# REPORT
# Monitoring Researches of Marine Biota and Sea Water Quality During Dredging at LNG Jetty & MOF and Dumping Areas 2003 – 2006



Any engineering, procurement and other related matters, which are out of CONTRACTOR's scope but relevant to construction activities under the scope of other contractor i.e. engineering and procurement contractor referred to in this procedure are for the reference purpose only.

Federal State Unitary Enterprise
All-Union Fishery and Oceanography Scientific Research Institute и (FSUE «VNIRO»)

APPROVED BY
VNIRO Deputy Director

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# Conclusion

For the monitoring researches of marine biota condition and sea water quality during soil dredging operations at LNG Jetty and Material Offloading Facility (MOF) and soil dumping areas in Aniva bay in the period of 2003-2006.

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# 1. INTRODUCTION

Characteristics of soil excavation and dumping works during construction of Material Offloading Facility (MOF) and LNG Jetty as well as the predicted construction impact assessment to environment, including suspended solids and bottom sediments transport simulation, fish damage calculations and other works are specified in "The TEOC for the Integrated development of Piltun-Astokhskoye & Lunskoye License areas, Sakhalin II Project. Phase 2". The TEOC have obtained positive conclusion of the State Environmental Expert Review (SEER), approved by Russian MNR Order # 600 as of July 15, 2003.

During the period from October 2003 to December 2005 the activities for construction of MOF and LNG Jetty have been performed in the coastal strip of Aniva bay within the licence area boundaries based on the Water use License YuSH 00385 TMSBK as of May 19, 2003 (construction and operation of temporary hydraulic engineering structures and dredging operations) and YuSH 00064 TsMSBV as of September 6, 2004 (construction of LNG Jetty and dredging operations).

The soil excavated during MOF and LNG Jetty construction was dumped at 22,5 km off shore and sea depth 63 m. The amount of soil dumped within the allocated water area was 1317208.42 $m^3$. At the same time complex ecological and fishery surveys were performed in spring, summer and autumn of 2003-2006 according to the approved marine environment monitoring programs.

The obtained actual monitoring data were the basis for assessment and updating of consequences forecast for marine environment due to operations performed in Aniva Bay. Such data allowed to trace the marine environment change trends as well as influence of man-made factors within Aniva Bay coastal zone. The specified data on the background state of marine biota at the job sites as well as on the character and range of processes, which took place during soil moving and dumping.

All the above considered, below are the analyses of ecological and fishery researches in 2003-2006, conducted during soil dredging and dumping in Aniva bay from 2003 to 2005.

The following documents have been used as the actual basis in this report:

- ✓ "The TEOC for the Integrated development of Piltun-Astokhskoye & Lunskoye License areas, Sakhalin II Project. Phase 2".;
- ✓ Results of monitoring researches, reflected in the SakhNIRO reports for 2003-2006;
- ✓ Sakhalin UGMS (Territorial Administration for Hydrometeorological and Environmental Monitoring ) data on background characteristics of Aniva bay coastal waters (2003-2005 гг);

✓ Results of monitoring researches, given in the reports of ANO “Sakhalin Hydrometeorological Agency” for 2003-2005.

Marine Environment Monitoring Program during dredging operations and soil dumping has been prepared considering “Industrial environmental monitoring concepts” by Sakhalin Energy and approved by the Sakhalin regional control and supervisory bodies and being the integral part of the Program of Environmental Monitoring, industrial environmental and sanitary-hygienic control which is a part of TEOC documents.

The intention of construction monitoring of marine environment is:

- Control of marine water pollution level, bottom sediments and biota during dredging operations near LNG Jetty, Material Offloading Facility (MOF) and in the area of soil dumping.

Major tasks of constrution monitoring are as follows:

- Obtaining of true data on suspended solids and pollutants level in marine water during dredging and dumping operations;
- Assessment of grain-size and chemical composition of bottom sediments after soil dredging and dumping operations competion;
- Benthos state assessment at bottom adjoining the soil dredging and dumping areas after works completion;
- Assessment of the man-caused impact to marine environment components at the construction stage.

Objects of the marine environment monitoring are:

- Sea water;
- Bottom sediments;
- Marine biota.

## 2. RESEARCHES, CONDUCTED DURING DREDGING OPERATIONS AND AFTER THEIR COMPETION

The following data were used to get background hydrochemical characteristics of Aniva Bay water:

- ✓ Results of field works executed at 30 hydrological stations over the period from 1975 to 2000;
- ✓ Research data from 29 hydrological and hydrological and hydrochemical stations, performed by DVNIGMI on board the research vessel "Pavel Gordienko" in June-July of 2001;
- ✓ Data provided by SakhNIRO and shown in the report "Environmental fishery characteristics of Aniva Bay and preliminary evaluation of possible damage to marine bioresorces due to dredging and dumping operations". Book 1. Environmental fishery characteristic of Aniva Bay, Yuzhno-Sakhalinsk, 2001;
- ✓ Statements of Sakhalin UGMS on background concentrations of suspended solids in the coastal zone of Aniva Bay.

Dredging operations during MOF construction and soil dumping were conducted within the periods agreed and permitted by the supervisory and control bodies:

from September 2003 to April 2005, based on the permits issued by the MNR of Russia as of November 11, 2003 # ИГ-06-47/7628 and Federal Nature Management Service (RosPrirodNadzor) as of October 21, 2004 № BB-03-47/702 "On moving and dumping of excavated soil".

Dredging operations during LNG Jetty construction and soil dumping water areas were conducted within the periods agreed by the supervisory and control bodies:

- ✓ In March of 2005 (letter from RosPrirodNadzor as of October 8, 2004 # BB-03-47/534 "On moving and dumping of excavated soil during LNG Jetty construction");
- ✓ From the 3d decade of September to December of 2005 (letter from RosPrirodNadzor as of September 21, 2005 # CC-03-27/4985 "On issuance of the permit for moving and dumping of excavated soil).

## 2.1. Material Offloading Facility (MOF) area

### 2.1.1. Sea water

#### 2.1.1.1. Suspended solids

Sampling of sea water for suspended solids and pollutants content in sea water at MOF construction area was carried out in three periods: before dredging operations, during and after their competion.

Three stationary observation stations (14-16) are located within dredging area. Out of dredging area there were observation points (10-13) located 250 m from its boundary (westward, northward, eastward and southward).

Besides, over the period of dredging operations the sampling of water was taken from the mean water level at 3 temporary points:

- ✓ Along the plume centerline near the barge and the dredger;
- ✓ At dredging zone boundary;
- ✓ 250 m from dredging zone along the suspended solids transfer by current

**In August of 2003**, before commencement of dredging operations, the background level of suspended solids (SS) concentrations was determined. In August the influence of storm and wave action was detected at all the stations both outside and inside of MOF dredging area.

Concentration of SS varied within 4,9-14,7 mg/dm$^3$. Maximum content of SS - 14,4-14,7 mg/dm$^3$ was detected in mean and bottom levels of the dredging area, which was a little higher than background values measured before and were equal 14 mg/dm$^3$ (Table 2.1).

**In December of 2004** the samples were collected at three temporary points: at SS plume zone: near barge and dredger, at dredging zone boundary and 250 m from it.

SS content level dynamics during dredging, with regard to background level, showed insignificant variations of concentrations towards increase.

Inside dredging area and at its boundary at mean water level (4 m) the maximum values of SS 20,7–23,0 mg/dm$^3$ were noted.

At 250 m from dredging area boundary the concentrations of SS were equal 21,6 mg/l. This is slightly higher than background values, however, the concentrations are comparable to SS propagation simulation evaluations during dredging operations at MOF area (TEO Sakhalin II Project. Phase 2, Volume 5, Book 12, Part 2, Addendum F2). The results of simulation evaluation showed that maximum distance, where concentration of SS from the source (soil excavation area) decreases to 20 mg/l, makes 230 m.

**In 2005** during execution of marine construction works at MOF area, the maximum SS concentrations in water varied within narrow limits: from 26,7 to 29,6 mg/dm$^3$. The obtained results were within the range of SS propagation model, though they were slightly higher than background values.

The highest concentrations of SS (29,6 mg/l) were determined at station 11 (mean level). This station is located outside the dredging area, 250 m northward from area boundary. Sea depth at this point was only 3 m.

The increased SS concentrations in May were of local and short term character at the small area (Table 2.1).

The possible causes of this were as follows: carryover of SS with surface flow from Goluboy brook (average background values equal to 29 mg/l, SakhUGMS, 2005) and influence of dredging operations.

Table 2.1

Concentration of SS in sea water at MOF area (intermediete level)

| Stations | Depth, m | August of 2003 | October of 2003 | May of 2005 |
|---|---|---|---|---|
| MOF Dred 10 | 4 | 5,5 | 2,1 | 26,8 |
| MOF Dred 11 | 3 | 8,9 | 5,0 | 29,6 |
| MOF Dred 12 | 4 | 5,8 | 2,3 | 28,4 |
| MOF Dred 13 | 5 | 5,1 | 2,7 | 27,5 |
| MOF Dred 15 | 4 | 14,4 | 2,1 | 26,7 |
| Average concentrations | | 7,9 | 2,8 | 27,8 |

### 2.1.1.2. Petroleum hydrocarbons

In TEOC hydrochemical condition of Aniva Bay waters is assessed as moderately polluted, mainly, due to petroleum hydrocarbons (PH), phenols and polycyclic aromatic hydrocarbons (PAH).

Sea water sampling from mean water level for total PH content near MOF was done before dredging operations (points 10-13,15), during dredging (points 10-13) and after dredging (10-13).

There are three stationary observation points (14-16) located at dredging area. Moreover, for the period of dredging operations the water sampling was performed from the mean water level at 3 points: SS plume zone near the source (barge and dredger), at dredging area boundary and 250m from dredging area along the suspended solids transfer by current.

Background level of PH concentration before work commencement varied from 0,017 mg/dm$^3$ to 0,028 mg/dm$^3$.

**In December of 2004** water samples were collected at three temporary points at the dredging area: near the source (barge/dredger), at dredging area boundary and 250m from dredging area boundary.

During dredging operations the minimal content of PH – (<0,005 mg/dm$^3$)was registered at the dredging area boundary and beyond it, but maximum content 0,024 mg/dm$^3$ - near the source (barge/dredger), which is, though, lower than MPC for marine fishery waters.

In December of 2004, compared to 2003, concentrations of PH varied slightly from <0,005 to 0,0175 mg/dm$^3$ and didn't exceed MPC for marine fishery waters.

In May of 2005 concentrations PH in sea water at MOF area were also less than MPC (0,05 mg/dm$^3$) and are comparable to background data.

Dynamics of PH content level in sea water during dredging (with respect to background level) showed that mimimum concentrations of PH were less than the detection level <0,005 mg/dm$^3$. Maximum concentrations were equal 0,020 mg/dm$^3$ which was less than the background level and didn't exceed fishery MPC.

Table 2.2

Concentrations of SS in sea water at MOF area (intermediate level)

| Stations | Depth, m | August of 2003 | October of 2003 | May of 2005 |
|---|---|---|---|---|
| MOF Dred 10 | 4 | <0,0050 | 0,0175 | 0,0240 |
| MOF Dred 11 | 3 | 0,0280 | 0,0052 | 0,0290 |
| MOF Dred 12 | 4 | 0,0086 | 0,0042 | 0,0210 |
| MOF Dred 13 | 5 | 0,0077 | 0,0045 | 0,0240 |
| MOF Dred 15 | 4 | 0,0132 | - | 0,0230 |
| Average concentrations | | 0,0125 | 0,0079 | 0,0242 |

### 2.1.2. Bottom sediments

In the TEOC documents it is noted that the main flow of pollutants in bottom sediments ingresses together with SS, the content and level of which in Aniva Bay almost had not been studied before.

#### 2.1.2.1. Grain-size composition

Sampling of bottom sediments to determine grain-size and chemical composition was taken once at 4 points outside dredging area (10-13) and at one point – (15) within dredging area – 1 time before dredging operations and right after their completion.

Background parameters of the grain-size composition of the sediments surface layer (0-2 cm) in 2003 for the given dredging area were characterized by two types of bottom sediments – coarse grained soil in the form of grussed gravel and fine grained sand.

Fine sand and grussed gravel from hydraulic engineering and hydrobiology points of view are solid grounds, but fine aleurite silts and finer sediments are considered soft grounds.

In 2003, before dredging operations, soil at stations 11 (outside dredging area) and 15 (center of dredging) was characterized by clean fine sands (0.25-0.1 mm, solid grounds) - 70.1 и 83.1%, respectively.

Coarse grained soil, highly mixed with gravel (solid grounds), was recorded at stations 10 and 13 (two stations outside dredging area).

Near station 10 (eastern side, outside dredging) share of fractions of more than 1 mm reached 95%. Angular gravel appears with a slight increase of depth (from 8 to 9 m).

The amount of fragmental material reduces with the depth due to increase of 0,1mm fractions i.e. silting process started. Content of thin siltstone-pellite fractions (particle size less than 0,1 mm) in samples was insignificant and varied from 0,2 to 9,16%.

Amount of thin material increased with depth and reached maximum (9,2%) at a depth of 10m (station 15).

Fine grained clean and well assorted sands prevailed at a depth of 8 m.

**In 2005,** after dredging operations, the mentioned Aniva Bay area was characterized by presence of two types of bottom sediments – coarse-grained soil in the form of grussed gravel and unequally sized sand (from fine to gravel sand).

Sediment distribution pattern for this time period was unhomogeneous. Bottom sediments at station 10 as in 2003 were represented, mainly, with gravel-pebbble angular fractions. Fraction >1 mm was 82.84%, sand – 10,9%, fractions of <0,1 mm equaled 6.3%, i.e. bottom sediments practically remained unchanged as they were not subjected to dredging operations.

As in 2003, station 11, which was located at shallow waters, registered clean medium sands (0,5-0,25 mm) the fraction of which was 70%, fine and coarse fractions were absent , i.e. grain-size remained unchanged.

Sediments at station 12 (eastward of dredging area) were composed, mainly, of fine clean sands, the share of which reached 65,2%.

Soil at station 13 was formed of gravel-pebble sediments. Share of pebbly particles (>10 mm) was 29,4%, gravel (5-1 mm) – 68,5%, particles less than 1 mm practically were absent. In comparison with 2003 grain sized composition remained unchanged.

Gravel sand dominates at station 15 (center of dredging), its quantity was 59,0%, fractions from 0,5 to 0,1 mm – 22,2%. The share of siltstone-pellite fractions (<0,1 mm) increased from 9,2 to 18,8% at this station.

So, in 2005 after dredging operations, the change of grain-sized composition of bottom sediments was recorded at dredging area (station 15), where the fraction of aleurite-pellite increased from 9,2 to 18,8% with the fine sand share reduction from 83.1 to 59% (fig.2.1).

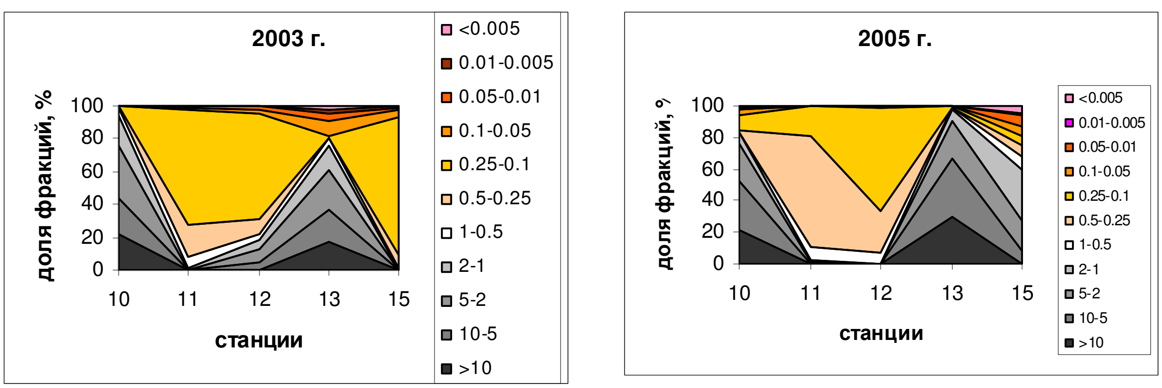



Fig. 2.1. Grain-size composition of bottom sediments at stations at the MOF dredging area in 2003-2005

### 2.1.2.2. Chemical composition

#### 2.1.2.2.1. Petroleum hydrocarbons

In 2003, before commencement of works, the studies of PH in the surface layer of sediments with 0-2cm thick were performed. Concentrations of PH varied from 0,5 to 1,4 mg/kg of dry mass. Minimum content of PH in bottom sediments - 0,5kg/kg of dry mass was recorded at station 13 (outside dredging area), maximum value – 1,4kg/kg of dry mass at station 15 (dredging operations point).

As a whole, the obtained results of total PH content in bottom sediments were comparable to previous data of SakhNIRO in 1999 for Aniva Bay (from 0.5-8.86 mg/kg of dry mass) and data, provided by DVNIGMI (from 4,02 mg/kg to 26,4 mg/kg of dry mass), which performed additional studies of bottom sediments in Aniva Bay in Summer of 2001 (Report of DVNIGMI, 2001).

Therefore, before commencement of dredging operations, total content of PH in bottom sediments corresponded to background data, As it is described in TEOC regarding PH level concentrations in bottom sediments, the soils shall be referred to as lightly polluted.

**In October of 2004 and April of 2005** the excavated soils were studied during dredging for PH content.

The studies showed that content of PH in October of 2004 was 31,8mk/kg, in April of 2005 – 3,8 mkg/kg of dry mass and the measured concentrations fell within background values.

**In May of 2005,** after completion of dredging operations, total composition of PH varied from 3.2 mg/kg of dry mass to 14,2 mg/kg of dry mass, which didn't exceed average content of PH for Aniva Bay for background data, reflected in the report of DVNIGMI (2001), when the minimum concentration was 4,02 mkg/kg and maximum 26,4 mkg/kg of dry mass.

Average concentration of total PH content in bottom sediments was 8,3 mg/kg of dry mass, which doesn't exceed average background data for Aniva Bay.

So, after dredging operations at MOF construction area, bottom sediments by petroleum hydrocarbons accumulation level were classified as lightly polluted.

Table 2.3.

Concentartions of total PH in bottom sediments at MOF area
mg/kg of dry mass

| Stations | MOF Dred 10 | MOF Dred 11 | MOF Dred 12 | MOF Dred 13 | MOF Dred 15 | Xcp. | Background data | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | SakhNIRO | DVNIGMI |
| August 2003 | 0,54 | 1,02 | 0,72 | <0,50 | 1,42 | 0.84 | from 0.5 to 8.86 | from 4,02 to 26,4 |
| May 2005 | 3,20 | 9,60 | 14,20 | 8,80 | 5,70 | 8.30 | | |

### 2.1.2.2.2. Polycyclic Aromatic Hydrocarbons

Concentrations of PAH were found equal 0,0067-0,271 mg/kg of dry mass in bottom sediments at three stations of Aniva Bay in 1998 during background concentrations studies (On results, 1999)

**In October of 2004,** before commencement of dredging operations the concentrations of particular PAH and sum of PAH in the surface layer of bottom sediments near MOF varied from 0,1547 to 0,2087 mg/kg of dry mass.

Average content of PAH were at level (station 16) or 1,4 times more (station11) and 1,5 times more (station 14) of background values for seashore but not higher than for the whole polygon area in the coastal zone of Aniva Bay (DVNIGMI Report, 2001) of dry mass. The highest concentration was recorded at station 14, the lowest – at station 16.

Phenanthrene prevailed among PAH (15-18,8% of PAH sum). Alkylated naphthalene homologes were next (with low level or absence of naphthalene), which indicated to availability of oil source of PAH. In sum they varied from 24,4 to 35,2%.

Perylene was the next (6,9-10,6%).

PAH have both natural and man-caused sources.

The sum of PAH reached the maximal values at deep water stations with big amount of fine fractions of soil. Near the shore the content of PAH was 0,141 mg/kg. Phenanthrene prevailed.

In December of 2004 during dredging operations at MOF area, total amount of PAH increased at point 14 – two times, at point 16 – 2,8 times. Besides total content increase the changes in qualitative content of PAH took place.

Quantity of alkylated naphthalene homologes – 17,3% at station 14 and 18,2 at station 16. Perylene quantity increased reaching 19,7% at station 14 and 16,7% at station 16, which is indicative of vegetable hydrocarbons increase. Quantity of phenathrene remained unchanged and was equal 15-17%.

In April of 2005 during dredging operations at MOF area, westward of station 11, total content of PAH in the samples of the excavated soil was 58,6 mg/kg of dry mass, which was 3,3 times less than total content of PAH in the surface layer of bottom sediments in October of 2004 before dredging.

Naphthalene and its methyl homologs (63,7% of PAH sum) prevailed among PAH, then followed phenanthrene (16,7% of PAH sum).

The concentrations of PAH sum in bottom sediments were comparable to background values for Aniva Bay, measured in 1998-1999, which varied from 6,73 to 271.00 mkg/kg of dry mass and in 2001 varied from 15,2 to 217,2 mkg/kg of dry mass.

#### 2.1.2.2.3. Organochlorine pesticides

Before commencement of dredging at MOF area concentrations of particular OCP and sum of OCP in the surface layer of bottom sediments were found within 0.000461-0.005422 mg/kg, in the mid-water layer - 0,002242±0,0027606 mg/kg of dry mass. Maximum concentrations were recorded at station 16, minimum at station westward of point 11.

Only 6 OCP types were found in the samples among 21 substances. The most various OCP were found at station 16 (5 types of OCP).

Station 14 recorded 4 types of OCP, the station westward from point 11 – 3 types. All the stations recorded hexachlorobenzene and various DDT metabolites. Despite proximity of stations ratio of OCP differed greately:

- 4, 4´-DDE prevailed (88% of OCP sum) at station westward from point 11
- 4, 4´-DDE (45,6%) и 4, 4´-DDD (32,5%) at station14;
- 4, 4´-DDT (86,5%).at station 16.

If ratio of DDT metabolites and total absence of initial substance (DDT) at stations 14 and 11 evidenced about a far gone decomposition process and, therefore, showed longstanding ingress of DDT, but the traces of recent ingress of DDT in the bottom sediments at station 16 was quite unexplainable.

In December of 2005 near MOF the concentration of all OCP at the control stations in the deep soil layer were less than the detection level.

**2.1.2.2.4. Heavy metals**

Distribution of heavy metals and arsenic in bottom sediments of Aniva Bay according to research data made in June-July of 2001 (DVNIGMI report, 2001) was mosaic and their concentrations varied as follows: As (arsenic) from 4,65 to 28,1 mg/kg; Ba – from 2,67 to 171 mg/kg; Cd – from 0.008 to 0.263 mg/kg; Cr - from 5.51 – 39.5 mg/kg; Cu – from 4.12 – 18 mg/kg; Hg – from <0.005 to 0.124 mg/kg; Zn – from 19,0 – 61.7 mg/kg of dry sediment.

In 2003 bedore commencement of works, background parameters of heavy metals in bottom sediments showed also their significant dispersion.

Maximal inhomogeneity in distribution of metals concentrations is typical for Pb from 7,5 mkg/g of dry mass to 47,5 mkg/g of dry substance with an average concentration 19 mkg/g of dry substance.

Concentrations of most elements (excluding Cr and Pb) were maximum at station 13, located deeper than others. Bottom sediments at this station were characterized with highest content of fine aleurite-pellite fractions (more than 18%) and great quantity of coarse grained terrigenous material.

Minimal concentration values of all metals and maximum concentrations of Pb were recorded at station 11, where soil was represented by well assorted fine sand with little admixture of medium sand.

Correlation dependences between granulometric fractions and metals were registered for Aniva Bay, as a whole. Cd and Cr were tightly associated with aleurite-pelites.

Mn and Cu were found in positive interrelation with gravel sediments.

The obtained metal content values in the bottom sediments were at background level for Aniva Bay.

In 2005, compared to 2003, concentrations of Cu, Fe, Mn, Zn increased and Cd и Pb и Cr decreased in the bottom sediments of the study area.

If in 2003 maximal concentrations of metals were recorded at stations # 10 (Cr); # 13 (Fe, Mn , Zn); # 11 (Pb), but in 2005 maximum concentrations of the mentioned elements were recorded at the opposite stations: Cr – st.12, Fe – st.10; Mn – st. 15, Pb – st. 13 и Zn – st. 10.

Minimal concentrations of heavy metals were obtained at the same stations as in 2003 (Fig.2.2).

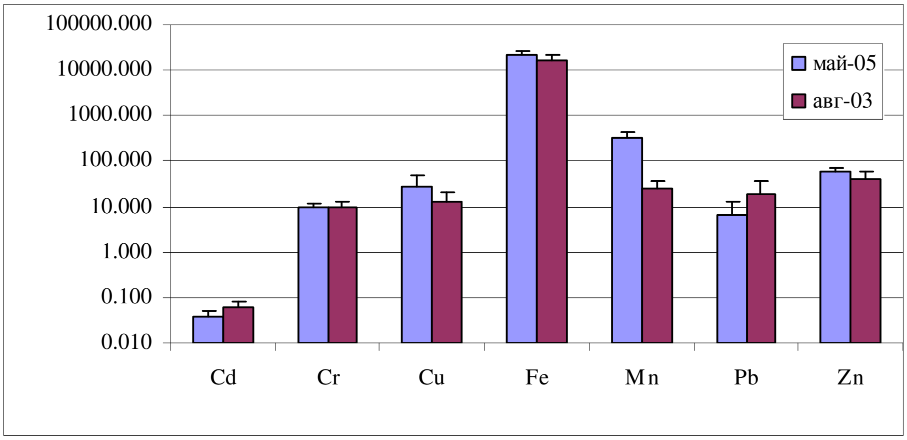



Fig. 2.2. Average concentrations of acid-soluble metals (mkg/g of dry mas) in the MOF area in 2004-2005

Differences in metals concentartion in the bottom sediments can be caused both by chemical composition and sediments type and by additional pollution from external pollution sources such as atmospheric precipitations and flood waters.

