A tidal power environmental impact assessment : case study of the Kislogubskaija experimental tidal power station (Russia)

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I ■ INTRODUCTION

The experimental Kislogubskaija Tidal Power Station (KTPS) was constructed in Russia near Murmansk at the bay of Kislaija in 1963-68 *(fig. 1)*. The tidal amplitude here is up to 4 m, with maximum stream velocity up to 3,6 m/sec. KTPS has one turbine of 400 kW capacity, and one near-bottom floodgate. Kislaija Guba is a long (3.3 km) and narrow bay, whose general surface is 1.1 sq.km with a narrow opening 65 m wide and 10 m deep. The bottom of the bay has two hollows, both 35 m deep, with a high threshold up to 4 m deep between them. A freshwater stream empties into the bay from the nearest lake.

Previous investigations of the Kislaija Guba were done in the 1920s, and in 1964. Those researches were different one from another by methods, final goals, and studied areas. The investigation of the 1920s was a part of the first pilot exploration of the Barents Sea shallow water marine fauna.

Second faunistic description has been made in 1964 for the special purpose of scientific prediction of possible marine fouling risk for the future tidal power building underwater part and hydroaggregate. Therefore both faunistic lists are differed significantly, including only 1/4 common species. After the construction of KTPS it was studied episodically.

Impact environnemental de la production marémotrice d'électricité : étude de cas sur la centrale expérimentale de la baie de Kislaija

La centrale marémotrice expérimentale Kislogubskaija a été construite en Russie près de Mourmansk dans la baie de Kislaija entre 1963 et 1968. La production démarrée en 1974 était discontinue. L'échange d'eau entre la baie et la mer a été beaucoup réduit. En conséquence, les 15 mètres supérieurs de la couche d'eau sont devenus moins salés et les 20 mètres en dessous contenaient de l'hydrogène sulfuré. L'écosystème marin normal a été complètement détruit.

A partir de 1984, les échanges d'eau avec la mer ont augmenté de 30 à 40 %, la centrale ayant atteint son régime de croisière. Les écosystèmes ont été restaurés lentement, le plancton plus vite que la faune benthique. Actuellement, on observe peu de différences avec la population antérieure. Le nombre d'espèces de polychaetes a même augmenté.

Le cas de l'usine KTP illustre le plus important impact qu'une usine marémotrice puisse avoir sur les écosystèmes marins. On suppose que sur des sites plus étendus, l'impact serait moins important.

II ■ RESULTS AND DISCUSSION

Beginning in 1974, KTPS produced electricity discontinuously. Water exchange between the bay and the open sea declined drastically *(fig. 2)*. As a result, the upper 15 m layer of water was less saline, and the deeper 20 m of water contained hydrogen sulphide.

The negative ecological effect born by some problems of KTPS exploitation became much stronger because of the unique topography of the Bay : long form, narrow and shallow opening, and high threshold, dividing the bottom zone on two deep holes one after another. The normal marine ecosystem was destroyed significantly.

A complex oceanological study of the KTPS environmental impact began in 1983 under leadership of Dr. V.N. Semenov [1] from the Murmansk Marine Biological Institute. From 1990 up to now the investigations were continued by scientists from the Moscow State University headed by Prof. N.N. Marfenin [2, 3, 4, 5].

The expedition of 1983 described the complete absence of alive animals below 20 m in the hydrogen sulphide zone, and some obvious signs that the life has been there before the disaster. There was found significant decline of the marine invertebrates abundance above 20 m deep in the shelly water zone. The association of the algae belt on littoral zone vanished together with algae itself.

Nevertheless the general fauna list has been rich enough including 92 species of the zoobenthos *(fig. 3)*.

Beginning in 1984 the water exchange of the Kislaija Guba with the open sea increased up to 30-40 % of the natural one, which corresponded to project regime.

As a result in 1992 it was possible to recognize four water layers in Kislaja Guba differed by temperature and salinity parameters *(fig. 4)*. The surface layer is a less stabile water body, which is timely significally freshed by terrestrial flow. The subsurface layer takes the outside water, coming during a water exchange through the near-bottom floodgate. The deep water layer is more stable because of the low vertical convection during the summer season.

