Benthos community of a dumping area during liquid natural gas plant construction: Effects of technical impacts or natural changes?

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Introduction

According to the technical-economic substantiation (TES) of the Project "Sakhalin-II. Phase 2", two marine exploration platforms were constructed in the Lunskoye and Piltun-Astohskoe oil-gas fields, and were connected by pipelines to an oil terminal in Aniva Bay (south coast of Sakhalin island) for year-round exploration. Another aspect of the Project involved a liquefied natural gas (LNG) terminal and material operations facilities (MOF) to be added to the LNG plant that was built in 2003–2006 on the Aniva Bay shore near the settlement of Prigorodnoye.

A dredging operation needed to be carried out in the area of the LNG terminal and MOF beforehand in order to provide safe entry and mooring for ships. The dumping of dredged ground was approved in Aniva Bay outside of the 12-mile zone where water depth was 60–65 m. The Project also included comprehensive environmental monitoring.

The purpose of this research was to observe marine biota and the environment in the dredging and dumping areas in Aniva Bay. One of the main monitoring tasks was to estimate the impact of dumping on the benthos community and to forecast the time needed to restore its original abundance and structure in the affected area.

The Sakhalin Research Institute of Fisheries and Oceanography conducted research based on the Agreement with CTSD Ltd. Company. The schedule of observations included the following phases: before dredging, during the dumping, and after the work was completed.

Materials and Methods

Benthos was sampled in August 2003 – before any ground dumping; in October and December 2004, in May and August 2005 – during the operations; in August 2006 and August 2007 – after all the work had been completed. Sampling stations were located at 300, 800 and 2000 m off the central dumping point (coordinates 46°24.5′ N latitude and 142°55.0′ E longitude) to the north, east, south and west. Benthos was sampled from the R/V *Dmitry Peskov* using a Van-Veen grab (0.2 m^2).

The following structure indices and coefficient were used for the assessment of state and comparison of benthos communities:
1. Index of diversity (Shennon),
2. Index of cenotic similarity (Shoener),
3. Species similarity coefficient (Serensen),
4. Community succession index (ABC-method).

Results

Dredging and dumping operations were carried out from March until the middle of May and from mid-September until December to lessen the impact on the environment and biological resources.

In August 2003, before the dumping operation began in the described area, the bottom community was surveyed and a dominance of sipunculids (*Golfingia margaritacea*) and a significant number of polychaetes (*Axiothella catenata*, *Praxillella* spp., *Prionospio* sp.) were observed. There was also a high abundance of amphipods and cumaceans. Average benthos biomass was 53.7 g/m^2 (Table 1).

In December 2004, after the first phase of dumping, the number of species and their abundance was the same as in 2003 and high due to small crustaceans, but mean biomass was about half as much (Table 1). The bivalve *Nuculana pernula pernula* dominated in most of the area. Therefore, this type of community could be considered an indicator of dumping.

In August 2005, the mean benthos biomass was high, reaching 48.6 g/m^2 (Table 1); most of the biomass (71%) was formed by sipunculids. Almost all of sipunculid biomass (413 g/m^2) was accumulated at the station located 2000 m west of the central dumping point (figure not shown). The benthos community here can be characterized as refugial, that is, recovering to the pre-dumping state. At the rest of the stations, the sipunculid biomass was close to zero, and the total benthic biomass did not exceed 36 g/m^2. In August, benthos biomass (6.5 g/m^2) in the dumping zone (within the 300 m radius), as in May (5.3 g/m^2), was very low; this may be due to the impact of the second dumping phase on the bottom community.

At the station located 300 m north of the dumping point, a high biomass of bivalves (3.5 g/m^2) which was being formed by the common shallow mollusks *Callista brevisiphonata* and *Turtonia minuta*, was observed (figure not shown). Finding these and some other shallow water species, such as green algae and the isopod *Arcturus crassispinis* allows us to suppose that they were discharged here with the extracted nearshore ground.

In August 2006 the mean benthos biomass was 18.2 g/m^2; the major portion of the biomass (69%) was formed by bivalves. Distribution regularities were observed in benthic group's biomass. Figure 1 shows that bivalves (*Nuculana pernula pernula*) prevailed at stations located near the dumping point (0–800 m to the west, east and north), and also 2,000 m to the north of it. Correspondingly, the post-dumping community was observed in this area.

Table 1 Comparison of benthic quantitative indices on the dumping area at different time periods.