Since there are no normative documents on regulation of metals content in the bottom sediments, comparative analysis of their accumulation was performed for soil criteria, particularly, by approximate permissible level (APL) for sandy and loamy soils (moving form) for a number of metals such as Cu, Pb, Zn, Cr, Mn.

The analyses results showed that actual content of heavy metals in the bottom sediments at the dredging area didn't exceed APL.

### 2.1.3. Benthos

Monitoring of marine biota (benthos) was provided for during dredging operations at MOF area.

Sampling of benthos for impact assessment of dredging operations to benthos condition was taken in four points outside dredging area and in one point within dredging area.

Monitoring frequency:

- Once before dredging;
- Once after their completion within dredging area and outside it;
- In 1 year within dredging area after completion of dreging operations.

**In August of 2003,** low similarity of benthos samples, collected at nine dredging stations was registered during background studies for benthos condition directly before commencement of works at MOF area. Pebbly-gravel-muddy soils were registered at

40% of stations located at 9-10 depth lines. Community of polychaete worms with dominance of *Scoloplos armiger* (Fig) was discovered at these stations.

The quantity of the discovered types of macrobenthos was 57; population varied within 356 specimen/$m^2$ – 1941 specimen/$m^2$; average population – 811 specimen/$m^2$; biomass varied from 1,7g/$m^2$ to 14g/$m^2$, average biomass content – 8,4 g/$m^2$.

**In May of 2005** during completion of dredging operations at MOF area low similarity of benthos samples at dredging stations (except samples at 2 stations out of 9) was recorded as in 2003.

As a whole, number of the discovered types of microbenthos through MOF area was 46; population varied from 178 specimen/$m^2$ to 2356 specimen/$m^2$, average value was 1397 specimen/$m^2$; biomass was within 6,987g/$m^2$ to 42,231 g/$m^2$, average value – 17,547 g/$m^2$. Moss animals *Scurpocellaria scarba* played an important role, biomass of which was 87-89% of total benthos mass.

After dredging completion at MOF area the expected change of soft soils biota with domination of bristle worms to fouling biota was observed. However, benthos abundance (population density and biomass) were slightly higher than those of 2003 but quantity of discovered species was little less.

So, dredging operations at MOF area stipulated the change of species composition and structure of bottom-living communities but didn't entail reduction in bottom-living population abundance index.

The similar picture is described in reference literature: the values of abundance are recovering very quickly (due to rapid development of fouling fauna), when the communities at the disturbed substrates are restored, it takes several years for restoration of the former structure of bottom-living community (in this case – communities with prevailing of bristle worms).

## 2.2. LNG Jetty area

### 2.2.1. Sea water

#### 2.2.1.1. Suspended solids

**In 2003 (August, October)** background level of SS concentrations was within 7,1-8,6 mg/dm$^3$ in the surface water layer at stations 1, 3, 5, where weak influence of river flow was registered.

In the mid-water and botom layers concentration of SS varied within 3,1-8,6 mg/dm$^3$.

**In 2004** dredging operations at LNG Jetty area were not performed, however hydrochemical researches of sea water were carried out in accordance with the applicable monitoring program.

**In December of 2004** studies for SS content in sea water were performed at the same points as in 2003. Concentrations of SS from minimal value 13,3 mg/dm$^3$ (st.3 – 0m) to maximum – 22,9 mg/dm$^3$ (st. 1- 8 m) were typical for this period of time. When compared with the results of 2003, the increase of SS in 1,2 times, on an average, was observed, irrespectively of works execution.

**In May of 2005,** just after dredging operations, concentrations of SS in water layer were within 17,3 to 27,3 mg/dm$^3$. SS content exceeded the background values, on an average, in 1,7 times (background average SS content is 14 mg/dm$^3$).

**In March of 2006,** after dredging operations completion in December of 2005, mass concentrations of SS in the near-surface sea water level at all the stations varied from 3,3 mg/l to 13,0 mg/l and were comparable to the background level for nearshore waters of Prigorodnoye settlement.

The major source of SS ingress in the nearshore waters in the given period of time was the surface flow, which during spring snow-rain flood, carried out SS to coastal zone varying from 85 to 112 mg/l (Report on Monitoring of surface waters, SakhUGMS, 2005).

Table 2.4

Content of suspended solids at the LNG Jetty area, mg/dm$^3$

| Stations | Depth, m | August 2003 | December 2004 | May 2005 г. | March 2006 |
|---|---|---|---|---|---|
| LNG Dred 1 | 0 | 7,1 | 20,3 | 21,2 | 4,0 |
| LNG Dred 1 | 12 | 4,5 | 22,9 | 17,3 | - |
| LNG Dred 2 | 4 | 4,7 | 15,4 | 24,0 | 6,5 |
| LNG Dred 3 | 0 | 8,6 | 13,3 | 24,4 | 4,2 |
| LNG Dred 3 | 12 | 3,1 | 19,6 | 25,6 | - |
| LNG Dred 4 | 0 | 6,4 | 20,6 | 23,7 | 3,3 |
| LNG Dred 4 | 12 | 6,2 | 19,7 | 23,1 | |
| LNG Dred 5 | 0 | 7,3 | - | 24,2 | 13,0 |
| LNG Dred 5 | 12 | 6,7 | - | 27,3 | - |
| Average concentrations | | 6,1 | 18,8 | 23,4 | 6,2 |

Average concentrations of SS during the whole observation period at the dredging MOF and Jetty areas were not higher than 20,5 mg/l with maximal single deviation to 29,6 mg/l, which was substantionally less than the values, obtained based on the SS spreading simulation results during dredging operations.

Considering the continuous operation of dredgers and shallowness of job site, higher and more stable levels of SS content in water were expected. However, according to the measurment results there were no any substantional differences in ranges and average concentretions.

It is typical that in the direct proximity to the operating dredger the content of SS was 23 mg/l and practicaly didn't differ from concentrations at 250 m away the job site. Quick sedimentation of basic mass of coarse grained soil and quite quick spread of fine SS took place on the job site.

increase of SS concentrations at the small area were of local and short term character. At the same time the natural background level of SS for Aniva Bay was highly changeable (from 6,2 to 14,0 mg/l) with possible increases to 40-50 mg/l in the nearshore zone during stroms.

### 2.2.1.2. Petroleum Hydrocarbons

**On November 23-24, 2000** SakhNIRO performed the studies for total PH content at LNG Jetty area at 14 stations (SakhNIRO report “Background ecological researches of Aniva Bay coast, Autumn 2001, Books 1 and 2).

**June-July of 2001** DVNIGMI, within ecological monitoring, carried out additional measurments for pollutants content in sea water at the LNG Jetty area (DVNIGMI Report, 2001).

Statistical evaluations for PH content in different sea water layers as well as according to the samples, collected in November of 2000 (SakhNIRO Report), showed that PH content varied from 0,40 to 40,26 mkg/l (0.008-0.805 of MPC).

Content of PH in the bottom water layer by average and maximal values was higher compared to the surface sea water layer.

**In November of 2000,** as a whole, total content of PH in sea water of the LNG Jetty area were 0,23 of MPC and none of the samples exceeded MPC (0,8 MPC) by maximum values.

**In June-July of 2001** statistical data of PH content in sea water at LNG Jetty area (DVNIGMI Report) showed that PH content in sea water at that time was essentially higher compared to November of 2000 and varied within 10,5 to 95,6 mkg/l (0,2-1,9 of MPC). Average value was 43,6 mkg/l (0,87 of MPC). Maximal values of PH content were recorded at the bottom water layer and equaled 1,9 of MPC. Vertical distribution of PH in sea water was practically even.

Comparison of data shows that in summer of 2001, compared to November of 2000, average content of PH in sea water (for all samples) increased in 3,79 times. Minimal values increased up to 30 times and maximal - 2,37 times, i.e. man-caused load to water area in 2001 was higher and average value of PH in sea water was 43,6 mkg/l (0,86 of MPC), which approached the Maximum Permissible Level (MPL).

As a whole, according to the results of the integrated monitoring in 2001 sea water of Aniva Bay was characterized by higher level of pollution with PH, in comparison with other studied areas of Sakhalin shelf.

In 2003 sampling of sea water for PH content from the mid-water level at LNG jetty was collected before commencement of dredging operations (points 1, 2, 3, 4, 5) during works performance in 2005 (points 1,2,3,4) and after works completion in 2006 (points 1, 2, 3, 4, 5).

Before commencemnt of dredging works (August, October of 2003) natural level of PH concentrations in the area of the planned works varied from 0,065 mg/dm$^3$ to

0,0559 mg/dm$^3$ (which slightly exceeded fishery MPC for sea water) and average background value of PH as per survey of 2001 - 0,0436 mg/l. Maximal concentrations were determined in the bottom water layer at two stations # 4 and 1.

**In 2005,** at LNG Jetty dredging area, the level of PH in water was very low. Minimal PH content – <0,005 mg/dm$^3$ was recorded outside LNG Jetty dredging area in the near-surface water layer at station 3 and in the bottom water layer at station 4. Maximal concentrations - 0,0460 mg/dm$^3$ at station 2 in the near-surface water layer. At station 5 (center of dredging area) concentrations of PH in the bottom water layer were less than 0,02 mg/l.

Table 2.5

Total content of PH in LNG Jetty water area, mg/dm$^3$

| Stations | Depth, m | August 2003 | December 2004 | May 2005 г. | March 2006 |
|---|---|---|---|---|---|
| LNG Dred 1 | 0 | 0,0253 | 0,0070 | 0,0210 | 0,013 |
| LNG Dred 1 | 12 (14,5) | 0,0559 | 0,0120 | 0,0210 | 00,09 |
| LNG Dred 2 | 4 (10) | 0,0287 | 0,0050 | 0,0460 | 0,007 |
| LNG Dred 3 | 0 | 0,0128 | <0,0050 | <0,020 | <0,002 |
| LNG Dred 3 | 12 | 0,0112 | 0,0070 | 0,0250 | 0,01 |
| LNG Dred 4 | 0 | 0,0231 | 0,0200 | <0,020 | 0,015 |
| LNG Dred 4 | 12 (18) | 0,0653 | <0,0050 | 0,0230 | 0,029 |
| LNG Dred 5 | 0 | 0,0199 | - | 0,0220 | 0,012 |
| LNG Dred 5 | 12 (17) | 0,0180 | - | <0,020 | 0,018 |
| Average concentrations | | 0,029 | 0,009 | 0,024 | 0,02 |

In comparison with background data of 2000, 2001, 2003 PH content in sea water was less and didn't exceed MPC (0,05 mg/dm$^3$).

So, PH concentration at the LNG jetty dredging area on an average was less than MPC (0,05 mg/dm$^3$) as before and during dredging operations (Table 2.5)

**In 2006**, after works completion in 2005, the samples of water were collected at the LNG Jetty area to determine PH content. The obtained concentrations were less than MPC and were within the range from 0,007mg/l to 0,018 mg/l.

### 2.2.2. Bottom sediments

#### 2.2.2.1. Grain–size composition

In comparison with polygons in north-east of Sakhalin, composition of bottom soils of Aniva Bay differs in a great variety with high content of coarse and fine aleurite-pelite fractions in samples. The first one is connected to features of geological conditions of the water area under study, the second one – with significantly lower rates of bottom currents.

Bottom sediments of the area under discussion are composed of terrigenous fine sands (32% on an average) with fine pebble (9% on an average) and gravel (25% on an average). Portion of aleurite and clay fractions is 17% on an average. Moreover, maximal quantity of fine fractions was observed in the west of the area, which was probably related to local zone of accumulation of Mereya flow (On the results…, 1999).

High concentration of pellite and aleurite-pellite fractions correlate content of PH, PAH and many other heavy metals.

Mosaic of bottom sediments is typical for LNG jetty area. The dredging area lies within coastal wave-cut terrace. Active hydrodynamic regime of the area is determined by storm wave. Fine materials are carried over to the bottom by current, coarse materials are settled in seashore, where wave abrasion process takes place.

The stations # 1,2,3,4,5 are located fairly far away from each other.

Sampling of bottom sediments for grain-size and chemical composition was performed at 4 stations outside dredging (1-4) and within dredging area (station 5) with 2 times periodicity: one time before commencement and right after completion of dredging operations.

In 2003 the picture of sediments distribution was rather inhomogeneous and changed with depth.

Station # 2 is located at a depth of 4 m, closer to coastal zone, which is covered by clean fine sands of 0,25-0,1mm in diameter, share of the modal dimension is 76%.

Gravel-pebbly soil prevailes at depths 12-14m, the maximum quantity of pebbles at station 5 is 65,4%.

Here, at adepth of 12 m (station 1), lensed deposit of fine silty sand was discovered, in which quantity of fine and coarse aleurite amounted to 42,1%.

Regularities of dimmensional fractions distribution depending on depth are so that fine sands, prevailing at a depth of 4 m, starting from a depth of 12 m, are replaced by gravel-pebbly material.

In May of 2005 after completion of spring dredging operations the similar distribution of the sedimentary material was observed as in 2003 at stations 2, 3, 4 and 5: considerable quantities of fraction more than 1mm, almost total absence of fractions less than 0,1 mm and insignificant availability of sand fractions. However, the differences were recorded at stations 1 and 2 in comparison with 2003.

At station 1 in 2003 the content of aleurite-pellite particles was 46,5% and fine sand - 50,1%. Particles of larger than 1mm were absent, while in 2005 particles from 1mm and more were only 12%, mean size sands – 66%, fine sands – 24%,

So, change of grain size composition of bottom sediments towards their coarsening at station 1 in 2005 took place

Grain-size composition practically changed insignificantly at station 2. In 2003 content of fine sands (fractions from 0,25 to 0,1mm) made 76%, in 2005 – 65,57%.

In 2006, upon dredging operations completion, considerable changes in grain-size composition at all the stations were recorded.

At station 1 grain-size composition of bottom sediments mainly composed of sandy silt (fractions from 0,1 to 0,005 mm) – 57% and clays (fractions from 0,01-0,005 to <0.005 mm) – 40,5%. Fine and medium sands practically were absent.

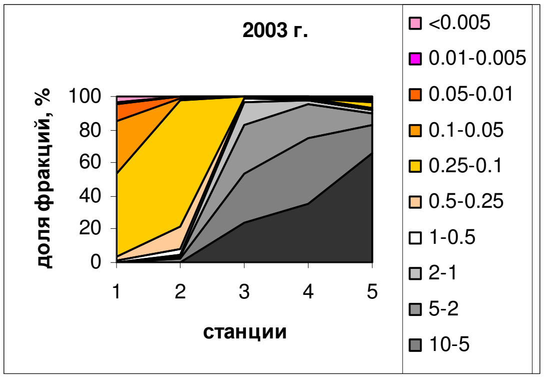
At station 2 content of fine sands (fractions from 0,25-0,1mm) was 70% and was close to the value of 2003 (76%).

At station 3 quantity of coarse fractions (particles from 1mm to >10 mm) significantly reduced (from 58% to 14%). Content of aleurite-clayed silts amounted to 83%, in 2005 fine fractions were absent.

At station 4 share of coarse fractions (more than 1 mm) was only 39%, but as for aleurite-clayed silts (fractions from 0,1mm to <0.005mm) was more than 50%, while in 2005 share of coarse fractions (more than 1mm) was 97%, aleurite-clayed silts were absent at all.

At station 5 (center of dredging area) in 2006 coarse fractions were not found at all. Marine sediments were referred to dust silts by grain-size composition. Fine fractions from 0,1 to <0,005mm was 98%, while in 2003 quantity of coarse fractions (>1mm) was 91,9%, quantity of sandy fractions – 4,27% in total, small amount of fine fractions (<0,1 mm) – 3,8% ).

Grain size composition of the samples discovered variety of bottom sediments. Practically all their varieties were found: pellites, aleurites, sands, gravel.



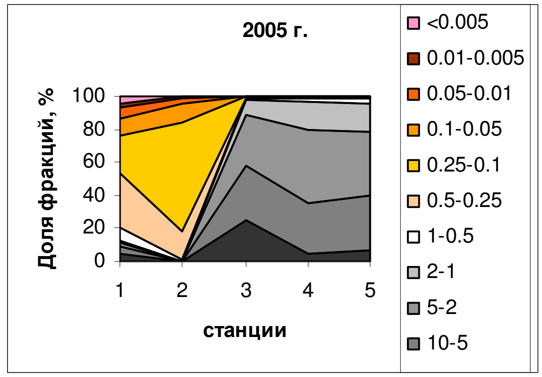




Fig. 2.3. Structure of bottom sediments at the LNG jetty dredging area in 2003 and 2005

**2.2.2.2. Chemical composition**

**2.2.2.2.1. Petroleum hydrocarbons**

In 1998 total content of PH in bottom sediments of Aniva Bay within dredging area was 0,5-8,86 mg/kg of dry mass.

Average content of PH in Aniva bay as per 2001 data (Report of DVNIGMI, 2001) was 4,02 mg/kg and maximal – 26,4 mg/kg.

Comparison of PH content at the LNG Jetty area in 1988 with those of 2001, showed that their close values characterized bottom sediments as lightly polluted.

The zones in the west and east were pointed out, when analyzing spatial distribution of PH in bottom sediments.

Factor analyses showed that PH distribution was controlled by tracers of terrigenous flow.

Correlations of PH with PAH such as perylene tells about natural source of PH.
In 2003, before commencement of works, parameters of petroleum hydrocarbons in the surface layer of bottom sediments varied within 0,89 mg/kg of dry mass (station 2) – to 5,58 mg/kg of dry mass (station 5).

High content of PH as well as a number of heavy metals is connected to high concentrations of clay fractions in bottom sediments (stations 1,3,5).

On the whole, the results of total PH content were comparable with earlier data of SakhNIRO in 1998 for Aniva bay (from <0,5 to 8.86 mkg/g and DVNIGMI data for Aniva Bay (average content of PH is 4,02 mg/kg, maximal 26,4 mg/kg).

In October of 2004 before dredging operations, total content of PH varied from 9,71 to 36,8 mg/kg, averaging 19,4 mg/kg of dry mass. Maximal value was recorded at station 6, minimal – at station 7.

In May of 2005 (after dredging operations) concentrations of PH varied in broad range: from 6,6 mg/kg of dry mass (at station 4) to 54 mg/kg of dry mass (at station 1), which was higher than those, measured before.

Average total PH content at the job site was equal 22,3 mg/kg of dry mass, which was comparable with background data for Aniva bay.

In October and November of 2005 samples of the excavated soil for PH content, collected at a depth of 14,5 m during dredging near LNG Jetty showed minimal content of PH <0.5 mg/kg of dry mass at stations 6 and 9, maximal – 13,6 mg/kg of dry mass – at station 8.

In 2006, after dredging operations, average concentrations of PH in the bottom sediments equaled 15,64mg/kg of dry mass and fall within background values of PH for bottom sediments of Aniva bay.

According to SakhNIRO reports (SakhNIRO report, 1998) and DVNIGMI (DVNIGMI Report, 2001), when analyzing spatial distribution of PH in bottom sediments, the zones in the west and east out with high natural content of PH in bottom sediments at the dredging area were pointed.

The analytical studies of bottom sediments during 2003-2006 confirmed that fact.

Before works commencement and upon their completion the highest concentrations of PH were determined in the west of the area (station 3, muddy soil, PH content – 16,2 mg/kg), in the east (station 1, muddy soil, PH content – 36,6 mg/kg of dry mass).

Table 2.6 Total concentration of PH in bottom sediments at LNG Jetty
Mg/kg of dry mass

| Stations | LNG Dred 1 | LNG Dred 2 | LNG Dred 3 | LNG Dred 4 | LNG Dred 5 | Xcp. | Background data | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | SakhNIRO | DVNIGMI |
| August 2003 | 1,07 | 0,89 | 0,91 | 1,12 | 5,58 | 1,9 | from 0.5 to 8.86 | from 4,02 to 26,4 |
| May 2005 | 54,00 | 17,50 | 7,40 | 6,60 | 26,20 | 22,3 | | |
| March 2006 | 10,7 | 5,7 | 16,2 | 9,0 | 36,6 | 15.6 | | |

Generally, the obtained results of total PH content in bottom sediments after dredging operations during LNG Jetty construction were comparable with background data for Aniva Bay and obvious signs of sea bottom pollution with petroleum hydrocarbons were absent.

So, soils, excavated during dredging operations at the LNG jetty area could not be PH pollutants of sea bottom and water layer at dumping area.

**2.2.2.2.2. Polycyclic Aromatic Hydrocarbons (PAH)**

In 1998 PAH (Report on the results…, 1999) were fixed only at 3 samples of Aniva bottom sediments at stations: AB 1 (western part of area); 21 (dredging area center); 41 (northern part of area).

Content of PAH in the studied samples of bottom sediments varied from 6,7 to 271 mkg/kg of dry mass.

Maximal content of PAH was discovered in clays in the western part of the area, i.e. there, where maximal content of PH and high content of many metals. 20 individual PAH were determined quantitatively.

Ratio of molecular PAH structures at the stations was different, perylene content was low (1-5%), fluoranthene/pyrene in the northern part of the area tells about admixture of pyrogenic PAH.

Direct relationship of many PAH with perylene speaks well for their natural source.

Content of the most toxical PAH in bottom sediments of Aniva Bay – 3,4 benzpyrene (benz(a)pyrene) was equal 0,5-14 mkg/kg of dry mass, which was less than MPC for 3,4 benzpyrene in soils (20 mkg/kg).

Hence, comparatrive analyses of data showed that bottom sediments of Aniva bay by PAH content were referred to unpolluted or slightly polluted.

In 2001, in the LNG jetty dredging area, the total content of PAH was determined at three stations (A5-20, A2-35, A3-10).

PAH sum content (similar to 1998 data) in the studied bottom sediments differed enormously both by content (from 22 to 218 mkg/kg) and by their individual compounds.

As in 1998 maximal concentrations of PAH was discovered in bottom sediments with maximal content of PH (26.4 mg/kg, st. A2-35).

Presence of heavy PAH and cancerigenic benz(a)pyrene as well as specific relations with naphthalene and phenanthrene speak well for pyrogenic genesis of the PAH and their accumulation from different coastal sources.

As a whole, at the LNG Jetty area, the variation limits of PAH concentrations, according to measurements of 1998 and 2001, were of the same order from 6,7 to 271 mkg/kg in 1998 and from 22,2 to 218 mkg/kg in 2001).

Average values of PAH sum content were also close (130 and 108 mkg/kg, respectively).

PAH content in Aniva bay (according to 1998 and 2002 data) was three and more times higher than the North-Estern shelf of Sakhalin, Piltun-Astokhskoye and Lunskoye areas.

In 2004, before dredging operations at LNG Jetty area, the sum of PAH, on an average, was 86,3 ± 15,4 mkg/kg, which was less than values obtained in 1998 and 2001.

The highest concentration of PAH - 110,5 mkg/kg of dry mass was recorded at station 6 (western part of the area), the lowest – 70 mkg/kg of dry mass at station 8 (eastern part of the area).

In 2004 (before works commencement) phenathrene prevailed (23,04 mkg/kg on an average or 22,2% of PAH sum), while in 1998 its content at this area was 13,37 mkg/kg and made up 10% of the total sum.

Alkylated naphthalene homologes were next – 2-methylnaphthalene (8,92 mkg/kg or 10,3%) and 1- methylnaphthalene (7,92 mkg/kg or 9,2%).

In 2004 the sum of Alkylated naphthalene homologes averaged 16,84 mkg/kg of dry mass or 19,5% of the PAH sum; in 1998 – 15,61 mkg/kg or 4%; in 2001 – 22,05 mkg/kg of dry mass, or 18,6%.

Specific relations of naphthalene and phenanthrene confirmed the assumption on their accumulation from different coastal sources.

In 2004 the fluoranthene content was 4.98 mkg/kg or 5,8% of the total PAH content, while in 1998 its content was 16,36 mkg/kg or 4,2%, in 2001 – 9,5 mkg/kg or 8,0% of the total PAH content.

Content of perylene averaged 9,42 mkg/kg or 10,9%, while in 1998 it average concentrations were equal 6,68 mkg/kg of dry mass or 1,7%: in 2001 – 12,5 mkg/kg or 10,5%.

High content of perylene with fluoranthene 5.8% and pyrene 5,7% confirmd their ingress from natural source.

Content of the most toxical PAH in the bottom sediments - 3,4 benzpyrene (benz(a)pyrene) within a range of 1,4-1,9 mkg/kg of dry mass or 1,9% of the PAH sum and was within the background parameters of 1998 (from 0,5-14 mkg/kg or 1,8% of PAH sum) and parameters of 2001 (3,45 mkg/kg of dry mass or 0,7% of PAH sum).

In October-November of 2005 average content of PAH inside dredging area of LNG Jetty was 161,74 mkg/kg of dry mass, while in 2004 concentrations varied from 86,3± 15.4 mkg/kg of dry mass.

The obtained results were close to background data of 1998, when average sum of PAH was 130mkg/kg and maximal – 242mkg/kg of dry mass. In 2001 – average sum of PAH was 108 mkg/kg of dry mass, maximal – 218 mkg/kg of dry mass.

In 2005 maximal total content of PAH in the bottom sediment samples at LNG Jetty area was recorded, as in 2004, at station 6 (west of area), minimal at station 8 (eastern part of area).

Perylene prevailed among PAH and averaged 46,01 mkg/kg of dry mass or 28, 45% of PAH sum (in 2004 – 9,42 mkg/kg or 10,9%, in 1998 – 6,68 mkg/kg or 1,7%; in 2001 – 12,5 mkg/kg or 10,5%). Maximal concentrations of perylene were determined in 2001 (Report of DVNIGMI, 2002) and were equal 29,5 mkg/kg of dry mass. As perylene is polycyclic aromatic compound of natural origin, its domination can speak well for the natural ingress source of PAH.