As a result the marine ecosystems began slowly to be restored. The plankton community in the KTPS basin developed according to the norm better than the benthos. Already in 1991-92 we did not find considerable differences in species composition and the age structure of inner and outer communities. Nevertheless zooplankton abundance in the upper 10 m water layer of the inner community continued to be about a half of the outer one *(fig. 5)*.

The benthic ecosystems of the KTPS basin are slowly coming according to the norm. From 1983, the biomass and quantity of benthic invertebrates increased significantly.

They even recolonized the nearest hollow to the KTPS, where no hydrogen sulphide contamination is registered now.

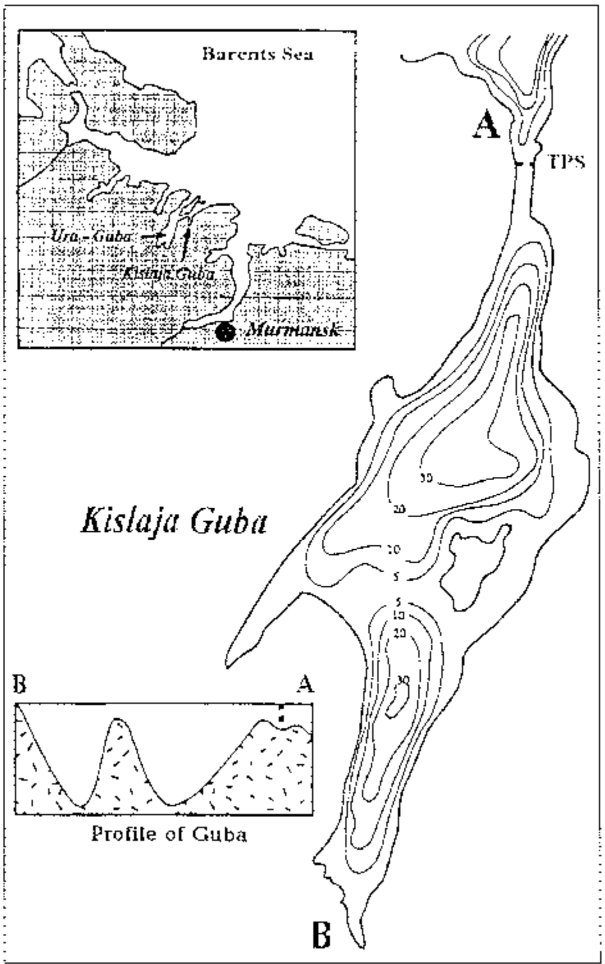
The macrophytes belt is slowly regrowing around a rocky littoral zone, creating a biotope for the sedentary invertebrates such as sponges, hydroids, and bryozoans, which had vanished from Kislaija Bay after the disaster.

Benthos species diversity of the Kislaja Guba changed significantly since 1983. In 1992 we found 140 species of macrofauna from 52 sample plots *(fig. 3)* (compare with 91 species in 1983), although we use for collection only the small Petersen grab (0.04 sq.m) without squba diving methods.

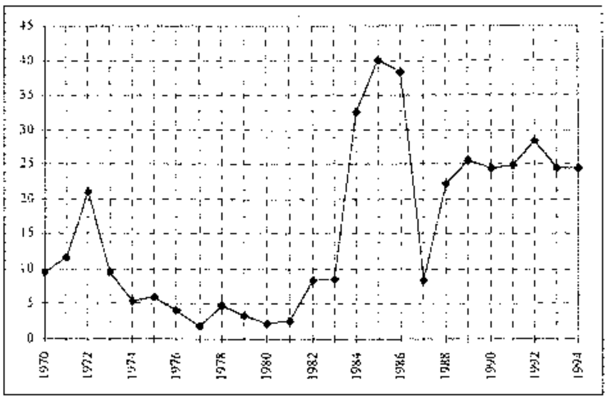
37 benthos species proved to be highly resistant to the dramatic changes of the water environment *(fig. 6)*. 11 species most probably vanished after the catastrophic environment change in the bay. 6 of them did not collected since 1983, and 5 more did not registered in 1992 *(fig. 7)*.