Time period	**Length of species list**	**N (ind./m^2)**	**B (g/m^2)**	**B (g/m^2) (radius 300 m)**
August 2003	36	200	53.7	53.7
October 2004	7	13	26	26
December 2004	35	205	26.3	24.5
May 2005	15	74	5.3	5.3
August 2005	39	120	48.6	6.5
August 2006	35	68	18.2	17.5
August 2007	71	142	12	1.4

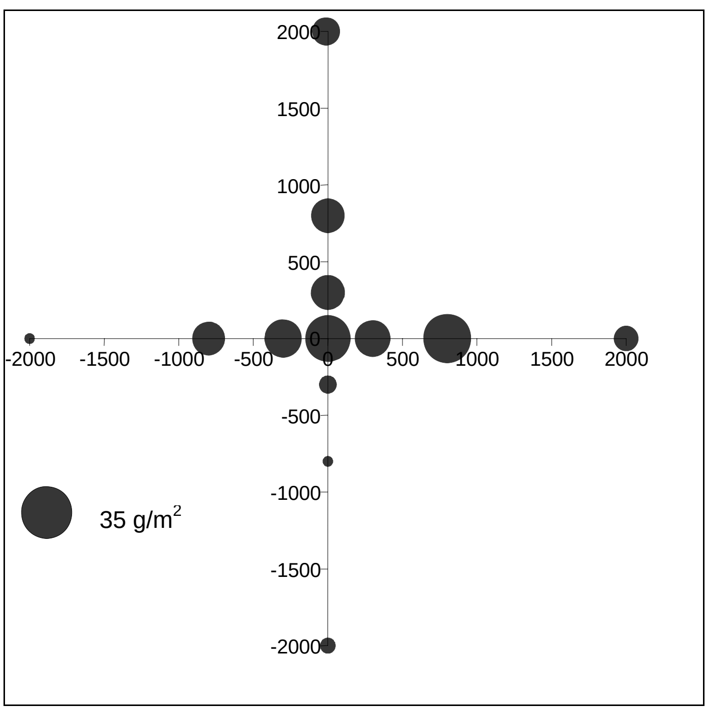

Fig. 1 Bivalve biomass distribution in August 2006 (circle scale is from absence 0 to maximum 35 g/m^2).

Maximum polychaete biomass was observed at a distance 2,000 and 800 m to the west, and 2,000 m to the east and north of the dumping point (Fig. 2); sipunculid biomass was observed 800 m to the west and east of the dumping point) (Fig. 3). Therefore, the bottom community at these stations could be characterized as refugial. In general, high biomasses (from 13 to 30 g/m^2) were observed within a radius of 300 m from the dumping point to the west, north and east. This could be considered a result of the gradual restoration of bottom biota after dumping. The mean biomass within the radius of 300 m of the dumping point was 17.5 g/m^2 which is higher than the indices of May and August 2005.

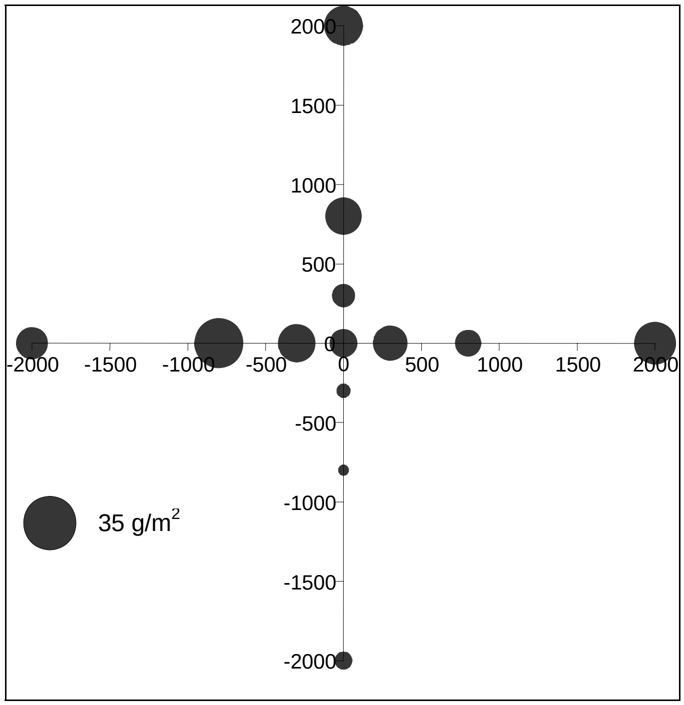

Fig. 2 Polychaete biomass distribution in August 2006 (circle scale is from absence 0 to maximum 10 g/m^2).