Content of phenathrene reduced a little against 2004 (when its concentrations were 23,04 mkg/kg) and made up 17,72 mkg/kg or 10.96%, (in 1998 – 13,7 mkg/kg or 10% of total PAH sum; in 2001 its average value was 6,08 mkg/kg or 5,1% of PAH sum).

Average value of naphthalene was 11,09 mkg/kg or 6,86% and the sum of its alkylated homologs: 2methylnaphthalene (16,84 mkg/kg or 10,4%) and 1-methylnaphthalene (18,64 mkg/kg or 11,65%) was 35,48 mkg/kg or 21,9% which was higher than the sum of 2004 (16,84 mkg/kg of dry mass or 19.5%), 1998 (15,61 mkg/kg of dry mass or 4% of PAH sum) and 2001 (22,05 mkg/kg of dry mass or 18,6%).

Specific ratio of naphthalene and phenanthrene were confirmed when acumulating in bottom sediments from various coastal sources.

Concentrations of pyrene varied from 4,7 mkg/kg to 35,4 mkg/kg of dry mass. Average value was 14,86 mkg/kg or 9,19% of PAH sum.

High values of pyrene (32,3 mkg/kg) were recorded in 1998 (SakhNIRO Report, 1998), maximal values in 2001 (DVNIGMI report, 2001) – to 20,4 mkg/kg.

Content of fluoranthene in bottom sediments was 7,09 mkg.kg of dry mass (4,38%), which was slightly higher than in 2004, when average concentrations made up 4,98 mkg/kg (or 5,8% of total PAH content). In 1998 its average content was 16,36 mkg/kg or 4,2%, maximal concentrations equaled 30,1 mkg/kg. In 2001 average content was 9,5 mkg/kg of dry mass (8,0%), maximal value – 20,4 mkg/kg of dry mass of total PAH content.

Content of the most toxical PAH in the bottom sediments - 3,4 benzpyrene (benz(a)pyrene) varied from <0.5 mkg/kg of dry mass or 0,6% of the PAH sum and was within the background value of 1998 (from 0,5-14 mkg/kg or 1,8% of PAH sum) and 2001 – 3,45 mkg/kg of dry mass or 0,7% of PAH sum. Maximal values of benz(a)pyrene were recorded in 1998 and equaled 14,0 mkg/kg of dry mass.

So, content of PAH in 2005 in soil excavated at the LNG jetty area, mainly, didn't exceed the early studied values for surface layer of bottom sediments.

**2.2.2.2.3. Organochlorine pecticides (OCP)**

In October of 2004 sum of OCP ranged within 0,000084-0,000268 mkg/kg of dry mass, averagy in the area - 0,000127± 0,0000789 mg/kg.

Maximum concentration (0,000269 mg/kg) was registered at station 5, minimum (0,000084 mg/kg) – station 9.

5 types of OCP were found among 21 studied substances in the samples as follows:

- Hexachlobenezene (stations 5-8) varying from 0,000012 to 0,000019 mg/kg;
- β-hexachlorocyclohexane – station 5 with a concentration 0,0001 mg/kg;
- 4, 4´-DDE – at stations 4,9 with concentrations 0,000038 and 0,00004 mg/kg;
- 4, 4´-DDD – at all the stations varying from 0,000037 (st.9) to 0,000090 mg/kg (st 7);
- 2, 4´-DDT – at station 5 - 0,000051 mg/kg.

The most various were OCP at station 5, where all 5 types of OCP were found.

In bottom sediments of other stations two types of OCP were recorded.

The maximum frequency of occurrence is typical for DDT metabolites and Hexachlobenezene.

DDT metabolites also prevailed in quantitative content (56-100% of OCP) with absence of DDT itself, which indicated to longstanding ingress of DDT to bottom sediments of the area under investigation. One of the isomers of the original substance – 2, 4´-DDT,4 aws found at station 5 only.

In October-November of 2005 summary content of OCP in bottom sediments varied from 0,032 to 0,39 mkg/kg of dry mass (0,132±0,147 on an average).

Maximal total OCP content was marked at station 5, minimal at station 8. Hexachlobenezene was the only among OCP.

In october-November of 2005, compared to October of 2004 at LNG Jetty area, quantitative parameter of OCP accumulation level, practically remeined unchanged, qulitative – noticable changed: concentration of Hexachlobenezene (HCB) increased and share of other compounds reduced. Nevertherless, the value of HCB doesn't exceed MPC, developed for soils (30 mkg/kg).

On the whole, amount of OCP in the excavated soil was not too large and could not be a source of pollution of bottom sediments at dumping area.

#### 2.2.2.2.4. Heavy metals

Characteristic of bottom sediments pollution in Aniva bay, within the LNG jetty dredging area was performed according to SakhNIRO data about gross content of $C_{org}$, Al, Fe, Zn, Ba, Cr, Cu, Pb, As, Cd, Hg, petroleum hydrocarbons (aliphatic hydrocarbons, alkanes, PAH (Report on the results…, 1999).

In 2001 (from June 18, 2001 to July 10, 2001) additional studies were performed for bottom sediments pollution in Aniva Bay (DVNIGMI Report, 2001).

The research results are considered as background gross concentrations of heavy metals and arsenic at the LNG jetty construction area.

Gross content of heavy metals in bottom sediments depends on many factors, among which are: ratio of pollutants, coming from various sources; concentrations of pollutants in them, grain-size composition of sediments.

The important factor is the content of heavy metals in the erodiable rocks and onland soils.

There are areas where high content of many heavy metals (e.g. Fe, Mn, Pb, Au, Ag and others) in the bottom sediments was determined by the composition of onland soils.

That's why it is rather difficult to assess the input of natural and anthropogenic components as well as to judge about man-caused pollution of bottom sediments, therefore, at present, there are no MPC for heavy metals and organic pollutants in bottom sediments.

It should be noted that, at present, there are no any Russian and international standards available for natural geochemical background, therefore, the mentioned evaluations of bottom sediments pollution level shall be considered as preliminary evaluations, based on the small amount of material.

Characteristic of bottom sediments pollution in Aniva bay, within the LNG jetty dredging area was performed according to SakhNIRO data about gross content of $C_{org}$, Al, Fe, Zn, Ba, Cr, Cu, Pb, As, Cd, Hg, petroleum hydrocarbons (aliphatic hydrocarbons, alkanes, PAH (Report on the results…, 1999).

Content of heavy metals and arsenic were defined by 31 samples of Aniva bottom sediments.

Data for metals and arsenic content showed that their average content in the surface flow of bottom sediments was as follows:

Al – 5.0%, Fe – 2.0% dry depositions; Zn - 50.3, Ba - 779, Cr - 31.2, Cu - 12.3,Pb - 8.06, As - 11.6, Cd - 0.05, Hg - 0.14 mg/kg of dry mass (Report on the results, 1999).

Two types of metals distribution are traced in bottom sediments of Aniva bay.

The first type of distribution is typical for arsenic and mercury. Their high concentrations are limited to northern part of the area and areas close to coast.

The second type of distribution is typical for Cr, Cu, Zn, Cd and expressed in availability of enrichment zone, different by grain-size composition of sediments, widespread in the west and east of the area. The sediments stretch in the form of strip of elevated concentrations in the middle of the area under investigation.

According to the specialized studies (DVNIGMI Report, 2001), distribution of heavy metals and arsenic in the bottom sediments of Aniva Bay was mosaic and their concentrations changed in a broad ranges:

As – from 4.65 to 28.1 mg/kg; Ba – from 2.67 to 171 mg/kg; Cd – from 0.008 to 0.263 mg/kg; Cr – from 5.51 to 39.5 mg/kg; Cu – from 4.12 to 18 mg/kg; from 2,18 to 12, 4 mg/kg; Hg – from <0,005 to 0,124 mg/kg; Zn – from 19,0 - 61,7 mg/kg of dry mass.

Average content of heavy metals in bottom sediments of Aniva bay is 4-8 times higher than in other areas of Sakhalin shelf.

According to 1998 and 2001 data fluctuation limits of As, Cd, Cr, Cu, Pb, Zn in bottom sediments of Aniva bay didn't differ substantialy.

Content of Hg in bottom sediments of 2001, (Report of DVNIGMI, 2001), was less (<0.005-0.124 мг/кг), than the data, performed in LNG area in 1998, and amounted to 0.03-0.70 mg/kg.

Comparison of these data with background concentrations of metals in sediments of Piltun-Astokhskiy and Lunskiy areas (About the results…, 1999) shows that concentrations of As, Cr, Cu, Zn, Hg exceed natural geochemical background of the area and they indicate to a man-made pollution of Aniva bay sediments by these elements. First, it means the pollution of sediments by arsenic and mercury.

In 2003, before dredging operations at LNG Jetty area, background parameters of chemical composition of the sediments surface layer were rather mosaic through the whole area.

Maximal inhomogenuity was typical for every station with regard to other stations.

Thus, at station 1 (sediments presented by fine silty sand) concentrations of most elements were the highest but didn't exceed the values of 1998 and 2001 by cadmium (0,165mkg/kg), zink (40,0 mkg/kg) and manganese (16,3 mkg/kg)

At station 3 (sediments presented by gravel) content of lead (37,5 mkg/kg) was higher than at other stations, while in 1998 it content was 8,06 mkg/kg.

At station 4 (sediments presented by gravel) content of zink (57,5 mkg/kg); iron (18250 mkg/kg); chrome (19,3 mkg/kg) and copper (15,5 mkg/kg) was higher than that at other stations but within the values of 1998, 2001.

At station 5 (sediments presented by gravel) content of Mn (17,5 mgk/kg), which was not studied before, was higher, compared to other stations.

Soils of the survey area contained more cadmium and lead.

However, the values of metal content in bottom sediments were at the level of early measured concentrations for Aniva bay.

In 2004 dredging operations at LNG Jetty area were not performed.

In May of 2005 the content of Cd in bottom sediments of LNG erea varied from 0,032 дto 0,125, averaging 0,088 mkg/kg of dry mass, which was lightly higher than in

1998 and 2003 (0,05 and 0,059 mkg/kg of dry mas). Maximal concentration was marked at staion 1, minimal – at station 2.

The most maximal concentrations of Cd were recorded in 2001 making up 0,263 mkg/kg.

In 2005, as in 2003, maximal concentration of Cr in bottom sediments was recorded at station 4, minimal – at station 2. Content of Cr in bottom sediments in May of 2005 varied from 7,5 to 22,9 averaging 16,6 mkg/kg of dry mass, which was less than the concentrations of 1998 931,2 mkg/kg) and 2001 922,5 mkg/kg).

Minimal concentrtaions of Cr were marked in 2003 – 12,7 mkg/kg of dry mass. Maximal concentrations were fixed in 2001 – 39,5 mkg/kg of dry mass.

Maximal concentrations of Cu were recorded at station 3, while in 2003 – at stations 4 and 5, minimal at station 2 as before.

In May of 2005 content of Cu in bottom sediments of the LNG area varied from 7,5 to 35,5, averaging 19,7 mkg/kg of dry mass, which was higher than values of 2003 (11,26 mkg/g of dry mass) and 1998 (12,3 mkg/g of dry mass). Maximal concentrations of Cu – 18 mkg/g of dry are fixed in 2001.

In 2005 maximal concentrtaions of Fe was registered at station 3, while in 2003 minimal concentrations were registered at the mentioned station.

Content of Fe in bottom sediments varied from 14000 to 30892 averaging 20578 mkg/g of dry mass, which is lightly higher than values of 2003 (average value is 15600 mkg/g of dry mass).

In May of 2005 concentrations of Mn in bottom sediments of LNG area varied from 150 to 458 averaging 237 mkg/g of dry mass. Maximal concentration is recorded at station 3, minimal – at station 2, as in 2003.

In August of 2003 content of Mn in bottom sediments of LNG area varied from 15 to 17,5 mkg/g of dry mas, averaging 16,0 mkg/g of dry mass, which was less than in 2005. Maximal concentrations in August of 2003 was marked at station 5, minimal – at stations 2 and 4. The content of Mn in bottom sediments was not studied before.

In May of 2005, maximal concentration of Pb in bottom sediments of the LNG area was registered at station 3, minimal – at station 4, which was similar to 2003. Content of Pb varied from 5,0 to 11,5, averaging 7,8 mkg/g of dry mass, which was less than in August of 2003 (10 - 37,5, averaging 17,0 mkg/g of dry mass), while in 1998 average concentration was equal 8,06 mkg/g of dry mass.

In May of 2005, maximal concentration of Zn in the bottom sediments of LNG area was registered at station 3, minimal – at station 5. Content of Zn varied from 6,5 to

80,1, averaging 56,3 mkg/g of dry mass. The obtained values were higher than in August of 2003, when content of Zn varied from 5,5 to 57,5 (averaging 30,7mkg/g of dry mass) and also higher than those of 1998 (average 20,53 mkg/g) and data of 2001 (40,35 mkg/g).

So, in 2005, in relation of 2003, the concentrations of Cd, Cr, Cu, Fe, Mn, Zn increased and Pb decreased in the bottom sediments of the area under investigation.

As for 1998 average concentrations of Cr and Pb decreased, values of Zn and Cu increased.

In comparison with 2001 concentrations of Cd and Cr decreased, values of Zn and Cu were close to the measured level.

In 2006, after dredging operations, the data, provided by the DVNIGMI report, were confirmed. The Report is included into TEOC regarding 2 types of metals distribution depending on the grain-size composition of the bottom sediments.

The first type of distribution covered arsenic and mercury.

As it was supposed their high concentrations should have been limited to the sediments of the northern part of the area, located close to the coast. According to the researches the highest concentrtaions of arsenic – 5,15 mkg/g and mercury – 0,117 mkg/g were found at station 2 (northern part of the area, shallow water).

The second type of distribution is typical for Cr, Cu, Zn, Cd and expressed in availability of enrichment zone, different by grain-size composition of sediments, widespread in the west (st.1) and east (st.3) of the area. The sediments stretch in the form of strip of elevated concentrations in the middle of the area (st.5).

The highest concentrations of Cr were found at station 1 (20 mkg/kg) and station 5 (17,5 mkg/kg).

The highest concentrations of Cu (32,5 mkg/g and 35 mkg/kg of dry mass) and Zn (97,5 mkg/kg) were found at stations: 1 – 95 mkg/g; 5 – 97,5 mkg/g; 4 - 113 mkg/g of dry mass, concentrations of Cd were found at station 1 (0,093 mkg/g); station 5 (0,09 mkg/g of dry mass).

Concentrations of Fe were the same at stations 1, 4, 5 and equaled 22500 mkg/kg. Slightly lower concentrations – 17250 mkg/g were found at station 2. Average concentrations of Fe were 19850 mkg/g, which was less than the values of 2005 – 20578 mkg/g.

In 2005 concentration of Cd reduced from 0,088 mkg/g to 0, 072 mkg/kg; Cr – from 16,6 to 15,28 mkg/g, but the following concentrations increased: Pb – from 7,8 mkg/g to 10 mkg/g; Zn – from 56,3 mkg/g to 80,6 mkg/g.

In 2006, in relation todata of 1998, the following average concentrations decreased in 2006: As – from 11,6 mkg/g to 4,04 mkg/kg, Ba – from 779 mkg/g to 102, 84 mkg/g, Hg – from 0,14 to 0,064 mkg/g.

Since there are no normative documents on regulating the content of metals in the bottom sediments, the comparative analysis of metals accumulation was performed for sand and loamy soil, particularly, by approximate permissible level (APL) of metals (moving form) for a number of metals such as Cu, Pb, Zn, Cr, Mn.

The results of analysis showed that actual content of heavy metals in the bottom sediments in the dredging area didn't exceed the established MPL. The measured concentrations also fell within the natural background and typical levels, specific for coastal marine zones.

### 2.2.3. Benthos

Monitoring of marine biota (benthos) was provided for during dredging operations at LNG area.

Sampling of benthos for impact assessment of dredging operations to benthos condition was taken in four points outside dredging area and in one point within dredging area.

Monitoring frequency:

- Once before dredging;
- Once after their completion within dredging area and outside it;
- In 1 year within dredging area after completion of dreging operations.

In August of 2003 at LNG Jetty area (and at MOF area) rather low similarity of benthos samples was registered. One can point out two major communities by benthos samples similarity at the dredging stations.

Little gastropods *Cryptobranchia kuragiensis* prevail in one community at the depth of 12-15 m on the gravel-muddy soils with rocks. Here gastropods dominate (5 species; 196 spec./$m^2$, 3,2 g/$m^2$; 32,6% of total biomass) and polychaete worms (19 species; 604 spec./$m^2$ ; 2,8 g/$m^2$ ; 28,6%).

Bristle worms *Scoloplos armiger* dominate In another community within 7-9 m depth lines on the pebbly-gravel soils (17 species; 733 spec./$m^2$; 9,1 g/$m^2$; 70,4%). Foraminifers dominate considerably but their contribution to total biomass was smallish (4,3%).

Number of the discovered species of macrobenthos was 70 through the LNG construction water area. Population varied within 267 spec./$m^2$ – 2341 spec/$m^2$, average population – 1055 spec./$m^2$; biomass varied from 5,8 to 1416 g/$m^2$, average biomass value – 184 g/$m^2$, not considering large casual forms, biomass varied from 0,82 g/$m^2$ to 41,3 g/$m^2$, average biomass value – 12,9 g/$m^2$.

Distribution analyses of the selected communities in the coastal zone showed that in August of 2003 in the seashore of s. Prigorodnoye two major background communities of zoobenthos with the belt type of distribution were widespread at MOF and LNG water areas. Community of *Scoloplos armiger* was observed within 7-10 m depth lines, community *Cryptobranchia kuragiensis* changed it with the depth.

**In May of 2005**, during completion of dredging operations at LNG Jetty area, the number of the discovered species of macrobenthos was 66 (against 70 in 2003). Population varied within 267 spec./$m^2$ – 3364 spec/$m^2$, average population – 1228 spec./$m^2$; biomass varied from 5,3 to 777,2 g/$m^2$, average biomass value – 144,9 g/$m^2$. Not considering coarse casual forms, biomass reached 227,8 g/$m^2$ with average value– 57,6 g/$m^2$.

Higher similarity of benthos samples od dredging stations was registered at LNG area (unlike MOF area). On can point out two basic groups by species similarity.

Little gastropods *Cryptobranchia kuragiensis* and *Testudinalia scutum* prevailed in one community at the LNG area. The given community is rather close to the community *Cryptobranchia kuragiensis,* marked in 2003. In the community gastropods dominated by quantitative values (7 species; 580 spec./$m^2$, 18,8 g/$m^2$; 70,2% of total biomass) and polychaete worms (19 species; 604 spec./$m^2$ ; 2,8 g/$m^2$ ; 28,6%).

The dominants of community were two types of gastropods *Cryptobranchia kuragiensis* (206 spec./$m^2$, 9,5 g/$m^2$, 35,4%) and *Testudinalia scutum* (113 spec./$m^2$; 6,3 g/$m^2$; 23,7%). Considerable contribution to total biomass was made by chiton *Tonicella granulata*, bivalved mollusks *Protothaca euglypta*, gastropods *Limalepeta lima*, algae *Rhodymenia pertusa* and sea urchins *Strongylocentrotus intermedius* (they altogether formed 28 of the total biomass). As a whole, average values of community were 37 species, 1389 spec./m2 26,7 g/$m^2$.

in another community at LNG area – *Strongylocentrotus intermedius* – gastropods prevailed by population (5 species; 331 spec./$m^2$; 9,96 g/$m^2$; 16,5%), byr biomass – sea urchins (37 spec./$m^2$; 34,5 g/$m^2$; 57%).

The dominating type of community were sea urchins *Strongylocentrotus intermedius* (57% by biomass). Gastropods *Cryptobranchia kuragiensis*, *Limalepeta lima* and *Testudinalia scutum*, chitons *Tonicella granulata*, algae *Phycodryx riggii, Odonthalia ochotensis* were significant for community. The mentioned species added more 33,1% of benthos biomass. On the whole, averaged values of community were 24 species, 533 spec./$m^2$; 60,5 g/$m^2$.

The structure of benthos, close to background, remained at stations 1 and 2 (LNG Jetty area). From other stations the community with domination of bristle worms *Scoloplos armiger* disappeared and considerable changes took place in the structure of the community *Cryptobranchia kuragiensis,* reduced to domination of gastropods and polychayte worms loosing significance..

Generally, less species of benthos with population close to average and big biomass,compared to background, were observed after dredging at the LNG jetty area. In addition, incomplete change of species composition and structure of bottom community was registered (unlike MOF water area). Probably, it can be referred to the changes of bottom sediments composition, caused by dredging.

So, the changes in the structure and abundance of benthos were observed at the MOF and LNG Jetty water areas after dredging. This fact can be reduced to insignificant shortening of the species list of benthos under parallel increase in abundance indexes - population and biomass. With this, the role of polychaete worms, which is a structure-forming group in the bottom community at the background stage, reduced and the role of gastropods and fouling species increased.

The described changhes are related to the changes in bottom sediments composition towards their enlargement during dredging operations.

## 3. STUDIES DURING DUMPING AND AFTER ITS COMPLETION

During dredging operations for construction of LNG Jetty and Material Offloading Facility the excavated soil soil was disposed into sea to the soil dumping site. Soil dumping area coordinates: 46º24' N., 142º55'E.

Sea depth at the dumping place – 63m. Dumping circle radius (on the water surface) – 200 m.

During the period from October 2003 to December 2005 the activities for construction of MOF and LNG Jetty have been performed in the coastal strip of Aniva bay within the licence area boundaries based on the Water use License YuSH 00385 TMSBK as of May 19, 2003 (construction and operation of temporary hydraulic engineering structures and dredging operations) and YuSH 00064 TsMSBV as of September 6, 2004 (construction of LNG Jetty and dredging operations).

The soil excavated during MOF and LNG Jetty construction was dumped at 22,5 km off shore and sea depth 63 m. The amount of soil dumped was 1317208.42 m3. As a result, morphology of bottom changed on the limited area and elevations up to 10 m were formed (Bathymetric survey, Peco, December, 2005).

The calculations supposed that 5% of the total dump volume was transferred to the supended state [A. Goncharov, A. Lyashenko, I. Shlygin], the rest of the disposed soil fell to bottom directly at the dumping point and spreaded in the form of cone.

Dispose of the excavated soil was performed within the terms, agreed by the supervisory and control bodies in the period from October of 2003 to April of 2004 and from October of 2004 to April of 2005, from October of 2005 to December of 2005.

### 3.1. SEA WATER

Monitored parameters:
- Concentrations of suspended solids;
- Petroleum hydrocarbons (sum);

Frequency of observations:
- One time directly before works commencement;
- Once per month during works;

Observation points:
- In the center of dumping circle;
- 300-500 m upstream from center of dumping circle;
- в 250 m downstream from center of dumping circle;
- 300, 400, 800, 1600, 2000 m from circle center:
- northward,
- southward,

- eastward,
- westward.

Observation levels:

- near surface;
- mid-water level (25-30 m);
- bottom.

### *3.1.1.* **Concentrtaion** ***of suspended solids***

**In June-**July **of 2001** DVNIGMI, within ecological monitoring, carried out additional measurments for pollutants content in sea water at the soil dumping area (5 stations ADD6). During coastal survey in November of 2000 water turbidity was reducing from coast to sea (DVNIGMI Report, 2001).

Stations on the soil disposal area are located far seaward of dredging areas and their depths reach more than 60m.

In August of 2003 sea waters were clearer than coastal and maximal concentration of suspended solids (SS) at the stations of dumping area was 5,9 mg/dm$^3$ in the surface water layer.

No distinguished dependence of SS content on the depth was not fixed.

**In october of 2003** concentrtaions of SS slightly increased through all the water layers compared to August. Maximal increase in concentrations took place 300 m eastward near bottom.

Nevertheless, concentrations of SS were at the background values level during all the studies and were within the interval 3-7 mg/dm$^3$.

In August – October of 2004 low concentrations of SS were recorded from 0,7 to 3,7 mg/dm$^3$ at dumping area stations throughout water layer, which corresponded to background values for this area.

In December of 2004 concentrations of SS during dumping significantly increased through all the water layers.

Maximal concentrations of SS were observed in bottom layers at all the stations: 300 m westward from center – 20,5 mg/dm$^3$., in the near-surface layer – 18,7 mg/l, which insignificantly exceeded background content from 1,4 to 2,5 times on an average.

**In January, March and April of 2005** the water samples were collected to analyse content of SS, Polyaromatic Hydrocarbons (PAH), petroleum hydrocarbons (PH) and heavy metals (cadmium, lead, mercury). The samples were taken in the soil dumping zone, limited by radius of 200 m, 400 m and 1200 from dumping area center to west, east, north and south in the near-surface, mid-water and bottom layers.

In March, additional sampling of water was taken at 400, 800, 1200, 1600 and 2000 m northward, eastward, southward to determine concentrations of SS before dumping commencement.

**In January-March of 2005**, before soil disposal at the dumping area, inhomogenuity of SS distribution was observed through all water layers. Values of SS varied from 8,9 to 22,1 mg/dm$^3$. The highest SS concentrations, exceeding background values in 1,2 times, were recorded in the bottom water layer. During soil disposal in January and April relatively homogeneous concentration of SS through all water layers were fixed.

**In April of 2005** during soil disposal relatively homogeneous distribution of SS took place. Maximal content of SS amounting 21,6 mg/dm$^3$ was fixed in the bottom layer at a depth of 50 m, 1200 m northward from center. Minimal concentrations were 13,3 mg/dm$^3$ at a depth of 20 m at the northern station.

