lace *A. hexapterus* has a high frequency of occurrence in zone of fine and medium sand grounds, mostly in the south and middle regions at depth exceeding 10 m. The frequency of occurrence of that species was 32 % in samples taken by the diver’s bottom sampler. The specific of ecology of the species is that in the day time period individuals of that species hide in surface layer of sand, which enables to count them in the gatherings precisely enough. Young individuals of sand lace prevailed in samples (Photo 8). In the most dense aggregations density of the sand lace reached 40-60 ind/$m^2$. Aggregations of the sand lace in the considered area are not related with any certain macrobenthos community - the nature of ground was decisive. Taking into account a high biomass of the sand lace in clumps and its high caloricity, it is possible to consider this species as additional food object of gray whales. Particularly that the sand lace was already recorded as their food object [70].

Photo 7. Large isopods *Saduria entomon* and juveniles of crabs *Hyas coarctatus* in epibenthic sample (count area 1 $m^2$, transect S2; depth 10 m; fine sand with admixture of medium-grained sand; hollows crests of sandy waves)

Photo 8. Pacific stout sand lace *Ammodytes hexapteris* in benthic sample (diviner's bottom sampler; transect P2; depth 15 m; fine sand)

4.3. Structure and distribution of meiobenthos.

The effect of different pollutants in water environment is seen, first of all, in changes of community species composition. Pollution monitoring at the level of communities has a number of advantages. Until recently, the majority of ecotoxicological studies have covered only one component of the community - macrofauna. The main explanation for this is that macrobenthos is easier to collect and to use for further taxonomical treatment than animal groups of other size. Meio- and microbenthos have been studied more poorly, although it is known that small organisms can easier react to environmental changes and they often represent “ecological targets” of technogenous influence [41]. Platt et al. [42] showed that “macrobenthos does not give a full analysis of the reaction of the environment to pollution. It is time now to put meiofauna into the center of our attention».

The potential role of meiobenthic organisms for monitoring of pollution, and, first of all, the dominant groups – *nematodes* and *harpacticids* was discussed many times in literature [43-49]. The reason for choosing this group for this role is the presence of certain characteristics in it. Meiobenthos is one of the most numerous groups in the marine ecosystems and is characterized by a high diversity, which makes it suitable for ecological and statistical studies.

Meiobenthos is in closer contact with pore water and has more generations throughout the year than macrofauna, which determines a high sensitivity of these animals to possible environmental changes. For this reason, they demonstrate a quicker reaction to pollution than macrobenthos.

In the meiobenthos composition, constant and temporary components are distinguished. The constant components (**eumeiobenthos**) include the animals which size does not exceed 3 mm at all stages of development, the temporary components (**pseudomeiobenthos**) – includes the representatives of macrofauna, which have benthic juvenile stages and only at early stages of development have relation to meiofauna. Eumeiobenthos of the area studied is represented by *foraminiferans, nematodes, harpacticoides, ostracods and turbellarians*. Pseudomeiobenthos includes the juvenile forms of *polychaetes, oligochaetes, bivalves, holothurians, priapulids, galacarids, sand dollars, nemerteans* and *cumaceans.* The most numerous representatives of meiofauna are *harpacticidae, nematodes, foraminiferans*, juvenile *oligochaetes* and *polychaetes.* The high occurrence is typical also for turbellarians, infusorians, juvenile bivalves and sand dollars. Other animals form a specific background occurring rarely or individually: *ostracods, galacarids,* larvae of *cumaceans, holothurians* and *priapulids.* In both study areas, eumeiobenthos dominates in number, the larvae stages of macrobenthos – pseudomeiobenthos – in biomass (Fig. 23, 24). As a result of the analysis of 30 quantitative samples collected at 5 transects at a depth of 5 and 15 m a general picture of the distribution of number and biomass of meiobenthos was obtained (Table 14, 15). The abundance of meiobenthos in the studied area varied from 177.6 to 584.7

thousandsind./m$^2$. The mean number comprised 350 thous. ind./m$^2$. In the aquatorium studied, significant fluctuations of the biomass meiobenthic organisms were observed – from 585.4 to 15837 mg/m$^2$. Mean biomass was 4168 mg/ m$^2$. In the studied communities, a mosaic picture of the distribution of meiobenthos was observed: sites with high biomass values alternated with those with low values. Odoptu, meiobenthos abundance reached 400 – 584.7 thous. ind/m$^2$ (mean population density was 455.2 thous. ind/m$^2$ ); biomass varied from 585.4 to 3705 mg/m$^2$ (with mean biomass 1381.9 mg/m$^2$).

In Chaivo-Piltun area, the biomass values increased significantly and varied within the range of 1542-15837 mg/m$^2$ (with mean biomass of 6956 mg/m$^2$). However, the meiobenthos biomass was twice as low as in Odoptu area – 177.6 – 260.2 ind/m$^2$. In the community structure, the share of the meiobenthos larvae increased – from 94.2%, which resulted in an increase of o meiobenthos biomass.

Noteworthy, the visual observation did not show any anomalies in the development of macrobenthos larvae, all of them were in normal physiological condition. The most numerous group among meiobenthos organisms were *nematodes* (74% total number), *harpacticoides* and flat worms. The population density of nematodes in the area studied varied within the range of 21 – 528 thous. ind./m$^2$. They were registered at all depths. A tendency for an increase in abundance with depth from to 5 to 15 m was observed.

Among the meiobenthos larvae, a high population density was observed for *polychaetes* (2.7 – 17 thous. ind/м$^2$), *cumaceans* (1 – 37 thous. ind/m$^2$), *bivalves* (to 7 thous. ind/m$^2$) and *amphipods* (to 5.3 thous. ind/m$^2$).

On the basis of the generalizing works on the effect of oil pollution on marine ecosystems two main conclusions can be made: a) oil pollution causes significant changes both in abundance and biomass of individual species and community structure as a whole, b) after oil pollution effect the restoration of structure occurs much quicker in the planktonic communities than in the benthic ones. In accordance with literature, meiobenthos in contrast to macrobenthos reacts quicker even to non-significant penetration of oil hydrocarbons to the ground. A sharp decrease in abundance is observed in this case and dead organisms are found in the samples [50].