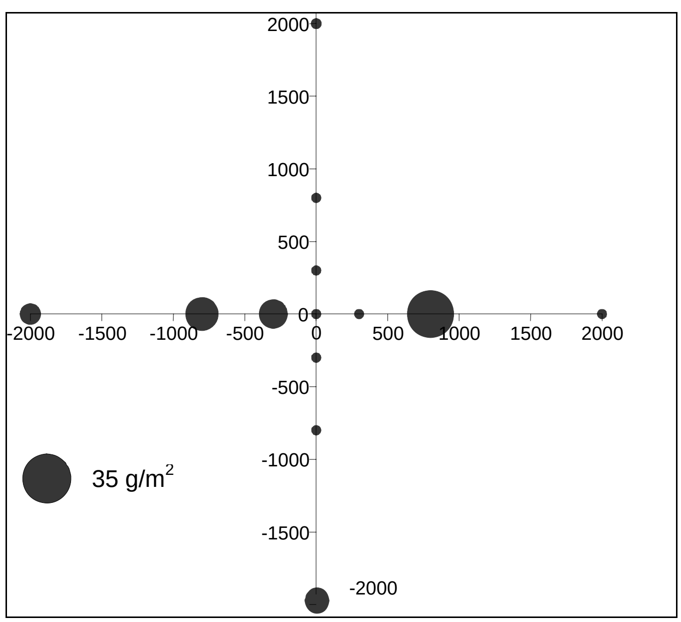

Fig. 3 Sipunculid biomass distribution in August 2006 (circle scale is from absence 0 to maximum 15 g/m^2).

Next, we compare benthos structure characteristics on the dumping area by the study periods (Table 2). In August 2005 the community structure was also close to that of the background (pre-dumping) phase (August 2003); this is supported by Shennon's index and the ABC-index. The level of cenotic and species similarity (Serensen's coefficient) with the background community was also high; this shows that there was a gradual recovery of the post-dumping benthic community similar to the background one, although the predominance of bivalves was significant. Thus, in August 2005, the negative impact of dumping on the bottom community was generally less significant than expected, and a process of recovery up to the initial pre-dumping state was progressing rapidly. However, 2007 data showed an unexpected significant change in the structure and quantitative characteristics of the benthos community.

Table 2 Comparison of benthic structural characteristics on the dumping area (radius 300 m) by different time periods.

Time period	Shennon's index		ABC-index	Cenotic similarity (2003-other) (%)	Serensen's coefficient (2003-other) (%)
	Abundance	Biomass			
August 2003	1.34	0.79	35.6	–	–
October 2004	0.71	0.11	26.4	77	12
December 2004	0.81	0.67	17	30.5	39.4
May 2005	0.94	0.25	22.5	2.9	31
August 2005	1.25	0.45	30.7	74.6	39
August 2006	0.7	0.56	5.8	12.1	53.8
August 2007	0.99	0.67	45.4	2.4	33.3