Homogeneity of SS distribution was the same as in January – March.

In January, April of 2005, during soil disposal, the maximal distance, at which the decrease of SS concentrations to 16.9 mg/l was recorded in the near surface water layer, was 1200m eastward of dumping center; to 21,6 mg/l – in the near bottom layer northward.

So the SS distribution simulation evaluation during dumping, given in TEOC, are comparable with the obtained data.

Sea water research in August - September and November of 2005 were performed in the soil dumping area, 400 m from area center: westward, eastward, northward and southward in the surface, mid-water and bottom water layers before and during soil dumping.

**In September of 2005,** before soil dumping, water samples for SS content were picked up in diametrical direction from center, 1200 m westward, eastward, northward and southward at three water layers (surface, middle, bottom).

In the surface water layer SS concentrations along all the directions were less than detection limit (<2,0 mg/dm$^3$).

In the intermediate layer amount of SS was not too large along all the directions and varied within <2,0-2,7 mg/dm$^3$).

In the bottom water layer content of SS was insignificant along all the directions and amounted to <2,0-2,5 mg/dm$^3$.

Content of SS was less than MPC at all the stations.

In whole, quantity of SS was minimal westward, maximal – northward.

**In September of 2005**, during soil disposal, water sampling was done to determine SS content at 400, 800, 1200, 1600 and 2000 m from center westward, eastward, northward and southward, in November of 2005 – 1200 along the above mentioned directions.

Distribution of SS less than the detection limit (<2,0 mg/dm$^3$) was observed in the southward direction in the near-surface water layer.

Concentrations of SS in the eastward direction spreaded uniformely from <2,0 mg/dm$^3$ (from 400 to 1600m) to 9,8 mg/dm$^3$ (2000 m) from dumping area center.

The same picture was traced in the northward direction.

Reduction of SS from 7,5 mg/dm$^3$ (400m) to minimal values <2,0mg/dm$^3$ (800, 1200, 1600, 2000m) took place In the westward direction from center of dumping area.

The different picture was seen In the intermediate water layer (sea depth – 20m). Minimal concentration of SS (from <2,0mg/dm$^3$ to 2,7 mg/dm$^3$) were registered in westward, eastward and southward directions.

Reduction of SS concentrations from 7,2 mg/dm$^3$ (400 m) to <2,0mg/dm$^3$ (2000 m) took place from center northward.

Distribution of SS was inhomogenous at a depth of 50 m along all the directions from the center.

Uniform distribution of SS with minimal concentrations from <2,0mg/dm$^3$ to 3,7 mg/dm$^3$ was fixed in the westward and southward directions.

Concentrations of SS varied from 3,9 to 7,5 mg/dm$^3$ at 400-800-1200-1600 m from center in the eastward direction. Minimal SS content was registered at 2000 m from center.

The same picture of SS distribution from 3,8 to 4,9 mg/dm$^3$ was traced in the northern direction. Maximal content of SS – 13,1 mg/dm$^3$ was fixed at 1200 m from center.

Vertical distribution of SS westward from dumping center was characterised by uniform distribution of SS through depths – less than 2,0 mg/dm$^3$. Only station 400m fixed maximum of SS - 7,5 mg/dm$^3$ in the surface water layer.

The same picture of distribution was typical for southward direction with maximum values at stations 400m and 1200 m in the mid-water layer – 2,7 mg/dm$^3$ and 2,2 mg/dm$^3$, respectively.

The tendency of SS content increase with depth varied from <2,0 to7,5 mg/$dm^3$ in eastward direction.

In the northward direction concentration of SS increased in the bottom water layer (maximum 13,1 mg/$dm^3$) during vertical distribution of SS, minimal concentrations are fixed on the surface (<2,0 mg/$dm^3$).

In whole, concentrations of SS insignificantly exceeded MPC only near bottom at station 1200m northward.

The obtained values of SS content were significantly less, compared to values, obtained in January and April of 2005 during soil dumping.

In November, during excavated soil discharge, the sampling was performed at 1200 m from dumping circle center along all the directions.

It was noted that SS concentration decrease took plase both depthwise and directionally from dumping circle.

In the surface water layer concentrations of SS varied from 5,2 to 3,7 mg/$dm^3$, in the mid-water layer of 20 m – from 4,7 to 2,0 mg/$dm^3$, in the bottom water layer at a depth of 50 m – from 3,2 to 2,6 mg/$dm^3$. The minimal SS content was registered at station 1200m eastward at the mid-water layer and near bottom – 2,0 and 2,5 mg/$dm^{3,}$ respectively.

Generally, concentrations of SS didn't exceed MPC (10 mg/l) for shelf zone of marine fishery waters (Addendum 2 to the List of MPC, approved by the Order of Goskomrybolovstva of Russia #02-46/561 as of May 4, 2001).

**In September of 2005** as a result of observations in the dumping zone during soil disposal it was found out that, with the depth, SS content increase occurred from center to 1200 m eastward and northward.

No specific picture in the southward and westward was observed: SS distributed uniformly both depthwise and direction-wise.

**In November,** the maximum concentration of SS was detected in the surface water layer,1200 m from discharge point. Probably, sampling was picked up during completion phase of SS sedimentation to bottom, while in November sampling was performed directly during SS distribution in water layer.

Concentration of SS slightly exceeded MPC only September at a depth of 50 m northward (13,1 mg/$dm^3$).

Thus, acording to SS distribution data during soil disposal, dynamic process of quick distribution of SS in water layers occurred and the following was observed:

- quick sedimentation of basic mass of coarse and heavy fractions of soil (95%) at the discharge point;
- quick transport and dillution of fine material (pelite) in the water column

After soil discharge in the dumping area the levels of SS content in water reduced quickly up to background values, which is confirmed by the monitoring data. Average SS concentrations during soil dumping and directly at the dumping spot didn't exceed 20 mg/l.

SS content during dumping varied within 11,4-35,4 mg/l. Maximal concentrations of SS were registered 300 m from center to east and west.

Concentrations of SS in the near-surface water layer varied from 11,9 mg/l to 15 mg/l; in the bottom water layer - from 20,5 to 35,4 mg/l.

Concentration of SS more than 35,4 mg/l was not recorded during the monitoring observations in 2003-2005.

### 3.1.2 Petroleum hydrocarbons (total content)

**In June-July of 2001** DVNIGMI, within ecological monitoring, carried out additional measurments for pollutants content in sea water of Aniva bay (DVNIGMI Report, 2001).

In all sea water samples PH content varied from 0,40 to 40,26 mkg/l (0.008-0.805 of MPC). PH Content in the bottom water layer by average and maximal values was higher, compared to the surface sea water layer

On the whole, according to the integrated monitoring of 2001, sea waters of Aniva bay were characterized by higher level of PH pollution, compared to other studied areas of Sakhalin shelf.

In 2003 background level of PH concentrations before works commencement varied from 0,006-0,017 mg/l in the center of dumping circle in the near-surface water layer; in the mid-water layer – from 0.010-0.049 mg/l; in the bottom water layer – 0,025 mg/l.

Concentrations of PH were less than MPC for marine fishery water bodies at 300 m from center westward and eastward.

In 2003, during soil disposal, content of PH at all the stations was less than detection limit (<0.005 mg/dm$^3$). Maximal value – 0,082 mg/dm$^3$ was recorded in the surface layer in the soil dumping center.

In October PH concentrations didn't exceed MPC.

In 2004 during dredging operations PH content in water varied from <0.005 to 0,023 mg/dm$^3$.

Minimal PH content <0.005 mg/dm$^3$ was fixed near surface in the central dumping point and 300 m from center to east and at a depth of 50 m - 300 m from center to the west.

Maximal content - 0.129 mg/dm$^3$ was recorded in the bottom layer 300 m eastward from center of dumping.

So, PH values at the soil dumping area before and during dredging operations differed slightly and, on the whole, didn't exceed MPC.

In 2005, during soil disposal, individual cases of MPC excess by PH were fixed in northern direction from dumping center near surface – 0,124 mg/dm$^3$ (2,48 of MPC) and in the eastward direction at a depth of 20 m – 0,078 mg/dm$^3$ (1,56 of MPC).

In April, during soil disposal, PH content at all the stations and through all the water layers was at the detection level (0,020 mg/dm$^3$) and didn't exceed MPC.

In September, during soil disposal, maximal PH content was recorded in the westward direction at a depth of 50m – 0,054 mg/dm$^3$ (1,08 of MPC) and in the southern direction at a depth of 20 m – 0,096 mg/dm$^3$ (1,92 of MPC).

In November, at the north, south, east stations in mid-water and bottom layers concentrations of PH increased and exceeded MPC 1,32 to 7,3 times, despite low values of petroleum hydrocarbons in the excavated soil.

### 3.1.3 Polyaromatic hydrocarbons (PAH)

Background assessments of PAH content in sea water were obtained as per the data of ecological monitoring in June-July of 2001 (Report of DVNIGMI, 2001).

PAH in sea water of Aniva Bay according to the results of determination were presented by naphthaline and its homologs.

Among the detected compounds heavy polycyclic aromatic compounds, particularly, the most toxical benz(a)pyrene and its homologs (MPC for benz(a)pyrene is 5 ng/l) were absent. Total PAH content varied from 64 ng/l to 112 ng/l.

Average level of PAH content in Aniva Bay was almost twice as high as in other shelf areas of Sakhalin.

In December of 2004, during soil disposal at the dumping area, the total PAH content was less than detection limit (less than 50 mkg/dm$^3$). Naphthalene content didn/t exseed MPC (4 mkg/dm$^3$), other components of PAH in sea water are not normed.

In 2005 total content of PAH in water during soil disposal was also less than detection limit.

Naphthalene content through all the study period didn't exceed MPC.

### 3.1.4 Heavy metals

In June-July of 2001 DVNIGMI, within ecological monitoring, carried out additional measurments for pollutants content in sea water of Aniva Bay (DVNIGMI Report, 2001).

High concentration of metals in Aniva bay were not detected. Their concentrations were wihin the natural background oscillations for sea water, corresponding to concentrations of open Sakhalin shelf areas.

In 2004, before and during soil disposal, concentrations of the dissolved cadmium in the dumping area were characterized by equal values, averaging 0.00007 mg/dm$^3$. Cd distribution in water through water area and depth was rather uniform.

Content of the dissolved lead at all the stages averaged 0.00013 mg/dm$^3$ (less than MPC).

Content of the dissolved mercury during soil disposal (0.000360 mg/dm$^3$ on an average) was higher than before dumping (0.000231 mg/dm$^3$). Considerable inhomogeneity was observed both through area and vertical. Almost through all water layers concentrations of mercury exceeded MPC.

In September of 2005, during soil disposal and after it in November – concentrations of the dissolved Cd in the dumping area averaged 0.00004 mg/dm$^3$ (less than MPC). Areal and vertical distribution of Cd was uniform.

In September content of the dissolved Pb during soil disposal in the dumping area and in November after soil disposal, averaged 0.00010 mg/dm$^3$.

Areal and vertical distribution of Pb was uniform.

Maximal Pb value 0.00015 mg/dm$^3$ (less than MPC) was registered on September 28 in the surface layer, 400 m westward from dumping center.

In September, content of the dissolved mercury in water (0.00007 mg/dm$^3$ on an average) during soil disposal was higher than in November after soil dumping (0,00005 mg/dm$^3$), but less than MPC - 0,0001 mg/l.

Maximal Hg content was marked near surface, 400 westward from dumping center (0,00016 mg/dm$^3$), which exceeded MPC for Hg 1,6 times.

Increase in Hg content through depth layers is typical for vertical Hg distribution.

Compared to foregoing and background researches, concentrations of metals in water in 2005 decreased and the obtained values were comparable to 2004 data.

## 3.2. BOTTOM SEDIMENTS MONITORING

In 2001 additional researches for bottom sediments pollution in Aniva Bay including researches at the soil dumping area (DVNIGMI Report, 2001).

During soil disposal, sampling of bottom sediments for grain-size and chemical analyses was performed once before works commencement at 3 points:

- in the center of dumping circle;
- at two points lying 300 westward and eastward from center;
- and once after completion of soil disposal at the western and eastern points.

### 3.2.1. Grain-size composition

In 2003 background parameters of grain-size composition of the sediments surface layer at the dumping area, showed that silty sands and fine aleurite clays (fraction 0,1-0,01 mm) prevailed in the mentioned area. Their average share was 43,18%. Clayed silts (pelites, less than 0,01mm) and fine sands (0,25-0,1mm) were presented approximately equally, averaging 23,89% and 28,97% respectively.

This area was characterized by total absence of sediments with particles more than 2mm.

in 2006, after soil disposal completion, the sampling of bottom sediments was collected to determine its grain-size composition.

Sampling was performed by the dredger, which, due to its arrangements, creates low accuracy when determining small fractions in the samples, owing to their wash out during rise of bottom grab to the surface.

Compared to background data, sampling results showed the changes in the grain-size composition of bottom sediments in the circle center and 300 m eastward from dumping center. Thus, these stations recorded increase in gravel sand content from 37 to 48%, fine sand – from 37% to 45%, sandy silt up to 18%. While before works execution gravel content was 1%, fine sand up to 32%, aleurite-clayed silts – up to 66%.

At station 300m, westward from dumping center, grain-size composition of bottom sediments almost didn't change.

### 3.2.2. Chemical composition

In 2003 background parameters of the chemical composition of the surface layer of bottom sediments in different time periods were characterized by higher indexes of metals in summer: Cd, Cr, Mn, Pb; in autumn: Cu, Fe, Zn. The concentrations of metals did not exceed background values.

Results of total content of PH in bottom sediments are comparable with background values for Aniva bay (from <0,5 to 8,86 mkg/g of dry mass) (SakhNIRO, On the results…, 1998). Only in October concentration of PH didn't exceed background concentrations at station 300m eastward from dumping point.

In 2005 additional soil studies were performed in the center of dumping circle and 4 km from dumping zone (not exposed to soil disposal at the same depth) in order to determine organochlorine pecticides, petroleum hydrocarbons and polycyclic aromatic hydrocarbons.

### 3.2.2.1. Petroleum hydrocarbons

bottom sediments of Aniva Bay was 4,02 mg/kg, maximal – 26,4 mg/kg.

Data comparison by PH content in bottom sediments of Aniva Bay with neashore waters of Sea of Okhotsk evidences that bottom sediments of Aniva bay are referred to low polluted sediments by PH content.

In May of 2005, after completion of dredging operations in the MOF and soil disposal areas, soil samples were collected to analyse PH content in bottom sediments in the dumping area.

In parallel, control samples were collected to determine PH in bottom sediments at the points 4 km from dumping zone at the similar depths and soil type. Three samples were taken randomly in each of the area.

Stations within 200m radius circle were selected inside dumping zone. Control stations were located 200 m from each other.

PH concentrations in soil dumping area varied in a broad range from 4.0 to 20,5 mg/kg of dry mass and increased from east to west, while in the control points area PH concentrations varied slightly from 13,0 to 17,8 mg/kg of dry mass.

Average value of PH concentrations in bottom sediments in the soil dumping area was 13,1 mg/kg of dry mass and was close to background and at the same time was less than the control samples area – 15,1 mg/kg of dry mass. Spatial distribution of PH was nonuniform.

In 2006, after soil disposal, concentrations of total PH content in bottom sediments in the dumping circle center, were comparable with background values for Aniva bay and varied from 0,001 g/kg to 0,002 g/kg of dry mass.

### 3.2.2.2. Polyaromatic hydrocarbons (PAH)

Bottom sediments in Aniva bay are characterized by high PAH content, averaging 108 mkg/kg.

In May of 2005 soil samples were collected to analyze PAH content in bottom sediments in the dumping area after dredging operations completion at MOF and soil disposal area.

In parallel, control samples were collected to determine PH in bottom sediments at the points 4 km from dumping zone at the similar depths and soil type. Stations within 200m radius circle were selected inside dumping zone. Control stations were located 200 m from each other. Three samples were taken randomly in every area.

At the soil disposal area maximal PAH content in bottom sediments samples – 31,6 mkg/kg od gry mass, minimal – 27,2 mkg/kg of dry mass. Spreading of concentrations was not large.

Naphthalene (up to 14,6 mkg/kg of dry mass) and its methyl homologs (up to 6,2 mkg/kg of dry mass) as well as phenanthrene (up to 5,0 mkg/kg of dry mass) and pyrene (up to 0,9 mkg/kg of dry mass) prevailed among PAH.

In the control points area total PAH content in bottom sediments samples was 27,0 mkg/kg of dry mass.

Naphthalene (up to 9,2 mkg/kg of dry mass) and its methyl homologs (up to 6,0 mkg/kg of dry mass) as well as phenanthrene (up to 1,58 mkg/kg of dry mass) and pyrene (up to 1,68 mkg/kg of dry mass) also prevailed here among PAH.

In the soil disposal area total PAH content in bottom sediments was 29,1 mkg/kg of dry mass and slightly exceeded average value in the control samples area, which equaled 25,2 mkg/kg of dry mass.

In the soil disposal area PAH quantity slightly increased from east to west, in the control stations area – from north to south. Dominating PAH elements in the circle center and outside it were the same.

### 3.2.2.3. Organochlorine pesticides (OCP)

In May of 2005, after dredging completion in the MOF and soil disposal area, soil samples were collected to analyse OCP content in bottom sediments at the dumping area.

In parallel, control samples of bottom sediments were collected at the points 4 km from dumping zone at the similar depths and soil type. Three samples were taken randomly in each of the area.

Stations within 200m radius circle were selected inside dumping zone. Control stations were located 200 m from each other.

Total OCP content in the dumping circle center was characterized by considerable concentration spreading, ranging within 0,015-1,88 mkg/kg of dry mass, averaging 0,445±0,719 mkg/kg. Spatial distribution of PH was nonuniform.

Average total OCP content at the control points, despite considerable spread of values, was three times less (0,228±0,193 mkg/kg) than at stations located in the dumping zone (0,661±1,057 mkg/kg).

To check statistical assurance of the discovered differences is not practical due to small samples.

Among individual OCP only four compounds were pointed out – hexachlorbenzene (HCB) and DDT and its metabolites (4, 4´-DDE, 4, 4´-DDD, 4, 4´-DDT). HCB was present at all the samples within 0,015-0,17 mkg/kg, varying from 9 to 100% of OCP sum.

In the dumping zone concentrations of HCB on an average were higher (0,069±0,088 mkg/kg) than at the control stations (0,046±0,006 mkg/kg).

DDT and its metabolites were recorded both in the dumping zone and at the control stations.

In 2006, after dredging operations and soil disposal, total OCP content in bottom sediments was 0,03mkg/kg of dry mass, i.e. less than the values of previous researches.

## 3.3. HYDROBIOLOGICAL RESEARCHES

Hydrobiological researches in the soil dumping were caried out in order to itemize prediction estimates of damage due to hydrobionts affection extent, while being in water with various suspended particles (zooplankton) concentration, as well as about regenerative process of the destroyed or formation of new biotic communities (benthos).

### 3.3.1. Benthos

Before soil disposal samples of benthos was taken once in three points:

- in the dumping zone circle;
- in two points 300m eastward and eastward outside dumping zone
- after soil disposal: at western and eastern points.

1. In August of 2003 and October of 2004 background studies at dumping area showed that polychaete and sipunculoid worms were the dominating groups in the water area.

2. In December of 2004, after soil dumping commencement, the bottom community structure changed – polychaete abd sipunculoid worms were replaced by bivalve mollusks. Bivalve mollusks *Nuculana pernula pernula* were the dominating group (87,6% of total biomass). Polychatete *Lumbrineris heteropoda* were most abundant among other species (5,2% of total biomass).

3. Number of macrobenthos species, discovered during background studies in August of 2003 was 36, in October of 2004 – 7, after soil dumping in december of 2004 – 35.

4. In December of 2004, after soil disposal commencement, average organisms population in the dumping area amounted to 74 spec/$m^2$. This value is less than background data in August of 2003 (200 spec/ $m^2$, 53,7 g/$m^2$), but more than in October of 2004 (13 spec/ $m^2$).

5. In August of 2005 distribution of bottom hydrobionts population through water area (stations at 300, 800 and 2000 m from dumping point to north, east , south and west) didn't discover any trends: minimal values were recorded both near dumping point and some distance from it, along with maximal values.

Average biomass of benthos was rather big – 48,6 g/$m^2$, upon that, sipunculoid worms formed the basis of biomass (71%). But almost all biomass of sipunculoid worms (413 g/$m^3$) was concentrated at station 2000m westward of dumping point. At other stations influence of sipunculoid worms was close to zero but total biomass of benthos didn't exceed 36 g/$m^2$.

As for specific biomass distribution of benthos the maximum was recorded at the point, located 2000m westward of dumping point. The maximum was formed by sipunculoid worms and bristle worms. Therefore, bottom community at this station can be characterized as predumping.

Bivalve mollusks *Nuculana pernula pernula* prevailed at the stations, located eastward of dumping point as well as 2000m southward and northward from it. Respectively, postdumping community was observed at this water area. Distribution of biomass of separate groups at stations was highly similar with that for 2004: considerable biomass of sipunculoid worms at the maximum distant western point, increase in biomass of *Nuculana pernula pernula* eastward from dumping point.

Within 300 m radius from dumping point to the west, north and south rather low biomasses values (6,5 g/m$^2$) were observed, which was close to values of May of 2005. This fact can be regarded as a result of soil disposal impact to bottom biota.

**In August of 2005** similarity of abundance indexes, including the length of the species list, was observed with data of background stage. At that, structuredness of community was close to that at the background stage, about which the values of Shannon index of diversity and ABC-index evidenced. The level of coenotic and species similarity with background community was also rather high, which speaks about gradual recovery of postdumping benthos community up to background level, though the value of bivalve molusks was still high.

So, benthos during soil dumping differed by rather high diversity and high quantitative parameters. Bivalve mollusks *Nuculana pernula pernula* prevailed eastward, northward and southward of dumping point. Westward – sipunculoid worms prevailed. In August of 2005 similarity of abundance parameters, including species list, with background stage was noted.

On the whole, influence to the bottom biota in 2005 as in December of 2004 in the dumping area was less disastrous, than it was expected.

Benthos samples were collected after soil dumping completion (December of 2005) in August of 2006.

Processing of benthos samples showed availability of abundant population.

Average benthos biomass was 16,8 g/m$^2$, at that, bivalve mollusks formed the basis of biomass (69%), while in 2005 the sipunculoid worms formed the basis of biomass. It is necessary to note that almost all biomass of sipunculoid worms (413 g/m$^2$) was concentrated at the station 2000m westward of dumping point. At other stations influence of sipunculoid worms was close to zero and average benthos biomass without sipunculoid worms in 2005 was 14,1 g/m$^2$.

In 2006, average benthos biomass without sipunculoid worms was 14,9 g/m$^2$. Therefore, benthos biomass was comparable with prevoius year data.

In August of 2006 certain regularity was observed in distribution of bottom hydrobionts through water area (fig.2.1): maximal values were registered nearby dumping point (to 800m) westward, eastward and northward, in last case – to 2000m.

At the same time, southward from dumping point hydrobionts density reduced, but at 800 m southward macrobenthos was not recorded.