Experimental data also prove that the periodical penetration of oil products to the ground results in death of the majority (to 80%) of organisms of macro- and meiobenthos [61]. However, not all the groups of meiobenthic organisms are equally sensitive to oil products. Some species of sea nematodes and polychaetes can utilize the carbon of oil hydrocarbons, by which they participate in the self-purification of the ground in the places of natural oil seeping and in case of anthropogenous pollution of bottom sediments [52, 53]. Out of all groups of meiofauna the most sensitive to oil hydrocarbon pollution are *ostracods* that die even at low oil concentrations [54].

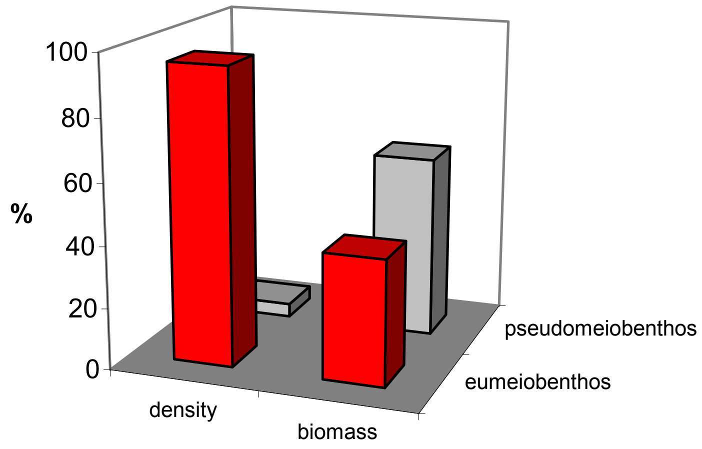



Fig. 37. Relation of constant and temporary components of meiobenthos in Odoptu area (transects N0,  N2)

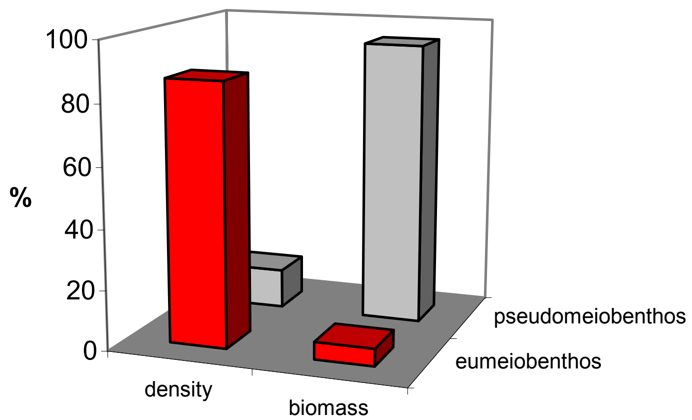



Fig. 38. Relation of constant and temporary components of meiobenthos in Chaivo-Piltun area (transects S1, P2, P4)

Table. 14

Qualitative characteristics of meiobenthos in Chaivo-Piltun Bay area.

| Group | Abundance (thous. ind./$m^2$ ) | | | Biomass ($mg/m^2$) | | |
|---|---|---|---|---|---|---|
| | min | мах | m | min | мах | m |
| *Nematoda* | 106 | 174 | 140.8 | 21 | 238 | 71 |
| *Harpacticoidea* | 11.6 | 58 | 22.78 | 42 | 304 | 135 |
| *Turbellaria* | 5 | 18.7 | 11.46 | 0.3 | 0.9 | 0.6 |
| *Foraminifera* | 7 | 22.3 | 13.6 | 3.5 | 9 | 6.4 |
| *Ostracoda* | 2 | 7.3 | 4.38 | 76 | 328 | 191 |
| *Gnathostomulida* | 0 | 2.3 | 1.32 | 0 | 0 | 0.1 |
| **Eumeiobenthos as a whole:** | **161.6** | **215.3** | **194.3** | **212.9** | **881.6** | **404.8** |
| *Cumacea* | 0 | 37 | 16.2 | 0 | 10.7 | 9.1 |
| *Bivalvia* | 4.3 | 7 | 1.6 | 956 | 14800 | 6353 |
| *Polychaeta* | 2.3 | 14.7 | 9.6 | 35 | 175 | 1441 |
| *Oligochaeta* | 0 | 0.3 | 0.06 | 0 | 3.7 | 0.7 |
| *Priapulida* | 0.3 | 0.7 | 0.2 | 0 | 0.1 | 0.02 |
| *Amphipoda* | 0 | 5.3 | 1.32 | 0 | 133 | 33.3 |
| *Hydrozoa* | 0 | 1 | 0.2 | 0 | 15 | 3 |
| *Nemertini* | 0 | 1.7 | 0.48 | 0 | 25 | 8.3 |
| **Pseudomeiobenthos as a whole:** | **8.6** | **47.3** | **29.18** | **1140** | **14955** | **6551** |
| **Meiobenthos as a whole:** | **177.6** | **260.2** | **223.5** | **1542** | **15837** | **6956** |

Table 15

Qualitative characteristics of meiobenthos in Odoptu Bay area.

| Group | Abundance (thous. ind./$m^2$ ) | | | Biomass ($mg/m^2$) | | |
|---|---|---|---|---|---|---|
| | min | мах | m | min | мах | m |
| *Nematoda* | 228 | 528 | 337 | 45 | 105 | 70 |
| *Harpacticoidea* | 20 | 139 | 60 | 160 | 1100 | 477 |
| *Turbellaria* | 12 | 44 | 26 | 1 | 6 | 2 |
| *Foraminifera* | 1 | 22.7 | 7.2 | 0.5 | 2.3 | 3 |
| *Ostracoda* | 0.3 | 1 | 0.26 | 0 | 38 | 10 |
| *Ciliata* | 3.3 | 15.3 | 4.78 | 0 | 0.3 | 0.4 |
| *Gnathostomulida* | 0 | 1.0 | 0.2 | 0 | 1.2 | 0.2 |
| **Eumeiobenthos as a whole:** | **378** | **580** | **435** | **269** | **1.160** | **562** |
| *Cumacea* | 0 | 1 | 0.26 | 0 | 2.7 | 2.1 |
| *Bivalvia* | 0 | 7 | 1.6 | 133 | 2800 | 640 |
| *Polychaeta* | 2.7 | 17 | 10.9 | 0.001 | 0.04 | 0.1 |
| *Oligochaeta* | 0.3 | 3.3 | 1.66 | 0.003 | 0.007 | 0.01 |
| *Priapulida* | 0 | 3.3 | 1.32 | 0 | 0.3 | 0.1 |
| *Holoturoidea* | 0 | 6.7 | 2 | 0 | 100 | 30 |
| *Halacaridae* | 0 | 1 | 0.2 | 0 | 23 | 4.6 |
| *Echinoidea* | 0 | 2 | 0.66 | 0 | 2 | 0.07 |
| *Nemertini* | 0 | 3.3 | 1.32 | 0 | 50 | 0.07 |
| **Pseudomeiobenthos as a whole:** | **4.4** | **37.7** | **19.96** | **39.3** | **2956** | **819.9** |
| **Meiobenthos as a whole:** | **400** | **584.7** | **455.2** | **584.4** | **3705** | **1381.9** |

In the bottom communities registered in the polluted areas there were no groups sensitive to high concentrations of oil hydrocarbons (*Ostracoda, Echinoidea, Bivalvia* etc..). High population density was observed in tolerant benthic organisms – free-living nematodes and polychaetes [55,56].