There is no doubt that the list of the vanished benthos species should be much longer including small groups, which are registered occasionally. 151 species have been described by 2 expeditions (1924 and 1964) before TPS construction, and 75 species from them were found only once. Approximately the same proportion of the rare species were in 1983 (26 %) and 1992 (48 %).

18 common species have absented in fauna list of 1983, have been then anew discovered in 1992 *(fig. 8)*. Following the gradual change of the biotope parameters numerous new species took root in the Kislaja Guba benthos ecosystem. 17 new species were found in 1983 and following expeditions *(fig. 9)*. More new species have been registered in 1992.



1. Disposition of KTS on the coast of the Barents Sea.



2. Water exchange reduction between the Kislaja Guba and Ura-Guba (data by I.N. Usachev).

	1924	1964	1983	1992	All expeditions together
Spongia	2	4	—	+	> 6
Hydrozoa	3	5	—	—	6
Actiniaria	1	2	2	1	3
Turbellaria	1	—	—	—	1
Nemertini	3	—	—	+	3
Polychaeta	29	21	32	66	89
Priapulidae	2	—	—	1	2
Sipunculidae	1	—	—	2	2
Loricata	2	—	3	2	4
Gastropoda	16	18	16	15	39
Bivalvia	9	11	21	19	27
Cirripedia	2	4	3	2	4
Isopoda	—	2	—	—	2
Cumacea	—	—	—	4	4
Amphipoda	3	1	2	15	19
Decapoda	5	3	3	4	9
Acarina	3	—	—	—	3
Bryozoa	2	20	—	2	22
Echinodermata	4	7	9	6	13
Ascidia	4	2	3	> 1	4
	92	100	94	140	262

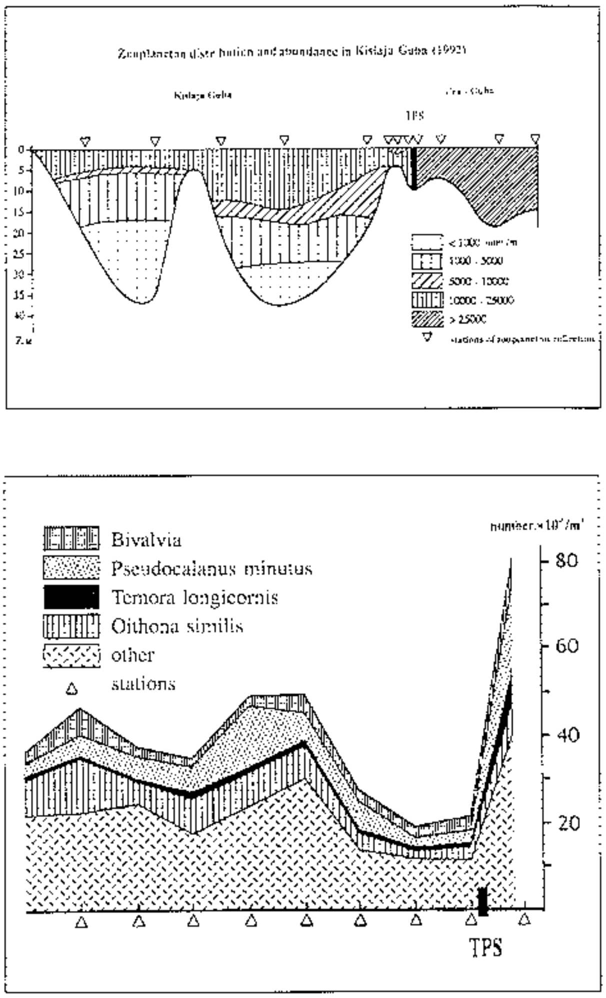
3. The number of invertebrate species in Kislaja Bay described by expeditions in 1924, 1964, 1983, 1992 separately, and the faunistic list according to all expeditions together.

Now the number of polychaetes species (which is 66) is about double the previously known number before the creating of the KTPS and after the dramatic deformation of the ecosystems in the late 70-s.