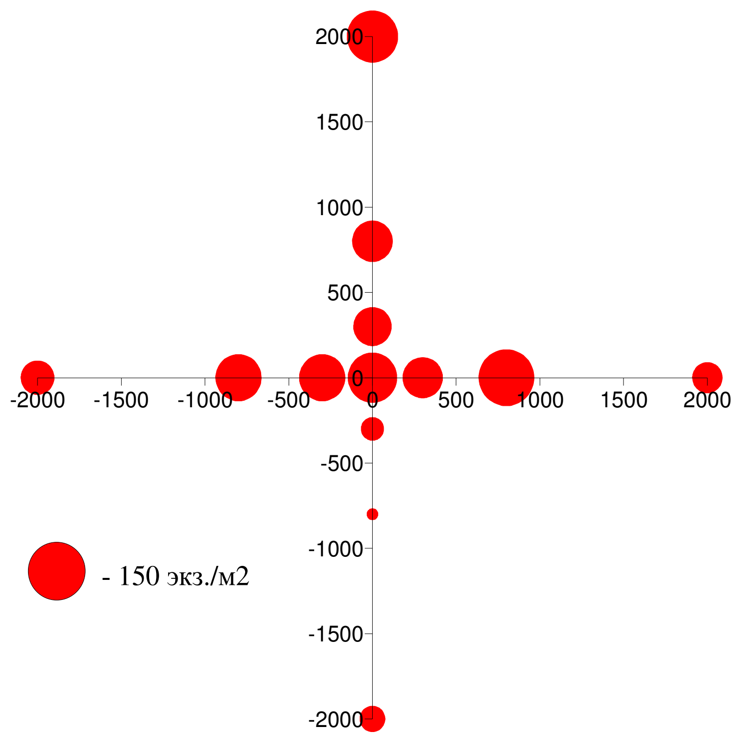
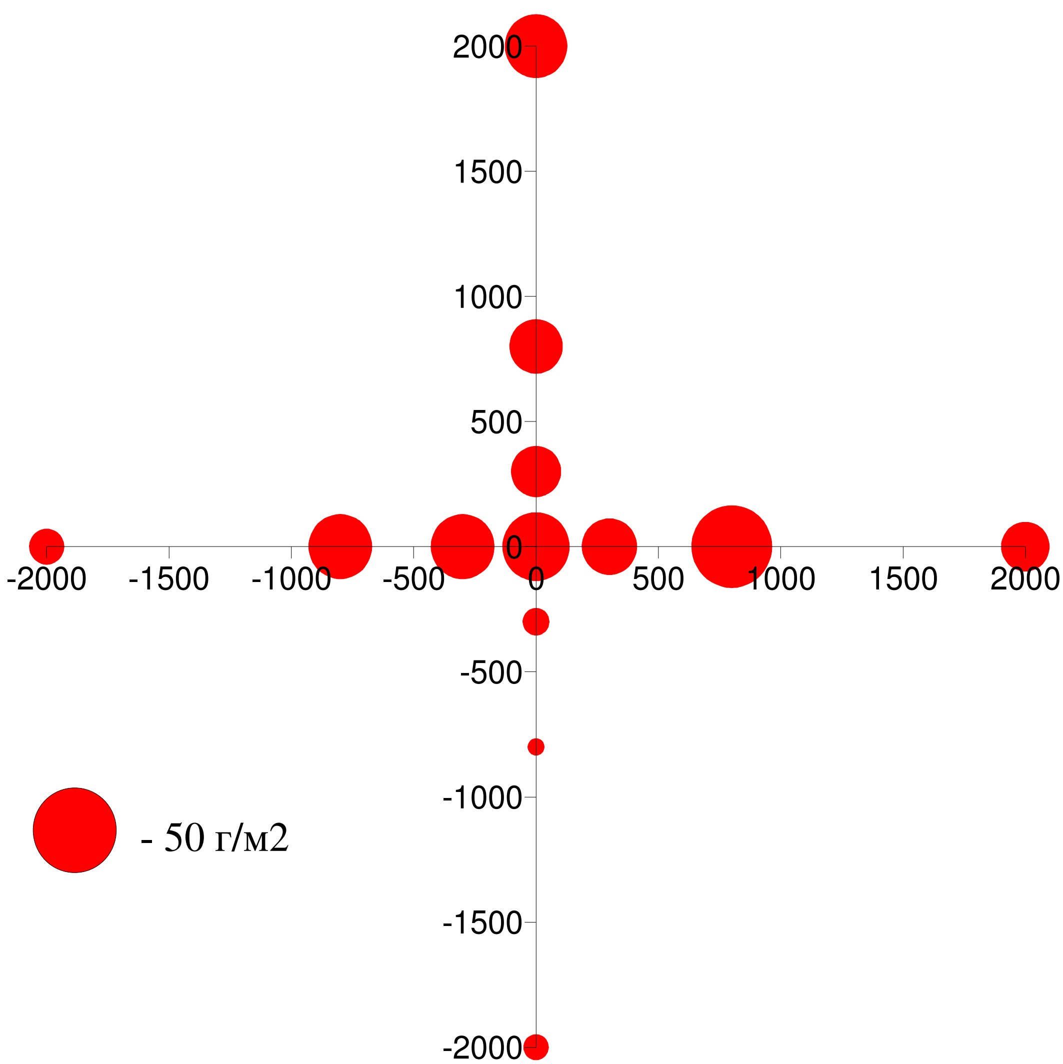



Figure 2.1 – benthos population distribution through water area

In distribution of specific benthos biomass (fig. 2.2) the same regularities were registered. The basis of biomass was predominantly composed of bivalve mollusks with domination of *Nuculana pernula*, bristle worms (2000 and 800m westward of dumping point, 2000 eastward from it) and sipunculoid worms (800 m westward and eastward of dumping point) (fig. 2.3, 2.4, 2.5).

Therefore, the bottom community at the stations (2000, 800m westward, 2000 and 800 m eastward) can be characterized as predumping (recoverable).

In 2005 such statement was applied only to the point, located 2000m westward.




Fifure 2.2 – Benthos biomass distribution through water area

At stations, located nearby dumping point (westward, eastward, northward) as well as at 800 and 2000 m northward from it, bivalve mollusks *Nuculana pernula pernula* prevailed (fig. 2.3). Postdumping community was observed correspondingly. Stations of southward direction were characterized by minimal biomass values.

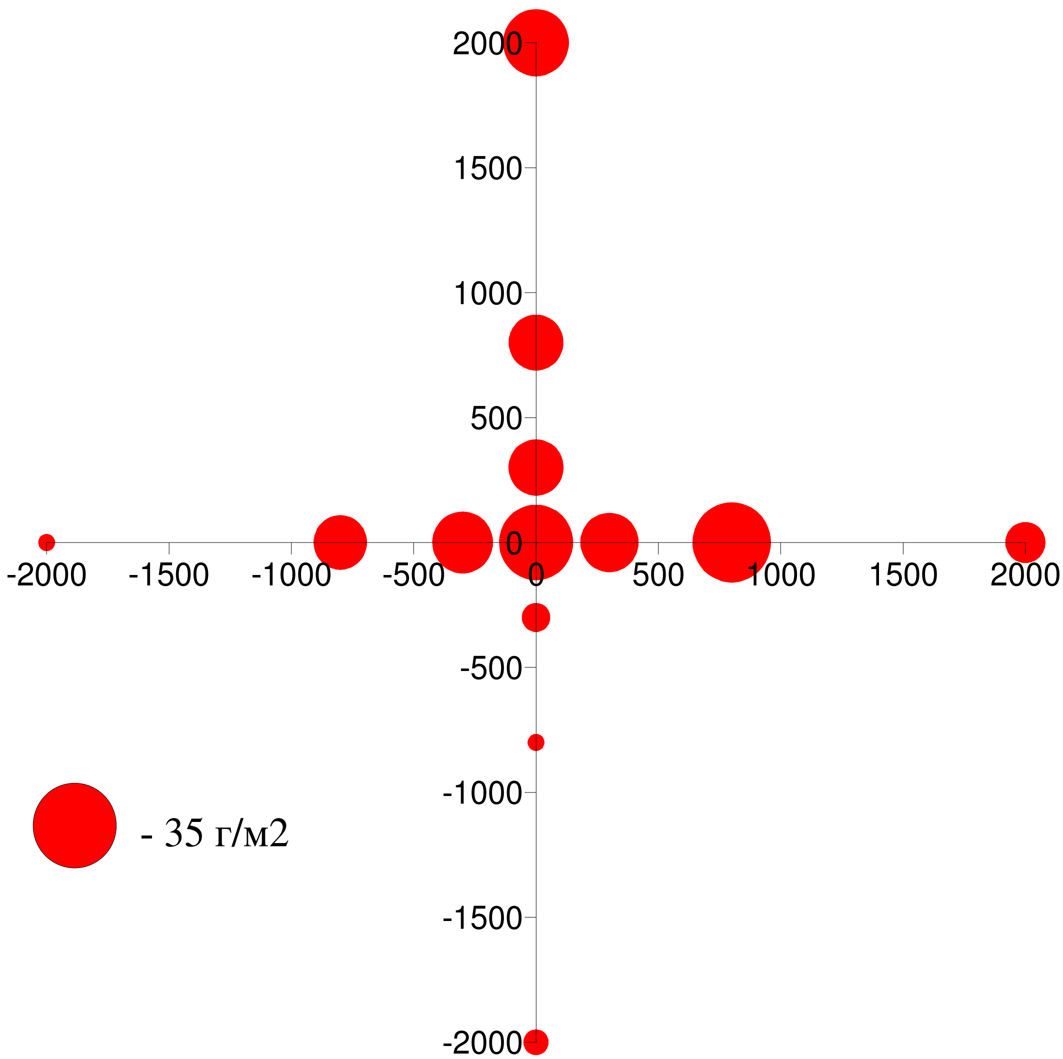



Fig 2.3 – distribution of bivalve mollusks through water area.

Macrobenthos organisms were absent in the samples of bottom biomass, collected 800 m southward from dumping center. In combination with prevailing type of bottom sediments – gravel – it indicated to soil drift to south (Bathymetric survey, Peco, December, 2005). Low characteristics of bottom population in the nearby points of southward direction – 300m (10 spec./m$^2$, 1,2 g/m$^2$) and 2000m (15 spec./m$^2$, 0,9 g/m$^2$) also indicate to this fact.

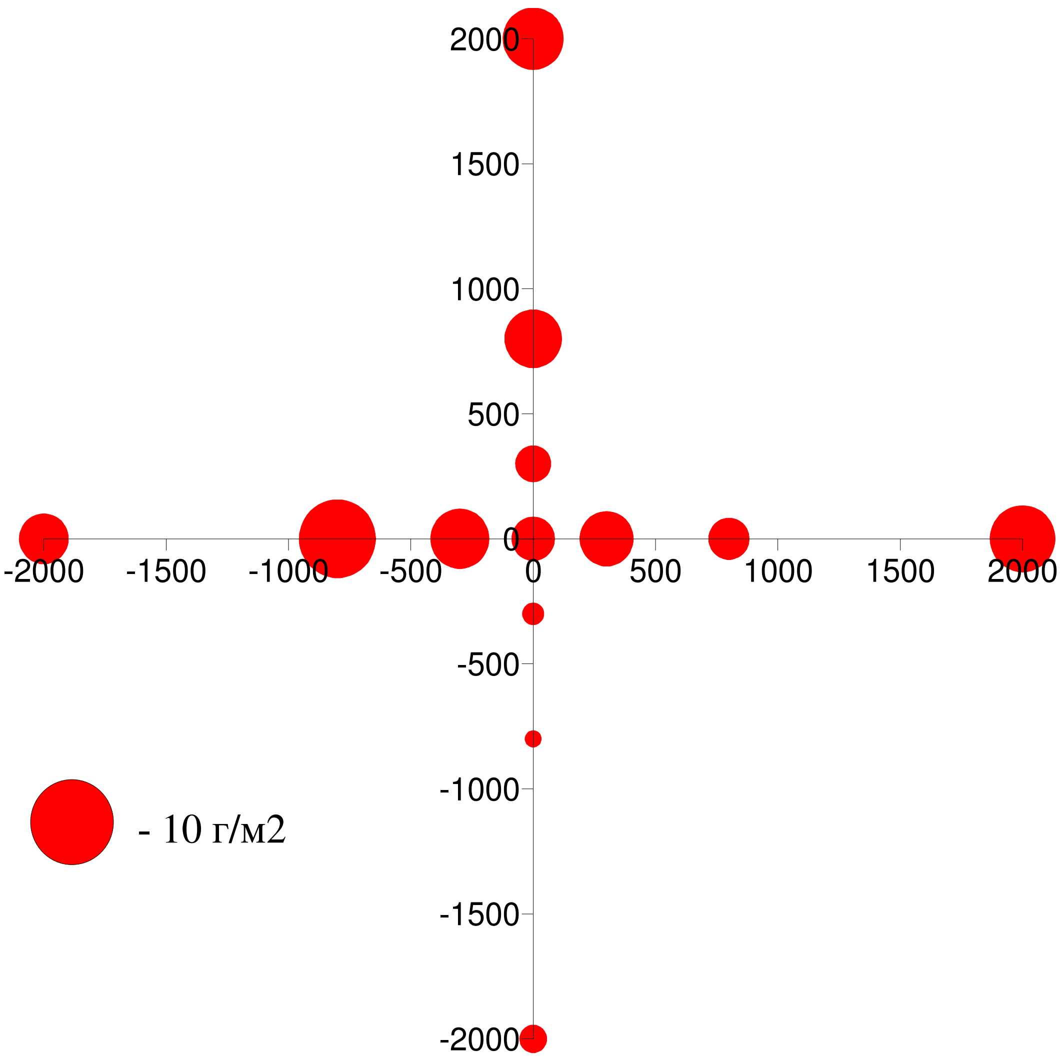



Fig. 2.4 – Distribution of polychaete worms biomass through water area

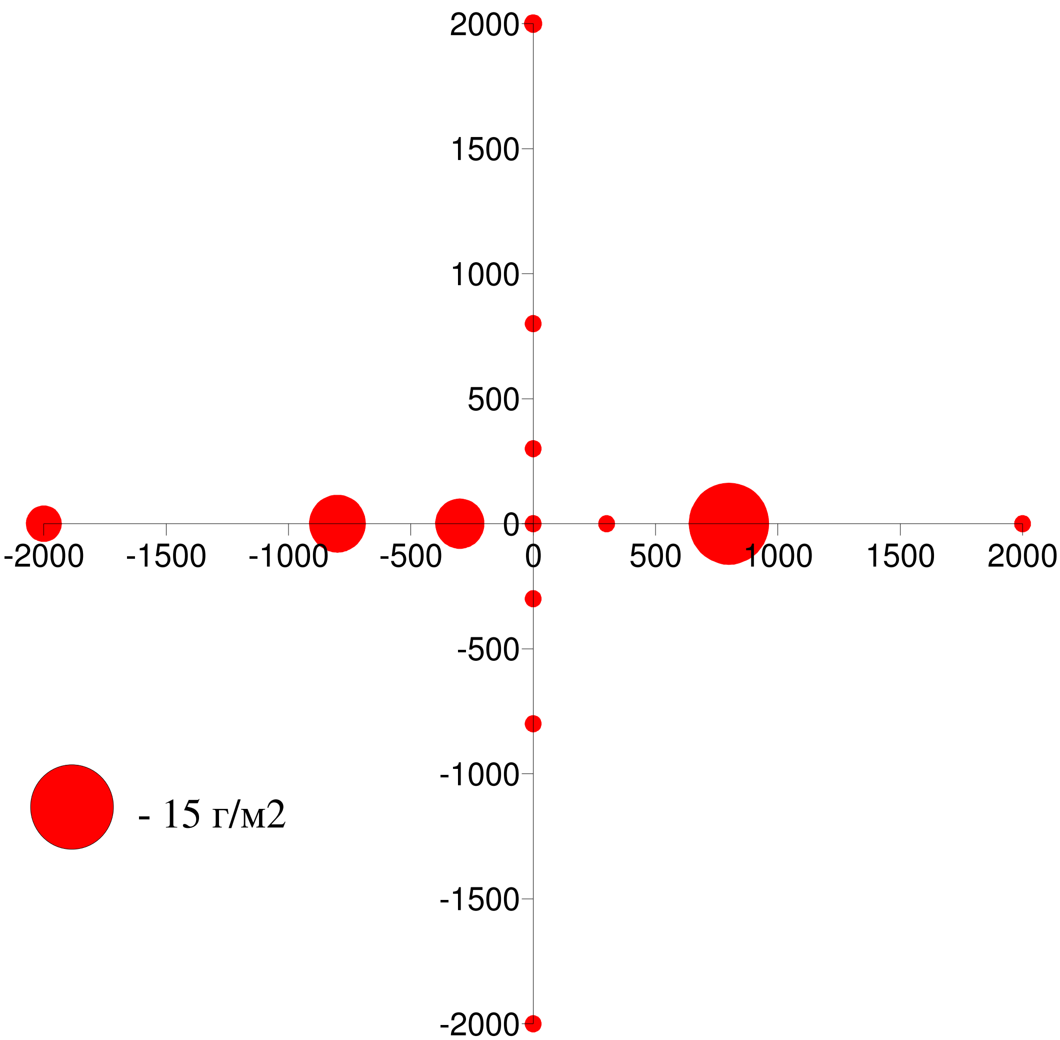



Fig. 2.5 – Distribution of sipunculoid worms through water area

On the whole, rather high biomass values (from 13 to 30 g/m2) were observed within 300m radius from dumping point westward, northward and eastward, which can be regarded as a result of gradual recovery of bottom biota after soil disposal. At that, average biomass within 300m radius from dumping point was 17,5 g/m2, which was much higher than values of May and August of 2005.

On the whole, soil dumping influence to the bottom biota was less disastrous, than it was expected and recovery to the initial condition goes rather quickly.

### 3.3.2. Zooplankton

Zooplankton researches were done in September of 2005 at 400 and 800m from dumping point northward, eastward, southward and westward.

27 species of plankton out 11 taxons were recognizied in the samples. Out of them 14 species of copepods with domination of medium and small-sized forms and 4 species of euphausive crawfish. Other taxon are presented by 1 specie. Meroplankton was formed by gastropods larvas, echinoderms and decapods (megalopa stage)

At 400 m from dumping point species composition by stations didn't exceed 5-10 species, 800m from dumping point amount of species slightly increased and reached 11-15.

Three species were the basis of biomass: two of them – copepods *Pseudocalanus minutus, Ps. newmani* and giperiida *Themisto japonica*, where the share of dominating *Ps. minutus* was more than 51,4% of total biomass.

Zooplankton biomass at 400m from dumping point was equal 320.5 mg/m$^3$, 800m – 439,8 mg/m$^3$, average for two radiuses – 380,2 mg/m$^3$. The least biomasses were recorded in southward and eastward directions from dumping point – 230-289 mg/m$^3$.

By population the community core was formed by Copepods *Oithona similis, Pseudocalanus minutus, Ps. Newmani* and one representative of tunicates *Fritillaria borealis.* Totally, the first four species formed more than 92,3% of total population.

On the whole, population oscillations by stations varied within broad ranges and averaged 6926,2 spec./m$^3$, average values for 400 m radius was equal 5553,1 spec./m$^3$, for 800m radius – 8299,25 spec./m3.

During soil dumping on September 28, 2005 low zooplankton mortality (less than 1%) was registered 400 m from dumping point. The highest zooplankton mortality rate – 0,84% by population and 0,89% by biomass was recorded northward at a depth of 20 m. The less impact was recorded 800m from dumping point.

Maximal SS concentration at a depth of 20 m was 7,2 mg/dm$^3$, which could not make a significant effect on zooplankton mortality, since MPC of SS for shelf zone of fishery seas is 10 mg/l.

Since only one sample was collected in every studied direction and distance, it is rather difficult to speak about stable trend or just about real picture of plankton distrubution and death values after dumping, therefore additional researches are to be performed.

# 4. COMMERCIAL AND PLANKTON ORGANISMS CONDITION STUDY DURING SOIL DREDGING AND DUMPING OPERATIONS IN ANIVA BAY.

## 4.1. COMMERCIAL INVERTEBRATE STUDIES

Analyse of minitoring data was done mainly according to diving surveys results, since trawl net was not a representative fishing equipment registered for fishing grounds.

Three species out of massive invertebrates were registered on the studied water area (zones A-J) in 2003-2005: *Mizuhopekten yessoensis* (bivalve mollusks –Japanese scallop), *Strongylocentrotus intermedius* (echinoderms – grey sea urchin), *Cucumaria japonica* (holothuria – Japanise cucumaria).

### 4.1.1. Japanese scallop Mizuhopecten yessoensis

In 2003 distribution of animals in the area was aggregative. Within the depths from 5-20m mollusk forms various, by specific population and biomass, local accumulations on sandy, silt-sand and pebbly grounds. Total area, occupied by Japanese scallop was 3789m$^2$. At most water area its biomass doesn't exceed 241 g/m$^2$.

As in 2003, Japanese scallop (*Mizuhopekten yessoensis*) was distributed aggregatively in 2004. Total area, occupied by Japanese scallop, was 7250m$^2$. At most water area its specific biomass didn't exceed 199,1 g/m$^2$. Maximal values of specific biomass (more than 200g/m$^2$) were fixed in two local accumulations, located in A zone at a depth of 10 and 20m. Value of Japanese scallop reserves on the studied area was 0,73 t.

In 2005, despite scallop population area decrease and reduction of individual body size and mass, value of Japanese scallop reserves on the studied area didn't undergo essential changes in comparison with 2004. This fact can be explained so that the compression of early registered accumulations in zones A and C took place, followed by increase in specific biomass, which compensated decrease in total area populated by mollusks. According to the preliminary estimate, Japanese scallop reserves remained on the same level and was equal to about 0,85 t in 2005, compared to 0,73 t in 2004. Japanese scallop distribution in 2005 through the studied area is shown in figure 4.1.1.

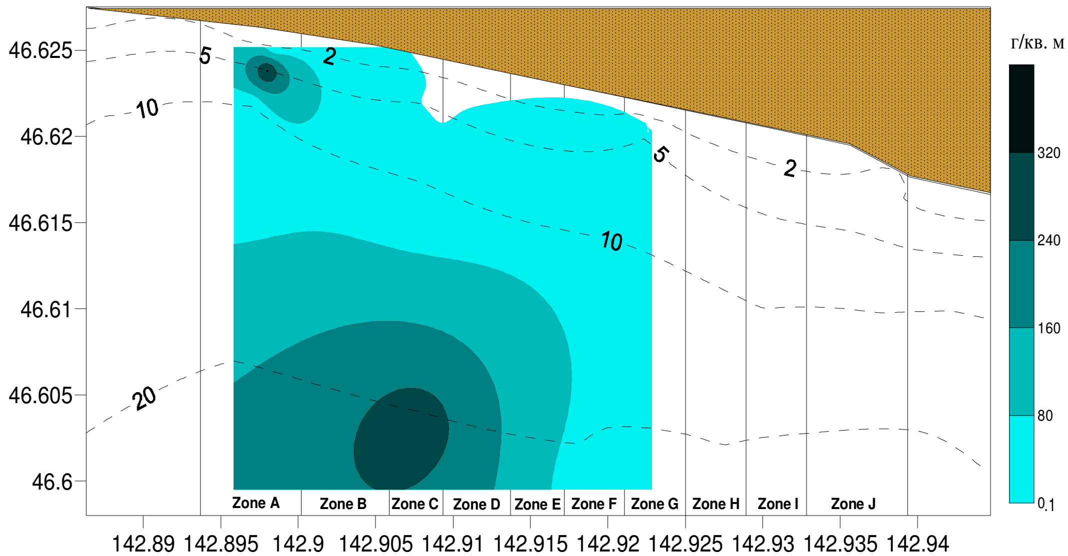



Fig. 4.1.1. Japanese scallop distribution by biomass (g/m2) in neashore of s. Prigorodnoye, August 2005

According to monitoring observations over Japanese scallop distribution near s. Prigorodnoye from 2003 to 2005, changes in distribution and biological parameters of mollusks were within natural oscillations of population and biomass.

### 4.1.2. Grey sea urchin Strongylocentrotus intermedius

The most massive commercial species of invertebrates in the neashore shallow waters of s. Prigorodnoye. Grey sea urchin can be found as on hard and soft bottom sediments, forming different in density assemblies within 2-20m depth lines, main assembly was kept in C zone at a depth of 10mduring study period of 2003-2005.

In comparison with previous year, in 2005 total area, occupied by sea urchin, decreased from 18239 to 12154 $m^2$ respectively. Sea urchin distribution through study area is shown in figure 4.1.2.

Fraction of noncommercial size species (with crust diameter less than 45mm) remained less than in 2003 – 32,1% of total samples, but increased from 4,8% in 2004 to 18,5% in 2005, which evidences about relatively favorable conditions for juvenile development. At that, quantity of species of 50-60 cm increased. Specific population and biomass of animals in 2005 reduced practicaly twice compared to 2004: from 1,25 to 0,61 spec./$m^2$ and from 64,8 to 31,3 g/$m^2$, due to compression on the limited area.

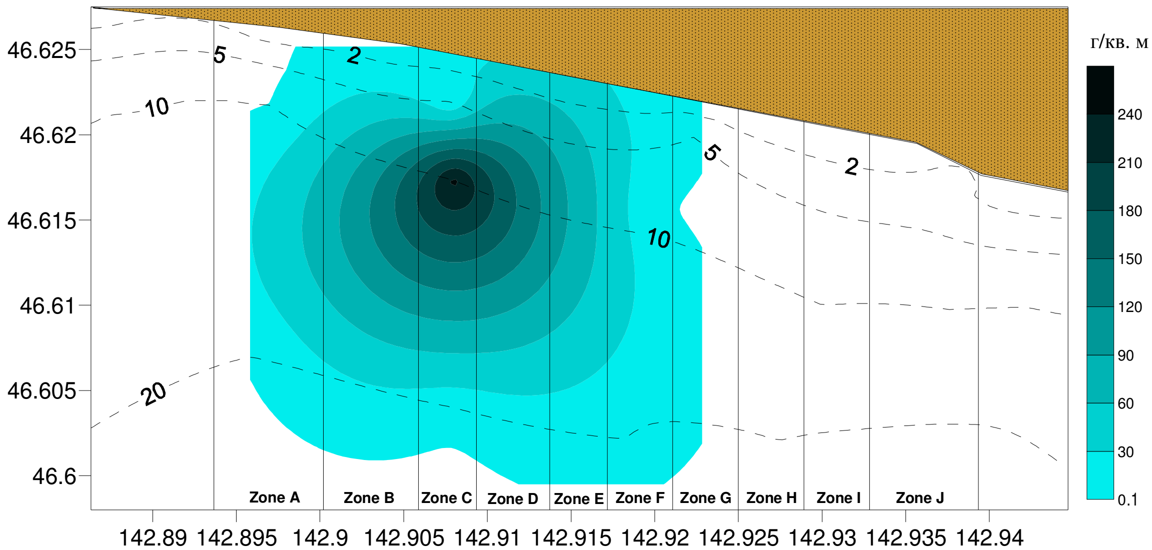



Fig. 4.1.2. Grey sea urchin distribution by biomass (g/m2) in neashore of s. Prigorodnoye August 2005

According to monitoring observations over sea urchin distribution near s. Prigorodnoye, Aniva bay from 2003 to 2005, changes in distribution and biological parameters of sea urchins were within natural oscillations of population and biomass.

Increase in noncommercial size spacies in 2005 compared to 2004 evidences about relatively favorable conditions for juvenile development.

### 4.1.3. Japanese cucumaria Cucumaria japonica

The range of cucumaria habitation depths on the study area varied from 10 to 20m.

Cucumaria in 2005, as in 2004, was found at depths from 10 to 20m on the coarse material. Maximal biomass was recorded in Zone C at a depth of 20m and was equal 81,55 g/m$^2$ (see fig.). Juvenile groups of animals do not form separate aggregations.

Total area, occupied by assemblies of this specie of erchinoderms decreased from 6062 m2 in 2004 to 5302 m$^2$ in 2005. Cucumaria distribution on the study area is shown in Fig 4.1.3.

Average mass value of dermomuscular tube of animals - 164,52±16,2 g, practically remained at the level of 2004 – 173,5±13,9 g, greatly exceeding the values of 2003 - 103,1±6,4 g.