Meiobenthos of the northern part of the Okhotsk sea remains poorly studied. Only data by A.M. Sheremetevsky [57] on fauna and ecology of meiobenthos from the area of Starodubskoye Village (Eastern Sakhalin).

Data obtained by us show that meiofauna of the area studied has a high diversity of taxonomic groups. In Chaivo-Piltun area, 14 groups of meiobenthos have been registered, in Odoptu area - 16. The composition of the taxonomic groups of meiobenthos and their relation correspond to the general regularities stated for the meiobenthos of the polluted shelf areas of Sakhalin Island [57, 58], as well as other parts of the World Ocean [59].

In the macrobenthos collections from the studied areas the sand dollars Echinarachnius parma are numerous and are a dominant species in the community with the same name. The meiobenthos collections in which the settled actively growing juvenile sand dollars have been observed confirm the conclusion that this community is a normally reproducing one. In the benthos larvae, polychaetes, bivalves, amphipods and cumaceans are dominant by biomass. These groups are also dominant by biomass in macrobenthos.

At some sites in the area of Odoptu at various sands with admixture of gravel and pebbles, **«**fauna of suspension feeders**»** rich with species is represented by hydroids and sestonophagous mollusks. The pseudomeiobenthos of that area is rich with the larvae of these groups.

Certain differences in the set of the groups of meiobenthos larvae and their qualitative characteristics in two areas studied have been observed (Table 14,15). In Chaivo-Piltun area 8, in Odoptu area – 9 groups of meiobenthos larvae have been observed. Six groups are common for both areas (*cumaceans, bivalves, nemerteans, oligochaetes, polychaetes and priapulids*). Only in Chaivo-Piltun area amphipod larvae have been registered in mass (to 5300 ind/m$^2$). On the opposite, the settled larvae of the sand dollar *E. parma* are found in mass at all depths in the northern area (Odoptu area).

Therefore, a result of the analysis of the composition and quantitative characteristics of meiobenthos it has been established that in the area studied the structure and quantitative relation of the groups of *eumeiobenthos* are typical for non-polluted sandy grounds, and the presence of a significant number of ostracods – the indicator of oil carbohydrate pollution – is indicative of the lack of such pollution.

The presence in meiobenthos of a large number of the larvae of benthic animals (*pseudomeiobenthos*) is indicative that the coastal benthic communities reproduce normally. In Chaivo-Piltun area the larvae of *cumaceans, polychaetes, bivalves and amphipods* are dominant, in Odoptu area – those *of poychaetes, bivalves, holothurians, priapulids***,** *nemertins*.

Only in Odoptu area at a depth to 15 m, the settled larvae of the sand dollars *Echinarachnius parma* are found in mass, in more southern areas at such depth only individual specimens of the sand dollars larvae have been observed.

Noteworthy, the meiobenthos larvae in Chaivo-Piltun area shows a "shallow water character", i.e. they are represented by the larvae of those animals that actually inhabit the zone of the collection of meiobenthos samples (*amphipods, molluscs, polychaetes*). A different situation id observed in Odoptu area, where meiobenthos larvae show a "deepwater character". The larvae of the animals that do not live in the zone of meiobenthos sample collections (5-15 m) dominate there: *holothurians, priapulids, nemerteans, sand dollars*. All these species inhabit much greater depths. The appearance of those groups in the pseudomeiobenthos of the shallow-water zone is due to a significant larval pull from the more deep-water zones.

## 4.4. The comparative analysis of macrobenthos distribution in 1992 and 2001.

Of a special interest for ecologists is the analysis of quantitative samples of benthos, which is conducted in the same area but with significant time intervals. There have been not many studies of the multi-year changes of benthos in the far-eastern seas. For example, for the shelf of Eastern Sakhalin and the northern part of the Okhotsk Sea, no significant changes in benthos distribution occurred in these areas in late 1980-ies [60, 61, 65].

Blagoderov and Markina [62] made a conclusion of a 10-20 times increase of total benthos biomass at some bottom sites of the shelf of Western Kamchatka, which was based on a comparison of bottom-dredged samples of benthos taken at different time periods. After Fadeev and Tarasov [63] repeated the bottom-dredging samples collection at the South Kuriles shallow waters 50 years after it was conducted in 1949 by the Kuriles-Sakhalin expedition of ZIN-TINRO, they came to a conclusion that there were no significant changes in the quantitative distribution of benthos.

With the availability of enough results of the assessment works and the presence of significant differences in the abundance values, a comparative analysis of the material collected at different time allows to make a conclusion of the multi-year changes of benthos. The reliability of the conclusions obtained as a result of a comparison of benthos samples taken at different time depends on a number of reasons. Let us formulate the minimal requirements to the material used for analysis. Firstly, the collection must be conducted using the same catching instruments or those with similar catching capacity, which allows if not to lessen then at least stabilize the systematic error of assessment works. Secondly, the material collected at different time must be "representative" and similar in quantity. Thirdly, the stations compared must be situated within the range of one profile "bottom-depth", and in the ideal case, the condition of their geographical closeness must be met. The last one is important due to the inter-biotopical variation of benthos abundance values.

To what extent the materials collected in 1992 and 2001 meet these requirements?

1. In 1992 and 2001, as a result of diving works, the same sample collectors (the diver's bottom sampler) using the same techniques developed for diving hydrobiological works [2].