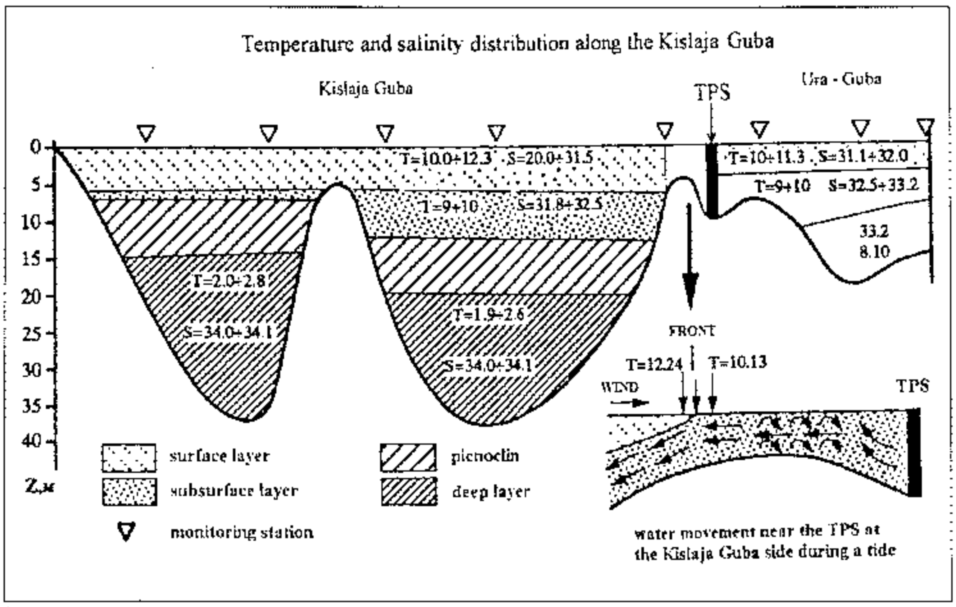
Gastropoda and Amphipoda fauna changed significantly. Although the total number of Gastropoda species varied little in comparing the data, the shallow water species which once dominated the fauna, are now characterized by low abundance.

Remarkable fact is the absence of Isopoda group in last collecting, and almost completely declining of the Bryzoan species number, and on the contrary finding in 1992 Cumacea group species from Crustacia.

If the abiotic environment continues to be stable in the future, we may expect subsequent development of the benthos community.



5. Zooplacton distribution and abundance in the Kislaja Guba :
the top picture — total number of zooplancters along the longitudinal section of the bay ;
the bottom picture — numbers of the dominant zooplancters in upper 10 m water layer same section of the bay.



4. Temperature and salinity distribution along the Kislaja Guba.

Nevertheless its structure should be different from the initial one. There are several main reasons for the ecosystem changes which still exist, such as a significant decrease of the water exchange, which has produced a deformation of the basin hydrography structure and the near-bottom water dynamic.

Developing ecosystems have to be adapted to a new environmental situation. This adaptation is reflected in a changed species structure and changed trophical characteristics of the dominants. Thus the ecosystems of Kislaija Bay underwent a dramatic collapse after 8 years of the KTPS mismanage, but since then we have found a trend of recolonization of the bay and improvement of heavily destroyed communities.

This progress has happened in a situation extremely unfavorable for the pelagic and benthic communities inhabiting the aquatorium of this tidal power station, due to atypical configuration of Kislaija bay coast, a narrow and shallow opening, two deep hollows in the basin, and very low water exchange between the bay and the open sea.

The Kislaija Guba case study helps us to expose the most strong impact of TPS on marine ecosystems, which probably could be avoided on big tidal power stations.

We suggest that the environmental impact of typical TPS would not threaten biological diversity and productivity of isolated marine ecosystems as much as we observed on KTPS during the present study.