Fraction of noncommercial sized species (with mass of dermomuscular tube less than 100g) in total samples increased from 16,5% in 2004 to 18,5% in 2005.

Thus, according to monitoring observations near s. Prigorodnoye, Aniva bay from 2003 to 2005, changes in distribution and biological parameters of cucumaria were within natural oscillations of population and biomass. Increase in noncommercial sized species in 2005 compared to 2004 evidences about relatively favorable conditions for cucumaria development.

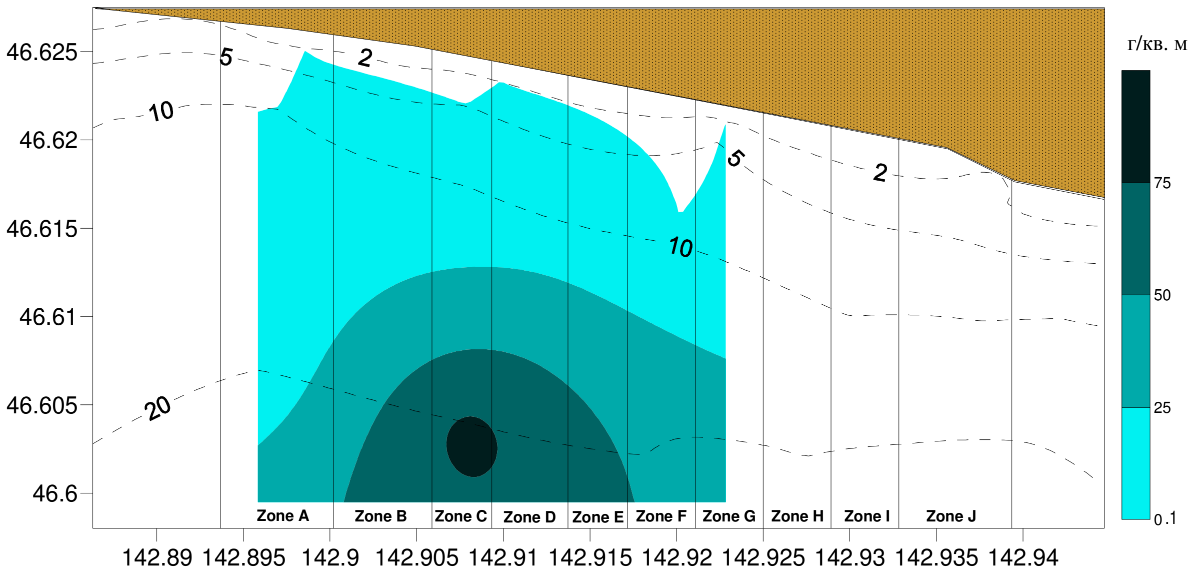



Fig. 4.1.3 – Japanese cucumaria distribution by biomass (g/m2) in neashore of s. Prigorodnoye August 2005

## 4.2. GENERAL CHARACTERISTICS OF MACROBENTHOS ACCORDING TO DIVING AND TRAWLING SURVEYS

Comparative analyses of data obtained in 2003-2005 according to diving surveys showed that during the previous two years some changes in qualitative and quantitative composition of bottom communities in the nearshore of LNG Plant took place.

Compared to previous years, decrease in species composition of macrobenthos in 2005 was registered from 38 (in 2003) to 28 (in 2005). Quantity of taxonomic groups decreased from 13 (in 2003) to 10 (in 2005). In 2005 species of some taxonomic groups were absent in the samples: *Ascidiae, Cephalopoda, Ophiuroidea.*

Species diversity of taxonomic groups in 2005, compared to 2004, remained practically unchanged. From 1 to 5 of benthos organisms were present in each group (in 2004 1-7 species). Compared to 2003 species diversity of taxonomic groups of macroorganisms decreased as much as twice (1-12 species in 2003). Reduction of specific values for population and biomass happened from 134,37 spec/m$^2$ (2003) to 5,73 spec/m$^2$ (2004) and 5,36 spec/m$^2$ (2005) and from 1410,67 to 463,4 g/m$^2$ and 323,2 g/m$^2$, respectively. Compared to 2004, reduction of specific values for population and biomass continued in 2005 but not so considerably.

The change of domintaing by biomass taxonomic groups was noted in the structure of bottom communities. Three groups dominating in 2003: *Asteroidea* (sea stars), *Echinoidea* (echinoderm) and *Bivalvia* (bivalve mollusks). Their biomass in percentage to total biomass of all benthos species was 33,8, 31.7 and 12.7%. *Bivalvia* и *Asteroidea* remained in 2005 as in 2004. *Bivalvia* remained the first. Biomass of *Bivalvia* and *Asteroidea* against the total biomass of all benthos species was 38,5 and 22,2%, respectively, at the study period in 2005

Stable biomass condition before study in 2005 were kept only by *Bivalvia* out of dominating taxonomic groups in 2003-2004. Mass fraction of *Asteroidea* and *Echinoidea* considerably decreased, which is connected to the total absence of sea urchin (*Scaphechinus griseus*) in 2005. In 2003 *Echinoidea* was one of three dominating by bionass taxons only because of sea urchin. Mass fraction of groups decreased greatly. As for *Echinoidea* this is related to total absence of flat urchin in 2005. In 2003 just because of this species the group was one of three taxons dominating by biomass. In 2004, in zone A, at a depth of 2m, practicly total absence of flat urchins was also observed.

Mass fraction of *Asteroidea* in total biomass of all benthos species was 22,2% (2003 – 33,8%, 2004 – 10,6%), as a result of which it was shifted to the second place. This happened due to considerable increase in 2005 of biomass of all the species composing the species group.

Mass fraction of *Loricata* (chitons) in total biomass of all benthos species was 12,3%. Comparing the studies of 2003-2004, its biomass slightly increased in 2005, only because of this fact the group became the third out of taxon dominating by biomass.

**According to trawling surveys** in 2005 Kamchatka crab *Paralithodes camtschaticus* was registered at two stations (frequency of occurrence 33,3%), which corresponds to the level of 2003 and 2004. Biomass per trawling was 6875 kg on an average, which is a sequence higher than in 2003 and 2004. Maximal catch of *P. camtschaticus* was recorded at 23 m depth. Average biomass increase was obtained due to accumulation of puberal females, which was not recorded in prevoius two years.

Erimacrus isenbeckii Kegani crab *Erimacrus isenbeckii* was found at two stations (33,3%), mainly in zone A at 22-27m depth, which corresponds to the data of 2004. In 2003 the crab was not recorded in trawl conditions. Average biomass value was less than in 2004. The crab males were present in the catches. Average male size was smaller than in 2004. Female crabs were much bigger than in 2004.

*Telmessus cheiragonus* was found in one specimen at one station (16,7%) at 7-14 m depth. Biomass per trawling was 0,35 kg, the catch was presented by male crab. In 2003 and 2004 this specie was of widespread occurrence: in 2003 – at two stations by one specimen (12,5%), biomass per trawling varied from 0,15 to 0,25kg. In 2004 this specie was found at four stations (28,6%) as in 2003, mainly in zones C and E at 15-20m depth biomass per trawling varied from 0,25 to 0,85 kg.

Species diversity of shrimps in 2005, compared to 2003 and 2004, increased from 2 (*Pandalus sp.* and *Sclerocrangon)* to 6 species (two species of Pandalidae - *Pandalus borealis* and *Pandalus meridionalis* families*,* three species of Crangonidae - *Sclerocrangon boreas, Crangon dalli* and *Argis lar kobjakovii families,* as well as species *Lebbeus groenlandicus family.* In 2003 catches of shrimps were less than in subsequent years.

## 4.3. DISTRIBUTION OF POLLUTANTS IN INVERTEBRATES AND MACROPHYTES

Massive species of echinoderms were studied at 5,10,15 m depth (gonads of grey or intermediate sea urchin *Strongylocentrotus intermedius* and dermomuscular bags of Japanese cucumaria *Cucumaria japonica)*, bivalve mollusks (muscle of Japanese scallop *Mizuhopecten yessoensis*), seaweed (stems and leaves of Asiatic Zostera *Zostera asiatica)* and red algae (*Phycondrys vinogradovae)* in order to determine total content of Organochlorine pecticides (OCP) – DDT and HCCH, petroleum hydrocarbons (PH), heavy metals (Cd, Cr, Cu, Fe, Hg, Pb, Zn, As, Mn).

According to monitoring studies, total content of OCP in hydrobionts in 2003-2005 didn't esceed Hygienic normatives - Maximal Permissible Level (MPL).

Quantity of OCP in seaweed were within 0,00026-0,00179 mg/kg of dry mass, in invertebrates tissues - 0,00022-0,00045 mg/kg of dry mass.
Concentrations of PH in August of 2005 in invertebrates tissues were much less than in 2003-2004 and in macrophytes – less than in 2004 but more than in 2003.

Concentration of metals in invertebrates tissues in August of 2005 even for dry mass didn't exceed MPL (Hygienic normatives of metals content in hydrobionts, SanPIN 2.3.2.1078-01).

Species specificity of metals accumulation and zonal diversity of macroelemental composition of macrophytes (*Phycondrys vinogradovae*, as an example). Maximal quantities of many elements were fixed in Phycondrys thallomes, minimal – in the leaves and stems of Zostera. The minimum spread in values was typical for Hg, which was not involved in metabolic process of plants. Comparison with MPL (corrected to raw mass) did not show the metals excess for marine organisms.

Concentrations of metals were within their natural change in the hydrobionts bodies.

## 4.4. COASTAL ICHTHYOFAUNA STUDY

During a study period 57 species of fish out of 24 families were found. Studies for 2005 broadened the species composition: 10 new fish species, earlier absent in cathes, were found. They are: pond fish (found in small trawl), Bering poacher, yellow Irish lord, banded Irish lord, Stichaeus nozawae, stippled gunnel, blackline prickleback, Sakhalin sole, crested sculpin (catches of bottom trawl), Alaska pollack (midwater trawl). The following species disappeared from catches but found in 2004: lamprey, common icefish, short fin sand lance, Pacific anchovy, wakasagi, chum salmon, ninespine stickleback, Sebastes viviparus, buterfly sculpin, Okhotsk snailfish Stichaeus grigorjewi, Pacific sand lance, Japanese sandfish, north toadfish, rock greenling.

Seasonal variation in distribution of some species was fixed – in summer catches were lack of salmon producers, but juvenile fishes of this specie were found. Autumn catches were lack of capelin as the season of its propagation finished and it moved from shore to open water areas. Other species were relatively rare and their availability in the catches was rather casual.

### 4.4.1 Comparative characteristics, species composition and frequency of occurrence of fish by zones in August and September of 2003-2005

In zone E in August-September of 2003-2005 21 species of fish recorded. Shishamo smelt *Hypomesus japonicus,* Japanese dace *Tribolodon hakuensis*, navaga *Eleginus gracilis* were found in the catches every year.

Species composition in 2003 was presented by 8 species of fish, two of which were bottom species (longnosed flounder *Pleuronectes punctatissimus,* Okhotsk snailfish *Liparis ochotensis)* and 1 specie – near-bottom (whitespotted greenling *Hexagrammos stelleri*). Bottom type fish are confined to sandy-pebble grounds.

In 2004 12 fish species were fixed. Two of them were bottom type (Legless gunnel *Opisthocentrus dybowskii,* ocellated blenny *Opisthocentrus ocellatus*). The former specie preferrs pebbly or rocky soils with aquatic vegetation, the latter – silty-sandy soils. Near-bottom – 2 species (Alaska greenfish *Hexagrammos octogrammus* and Japanese dace *Tribolodon hakuensis.* Alaska greenfish *Hexagrammos octogrammus*, as a rule is found on the rocky soils, covered by seaweed.

In catches of 2005 13 species of fish were found, 5 of which were bottom ones. Ocellated blenny, frog sculpin *Myoxocephalus stelleri* and Limanda schrenki *Pseudopleuronectes schrenki* can be found on the pebbly of rocky soils with aquatic vegetation; notched-fin eelpout *Zoarces elongatus* and Legless gunnel *Opisthocentrus dybowskii* can be found in silty-sandy soils. Near bottom species were presented by

Japanese dace *Tribolodon hakuensis*, White-edged rockfish *Sebastes tazanowskii*, Alaska greenfish *Hexagrammos octogrammus* and whitespotted greenling *Hexagrammos stelleri*.

So, fish of near-bottom group initially were found in zone E in summer-autumn period and were confined to sandy-pebbly soils (longnosed flounder *Pleuronectes punctatissimus*, Okhots snailfish *Liparis ochotensis*, whitespotted greenling *Hexagrammos stelleri*).

Later there was a substitution to bottom species (ocellated blenny *Opisthocentrus ocellatus* and Legless gunnel *Opisthocentrus dybowskii*), preferring pebbly or rocky soils, covered with aquatic vegetation or silty-sandy soils.

Near-bottom group of species was presented by Alaska greenfish *Hexagrammos octogrammus,* habitant mainly on rocky soils with brown or other algae. The similar distribution dynamics of the mentioned species was registered in 2004 and 2005. The catches of 2005 had new near-bottom species - frog sculpin *Myoxocephalus stelleri*, *Pseudopleuronectes schrenki*, habitant on pebbly-rocky soils and notched-fin eelpout *Zoarces elongates*, which is confined to silty-sandy soils.

Longnosed flounder *Pleuronectes punctatissimus* and Okhotsk snailfish *Liparis ochotensis* were not fixed in zone E in 2004, 2005.

17 species of fish were recorded in zone C in August-September of 2003-2005. Japanese dace *Tribolodon hakuensis* was found in catches every year.

Catches of 2003 were presented by 7 species, one of which was referred to bottom species (Okhotsk snailfish *Liparis ochotensis*) and three species – to near-bottom group (whitespotted greenling *Hexagrammos stelleri*, Alaska greenfish *Hexagrammos octogrammus* and White-edged rockfish *Sebastes tazanowskii*), inhabiting, mainly, sandy-pebbly soils. The exception was Alaska greenfish *Hexagrammos octogrammus*, preferring rocky soils with brown or other algae.

10 fish species were found in catches of 2004. Two of them were bottom species (Legless gunnel *Opisthocentrus dybowskii*, ocellated blenny *Opisthocentrus ocellatus).* The former prefers pebbly or rocky soils with aquatic vegetation, the latter – silty-sandy soils. The Group of near-bottom species included whitespotted greenling *Hexagrammos stelleri* and Japanese dace *Tribolodon hakuensis.*

The catches of 2005 were presented by 7 fish species, one of which was referred to bottom species group - frog sculpin *Myoxocephalus stelleri*, habitant on pebbly-rocky soils. The group of near-bottom was composed of Japanese dace *Tribolodon hakuensis* and White-edged rockfish *Sebastes tazanowskii.*

The catches of 2003 in zone C included one specie - Alaska greenfish *Hexagrammos octogrammus,* which is confined to rocky and pebbly soils with aquatic vegetation. Visually rocks were registered in this zone. In subsequent years the fish species, habitant in natural covers, increased. In this zone there were no species, which were permanently registered from year to year, as, due to continuous construction operations, the composition of near-bottom and bottom ichthyfauna was not established. In 2005 absence of some species related to high concentration of humpback salmon. In this zone population and biomass of the specie was 0,060 spec/$m^2$ and 83 250g/$m^2$, respectively.

Okhotsk snailfish *Liparis ochotensis* and Alaska greenfish *Hexagrammos octogrammus* were not found in catches in 2004, 2005 in zone C.

There were 10 fish species registered in August-September of 2003-2005 in zone A. Japanese dace *Tribolodon hakuensis w*as found in catches every year.

Catches of 2003 were presented by 10 fish species, two of which were bottom ones: Okhotsk snailfish *Liparis ochotensis* and longnosed flounder *Pleuronectes punctatissimus*) and 2 species – near-bottom (whitespotted greenling *Hexagrammos stelleri,* Japanese dace *Tribolodon hakuensis*). These species are referred to inhabitants of sandy-pebbly soils.

In 2004 there were 4 fish species found. Near-bottom species include only one specie – Pacific sand lance *Ammodytes hexapterus*, preferring sandy soils.

In 2005 one specie was found - Japanese dace *Tribolodon hakuensis*. High population and biomass of humpback was recorded that year (0,025 spec/$m^2$, 34 300 g/$m^2$), respectively.

In zone A population and biomass were formed by migratory and semidiadromous fish. Absence of marine bottom fish was because of sea water conversion by fresh waters of Mereya river.

### 4.4.2. Comparative characteristics, species composition and frequency of occurrence of fish by zones in May-June 2004-2005

19 fish species were registered in zone E in May-June of 2004-2005. Every year the catches showed white-spotted char *Salvelinus leucomaenis,* longsnout poacher *Brachyopsis segaliensis*, longnosed flounder *Pleuronectes punctatissimus*, Alaska smelt *Osmerus mordax*, herring *Clupea pallasii*, frog sculpin *Myoxocephalus stelleri*, Shishamo smelt *Hypomesus japonicus*, navaga *Eleginus gracilis*.

Species composition in 2004 was presented by 12 fish species, 3 of which were bottom. They were: longnosed flounder *Pleuronectes punctatissimus*, longsnout poacher *Brachyopsis segaliensis* and frog sculpin *Myoxocephalus stelleri*. Migrants of Humpback salmon *Oncorhynchus gorbuscha* and chun salmon *Oncorhynchus keta* were found in catches.

15 species of fish were found in the catches of 2005, 5 of which were botom ones. Frog sculpin *Myoxocephalus stelleri* with aquatic vegitation abundance was found on pebbly and rocky soil. On silty-sandy soils - Legless gunnel *Opisthocentrus dybowskii.* Longnosed flounder *Pleuronectes punctatissimus,* longsnout poacher *Brachyopsis segaliensis* and starry flounder *Platichthys stellatus* were found on sandy and pebbly-sandy soils.

In zone A, in May-June of 2004-2005 19 fish species were found. White spotted char *Salvelinus leucomaenis,* humpback juvenile *Oncorhynchus gorbuscha,* longnosed flounder *Pleuronectes punctatissimus,* longsnout poacher *Brachyopsis segaliensis,* toothed smelt *Osmerus mordax,* Shishamo smelt *Hypomesus japonicus* are registered in the catches every year

In 2004 9 fish species were registered, two of which – bottom type (longnosed flounder *Pleuronectes punctatissimus* and longsnout poacher *Brachyopsis segaliensis)* encountered on sandy and pebbly-sandy soils.

In 2005 11 fish species were recorded, 5 of which were bottom species. On the pebbly or rocky soils with aquatic vegitation one can encounter frog sculpin *Myoxocephalus stelleri,* snowy sculpin *M. brandti.* On silty-sandy soils - Legless gunnel. On sandy and pebbly-sandy soils - longnosed flounder *Pleuronectes punctatissimus* and longsnout poacher *Brachyopsis segaliensis.* Distribution of frog sculpin *Myoxocephalus stelleri*, and snowy sculpin *M. brandti,* habitant on rocky and pebbly soils, is not typical for the mentioned area, which relates to spawning of shishamo smelt *Hypomesus japonicus* in this area.

In spring and early summer, during nearshore waters warm-up, most massive local species have spawning period at shallow waters. They are: shishamo smelt, herring, capelin, starry flounder, Japanese sandfish. Abundance of readily available food attracts other fish (frog sculpin, whitespotted char), which results in sharp increase in species quantity to the station (up to 15).

Fish, confined to sandy-pebbly soils (longnosed flounder *Pleuronectes punctatissimus*, Okhots snailfish *Liparis ochotensis*, whitespotted greenling *Hexagrammos stelleri*) were initially found In zone E in summer-autumn period of 2003.

Later there was a substitution to bottom species (ocellated blenny *Opisthocentrus ocellatus* and Legless gunnel *Opisthocentrus dybowskii,* Alaska greenfish), preferring pebbly or rocky soils, covered with aquatic vegetation.

Next years zone C recorded bottom species, habitant on pebbly-rocky soils, population of such species increased.

There was no change in ichthyfauna of bottom communities, noticable changes were observed in May-June in zone A. Spawning of Shishamo smelt was noticed in this area, which resulted in increase in population of other (predatory) fish species.

## 4.5. STUDY OF SPAWNING GROUNDS IN COASTAL ZONE.

Capelin spawns on sandy soils and potential spawning grounds of Pacific herring are located In coastal zone of Aniva bay, near LNG Plant facilities construction in s. Prigorodnoye.

Pacific herring (*Clupea pallasii* Cuvier et Valenciennes, 1847).

Due to low herring population near Sakhalin coast in 1980-2000 herring spawning in Aniva bay was not recorded.

During studies in 2003, 2004, 2005 at depths 2,4,7 m herring roe was not discovered.

Pacific capelin *(Mallotus villosus socialis* Müller*).*

Practically all coast is the potential spawning grounds in Aniva bay, where coarse sand, pebble and shell rocks are registered. Maximal spawning approaches of capelin were recorded in 1980's and 2002. At present, spawning approaches reduced.

In June of 2003 in the study area (46°37´55 N, 142°54´13 E. – 46°37´02 N 142°56´34 E) capelin roe was registered practically everywhere (except zone J), both on the dried littoral zone and lower the coast line. In 2004 roe was found in zones A-G (in zones H and I capelin roe was not found). In June of 2005, in close vicinity from LNG Plant roe was found in zones A, B, C, D. Spawning intensity during study years was low, averaging 0,432; 0,0692 and 0,0004 mln.pcs/$m^2$, respectively. Total spawning area (areas with roe) was 22750, 41850 и 4200 $m^2$, respectively.

## 4.6. POLLUTANTS CONTENT IN FISH

Tissue of fishes is taken for analysis of Ttoal Chlororganic Pesticides (ХОП), Metals: Cd, Cr, Cu, Fe, Hg, Pb, Zn, As, Mn and Oil Hydrocarbon(HC)
.

Tissue and organs of fish near bottom are taken (*exagrammos stelleri, Myoxocephalus jaok, Pseudopleuronectes schrenki*).

### 4.6.1. Organochlorine pesticides (OCP)

OCP content in fish tissues varied from 0,0006 to 0,242 mg/kg of dry mass and was higher than in seaweed and invertebrates.

Organs of all fish species by OCP accumulation level were in the following order: liver>gonads>muscles. The most pesticides were found in all organs of female frog sculpin, collected at 0-4m depth. The minimal accumulation of pesticides in all organs was observed at Limanda schrenki males from 10-15m. The obtained OCP accumulation levels reflect sex and species differences.

Comparison with hygienic normatives showed that obtained values did not exceed permissible levels.

#### 4.6.2. Total PH content

Total PH content in fish tissue varied from < 0,05 to 131 mg/kg of dry mass. Maximal values were noted in liver of male Limanda schrenki, though PH concentrations in gonads and muscles of this sample were less than the detection level.

PH content in tissue is not regulated by normative documents.

#### 4.6.3. Metals

Practically all fish had maximal levels of metals accumulation in liver, in muscules – minimal.
Comparison with MPL showed excess of Maximal Permissible Level of some elements in fish tissue: cadmium amd lead were higher than MPL in liver of sculpins; arsenic in gonads of all species.

### 4.7. Haloplankton

#### 4.7.1. Phytoplankton

According to the stydy results in August of 2003 218 species and intragroup taxons of microalgae of plankton, belonging to eight groups were found: diatom Bacillariophyta (119 species and intragroup taxons), Dinophyta (84), Chlorophyta (4), Cryptophyta (3), Cyanophyta (3), Chrysophyta (2), Rhaphydophyta (1), Euglenophyta (2).

Frequency of occurrence: Diatom *Cocconeis scutellum* Ehr.(100% occurrence) and *Leptocylindrus minimus* Gran (96%), cryptophyte *Plagioselmis punctata* Butch. (100%), *Pterosperma cristatum* Schiller (93%), dynophyte *Amphidinium larvale* Lindem. (93%), *Gyrodinium flagellare* Shill (90%).

Marine and fresh water species prevailed in species composition. Brackish water forms were of considerable amount.

Average number of cells and biomass in the study area (excluding dumping area) amounted to 100,555 thous.cell/l and 237,92 mg/m$^3$ respectively. The maximal average values of quantitative characteristics were registered near MOF (145,085 thous.cell/l and 330,728 mg/m$^3$) and LNG Jetty (419,293 mg/m$^3$).

Analysis of vertical structure showed that distribution of quantity and biomass of phytoplankton in water column was random. On the average, population near surface exceeded that in near-bottom layer as much as twice owing to dominating development of cryptophyte and diatom flora. Biomass, on the contrary, was maximal near bottom, which was stipulated by availability of large dinophyte algae *Noctiluca scintillans* (Macart.) Kof. et Sw., which produced high biomass (703,402-1107,155 mg/m$^3$) near bottom at G2 area.

By population, the dominating role was given to diatom and cryptophyte species, by biomass – dinophyte. Several dominating species were discovered in the study area. Small cryptophyte *Plagioselmis punctata (*24-64% of total populaion), dominated through the whole water area by population; by biomass – big dinoflagellates *Noctiluca scintillans* (29-96% of total populaion). At some stations domination was by *Pseudonitzschia sp.* (30% of total populaion), *Gyrodinium flagellare* Shill (22%), *Prorocentrum minimum* (Pav.) Schill. (20-25%) and *Leptocylindrus minimus* Gran (20-24%).

At dumping area 46 species and intragroup taxons of microalgae, belonging to five groups were registered. Dinoflagellates *Noctiluca scintillans* prevailed by species number (36 species), making up 78% of totalnumber of species. Other groups were presented by relatively small number of species: diatom Bacillariophyta - 11%, cryptomonad Cryptophyta – 7%, Chrysophyta and Chlorophyta – 2%.

Quantitative values of phytoplankton were low and varied within the following limits: population - 10,233–25,584 thous.cell/l, biomass – 19,068–178,555 mg/m$^3$.

So, the basis of phytoplankton community in the study area were of the neritic complex. 10 groups of species with similar areal type, dominated by cosmopolitans and boreal species.