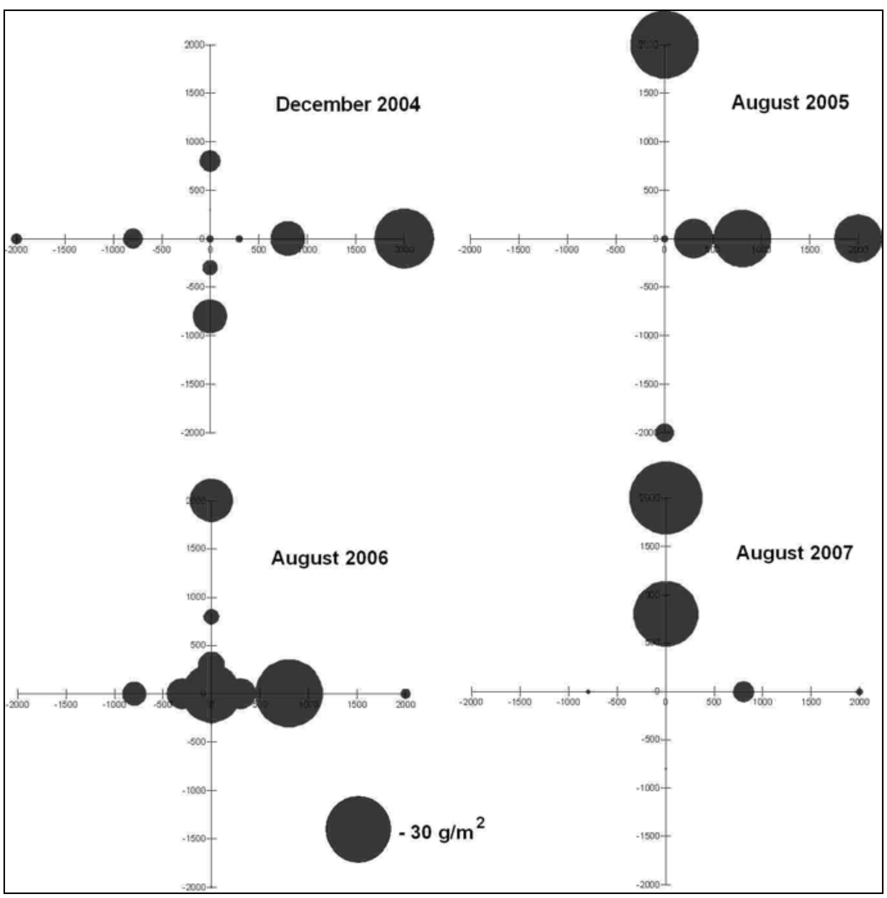

Fig. 4 Bivalve biomass distribution around the dumping site during liquid natural gas plant construction from December 2004 to August 2007 (circle scale is from absence 0 to maximum 30 g/m^2).

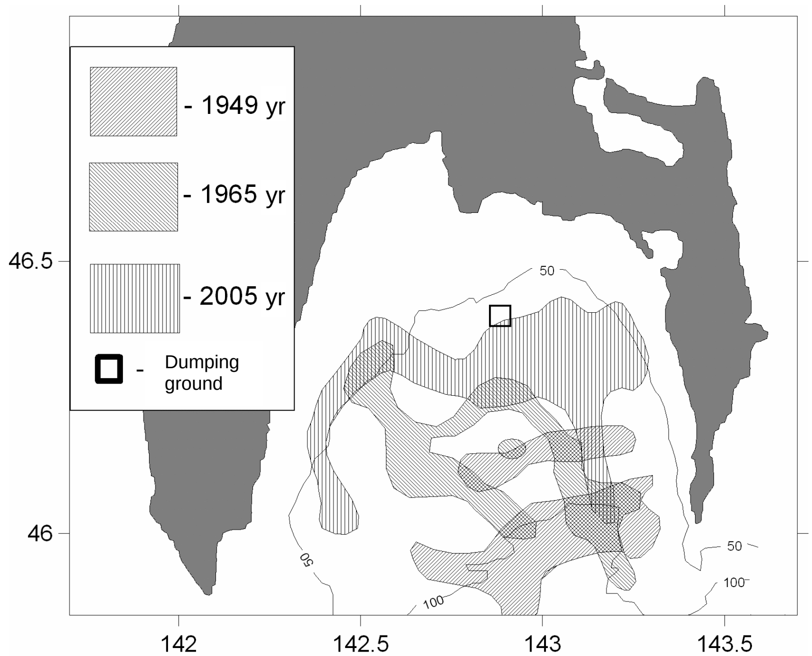

Fig. 5 *Nuculana pernula* community distribution during 1949–2005 in Aniva Bay.

In the radius of 300 m from the dumping point, low values of biomass (from 0.1 to 4 g/m^2) were observed. Such a decline in biomass was connected to the disappearance of bivalve mollusks from the dumping zone. Polychaetes became the dominant group. Structural characteristics show that the benthos community characterizes a high index of diversity and significant stability. Hence, the bottom community passes to the next level of succession. We do not know whether this reorganization was influenced by the construction. After 2005 no more dumping took place.

We next consider the distribution of the basic benthic group (Bivalvia) for different periods. Displacement of *Nuculana* sp. from the south and east to the north of the dumping ground from December 2004 to August 2007 is observed in Figure 4.

We then retrospectively analyse the distribution of the *Nuculana pernula* community in Aniva Bay. Figure 5 is a compilation of scientific, archival and our own survey data which shows the long migration of the *Nuculana pernula* community from deeper waters near the end of Aniva Bay at the middle of last century to shallower waters by 2005. The migration is accompanied by the breakup of a united area into two smaller ones (in 1949 and 1965), a change in community structure to a level of mass species and decrease of its biomass. The migration and changes of the *Nuculana pernula* community is accompanied by a simultaneous decrease in the total benthic biomass. The figure also shows that the dumping area is located on the border of a modern community. Hence, observed changes in the dumping area are connected to natural changes in the benthos.

Conclusion

The influence of ground dumping is traced only directly after impact. Later on it is masked by natural benthos changes.