Some problems appeared with bottom-dredging collections. In 1992 the material was collected using a bottom dredge "Okean-50" (catch area 0.25 $m^2$), in 2001. – a Petersen dredge (0.1 $м^2$). Weight of bottom dredge «Okean» - 125 kg, Petersen dredge – 48 kg. Even without taking into consideration different catch area, Petersen dredge and "Okean-50" differ by dredging depth and, correspondingly, catching capacity. The work of both dredge models strongly depends on bottom type. The greatest differences in the number of collected animals are observed at dense sandy bottom (widely represented in the studied area), where "Okean" that is heavier than Petersen dredge (by its characteristics corresponds to the widely used Van Veen model) produces more catch. However, taking into consideration, the difficulty, if not impossibility due to the aggregation of benthos distribution, of finding the coefficients for the calculation of the catching capacity of bottom dredges, we assume it as similar for both models. All further arguments are based on this assumption.

2. In 1992, 24 stations at 4 transects were made. The total material included 88 samples (76 diving samples and 12 – bottom-dredged ones). In 2001, 24 stations at 4 transects were made. The total material included 78 samples (66 - diving samples and 12 – bottom-dredged ones). Therefore, the material is available that is comparable by volume.

3. The location of the transects and the depth of the stations (5-10-15-20-25-30 m) coincide (Fig. 1). The stations of 1992 and 2001 are situated close to each other within the range of navigation adjustment error.

Let us consider data on bottom sediments, taxonomic composition and macrobenthos abundance using the material of 1992 and 2001.

#### 4.4.1. Granulometric composition of ground at stations 1992 and 2001.

For the granulometric analysis in 1992, 16 samples of bottom sediments were taken, and in 2001 – 24. The analysis of the samples was conducted using standard techniques in the same laboratory. Like in the collections of 2001, the majority of the stations of 1992 by the granulometric composition refer to fine sands (Group A) and middle sands (Group B).

#### 4.4.2. Comparative analysis of species composition of macrobenthos.

In the quantitative samples of 1992, 54 macrobenthos species were identified, and in the samples of 2001 – over 150 ones. However, it does not mean that the species diversity of macrobenthos increased by three times during 10 years. It is known that the number of the species found in biota depends, first of all, on the area studied (using the sample collectors of the same size – on the number of samples). In our case in 2001 a significantly greater number of samples was obtained, which allowed making a better identification of the taxonomic composition of the biota. However, this is true only for the species with low occurrence frequency. Noteworthy, out of 10 species that were mass species in 2001 (P> 50%) (see Section 4.1), 6 species had a high occurrence frequency in the collections of 1992 (from 30 to 70%): the isopod *Synidotea cinerea*, the amphipods *Pontharpinia longirostris, Eohaustorius eous eous, Pontoporeia affinis*, the polychaete *Onuphis shirikishinainensis* and the sand dollar *E. parma.*

Therefore, the group of the most common species in the collections of 2001 and 1992 was represented by the same species.

### 4.4.3. Comparative analysis of spatial distribution of common species of macrobenthos.

The analysis of the spatial distribution of sand dollars in 1992 and 2001 in the area of Odoptu at transects N0 and N2 showed certain differences. In 1992, the border of dense aggregations of sand dollars (> 10-15 ind. per 1 $m^2$) at those transect passed at an isobath of 20 m. At 15 m individual specimens were found (2-3 ind. at control site 5 $m^2$). In 2001, at both transects at the stations at a depth of 15 m dense aggregations of sand dollars were observed (at transect N0 to 20 ind. per 1 $m^2$, at transect N1 - 10-15 ind. per 1 $m^2$), close density values were observed at those transects at a depth of 20 m. Noteworthy, the adjustment accuracy of the transects to the shore line was quite high because the reference points for the transects in 1992 were oil derricks that were in operation in 2001. The location of the remote stations was controlled by use of GPS. It allowed to get a good coincidence of the transects in 1992 and 2001. Therefore, the differences in the multi-year distribution of the sand dollars at the transects could not be explained by their distinctions.

In Section 4.3 (Table 14, 15), the distribution of macrobenthos larvae at a depth of 5 and 15 m in the area of Chaivo-Piltun Bay (southern and intermediate areas) and Odoptu (northern area) was studied. Interestingly, the settled larvae of sand dollars at a depth of 5 and 15 m was found in mass only in the northern part, while only individual larvae were found in the southern and intermediate parts. Noteworthy, the collection of meiobenthos in all three areas was done simultaneously. This does not allow explaining the significant difference in the number of the settled larvae in the area of Chaivo-Piltun Bay and Odoptu by time difference in the collection of meiobenthos. A possible reason is the peculiarities of hydrological regime.

### 4.4.4. Comparative analysis of quantitative abundance of macrobenthos.

The comparison of the total macrobenthos biomass was conducted in two variants. In the first variant data of all 166 samples (48 stations) collected in 1992 and 2001 without taking into account the diversity of the material (the material collected both by diving and dredging with use of «Okean» and Petersen bottom dredges) were used. It was found that mean benthos biomass in the area studied in 1992 – 2001 significantly decreased from 424.0±34.4 g/m$^2$ to 298.0±16.5 g/m$^2$ (Student criterion value: $t = 3.65$, $t_{0.001} = 3.29$).

However, even a rough analysis of the compared biomass rows showed that the high biomass value based on the collections of 1991 was due to the biomass values over 2500 g/m$^2$ at two stations, where large specimens of bivalves were taken by a dredge**.** Removing even one anomalously high biomass value from the analysis makes the difference between the compared rows insignificant.

The second variant of calculations was made on the basis of diving collections – 142 samples collected in the zone of similar sandy bottom of Groups A and B (Fig. 13). This particular zone is interesting also from the point of view of the evaluation of the situation with the modern state of gray whales feeding stocks. It was found that for the sandy bottom the differences both in total benthos biomass and biomass of individual groups are insignificant. At those stations total benthos biomass in accordance with the collections of 1992 was 260.2±47.9 g/m$^2$, the collections of 2001 – 336.6±48.4 g/m$^2$ ($t = 0.12$; $t_{0.01} = 1.64$).

The results obtained illustrate a well-known truth: when even minimal requirements to the compared analysis may result in the opposite conclusions based on the same material.

Therefore, the results of the comparative analysis of the material of 1992 and 2001 do not allow speaking about any significant multi-year changes during that time period both in the mass species composition and the macrobenthos abundance. Some differences were observed in the spatial distribution of the background species – the sand dollar *Echinarachnius parma* in the area of Odoptu. In 1992, mass settlements of sand dollars were limited by the isobaths of 20 m, at 15 m individual specimens with low density were observed. At the same transects in 2001, at a depth of 15 –20 m mass settlements of sand dollars were registered.