Taxon/Species	Year 1924	1964	1983	1992
Anthozoa				
Metridium senile var. dianthus	+	+	+	+
Polychaeta				
Lepluonotus squamatus	+	+	+	+
Harmathoe imbricata	+	+	+	+
Pholoe minuta	—	+	+	+
Glycera capitata	+	+	+	+
Syllis armillaris	+	+	+	+
Castalia punctata	—	+	+	+
Nereis pelagica	—	+	+	+
Nephthys ciliata	+	—	+	+
Scoloplos armiger	+	—	+	+
Cirratulus cirratus	+	+	+	+
Scalibregma inflatum	+	—	+	+
Ophelia limacina	+	—	+	+
Ammotrypane aulogaster	+	—	+	+
Amphitrite cirrata	+	+	+	+
Potamilla reniformis	—	+	+	+
Protula media	+	+	+	+
Mollusca				
Tonicella marmorea	+	—	+	+
Testudinalia (Acmea) tesselata	+	+	+	+
Margarites groenlandicus	+	+	+	+
Littorina littorea	+	+	+	+
Criptonatica clausa	+	—	+	+
Buccinum undatum	—	+	+	+
Boreotrophon truncatus	+	+	+	+
Mytilus edulis	+	+	+	+
Modiolus modiolus	+	+	+	+
Tridonta (Astarte) borealis	+	+	+	+
Arctica (Cyprina) islandica	—	+	+	+
Hiatella (Saxicava) arctica	+	+	+	+
Mya truncata	+	+	+	+
Crustacea				
Balanus balanoides	+	+	+	+
Balanus balanus	—	+	+	+
Pagurus pubescens	+	+	+	+
Echinodermata				
Strongylocentrotus droebachiensis	+	+	+	+
Ophiopholis aculeata	+	+	+	+
Asterias rubens	+	+	+	+
Ascidea				
Styela rustica	+	+	+	+

6. List of the « resistent species » of marine macrofauna from the Kislaja Guba, collected both before, and after KTPS construction.

Lost before 1983	1924	1964	1983	1992
Obelia flexuosa	+	+	—	—
Dynamena pumilla	+	+	—	—
Fabricia sabella	+	+	—	—
Lacuna divaricata	+	+	—	—
Littorina palliata	+	+	—	—
Flustrellidra hispida	+	+	—	—
Lost before 1992	1924	1964	1983	1992
Chone unfundibuliformis	+	+	+	—
Anomia (Heteranomia) squamula	+	+	+	—
Chlamys islandicus	+	+	+	—
Balanus crenatus	+	+	+	—
Gammarus locusta	+	+	+	—

7. The « vanished » macrozoobenthos species, whose population obviously degradated up to 1983, or up to 1992.

Species	1924	1964	1983	1992
Littorina saxatilis (L. rudis)	+	+	—	+
Nicania montaqui (A. banksi)	+	+	—	+
Hyas araneus	+	+	—	+
Phyllodoce maculata	+	—	—	+
Syllis fasciata	+	—	—	+
Nephthys coeca	+	—	—	+
Flabelligera affinis	—	+	—	+
Stylarioides plumosa	—	+	—	+
Aricidia nolani (A. uschakovi)	+	—	—	+
Praxillela praetermissa	+	—	—	+
Terebellides stroemi	+	—	—	+
Priapulus caudatus	+	—	—	+
Buccinum sp.	—	+	—	+
Hydrobia ulvae	—	+	—	+
Phascolosoma eremita	+	—	—	+
Ichnochiton albus	+	—	—	+
Scrupocellaria scabra	—	+	—	+
Chiridota laevis	+	—	—	+

8. The « vanished » in 1983 macrozoobenthos species, which recolonized biotope again up to 1992.

Species	1924	1964	1983	1992
Phyllodoce groenlandica	—	—	+	+
Lumbrinereis fragilis	—	—	+	+
Spiochaetopterus typicus	—	—	+	+
Chaetozone setosa	—	—	+	+
Praxillela gracilis	—	—	+	+
Pectinaria hyperborea	—	—	+	+
Trichobranchus glacialis	—	—	+	+
Lepeta coeca	—	—	+	+
Cylichna alba	—	—	+	+
Leionucula tenuis	—	—	+	+
Crenella decussata	—	—	+	+
Elliptica elliptica (A. compressa)	—	—	+	+
Cerastoderma fasciatum	—	—	+	+
Macoma calcarea	—	—	+	+
Macoma baltica	—	—	+	+
Mya arenaria	—	—	+	+
Ophiura robusta	—	—	+	+

9. Immigrated into the Kislaja Guba macrozoobenthos species (registrated in the bay beginning 1983).

LITERATURE

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