Average values of quantitative characteristics of phytoplankton were low: biomass was 237,92 mg/m$^3$, cells population – 100,555 thous. cell/l. Zone G2 differed by the maximal values of quantitative characteristics. Diatom and cryptophyte were of great significance in formation of total amout of phytoplankton, but in biomass formation – dinophyte and diatom microalgae.

Comparing the study results of phytoplankton in April 2004 and May 2005 the following can be concluded:

1. Qualitative composition of microalgae in May of 2005 (76 species), compared to April of 2004 (74), practically remained unchanged. Main contribution in species diversity in 2005 was still made by diatom algae.

2. Quantitative characteristics of phytoplankton changed: average number of cells decreased twice – from 100 208 thous cell/l in 2004 to 53,93 thous cell/l in 2005; average biomass, on the contrary, increased twice – from 80.2 mg/m$^3$ in 2004 to 195,103 mg/m$^3$. In 2004 microalgae were concentrated in near-bottom layer and in 2005 – in surface layer.

3. Microalgae of diatom group played a dominant role in creation of population and biomass during two study periods. The main dominant specie was vernal diatom *Thalassiosira nordenskioeldii*.

### 4.7.2. Zooplankton

In 2003 near MOF dredging area at stations H1/10, H1/12, H1/15 (depths about 8m) 16 species of obligate plankton and meroplankton out of 7 systematic groups were detected. Most of the zooplankton community was formed by neritic copepods (69%). Two species of cladoceran were presented by 17% of their population. The community included considerable share of larva of benthic bristle worms of *Nephtyidae, Disomidae* and *Spionidae* families – 4 %, amounting to 290 spec/m$^3$. Besides polychates euphaisiids a few.juvenile and small Appendicularias were found. Integral meroplankton population reached 600 spec/m$^3$ (11%).

The trend in qualitative indexes increase from station H1/10 to H1/15 was observed in distribution of biomass and population.

Biomass and population averaged 155,06 mg/m$^3$ and 14595 spec/m$^3$ respectively. High quantity of zooplankton at station 15 was formed by cladoceran *Evadne nordmani*, copepods *Oithona similis* and nauplii of copepod.

Zooplankton community in the LNG Jetty water area was characterized by the limited number of species, which was stipulated by depths (10-12m) in sampling points. Despite small distance between the stations, considerable mozaic of plankton was noted, community was distributed through water area in the form of spots and stripes, which, probably, was determined by wave effect. The stations registered 5-fold differences in qualitative indexes.

In all, 15 species of zooplankton out of 6 taxonomic groups were detected in the samples. Half of all biomass fell on copepods – 51%, practically all species list was formed by massive neritic species – *Acartia hudsonica* (14%)*, Eurythemora herdmani* (8%)*, Centropages abdominalis* (10%)*, Pseudocalanus newmani* (1%), *O. similis* (16 %) and *O. plumifera* (1,5 %). Considerable fraction of biomass fell on cladoceran – 33 %, represented by two species – *Podon leucartii* (31%) and *E. nordmani* (2 %).

On the whole, 96% of community was formed by neritic species complexes. Other part fell on nektobenthic mysids.

Samples registered most fraction of meroplankton – larvas of echinoderm, gastropods and bivalve mollusks – up to 11% of total biomass, their total quantity reached 736 spec./m$^3$.

Average values of biomass and population were 307,68 mg/m$^3$ and 21446,94 spec./m$^3$ respectively. Rather high values of biomass at station 5 and population at stations 3 and 5 were caused by domination of cladoceran in the first case and copepods and meroplankton in the second.

In August of 2003 in the soil dumping point 15 species out of 5 systematic groups were specified. The maximum number of species (9) were counted in Copepoda among which were the forms massive for Sea of Okhotsk and Aniva Bay – P. newmani, O. similis, C. abdominalis, Acartia longiremis, Neocalanus plumchrus and others. In the sample point the mentioned spicies made up 78% of all community biomass. P. newmani – 39% dominated by biomass. Maximal population was characterized by O. similes – up to 6500 spec/m$^3$. On the whole, biomass of copepods was 139 mg/m$^3$ or 82% of all zooplankton community biomass.

Biomass of other groups was not so large, they were presented by only one-two species. By biomass after conepods there were coelenterates, presented by indeterminate juvenile

Propagation of some species of plankton community, presented by significant amount of juvenile copepod, euphaisiids, coelenterates and crustaceans eggs was recorded. About 11% of total zooplankton fell on juvenile species.

Total zooplankton biomass in the dumping point was 193,02 mg/m$^3$, population – 10960,83 spec./m$^3$.

Most of zooplankton biomass (52%) was concentrated on the upper active 10-m layer.

Comparing MOF and LNG Jetty water areas *N. plumchrus* and *T. Longipes* disappeared from species composition of zooplankton, quantitative values of *O. similes* were significantly less.

The mentioned values of quantitative parameters of zooplankton fit the results of other SakhNIRO studies, performed in the soil disposal area in summer months of 2003, but they were much less than the parameters, described in reference literature. For example, N. Fedotov defines average zooplankton biomass for Aniva bay as 350-500 mg/m$^3$, population – 1400 spec./m$^3$ (Fedotov, 1981, Kun 1975).

2004-2005. In spring the change of waters structure took place; water area was affected by southerly-okhotsky water masses, which was the reason for existence of rather specific species composition of zooplankton.

In April of 2004 zooplankton composition included 16 species out of 8 large systematical groups. The most diversified were copepods, even though they were of secondary importance by biomass. Arrow worms *Parasagitta elegans* prevailed by biomass, forming about 81% of all group biomass. Other groups were presented practically by singular specimens with relative biomass not more than 5% each. This relates to polychaete larvas necto-benthic mysids and specimens of ichthyoplankton (larval fish).

Copepods that traditionally abound in Aniva coastal waters, in April of 2004 were among secondary species. They were two species of open waters - *Pseudocalanus minutus* (1,7%) and *Neocalanus plumchrus* (1,4%) as well as number of species of neritic complex (0,3-1,7%). Moreover, tendency of cold water species domination was traced among copepods and among other groups.

**In May of 2005** the samples of net zooplankton showed 20 specimens out 6 systematic groups and copepods took a leading place as by species diversity and by quantitative characteristics. The group of copepods, counting 14 forms, including junior copepod and nauplial stages of massive small species, prevailed by biomass.

Copepods formed more than 90% of all net zooplankton biomass. Other groups were presented by 1-2 forms and were less than 10% by biomass.

Arrow worms that were abundant in 2004, were totally absent in 2005. This relates to bentho-nectic mysids and larval fish.

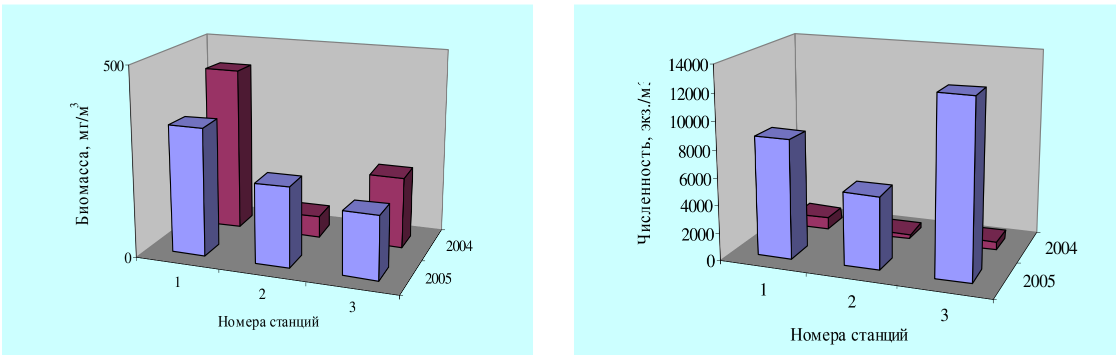
In May of 2005 *Neocalanus plumchrus,* practically completely was absent but it was substituted by *Calanus glacialis* with relative biomass about 5,5%. Among copepods wide-spread boreal species, encountered both in coastal, shelf and open waters of Sea of Okhotsk, prevailed and were characterized by stability to wide range of hydrological conditions (thermal and salt regimes): *Pseudocalanus minutus, Ps. newmani, Oithona similis*.

Specimens of neritic complex were encountered in large quantities, permanently present in catches of plankton nets practically year round, they are *Centropages abdominalis, Acartia hudsonica (=clausi), A. longiremis, Eurytemora herdmani.* As a rule, this complex prevails during major water warm up.

For all zooplankton community, average population in April of 2004 was altogether 614,23 spec/$m^3$, but in May of 2005 it was notably higher and reached 8934,5 spec./$m^3$ (fig. 4.6.2.1).

Average biomass as zooplankton density, increased in May, though its rise was less than amplification of planktons. It was associated with the fact that in April of 2004 the basis of biomass was formed by large-sized arrow worms (l ≈ 15-21 mm), in May of 2005 most of samples were composed of small-sized species and copepods larvas.

One can say that change of dominating forms during the period under review took place in about second half of April – early May, changing from winter composition with domination of large-sized nobilous cold water forms to vernal with domination of early development stages of numerous invertebrates, including bottom ones.




A B

Fig. 4.6.2.1. Comparison values of zooplankton biomass (A) and population (B) in spring 2004-2005

In August zooplankton was in peak of its annual development – maximal values of biomass and population are typical for community.

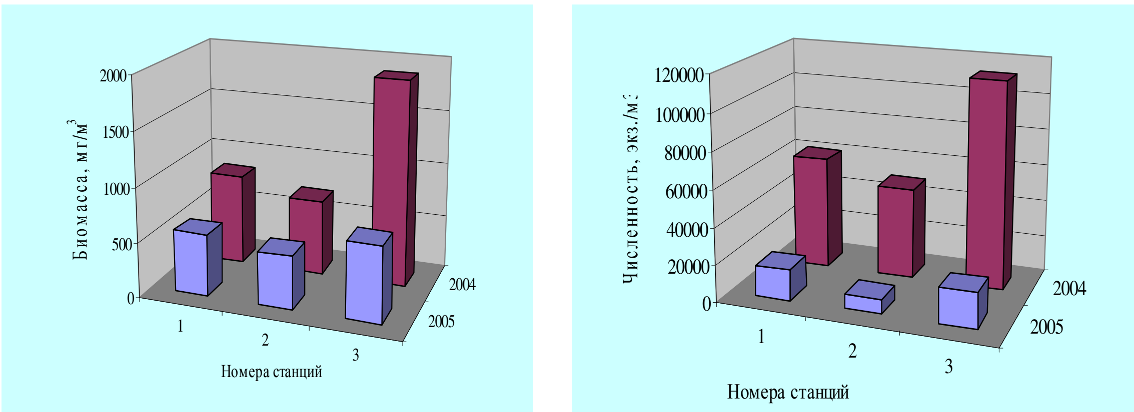
Zooplankton composition in August of 2004, mainly, was presented by copepods (9 specimens), that formed 83% of all group biomass; 60% of biomass formed 5 neritic species of *Acartia*, *Centropages* и *Eurytemora*, the remaining portion fell on open waters species – *Metridia okhotensis*, *Pseudocalanus newmani*, *Oithona similis*. *Acartia hudsonica* (25%) and *Centropages abdominalis* (20%) prevailed by biomass. The first specie also took the lead by population (19266 spec./$m^3$), in addition, copepods juvenile (14133 spec./$m^3$) and *O. similis* (12266 spec./$m^3$) were highly populated at this period.

As in August of 2004 copepods were variously presented with total number of species – 17 in 2005. Zooplankton composition, compared to the spring of 2005, largely expanded as for species and for taxons. Number of species reached 32 and taxons – 13. Besides, compared to August of 2004, as many as 2 times more forms in species composition were registered.

Core of community by biomass were formed by three neritic species of copepods *Acartia hudsonica, A. tumida, Centropages abdominalis,* by population – two species - *Acartia hudsonica, Oithona similes.*

In August of 2005 zooplankton biomass was about two times less than in August of 2004 and averaged 580, 1 mg/$m^3$ with small variations between stations (483,9-690,5 mg/$m^3$). Quantitative characteristics of zooplankton in August of 2004-2005 are shown in fig. 4.6.2.2.

On the whole, special changes in species composition of zooplankton, compared to the previous years studies, were not discovered. Main species kept their dominating role as for population and biomass, but absolute and average values were much higher in 2004, compared to 2003 and 2005.




A B

Fig. 4.6.2.2. Comparative values of zooplankton biomass (A) and population (B) in August of 2004 and 2005

### 4.7.3. Ichthyoplankton

In 2003, at MOF area, according to the vertical catches in water column from bottom to surface, the net IKS-80 found only Pacific anchovy roe *Engraulis japonicus*. Roe quantity averaged 2.31 spec./m$^3$.

According to the horizontal catches by plankton trawl number of ichthyoplankton species on the area increased to three species and number of forms – to four. In the surface layer roe and larva of Pacific anchovy averaged 0,43 and 0,78 spec./m$^3$, respectively, Alaska dab roe *Limanda aspera* averaged 0,43 and 0,78 spec./m$^3$ and larva of Alaska greenfish *Hexagrammos octogrammus* averaged 0,04 spec./m$^3$.

At LNG Jetty area two species were recorded: roe and larva of Pacific anchovy averaged 4,32 spec./m$^3$ and 5,83 spec./m$^3$ respectively and Alaska dab roe averaged 17,28 spec./m$^3$.

In 2003, in the dumping and MOF areas, ichthyoplankton was presented only by anchovy roe. Contrary to coastal zones this area differed by the elevated concentration of Pacific anchovy roe, which was quite typical, considering the fact that anchovy spawning areas were limited to seaward areas. Roe quantity reached there 276,02 spec./m$^3$.

LNG and MOF areas differed little in average total density of ichthyoplankton. Density variations were within 1,38 to 1,86 spec./$m^3$. Dumping area differed enormously from coastal zone in elevated ichthyoplankton concentration, averaging 14,8 spec./$m^3$.

**Dumping area**, unlike the coastal areas, differed in the elevated concentration of Pacific anchovy roe, which was quite typical, considering the fact that anchovy spawning areas were limited to seaward areas. Roe quantity reached there 276,02 spec./$m^3$.

Pacific anchovy enters Aniva bay when water is warmed up and reproduces intensively here only for the last several years late in July-August.

Anchovy repeated spawning affected the structure of assembly of anchovy infancy in the dumping area, where the roe-corns at closing development stage were found together with the newly spawned roe-corns, as well as larvas up to 4 mm long of 2-3 days age.

In the dimping area roe at the 1$^{st}$ development stage, amounting 42%, prevailed among normally developing roe. Roe at the III development stage was present but its relative quantity was significantly less – 18%. Percentage ratio of roe at various development stages in the dumping area withessed the continuous intense anchovy spawning at the area. Survival capability of roe-corns, obviously, was low. Roe at the 4$^{th}$ development stage was absent, number of larvas was at low level. Fraction of anomalously developing roe-corns, on the whole, reached 37%. Most embryonal development defects (23%) was observed at the I$^{st}$ stage, when row was most sensative to external adverse factors.

The obtained results witnessed the most significant role dumping area in anchovy reproduction. Roe density at LNG and MOF areas was less. Larval fish of this specie, to the contrary, increased with depth reduction and at shallow LNG and MOF water areas larval fish quantity in 1 $m^3$ was maximum.

Alaska dab spawning takes place at shallower waters. The maximal roe density was registered at LNG area. At MOF area the density was less, though Alaska dab larvas were found only at this area. The dumping area, located some distance from coast, was probably, less suitable for Alaska dab spawning. At least, roe and larvas of Alaska dab during survey period were not detected. At the same time, the depth of 60m is not a limit to find Alaska dab roe. Its spawning takes place at depths from 12 to 60m (Biology and population dynamics, 1997). Roe-corns at early stages were found in Aniva bay at depths above 45 m, at later stages – up to 75-82m. (Pertsev-Ostroumova, 1961).

LNG and MOF water areas differed slightly in average total density of ichthyoplankton. Density variations were within the limits from 1,38 to 1,86 spec./$m^3$. Dumping area

LNG and MOF area differed little in average total density of ichthyoplankton. Density variations were within 1,38 to 1,86 spec./$m^3$. Dumping area differed enormously from coastal zone by elevated ichthyoplankton concentration, averaging 14,8 spec./$m^3$.

**In 2004**, compared to the same period of 2003, the species composition of ichtyoplankton complex in the nearshore area remained the same. Anchovy larvas density was higher – 0,21 spec./$m^3$, on an average. At the same time, in 2003 the anchovy dead roe-corns were not found in the catches, while in 2004 roe death rate reached 100%.

Lack of regular observations, registering the change of all environmental parameters, limited number of ichthyoplankton stations in the area give no way to state for sure what factors affected the roe survival – abiotic conditions changes or man-caused influence.

**In April of 2005** according to the horizontal catches ichthyoplankton was presented by four fish families: gadoids Gadidae, sculpins Cottidae, prickles Stichaeidae, halibuts Pleuronectidae. Most number of species belonged to sculpin family. Larvas of five species from this family were found in catches.

Spawning of three fish species was registered during surveys: Alaska pollack *Theragra chalcogramma*, flat-headed flounder *Hippoglossoides robustus* and starry flounder *Platichthys stellatus* (average roe quantity 0,07, 0,18 и 0,37 spec./$m^3$, respectively). Number of species, presented at larval stage of development, reached six.

Ichthyiolankton larvas of Arctic shanny *Stichaeus punctatus* dominated with relative quantity 44,46% and frequency of occurrence – 100%. Larvas quantity varied from 0,60 to 5,70 spec./$m^3$ and averaged 2,50 spec./$m^3$.

Total population of larvas of horned sculpin p. *Myoxocephalus* amounted to 42,68%. The maximum quantitative parameters were typical for plain sculpin *Myoxocephalus jaok,* encountered in 66,7% of catches. Relative quantity of these species larvas reached 32,0%, absolute quantity varied from 1,80 to 3,60 spec./$m^3$ and averaged 1,80 spec./$m^3$.

Larvas of snowy *Myoxocephalus brandtii* and frog sculpins *Myoxocephalus stelleri* were found less frequently. Their population in the area varied from 0,20 to 0,40 spec./$m^3$.

Species composition of vertical catches was not so abundant.

Compared to 2004, in 2005 total population of ichthyoplankton in the surface layer increased from 3,75 spec./$m^3$ (2004) to 5,62 spec./$m^3$ (2005). Total roe quantity in 2005 averaged 0,62 spec./$m^3$, larvas – 5.0 spec./$m^3$.

Considerable ichthyoplankton population increase took place in vertical catches (in 2004 total ichthyoplankton population in water column – 1,82 spec./$m^3$, in 2005 this value increased to 21,24 spec./$m^3$).

So, ichthyoplankton population in the surface layer increased in 1,5 times, in water column – 11,7 times.

Composition of dominating species remained the same. As in 2004, larvas of Arctic shanny and plain sculpin prevailed in ichthyoplankton in 2005. In 2004 relative quantity of larvas of both massive spacies in horizontal catches was at the same level (20% of total ichthyoplankton quantity), in vertical catches the larvas of the mentioned species were not found.

In 2005, in horisontal catches, relative population of shanny and sculpin also had close values – 44,46 % and 32,01%, respectively. In vertical catches the population of shanny larvas was significantly higher than the sculpin – 73,25 and 18,32%, respectively.

In August of 2005, in the surface layer, roe and larvas of seven fish species from 3 families were found in horizintal catches: anchovy Engraulidae, smelts Osmeridae and halibuts Pleuronectidae.

The halibuts family was presented by maximum species. Roe and larvas of five spacies of this family were found in the catches: Alaska dab *Limanda aspera*, longnosed flounder *Limanda punctatissima*, Sakhalin sole *Limanda sakhalinensis*, longhead dab *Limanda proboscidea* and arrowheaded flounder *Cleistenes herzensteini*.

Longhead dab roe reached maximum, amounting to 53,6% in ichthyoplankton. Roe catches at the stations varied from 17,33 to 19,83 spec./$m^3$ and averaged 12,39 spec./$m^3$.

Halibuts also prevailed at larval stage of development. Larvas of Alaska dab and arrow headed flounder dominated in the surface water layer (1,44 and 1,44 spec./$m^3$ on an average, respectively).

Besides flounder roe and larvas, roe and larva of anchovy *Engraulis japonicus*, intensively propagating in Aniva bay in recent years, were found in the surface layer. Compared to flounder roe, the anchovy roe didn't form any dense accumulations, but was found in 100% of catches. Maximal roe population didn't exced 2,39 spec./$m^3$, average in the surface layer – 1,37 spec./$m^3$.

Larva of shishamo smelt *Hypomesus japonicus* of 5,42 mm was registered only at one station.

Species composition of ichthyoplankton in vertical catches traditionally was not so abundant. Roe and larvas of longhead dab, roe of Sakhalin sole and larvas of Shishamo smelt were present in the catches.

Maximal relative quantity of Alaska dab roe was typical in vertical catches, averaging 3,50 spec./$m^3$, which was slightly higher than in the surface layer.

Besides Alaska dab roe, roe of long-nosed flounder and anchovy (1,23 and 0,21 spec./$m^3$, respectively) was found in water column. Relative and absolute roe quantity of these species were essentially lower than in the surface layer.

Anchovy and arrowheaded flounder larvas didn't form any large accumulations.

Substantional increase in species diversity and ichthyoplankton population were noticed in the area compared to August of 2004. In 2004 ichthyoplankton complex was formed by early development stages of two fish species only: anchovy roe and larvas and Alaska dab roe. At the similar period of 2005 number of species increased to seven, where five species of flounders were detected in the ichthtyoplankton composition. Three species of them (Alaska dab, arrowheaded and longhead flounders) propagated intensively in the study area. So, domination of anchovy roe and larvas, that was observed in previous years, was changed to domination of flounder roe and larvas.

Total ichthyoplankton population in the surface layer increased more than ten times, averaging 23,11 spec./$m^3$ against 2,22 spec./$m^3$ in 2004. In vertical catches the total ichthyoplankton population increased more than 12,5 times, averaging 8,44 spec./$m^3$. In 2004 this parameter didn't exceed 0,67 spec./$m^3$, on an average.

In 2005 total roe quantity in horizontal catches varied from 12,44 to 26,78 spec./$m^3$ (20,18 spec./$m^3$ on an average), in vertical – from 3,06 to 6,17 spec./$m^3$ (4,32 spec./$m^3$ on an average).

Larvas quantity in August of 2005 in the surface layer varied from 1,51 to 5,38 spec./$m^3$ (2,92 spec./$m^3$ on an average), in vertical – from 3,7 to 8,64 spec./$m^3$ (4,12 spec./$m^3$ on an average).

It should be noted that essential Alaska dab and anchovy roe mortality reduced in August of 2005. In 2004, roe mortality essetially increased, compared to 2003, and relative quantity of anchovy dead roe was 100%, Alaska dab – 50%. In 2005 this value for anchovy roe reduced to 2,7%, for Alaska dab roe – to 13,7%.

# 5. CONCLUSION

The complex ecological studies, performed in the period of 2003-2005 in the coastal waters of Aniva bay (Sea of Okhotsk) showed that soil dredging and dumping it outside territorial sea of Russian Federation didn't result in any adverse consequences for marine ecosystem and bioresources of the mentioned sea water area. The effect is assessed as local and short-term duration.

## 5.1. Sea water

### 5.1.1. Suspended solids

During execution of dredging works the maximum SS concentrations in water varied within narrow limits: from 26,7 to 29,6 mg/dm$^3$.

Considering the continuous operation of dredgers and shallowness of job site, higher and more stable levels of SS content in water were expected, compared to dumping case. However, according to the measurment results, there were no any substantional differences in ranges and average concentretions. Quick sedimentation of basic mass of coarse grained soil and quite quick spread of fine SS took place.

The obtained results of SS were within the range of SS propagation model, though they were slightly higher than background values.

Insignificant increase of SS concentrations were of local and short term character. At the same time the natural background level of SS for Aniva Bay was highly changeable (from 6,2 to 14,0 mg/l) with possible increases to 40-50 mg/l in the nearshore zone during storms.

According to SS distribution data, during soil disposal, dynamic process of quick SS distribution of in water layers occurred and quick sedimentation of basic mass of coarse and heavy fractions of soil at the discharge point was observed as well as quick transport and dillution of fine material (pelite) in the water column.

After soil discharge in the dumping area the levels of SS content in water reduced quickly up to background values, which was confirmed by the monitoring data. SS content during dumping varied within 11,4-35,4 mg/l. Average SS concentrations during soil dumping and directly at the dumping spot didn't exceed 20 mg/l.

In 2006 after dredging operations completion concentrations of SS in sea water of the studied areas were insignificant and lied within background values for Aniva bay.

SS distribution simulation evaluation during dumping, given in TEOC, are comparable with the obtained data.

Calculated and actual concentrations of SS cannot be the cause of mortality of organisms, dwelling in the water or cause irreversible damages of bottom communities in Aniva bay.

Space-time scale of SS effect to organisms in sea water is evaluated as local and short term.

### 5.1.2. Petroleum hydrocarbons

Dynamics of PH content in sea water against background level during dredging operations and after their completion showed that minimal PH concentrations were<0,005 mg/dm$^3$, which was less than the detection level. Maximal concentrations were 0,020 mg/dm$^3$, which was also less than background level for Aniva bay and did not exceed MPC for fishery water bodies.

Concentration of PH in sea water at the soil dumping before and during dredging operations didn't exceed background values for Aniva bay, on the whole.

Content of PH in the bottom water layer, compared to the surface sea water layer, was higher by average and maximal values.

## 5.2. BOTTOM SEDIMENTS

Pollution levels in the excavated soils, mainly, did not exceed the background values for Aniva bay and couldn't be a source of secondary pollutants in the soil disposal area.