# CONCLUSION

1. August, 2001, SCUBA diving benthic survey of benthos was conducted at 10 transects over the range of depths from 5 up to 30 m. The transects covered as traditional feeding area of gray whales (Piltun Bay area), as the regions located to the south (Nyiskiy Bay – Chaivo Bay) and to the north (Odoptu Bay – Tront Bay). 4 transects were fulfilled in areas of 1992 expedition works. The cumulative material was presented by 280 quantitative samples.

2. Surge dominance of sandy fractions was specific for benthic sediments of the surveyed area. The ratio of fine sand fractions exceeded 60 % (maximum value – 98 %) at most stations. Medium sands prevailed at depths exceeding 15 m. More coarse fractions occurred only as admix to sandy fraction. Grading of 60 stations by fractional composition of grounds enabled to distinguish 3 groups of sediments in the surveyed area: **A** - well sorted fine sands (average depth – 12.2 м); **B** – moderately sorted variously grained sands (mixture of fine and medium grain sands; average depth – 23.7 м); **C** - poorly sorted gravel - pebble grounds with admix of sand and shell detritus (25.0 м). Periodic forms of microrelief, rifells of currents and sandy waves of extreme storm action (at depth 15-29 m), were widespread on sandy grounds. According to diving data, the gravel - pebble grounds occupied considerable bottom areas at depths 20-25 m in the central part of the Piltun Bay region. There outcomes of bedrock were also recorded at depths 20-30 m in the sand bottom area. In 9 studied points of whale feeding the ground was presented by well sorted fine sands.

3. The analysis of contents of OCH, HM, and OCP in sediments and their distribution in water area enables to conclude, that presently no any significant effect of pollutants on benthos was observed. That might be favored by active hydrodynamical regime of water area, and by transfer of water of East Sakhalin current along the coast that pended accumulation of pollutants in fine sand sediments.

4. 171 species was recorded in the quantitative samples of benthos and nektobenthos. 5 groups of animals prevailed by species number: amphipods (53 species or 31 % of the total number of species), polychaetes (41 species, 25 %), bivalves (27 species, 16 %), hydroids (15 species, 9 %) and gastropods (11 species, 7 %). In all the three areas♣ the greatest frequency of occurrence had isopod *Synidotea cinerea* and amphipods *Pontharpinia longirostris, Eohaustorius eous eous, Pontoporeia affinis, Eogammarus schmidti,* polychaete *Onuphis shirikishinaiensis*, flat sea urchin *Echinarachnius parma* and bivalves *Siliqua alta, Megangulus luteus, Macoma lama*.

5. The total biomass of macrobenthos varied over the entire area within considerable limits: from 12.1 g/m$^2$, on fine sands in the coastal zone, up to 2780 g/m$^2$ in the zone of mass development of sand dollars, averaging 595.3± 89.2 g/m$^2$ (n = 56). Population density of benthos was even more variable: hooded shrimps *Diastilis bidentata* had maximum values up to 92000

♣ As well as in the text of the report, division of all aquatory into 3 areas here is accepted: **south** (a hall. Nyiskiy – a hall. Chaivo), **mean** (area a hall. Piltun) and **boreal** (a hall. Odoptu – a hall. Tront).

ind/m$^2$. High population density was in settlements of polychaete *Onuphis shirikishinaiensis*, inhabiting tubes, more than 7000 ind/m$^2$ and in associated to tube mats of the polychaete isopods *Synidotea cinerea*, amphipods *Pontoporeia affinis* and *Eohaustorius eous eous* (2000-5000 ind/m$^2$). The trend of increase of benthic biomass of with depth increase was characteristic for the entire surveyed area. That was caused by increase with depth of biomass of sand dollars and, to a lesser degree, of hooded shrimps. The biomass of other groups of macrobenthos either decreased with depth (bivalves, crustaceans) or remained approximately at the same level (polychaetes, decapods).

6. The analysis of variation of the total biomass of macrobenthos displayed that general trend of increase of biomass with depth was common as for the entire water area, as for the individual distinguished regions. Maximum values of biomass were observed in all the regions at depth 25-30 m. The high values of total biomass were caused by mass development of sea urchins over there. With northward progress the average total biomass of macrobenthos varied from 322.3±51.8 g/m$^2$ in the **south** region up to 790.8±114.3 g/m2 in the **middle** region, being 671.2±134.9 g/m$^2$ in the north region. The average total biomass for the entire area studied was 595.3±89.2 g/m$^2$ (n = 56 stations).

7. Two ranges of depths were distinguished distinctly enough by similarity of quantitative abundance of taxonomic groups in the regions: from 5 up to 15 m and from 20 up to 30 m. Benthos had a transient character at depth 15 m in all the regions.

8. On fine sand bottoms at depth 15 m, i.e. beyond the zone of mass development of sand dollars, a considerable part took bivalves (35-49 % of the total biomass of benthos) and crustaceans (35-45 %) in all the three regions. The average value of biomass of bivalves over the entire area was 98.0±17.1 g/m$^2$. The greatest biomass of *Bivalvia* was recorded in the middle region at 10-15 m (> 200 g/m2) and in north region at 5-15 m depth (170-220 g/m$^2$).

9. The most common species of polychaetes at depth less than 15 m was *Onuphis shirikishinaiensis.* In the Piltun Bay area its biomass averaged 107 g/m$^2$ at 5 m depth and sharply decreased with depth increase. Patches, by visual assessment of divers the patch area was on the average 3-5 m$^2$, with population density from several hundreds to several thousand individuals per square meter of bottom (maximum biomass 960 g/m$^2$) were recorded over the range of depths 5-10 m. *O. shirikishinaiensis* is a potent environmental edificator. Tube mats of that polychaete stabilize sediments and create conditions for habitation of other animals in hydrodinamically active areas, in particular, of crustaceans and other species of polychaetes. That was also facilitated by some features of *O. shirikishinaiensis* ecology – individuals of that species, if necessary, can abandon tubes and built new ones. Actually, the tube mats of *O. shirikishinaiensis* play the same role, as tube mats of amphipods of fem. *Ampeliscidae* in other areas. It was displayed, that often formerly described communities *amphipod* + *isopod* in the Piltun Bay resulted from undercount of polychaetes in dredge samples.

10. The average biomass of isopods over the entire area was 22.9±6.3 g/m$^2$. The isopods had greatest average biomass, 42.6 g/m$^2$, in the middle region at depth 5-10 m. Large isopods *Saduria entomon* (average weight of individuals was 2.09 g) had frequency of occurrence 22 % (in the middle region – 25 %). The biomass of that species over the range 5-30 m varied insignificantly, from 1.5 up to 4 g/m$^2$. Isopod *Synidotea cinerea* had the maximum frequency of occurrence (86 %) among all macrobenthic species That species had the greatest parameters of abundance, more than 5000 ind./m$^2$, with biomass more than 90 g/m$^2$, at depths up to 15 m, in tubular mats of *O. Shirikishinaiensis.*

11. Amphipods had the greatest species richness among all benthic groups, 53 species. 10 species of them had frequency of occurrence more than 25 %, 3 species – more than 50 %. The average biomass of amphipods over the entire area was 36.9±9.7 g/m$^2$. The greatest average biomass of amphipods was observed in the Piltun Bay area, 66.7±15.7 the g/m$^2$, amphipods had the maximum ratio of biomass of benthos there, 22.1 %. The amphipod biomass over the entire area gradually decreased from 78.4 g/m$^2$ at 5 m depth to 9.4 g/m$^2$ at 30 m. That trend was observed as well in the individual regions. However, significant differences were observed in quantitative abundance of amphipods in regions at depths less than 15 m. Thus, average biomass in the Piltun Bay area reached 114.1 g/m$^2$, in the south region – 44.5 g/m$^2$, in the north – 24.3 g/m$^2$. The biomass of amphipods was similar at depth 20-30 m in all the regions and was less than 10 g/m$^2$. Among amphipod species with frequency of occurrence more than 25 %, 8 species had the greatest values of biomass: *Pontharpinia longirostris, Eohaustorius eous eous, Pontoporeia affinis, Eogammarus schmidti, Atylus collingi, Pontharpinia robusta, Synchelidium gurjanovae, Anonyx nugax pacificus and Westwoodilla sp.* The most of common species of amphipods had the greatest values of population density and of biomass in tube mats of *O. shirikishinaiensis.*

12. The average biomass of hooded shrimps was 27.8±7.9 g/m$^2$ with frequency of occurrence 26 % over the entire water area. Hooded shrimps and sand dollars occurred together at most stations. Nevertheless, sand dollars + hooded shrimps, either only sand dollars or only hooded shrimps might be recorded in some samples from the same station. The number of samples with hooded shrimps but without flat sea urchins did not exceed 5 % from total number of samples taken at depth 25-20 m (n = 56). When hooded shrimps occurred without sand dollars, their population density reached several tens thousand ind/m$^2$ (maximum – more than 92000 ind/m$^2$).

13. The boundary of dense aggregations of *Echinarachnius parma* sand dollars went over the depth range 15-20 m. Starting from that depth sand dollars prevailed by their biomass over other species of macrobenthos. *E. parma* was repeatedly recorded at diving counts at 5-meter transect (the count area = 5 m2) in all the three regions in minor quantities or individually at depths 5 and 10 m. In more than 40 % instances the sand dollars were presented by small size individuals. Population density of flat sea urchins varied from 1 up to 4 individuals at count area 5 m$^2$ (0.1 – 0.8 ind/m$^2$). The probability to seize sand dollar by dredge sampler at such population density is

extremely low. Thus, the distribution of flat sea urchins over the entire area is rather continuous than patched. Rather distinct boundary within the range 15-20 m was determined to a greater extent by probability of sand dollar seizure by bottom sampler, thanks to higher population density at that depth, i.e. the boundary mostly has the probabilistic character, which implies, that simple presence or absence of flat sea urchins in an area does not proof fitness or unfitness of the area for gray whale feeding.

14. The analysis of total caloricity of macrobenthos in the regions evidenced that ratio of bivalves in the total caloricity of macrobenthos was less, than their ratio in the total biomass. The ratio of high caloricity groups (crustaceans) in the total caloricity of benthos was higher in all the regions, than in the total biomass. In the south region the ratio of crustaceans in the total caloricity of benthos was 51.7 %, in the middle region – 65.8 %, in the north – 43.8 %. Thus, the ratio of the highest caloricity groups of crustaceans, amphipods and isopods, was the highest, 58.3 %, in the middle region (Piltun Bay area).

15. All mass species of macrobenthos had aggregated microdistribution (dispersion index varied from 49 up to 312). Patch microdistribution of tube mats of polychaete *Onuphis shirikishinaiensis* (the area - a few $m^2$) entailed aggregation of crustaceans and polychaetes living in those mats. Periodic forms of microrelief, sandy waves arisen on surface of sand bottoms in conditions of active hydrodynamics, detritus accumulated in hollows between crests of sandy waves. A higher abundance of detritophagous animals was observed at that sites. Some kind of corroboration of aggregation of benthos could be revealed in feeding behavior of gray whales. Thus, we observed gray whale performing vertical dives for food. Within the limits of small area the whale performed 4-6 vertical dives. Then it passed to a new area.

The feeding behavior of whales could be related exactly with macroaggregation of feed benthos, when they "remained at the same place (sometimes for several days) at the area less than 500 $m^2$" [74]. The values of dispersion index of common species of crustaceans and polychaetes at retained aggregation distribution were much lower in the south and north regions, than in the middle region, i.e. the patchiness of benthos distribution was higher in the Piltun Bay area, than in the other regions. The aggregated distribution of food resource plays important role for an animal consuming this resource. It is known that feeding in conditions of patch distribution of food is energetically more expedient to a resource consumer [66].

16. In animal sample, washed out from the mouth of emerged whale, a plenty of empty tubes of polychaetes, morphologically similar to tubes of *O. shirikishinaiensis* was observed. Fragments of polychaetes *Scoloplos armiger and Travisia forbesii* were recorded. Intact isopods *S. cinerea*, less often – fragments of amphipods *P. affinis* and *Anonyx sp.,* prevailed among crustaceans. All those species had high frequency of occurrence and quantitative abundance in the regions.

17. As probable food objects of gray whale in the area, the polychaete *Onuphis shirikishinaiensis,* opossum shrimp *Tenagomysis orientalis,* juveniles of crab *Hyas coarctatus* and sand lace Ammodytes hexapterus were considered.