### 5.2.1. Heavy metals

Gross content of heavy metals in bottom sediments depends on many factors, among which are: ratio of pollutants, coming from various sources; concentrations of pollutants in them, grain-size composition of sediments.

The important factor is the content of heavy metals in the erodiable rocks and onland soils.

That's why it is rather difficult to assess the input of natural and anthropogenic loads as well to judge about man-caused pollution of bottom sediments, therefore, currently, there are no MPC for heavy metals and organic pollutants in bottom sediments.

Background data on SS content in beach sediments of Aniva Bay are not available.

According to the results of the performed studies the metals in the areas of Aniva bay were distributed irregularly. Correlation dependances between grain-size fractions and metals content were noted.

Heavy metals content in bottom sediments didn't exceed approximate permissible level (APL) and the measured concentrations fall within the natural background and levels typical for coastal sea zones.

According to the obtained data, bottom sediments of the studied areas are considered unpolluted with heavy metals.

### 5.2.2. Polycyclic aromatic hydrocarbons (PAH)

PAH content in the excavated soil at the dredging areas didn't exceed background values for surface layer of bottom sediments in Aniva bay. Bottom sediments are referred to low polluted.

Near MOF area naphthalene and its methyl homologs (63,7% of PAH sum) prevailed among PAH, then followed phenanthrene (16,7% of PAH sum), therefore, specific ratios of naphthalene and phenathrene, specified in TEOC, were confirmed during their accumulation in bottom sediments from various onshore sources. Napthalene content didn't exceed MPC.

In the LNG Jetty area perylene, which is the polycyclic aromatic compound of natural origin and its domination with availability of fluoranthene, can speak well for the natural source of PAH ingress.

In the dumping area PAH content in the soils was also not high. Among PAH naphthalene (up to 9,2 mkg/kg of dry mass) was registered, the value of which doesn't exceed MPC and its methyl homologs (up to 6,0 mkg/kg of dry mass). Prevailing elements of PAH in the dumping circle center and outside it were the same.

The obtained values lie within background parameters for Aniva bay.

### 5.2.3. Organochlorine pesticides (OCP)

Quantitative value of OCP accumulation practically didn't change, practically remeined unchanged, qulitative – noticable changed. Concentration of Hexachlobenezene (HCB) increased and share of other compounds reduced.

Nevertherless, the value of HCB doesn't exceed MPC, developed for soils (30 mkg/kg).

On the whole, amount of OCP in the excavated soil was not too large and could not be a source of pollution of bottom sediments at dumping area.

Total OCP content in the dumping circle center was characterized by considerable concentration spreading, ranging within 0,015-1,88 mkg/kg of dry mass, averaging 0,445±0,719 mkg/kg. Spatial distribution of PH was nonuniform.

Average total OCP content at the control points, despite considerable spread of values, was three times less (0,228±0,193 mkg/kg) than at stations located in the dumping zone (0,661±1,057 mkg/kg).

In 2006, after dredging operations and soil disposal, total OCP content in bottom sediments was 0,03mkg/kg of dry mass, i.e. less than the values of previous researches and fall within background parameters for Aniva bay.

#### 5.2.4. Petroleum hydrocarbons

According to SakhNIRO reports (SakhNIRO report, 1998) and DVNIGMI (DVNIGMI Report, 2001), when analyzing spatial distribution of PH in bottom sediments, the zones in the west and east out with high natural content of PH in bottom sediments at the dredging area were pointed depending on their type and chemical composition.

The analytical studies of bottom sediments during dredging operations confirmed that fact.

Before works commencement and upon their completion, the highest concentrations of PH were determined in the west of the area (station 3, muddy soil, PH content – 16,2 mg/kg), in the east (station 1, muddy soil, PH content – 10,7 mg/kg of dry mass) and in the center of dredging (station 5, muddy soil, PH content – 36,6 mg/kg of dry mass).

Generally, the obtained results of total PH content in bottom sediments after dredging operations were comparable with background data for Aniva Bay.

Obvious signs of sea bottom pollution with petroleum hydrocarbons were absent.

So, soils, excavated during dredging operations at the LNG jetty area could not be PH pollutants of sea bottom and water layer at dumping area.

Average value of PH concentrations in bottom sediments in the soil dumping area was 13,1 mg/kg of dry mass and was close to background and at the same time was less than the control samples area – 15,1 mg/kg of dry mass. Spatial distribution of PH was nonuniform.

In 2006, after soil disposal, concentrations of total PH content in bottom sediments in the dumping circle center, were comparable with background values for Aniva bay.

So, the measured concentrations of widely spread pollutants in sea water and bottom sediments at the soil dredging and dumping areas fall within the limits of the natural geochemical background and the levels, typical for coastal zone when the sources of local pollution are absent.

Soil dredging and dumping didn't result in any significant excess of pollutants content in sea water and bottom sediments.

Overwhelmingly, the content levels of the studied substances did not exceed the normatives of ecological-fishery MPC for sea water.

### 5.3. Benthos in zooplankton

#### 5.3.1. Benthos in the dredging area

Data for bethos distribution in August of 2003 near s. Prigorodnoye differed highly from reference literature data and archival data of SakhNIRO 1998.

During studies in September of 1998 near s. Prigorodnoye SakhNIRO registered different types of soils on the studied area.

Mosaic structure of soils in the study area had an effect on zoobenthos distribution.

Silty components were widely present on the sandy soils with different admixtures of pebble, gravel, rocks. This, in turn, explains the domination of polychaete worms, bivalve mollusks, amphipods, the basic mass of which are collecting detritophags or soilphages, preferring relatively soft soils.

Two main communities of macrobenthos were pointed out: community of *Lumbrineris heteropoda+Yoldia toporoki* and community of *Archaeomysis japonica*.

The former was observed at a depth of 6-27m depth, on sandy-pebble – sandy-silty soils. The latter was registered near coast line.

In August of 2003, before dredging at LNG and MOF water areas, two major background communities of zoobenthos with the belt type of distribution were widespread at MOF and LNG water areas. Community of *Scoloplos armiger* (polychaete) was observed within 7-10 m depth lines, community *Cryptobranchia kuragiensis* (gastropods) changed it with the depth.

Mosaic structure of soils distribution and, respectively, benthos communities, remained the same after works completion, which was confirmed during further studies in 2003-2005.

After dredging completion at MOF area the expected change of soft soils biota with domination of bristle worms to fouling biota was observed. However, benthos abundance (population density and biomass) were slightly higher than those of 2003 but quantity of discovered species was little less.

Less species of benthos with population close to average and big biomass, compared to background, were observed after dredging at the LNG jetty area. In addition, incomplete change of species composition and structure of bottom community was registered (unlike MOF water area). Probably, it can be referred to the changes of bottom sediments composition, caused by dredging.

So, the changes in the structure and abundance of benthos were observed at the MOF and LNG Jetty water areas after dredging. This fact can reduce insignificant shortening of the species list of benthos under parallel increase in abundance indexes - population and biomass.

With this, the role of polychaete worms, which is a structure-forming group in the bottom community at the background stage, reduced and the role of gastropods and fouling species increased.

### 5.3.2. Benthos and zooplankton in the soil dumping area

Hydrobiological researches in the soil dumping were caried out in order to:

- itemize prediction estimates of damage due to hydrobionts affection extent, while being in water with various suspended particles concentration,
- study of regenerative process of the destroyed or formation of new biotic communities (benthos).

#### 5.3.2.1. Benthos

In August of 2003 and October of 2004 background studies at dumping area showed that polychaete and sipunculoid worms were the dominating groups in the water area.

In December of 2004, after soil dumping commencement, the bottom community structure changed – polychaete abd sipunculoid worms were replaced by bivalve mollusks.

Bivalve mollusks *Nuculana pernula pernula* were the dominating group (87,6% of total biomass). Polychatete *Lumbrineris heteropoda* were most abundant among other species (5,2% of total biomass).

Number of macrobenthos species, discovered during background studies in August of 2003 was 36, in October of 2004 – 7, after soil dumping in december of 2004 – 35.

In December of 2004, after soil disposal commencement, average organisms population in the dumping area amounted to 74 spec/m$^2$. This value was less than background data in August of 2003 (200 spec/ m$^2$, 53,7 g/m$^2$), but more than in October of 2004 (13 spec/ m$^2$).

In August of 2005 distribution of bottom hydrobionts population through water area didn't discover any trends: minimal and maximal values were recorded both near dumping point and some distance from it.

Distribution of biomass of separate groups at stations was highly similar with that for 2004: considerable biomass of sipunculoid worms at the maximum distant western point, increase in biomass of *Nuculana pernula pernula* eastward from dumping point.

Maximum of biomass was registered in point, located 2000 m westward from dumping point. It was formed by sipunculoids and polychaete worms. That's why the bottom community at this station can be characterised as predumping.

Bivalve mollusks *Nuculana pernula pernula* prevailed at the stations, located eastward of dumping point as well as 2000m southward and northward from it. Respectively, postdumping community was observed at this water area.

So, benthos during soil dumping differed by rather high diversity and high quantitative parameters. Bivalve mollusks *Nuculana pernula pernula* prevailed eastward, northward and southward of dumping point. Westward – sipunculoid worms prevailed. In August of 2005 similarity of abundance parameters, including species list, with background stage data was noted.

On the whole, influence to the bottom biota in 2005 as in December of 2004 in the dumping area was less disastrous, than it was expected.

In August of 2006, in the soil dumping area, typical postdumping community of macrobenthos with domination of bivalve mollusks was registered.

Rather high biomass values (from 13 to 30 g/m2) were observed within 300m radius from dumping point, which can be regarded as a result of gradual recovery of bottom biota after soil disposal. Recovery of qualitative hydrobionts composition, typical for predumping monitoring stage, confirmed this fact as well.

At that, average biomass within 300m radius from dumping point was 17,5 g/m2, which was much higher than values of May and August of 2005.

On the whole, soil dumping influence to the bottom biota was less disastrous, than it was expected and recovery to the initial condition goes rather quickly.

Gradual recovery of bottom biota in the soil dumping water area was noted less than 1 year after soil dumping.

Typical postdumping community of macrobenthos with domination of bivalve mollusks Nuculana pernula pernula was registered, i.e. new biotic community withy higher biomass, compared to predumping community, which was depauperated by species composition.

Bottom community is in active syngenetic phase.

### 5.3.2.2. Zooplankton

During soil dumping on September 28, 2005 low zooplankton mortality (less than 1%) was registered 400 m from dumping point. The highest zooplankton mortality rate – 0,84% by population and 0,89% by biomass was recorded northward at a depth of 20 m. The less impact was recorded 800m from dumping point.

Maximal SS concentration at a depth of 20 m was 7,2 mg/dm$^3$, which could not make a significant effect on zooplankton mortality, since fishery normative of MPC for SS for shelf zone of seas is 10 mg/l, i.e. concentration of SS was less than the permitted value.

Since only one sample was collected in every studied direction and distance, it is rather difficult to speak about stable trend or just about real picture of plankton distrubution and death values after dumping, therefore additional researches are required.

Any stable irreversable damages of zooplankton at local rises of SS background in sea are excluded, owing to adaptational capacities of zooplankton organisms: short life cycle, high rate of reproduction, vertical migrations, vast areals, distribution by currents and others. Therefore, one should expect quick biomass recovery in the soil dumping area.

## 5.4. COMMERCIAL AND PLANKTON ORGANISMS CONDITION DURING SOIL DREDGING AND DUMPING OPERATIONS IN ANIVA BAY

### 5.4.1. Massive commercial invertebrates distribution

According to specialized diving monitoring researches during 2003 (background), 2004-2005 for distribution of massive commercial invertebrates *Mizuhopekten yessoensis (*bivalve mollusks – Japanese scallop), *Strongylocentrotus intermedius* (echinoderm – grey sea urchin), *Cucumaria japonica* (holothuria – japanese cucumaria) near s. Prigorodnoye, Aniva bay.

- ✓ Changes in distribution and biological parameters of Japanese scallop are within the limits of natural fluctuations in terms of population and biomass, mollusks reserves remain at the same level (in 2005 about 0,85 t compared to 0,73t – in 2004 and 2003).
- ✓ Increase in noncommercial size species of grey sea urchin and cucumaria in 2005, compared to 2004, wgich vidences about relatively favorable conditions for sea urchin juvenile and cucumaria development.
- ✓ Changes in distribution and biological parameters of Japanese scallop and cucumaria are within the limits of natural fluctuations in terms of population and biomass.

According to trawling surveys in 2005 frequency of occurrence (33,3%) of commercial species:

- ✓ Kamchatka crab *Paralithodes camtschaticus* was registered at two stations which corresponds to the level of 2003 and 2004.
- ✓ *Telmessus cheiragonus* was found in 2005 in one specimen at one station. In 2003 and 2004 this specie was of widespread occurrence: in 2003 – at two stations by one specimen. In 2004 this specie was found at four stations. Spread of this specie in Aniva bay is characterized by unity occurrence.

### 5.4.2. Species composition, community structure and benthos distribution

In 2003-2005 according to diving surveys showed that during the previous two years some changes in qualitative and quantitative composition of bottom communities in the nearshore of LNG Plant took place.

- ✓ decrease in species composition of macrobenthos in 2005 was registered from 38 (in 2003) to 28 (in 2005). Quantity of taxonomic groups decreased from 13 (in 2003) to 10 (in 2005). In 2005 species of some taxonomic groups were absent in the samples: *Ascidiae, Cephalopoda, Ophiuroidea.*
- ✓ out of dominating taxonomic groups in 2003-2004: *Asteroidea* and *Echinoidea and Bivalvia* (bivalve mollusks), stable biomass condition before study in 2005 were kept only by *Bivalvia.* Mass fraction of groups decreased greatly. As for *Echinoidea* this is related to total absence of flat urchin in 2005.
- ✓ Biomass of Loricata (chitons) in 2005 slightly rediced in comparison with 2003-2004, due to this fact the group became the third out of the taxons, dominating by biomass.

According to the monitoring studies in Aniva bay, distribution of massive commercial invertebrates remain within the limits of natural fluctuations in terms of population, species composition and distribution in dredging and dumping areas.

Benthos communities are in active syngenetic recovery phase.

### 5.4.3. Pollutants content

**Pollutants researches –** total content of organochlorine pesticides – DDT and HCCH (OCP), petroleum hydrocarbons (PH), heavy metals (Cd, Cr, Cu, Fe, Hg, Pb, Zn, As, Mn) at depths 5, 10, 15 m in massive benthos representatives – echinoderms (gonads of grey sea urchin *Strongylocentrotus intermedius* and dermomuscular tubes of Japanese cucumaria *Cucumaria japonica)*, bivalve mollusks (muscle of japanese scallop *Mizuhopecten yessoensis*), sea weed (stems and leaves of *Zostera asiatica*), and red algae (*Phycondrys vinogradovae*) showed that:

- ✓ total content of OCP in hydrobionts in 2003-2005 didn't exceed Maximal Permissible Level (MPL) by hygienic normatives. OCP quantity in algae were within 0,00026-0,00179mg/kg of dry mass, in invertebrates tissue - 0,00022-0,00045 mg/kg of dry mass
- ✓ PH concentrations in August of 2005 in invertebrates tissue were considerably less than in 2003-2004, in macrophytes – less than in 2004, but more than in 2003. PH in invertebrates bodies varied from 0,2 to 3 mg/kg of dry mass, in macrophytes – from 37 to 70 mg/kg of dry mass. There were no any considerable changes in PH content for the period from 2003 to 2005.
- ✓ Concentrations of metals in invertebrates tissue in August of 2005 didn't exceed MPL even for dry mass (Hygienic normatives of metals content in hydrobionts, SanPIN 2.3.2.1078-01).

### 5.4.4. Specialized studies of the species composition and coastal ichthyofauna distribution

During a study period 57 species of fish out of 24 families were found. Studies of 2005 broadened the species composition: 10 new fish species, earlier absent in cathes, were found. They are: pond fish (found in small trawl), Bering poacher, yellow Irish lord, banded Irish lord, Stichaeus nozawae, stippled gunnel, blackline prickleback, Sakhalin sole, crested sculpin (catches of bottom trawl), Alaska pollack (midwater trawl).

15 species disappeared from catches but found in 2004.

Seasonal variation in distribution of some species was fixed:

- catches were lack of salmon producers, but juvenile fishes of this specie were found.
- autumn catches were lack of capelin as the season of its propagation finished and it moved from shore to open water areas.
- other species were relatively rare and their availability in the catches was rather casual.

In zones E and C in 2004, 2005 longnosed flounder *Pleuronectes punctatissimus,* Okhotsk snailfish *Liparis ochotensis* were not registered in the catches.

In zone A population and biomass were formed by migratory and semidiadromous fish. Absence of marine bottom fish was because of sea water conversion by fresh waters of Mereya river.

Fish distribution in water area during study years depends on the mass fish approach to Sakhalin coast, which is reflected in fish species composition yearwise in Aniva bay.

***Накопления в органах и тканях рыб загрязняющих веществ***

Studies in 2003-2005 (bottom dwelling fish - whitespotted greenling *Hexagrammos stelleri*, plain sculpin *Myoxocephalus jaok,* Limanda schrenki *Pseudopleuronectes schrenki)* for accumulation in fish organs and tissue of the OCP sum, metals: Cd, Cr, Cu, Fe, Hg, Pb, Zn, As, Mn and petroleum hydrocarbons showed that:

- ✓ OCP content in fish tissues varied from 0,0006 to 0,242 mg/kg of dry mass and was higher than in seaweed and invertebrates. Comparison with hygienic normatives didn't show the excess of the permissible levels for OCP content.
- ✓ Total PH content in fish tissue varied from < 0,05 to 131 mg/kg of dry mass. Oil products content in organisms is not regulated by russian documents. Maximal values were noted (the same as for metals) in fish gonads and liver, i.e. in organs, containing maximum fat. PH content increase in fish gonads and liver in 2005 against 2003 data was noted.
- ✓ maximal levels of metals accumulation were registered in liver of practically all fish, in muscules – minimal. Excess of hygienic normatives (MPL) was registered for cadmium and lead in liver of sculpins; arsenic in gonads of all species.

Continuation of monitoring studies is required to detect the reasons for

MPL excess of pollutants in tissue and organs of specific species of fish.

**5.4.5. Studies of the quantitative distribution of bottom roe and larva of dominant fish (capelin, herring).**

During studies on the spawning grounds in 2003, 2004, 2005 as well as before, starting from 1980 to the present, herring roe was not found due to lowherring population near southern Sakhalin coast.

Capelin roe on the spawning grounds is also related to capelin population approach to coast. In June of 2003 in the study capelin roe was registered practically everywhere (except zone J), both on the dried littoral zone and lower the coast line. In 2004 roe was found in zones A-G (in zones H and I capelin roe was not found). In June of 2005, in close vicinity from LNG Plant roe was found in zones A, B, C, D.

Spawning intensity during study years was low, averaging 0,432; 0,0692 and 0,0004 mln.pcs/$m^2$, respectively.

Total spawning area (areas with roe) was 22750, 41850 и 4200 $m^2$ respectively, which was due to fish approach reduction to Sakhalin coast.

## 5.5. HALOPLANKTON

### 5.5.1 Phytoplankton

The main reason of impact to phytoplankton (as well as to mictophytes) is the deterioration of light conditions for photosynthesis in the areas of water clouding. (However, rather high resistance of brown algae and other macrophytes, habitant in seashore under the conditions of continuous water turbidity, to high SS concentration was recorded).

With rather low SS levels in water, from 20-30 mg/l, phytoplankton reacts quickly by reduction of photosynthesis and primary production.

Unicellular algae with high division rate are also capable to recover their biomass quickly and population under reduction of adverse effects.

Comparing the results of phytoplankton study the following can be concluded:

- Qualitative composition of microalgae practically was not changed. The main contribution to species diversity was made by diatomic algae as before;
- Quantitative characteristics of phytoplankton changed: average number of cells decreased twice, average biomass, on the contrary, increased twice.

Study of phytoplankton in 2003-2205 in Aniva bay characterize the changes of quantitative parameters and qualitative composition of phytoplankton. The parameters are related, mainly, to the changes of hydrological and hydrochemical conditions (current directions, water temperature, illumination, salinity, biogenic elements etc.) in different years and seasons.

### 5.5.2. Zooplankton

On the whole, no specific changes were detected in species composition of zooplankton, compared to the previous study years, the primary species retained their dominating role both in population and biomass, but absolute and average values of these parameters were much higher than in 2004, compared to 2003 and 2005.

#### 5.5.3. Ichthyoplankton

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Substantional increase in species diversity and ichthyoplankton population were noticed. In 2004 ichthyoplankton complex was formed by early development stages of two fish species only: anchovy roe and larvas and Alaska dab roe. At the similar period of 2005 number of species increased to seven, where five species of flounders were detected in the ichthtyoplankton composition. Three species of them (Alaska dab, arrowheaded and longhead flounders) propagated intensively in the study area. So, domination of anchovy roe and larvas, that was observed in previous years, was changed to domination of flounder roe and larvas.

Total ichthyoplankton population in the surface layer increased more than ten times. In vertical catches the total ichthyoplankton population increased more than 12,5 times. It should be noted that essential Alaska dab and anchovy roe mortality reduced in August of 2005.

Thus, the soil dredging and dumping operations in Aniva bay didn't reveal any noticeable mortality of plankton organisms or other irreversible disturbances of plankton communities. Minor disturbances in plankton community shall be evaluated as reversible and weak and the impact scale during work execution as local and short-term.

As a whole, the results of ecological monitoring performed in 2003-3005 showed that the actually monitored changes in the elements of sea ecosystem (environment and bioresources), under dredging and dumping operations impact, did not exceed the predictive assessments and, frequently, were less essential.

## 6. REFERENCE LITERATURE

1. Conclusion of GEE for TEOC “Integrated development of Piltun-Astokhskoye and Lunskoye licence areas. Sakhalin II Project”, approved by the Order of MNR of Russia # 600 as of July 15, 2003.
2. Addendum F. Fish stocks damage evaluation due to soil dredging and dumping operations in Aniva bay in 2003-2005. Sakhalin II Project, Phase 2. M. 2003.
3. Addendum F.2. Suspended solids and bottom sediments spreading simulation during soil dredging and dumping operations in Aniva bay in 2003-2005. Sakhalin II Project, Phase 2. M. 2003.
4. VNIRO. Background ecological-fishery characteristics of offshore zones and river basins of the western and eastern shelfs of Sakhalin. - Scientific report. VNIRO, 1997.
5. I. Nemirovskaya. Hydrocarbons in ocean. Scientific world. 2004.
6. S. Patin. Ecological problems for development of offshore shelf oil and gas resources. VNIRO, 1997.
7. S. Patin. Man impact to marine environment and bioresources: methodology of evaluations and present-day situation// Collected works of MGU (Moscow State University). M: Publ.House of MGU, 2004.
8. The list of fishery normatives: Maximum Permissible Concentrations (MPC) and Safe Reference Levels of Impact (SRLI) for harmful substances for water of fishery water bodies. VNIRO, 1999.
9. PNDF 14.1.2.4.140-98 (TM).
10. PNDF 14.1.79.96 (pesticides).
11. FSUE “SakhNIRO” Report. Environmental monitoring for fishery purposes (13.8). Book1. Description of research results. SakhNIRO. Yuzhno-Sakhalinsk. February, 2003, 2004, 2005
12. FSUE “SakhNIRO” Report. Monitoring of hydrobionts communities and environment during dredging (13.3). Book1. Description of research results. SakhNIRO. Yuzhno-Sakhalinsk. February, 2004, 2005, 2006.
13. FSUE “SakhNIRO” Report. “Goluboy brook and Mereya river”. Book1. Description of research results. SakhNIRO. Yuzhno-Sakhalinsk. February, 2005, 2006.
14. Pacific engineering company. Report. Bathymetric survey, Aniva bay. Peco, Yuzhno-Sakhalinsk, December 2005.
15. LLC “Ecoterra Co, Ltd” Report “Impact to environement due to movement and dumping of the excavated soil in Aniva bay, performed in 2003-2005”, Moscow, 2005.
16. FSUE “SakhNIRO” Report. “Additional ecological monitoring during dredging operations at LNG Plant births and soil dumping in January-April of 2005». Book1. Description of research results. SakhNIRO. Yuzhno-Sakhalinsk. June, 2005.

17. FSUE “SakhNIRO” Report. “Additional ecological monitoring during dredging operations at LNG Plant births and soil dumping in August of 2006». Yuzhno-Sakhalinsk. October, 2006.
18. FSUE “SakhNIRO” Report. “Additional soil analyses to determine pollutants at the dumping area. Yuzhno-Sakhalinsk, February, 2006.
19. FSUE “SakhNIRO” Report. “Additional ecological monitoring during dredging operations at
LNG Jetty area and soil dumping in April and August - November of 2005». Yuzhno-Sakhalinsk. February, 2006.
20. FSUE “SakhNIRO” Protocols of Quantitative chemical analyses (QCA):

- ✓ № 126 as of April 10, 2006. Sea water. Bottom sediments. Suspended solids, grain-size composition. LNG Jetty area
- ✓ № 126-1 as of July 17, 2006. Sea water. Bottom sediments. LNG Jetty dredging area
- ✓ № 126-2 as of July 11, 2006. Bottom sediments. Heavy metals. LNG Jetty area.
- ✓ № 128 as of April 10, 2006. Sea water. Suspended solids. Dumping area.
- ✓ № 128-1 as of April 25, 2006. Bottom sediments. grain-size composition. Dumping area.
- ✓ № 128-2 as of May 25, 2006. Sea water. Bottom sediments. Oil products. Dumping area.
- ✓ 128-3. Bottom sediments. Heavy metals. Dumping area.
- ✓ № 144 as of April 30, 2006 Bottom sediments. PH, PAH, OCP. Dumping area.