18. The structure and quantitative ratios of basic groups *of meiobenthos* in the surveyed area were typical for pollution-free sand bottoms, availability of fair quantity of ostracods, the indicator of oil carbohydrate pollution, evidenced for absence of this type of pollution. The availability of plenty of larvae of benthic animals in meiobenthos (*pseudomeiobenthos*) evidenced for normal recruitment of coastal benthic communities. Larval meiobenthos in the Chaivo-Piltun region had "shallow-water" character, i.e. it was presented by larvae of those animals, that inhabited actually in zone of meiobenthos sampling *(amphipods, mollusks, polychaetes*). Other situation was in the Odoptu Bay region, where the larval meiobenthos had “deepwater” nature. Larvae of animals not inhibiting the zone of meiobenthos sampling (5-15 m) prevailed over there: *holothurians, priapulids, nemertines*, and sand dollars. All those groups inhabit much greater depths. Their occurrence in shoal zone pseudomeiobenthos was caused by great larval pool from deeper areas. Only in Odoptu Bay region a mass settling of larvae of flat sea urchin *E. parma* was recorded at depths up to 15 m, in more southern regions the larvae of sand dollars occurred incidentally.

19. Results the comparative analysis of materials of 1992 and 2001 do not enable to speak about any essential changes, which have occurred for the decade, both in structure of mass species, and in abundance of a macrobenthos on sand bottoms at 2001. Some differences were observed in spatial distribution of background species, sand dollar *Echinarachnius parma,* in Odoptu Bay region. 1992 mass settlements of settlements of sand dollar were confined to 20 m isobaths, there were only few individuals with low population density at 15 m depth. At the same sections there were recorded mass settlements of sand dollars at the depth 15-20 m at 2001.

20. The analysis of size structure of mass species of amphipods (the basic component of gray whale nutrition) displayed that there is a significant portion of young individuals in populations of all species. That data, concurrently with data on larval meiobenthos, evidenced for absence of disturbance in recruitment of benthic communities in the feeding area of Okhotsk-Korean population of gray whales (Appendix 8).

COMMENTS

Comparison of benthos data with patterns of distribution and behavior of gray whales in the feeding area.

1. Sea-depth the whales were recorded at. Practically all researches noted, that main portion of whales occurred at depths down to 20 m, and most of the feeding individuals – down to 15 m. That was shown by Weller with co-authors most in detail [74]: "average sea depth, which the shoals of whales were recorded at was 11.2 m (±3.37, n = 362), varying from 3.3 up to 27.0 meters. The whale shoals were recorded 96 % instances at depths less than 18 m."

That observations well coordinate with distribution of benthos in studied area. In all areas groups of invertebrates most valuable for whale feeding (first of all crustaceans) have the greatest absolute biomass and relative ratio in the total benthic biomass at depths to 10-15 m, at depth exceeding 20 m the basic role in biomass was taken by sand dollar *Echinarachnius parma.* We should note, that a small number of records on feeding whales at depths exceeding 20 m does not contradict benthos data (item 11 of the Conclusion). At depths more than 20-25 m local fields with pure settlements of hooded shrimps occurred. When hooded shrimps occurred without sand dollars, their population density might reach several tens thousand ind./$m^2$, and biomass more than 100 g/$m^2$. It is quite assumable, that whales incidentally might use fields with high biomass of hooded shrimps at depth exceeding 20 m. Summarizing all above-stated from the point of view of feeding of gray whales, we should note that gray whales from the Piltun Bay area have two main feeding alternatives available:

1. To dive to depth from 20 to 30 m and to consume more than 450 g of flat sea urchin *Echinarachnius parma* to obtain 100 kcal,

2. To dive to depth from 5 to 10-15 m and to receive the same 100 kcal consuming 150 g of amphipods and isopods.

Naturally, the gray whales at feeding areas of Piltun Bay region have chosen *more effective* alternative of the two available.

2. Areas of most often occurrence of whales. From Fig. 39, and figures of Appendices A, B follows, that the greatest number of whale record was connected to the middle and south parts of Piltun Bay. We should note, that incidental observations (regular observations were not included into the plan of works), carried out during diving works of 2001, have shown a presence of small number of feeding individuals at sufficient distance from exit of Piltun lagoon, to the south and to the north from the main area of whale distribution (see section 3.4).

Confinement of zone of maximum occurrence of whales to the middle and south parts of Piltun Bay quite matched the pattern of spatial distribution of quantitative abundance of feed benthos (Fig. 25-28, 30). Whales most often occurred at shallow areas with maximum absolute values of biomass of feed benthos and, respectively, with greatest ratio in total benthic biomass. We should note, that the zone of sufficiently high biomass of feed benthos (first of all crustaceans and bivalves) at depths to 10-15 m extends to the north and to the south from sites of mass occurrence of whales. Region of whale occurrence (Fig. 39,B) corresponds to the area between sections P1 - P3 (Fig. 39,A). Area with rather high biomass of feed benthos is significantly more extended and covers areas between sections N1 - S1 (Fig. 39,A), from Odoptu and Urkt Bays to the middle part of Chaivo Bay.

What caused rather narrow localization of gray whales in the feeding area?

The possible explanation is related to present low number of whales. Now it may be taken for granted, that the total number of the Okhotsk-Korean population of gray whales feeding at the East Sakhalin area, does not exceed 100 individuals [74, 75, 77-79]. In conditions of low number, the whales were localized for feeding in the most energetically favorable areas (shallow depths, maximal abundance of feed benthos). Only incidental individual leaved for more northern and southern areas for feeding (Section 3.4, Appendix D).

However, it is necessary to make an essential addition. In the Piltun Bay area not only biomass of feed benthos and its ratio in the total biomass is higher, but also bottom sites with depths less than 15 m are more extended from the coast, than in the region to the north (Odoptu and Urkt Bays). Respectively, the bottom area suitable for development of feed benthos is larger, and consequently its total stock is greater. In region to the south (from the north part up to middle part of Chaivo Bay) bottom area confined by 20 m isobath is greater than in Piltun Bay, but significant areas of bottom are occupied with mixed sandy grounds with significant portion of pebble, gravel and shell debris. Communities of attached animals not used by gray whales prevailed on that grounds.

Thus, the regions situated to the north and to the south from Piltun Bay, even at presence of sufficiently high biomass of feed benthos in coastal zone, may take only auxiliary part in gray whale feeding, because of less total resource of benthos.

The composition of benthos, its quantitative parameters and ratio of feed benthos within the limits of studied area enabled to presume two feeding regions:

- basic region, which comprises areas from Odoptu Bay up to the most south part of Piltun Bay (sections N2 - P4 at Fig. 39, A) and
- secondary region, which might be connected to the area located to the **north** of the basic region: from Urkt Bay up to Odoptu Bay (sections N1 - N2 at Fig. 39, A) and to the **south**, covering area from the south part of Piltun Bay up to the Chaivo Bay (sections P4 – S1 at Fig. 39, A).

Why areas of the greatest values of biomass of feed benthos are confined to Piltun Bay?

Piltun Lagoon is a productive basin, production-destruction process occurring there influences the hydrobiological regime of adjacent part of East Sakhalin shelf [69]. It is known, that daily primary production in coastal lagoons of the Boreal Pacific could reach 850 mgC/$m^2$, that is the order higher than values observed in majority of the most productive areas of shelf itself [86]. Lagoons significantly raise productivity of the open coastal waters for the account of outwelling carrying out biogenic elements by tidal flows [69]. It is corroborated by considerably increased values of primary production for the Northeast Sakhalin [87] (in the season summer "bloom" of microalgae it reached 368 mgC/$m^2$ [88]), comparing with the rest west water area of the Sea of Okhotsk. Significant bottom areas of Piltun Lagoon are occupied by eelgrass beds. During the ebb a plenty of dissolved organic matter produced by eelgrass and detritus resulted from its microbial decomposing are carried from the lagoon to coastal waters.

3. Deterioration of physical condition of gray whales in the feeding area. It was noted in Introduction, that explorers have recorded certain changes both in distribution, and in physical condition of whales 1999-2000. As possible causes were specified:

- arise of diseases;
- sharp changes in a metabolism under stress caused by long-term effect of anthropogenic factors, such as underwater noise;
- reduction of food supply caused by natural and/or anthropogenic factors.

Our benthos research in feeding area of the whales was carried out at 2001. It was established, that the area was specified by high values of biomass of feed objects, and for the past decade (since 1992) there were no statistically significant changes of benthos abundance observed in the surveyed area. Thus, a long-term average condition of feed base was recorded in 2001. Based on that, a normal physical condition of gray whale individuals should be expected already by the end of feeding season of 2001 and 2002. If divergence in physical conditions of whales will be observed, their causes cannot be connected to condition (abundance) of feed base.

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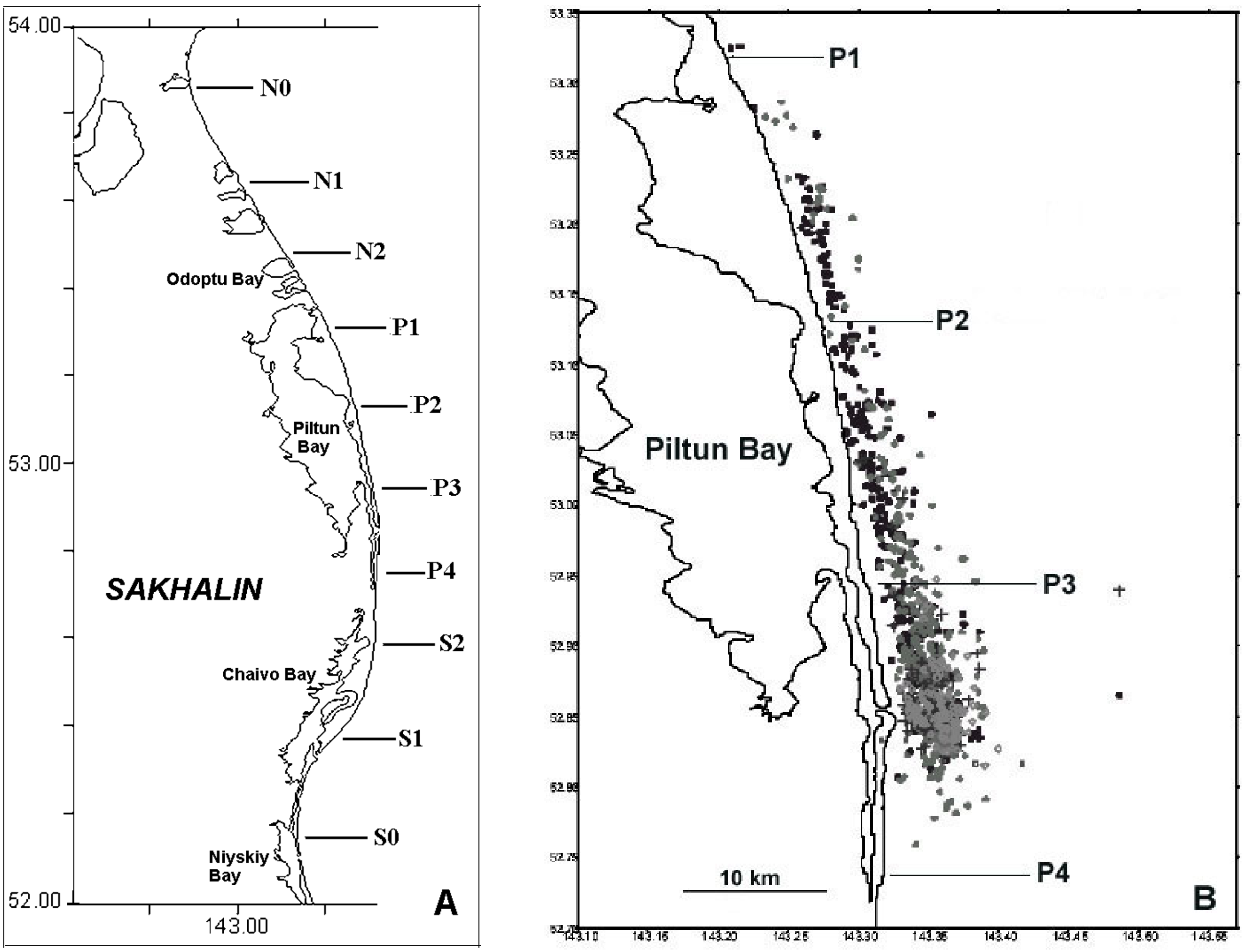


Fig. 39. The scheme of allocation of diving sections at 2001 (A) and spatial distribution of gray whales in 1995-2000 (B)

Distribution of gray whales at Fig. B corresponds to the Appendix 2 of the report [74]. Allocation of sections P1 – P4 is marked at Fig. B.

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