# Ecosystem alterations influenced by the tidal power station on the coast of the Barents sea

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## I ■ THE INSTALLATION OF KISLOGUBSKAYA

The basin of experimental Kislogubskaya TPS represents a little (1.1 sq. km) semi-isolated inlet with a narrow strait and underwater sill. In the middle and the upper part of the inlet there are two depressions with a depth of 36 m, separated by the second sill with the depth about 3 m. A rivulet flows into the uppermost part of the inlet. Before the construction of the TPS (in 1964-1968) the water-exchange of the Kislaya Inlet with the sea was free, the tides were regular semi-diurnal, the average height of tide was 2.4 m, the monthly alterations range of astronomical tides was from 1.1 to 4.0 m. The basin is holomictic by the type of convection : the winter vertical mixing gets down to the bottom. The common ice conditions were not very hard, as a rule, in winter a solid ice cover was not distributed as far as the inner part of the inlet with the low salinity of surface water. The wider middle part of the inlet was usually ice-free. The biota was mostly marine, brackish-water elements inhabited mainly the uppermost part. The constant animal population and seaweed of the inlet (regardless of plankton and microbenthos) consisted of about 210-220 species characteristic of inner bights and estuaries of Western Murman.

Kislogubskaya TPS is an installation of double-sided action (working during both flood and falling tide) with a hydro-aggregate, bottom water inlet and surface spillway. The TPS block is installed into the body of groin, dammed is the entrance of inlet. The relative tidal water-exchange with the sea can be controlled within the range of 0 and 50 % (in average per month) of the natural one. Its maximum is up to 60 % during low neap tides. The optimum operational regime provides an average water-exchange about 34-36 %. In the regime of idle water-letting (when the hydroaggregate is turned off) the water-exchange is in average up to 42 %, though in spring tides, it is limited by approximately 26 % to prevent the ground washout at the base of TPS block under heavy tidal currents.

As a result of the damming and inflow-outflow regulation of the Kislaya Inlet the damaging action of some environmental factors have dramatically increased which earlier had negative effects on marine components of biota. The freshening increased after long-term decrease of tidal water-exchange down to 20 % and lower during improper two-shift operation of the TPS and long stoppages when the ducts are closed due to other reasons. The fiord ice covers practically all the inlet's area in winter even during the normal operational regime of the station. The entrance of the Kislaya Inlet had been dammed in 1964-1968 by the filtering embankment. The water-exchange was literally absent, and the TPS basin was turned into the freshwater-marine basin.

**Les altérations de l'écosystème sous l'influence de l'usine marémotrice de la côte de la mer de Barents**

*Une usine marémotrice fonctionnant dans les deux sens de la marée est en fonctionnement dans le bassin de Kislogubskaya depuis 1968. Au départ, on comptait environ 210 à 220 espèces caractéristiques des baies et estuaires de cette région. Mais pendant la construction du barrage, qui a duré quatre ans, les échanges d'eau entre l'estuaire et la mer ont été nuls, puis réduits durant certaines périodes de l'année (printemps où l'on réduit volontairement les échanges, hiver quand l'eau est en partie prise en glace). L'écosystème a subi les conséquences d'une perte de salinité de l'eau : quinze ans après la construction, on a dénombré 115 espèces, avec surtout des pertes dans la zone intercotidale. Après une amélioration du fonctionnement de l'usine, le phénomène d'adoucissement de l'eau était moindre, ainsi que l'influence de la couche de glace en hiver. Certaines espèces sont revenues et on a pratiquement recouvré l'écosystème antérieur.*

## II ■ THE ECOSYSTEM 15 YEARS LATER

15 years later the marine ecosystem was restored partially, but the vestiges of extensive surface water freshening were evident in sea biota (the absence of *Lithothamnion*, dead shells, etc...) down till 3-5 m. The indications of hydrogen sulphide contamination of deep waters and muddy bottom sediments where noted already at 15-20 m both in the middle and upper parts of the basin. The marine fauna survived at the depths of 3-5 till about 12 m mainly in biocoenosis of branched *Lithothamnion*.

The significant surface water freshening and hydrogen sulphide accumulation in summer in deep water took place in early 80s during the long-term water cut-off in the ducts and other violations of project operational regime of TPS. Ecological monitoring was underway after 1983 in the TPS basin. At average values of water-exchange no more than 20 % in summer (July) the main pycnocline was at the depth of 12-13 m in wide middle part and at 7-8 m in its narrow inner part, separated by the sill. The period of spring-summer development of planktonic community was approximately late for a month, the deviations were noted in the species composition comparable with the outer one. Pyrrophytes predominated in phytoplankton, and the significant increase of representatives of estuarine complex (of genera Evadne, Podon, etc...) were marked in zooplankton ; the community was scarce (Rhyzhov's personal communication).

115 species of habitual marine dwellers and seaweed were found out in 1983-1984 (i.e. 53 %), including 14 species of macroalgae, 96 zoobenthic species and 5 species of fishes. The intertidal macroalgae (*Fucus, Ascophyllum*, etc...) were totally absent. The total species number of invertebrates and plants decreased approximately in 6 times on rocky and stony-boulder intertidal, down till 11 species contrary to 60-70 ones before the construction of TPS. The benthic biomass decreased by 2-3 orders. On the tide flats (watten*) the general species number decreased in 3 times, down till 3 species contrary to 24-25 ones. The inhabited area of the watten decreased about 4-5 times.

Intertidal benthic communities were at initial succession stage in connection with mussel *Mytilus edulis* resettling (after their die off in Murman in 70s). *Macoma balthica* predominated by biomass in lower part of the new intertidal, the mussels were sporadic. The brackish-water *Chironomus salinarius* was dominant in the upper part. *Arenicola marina* being typical of the watten vanished and has not yet recovered. This species is partially substituted by polychaete worm *Nereis virens* in the lower part of intertidal. The watten and sand beach above approximate mean sea level (M.S.L.) were turned into periodically flooded fringe of the coast with compacted sediments and sparse meadow vegetation. Among littoral and upper sublittoral producers remained euryhaline filamentous algae *Pylaiella litoralis, Ectocarpus*, and diatoms, blue-green algae also, forming felt-shaped dense fouling.

Technogenic tide transformation entailing long-term exposure of upper and flooding of lower littoral fringes is a disastrously damaging factor influencing littoral biota and its productivity as a whole in the TPS basin. It is caused by irregular water-letting of TPS during direct (in falling tide) and reverse (rising tide) turbine working that leads to gradual M.S.L. increase in the basin at least twice a month. Long-term tide component is being generated following monthly tide inequality with a period of about two weeks. The type of tide transformation close to that one and its effects on biota has been described in natural conditions too — in semi-isolated basins with a littoral sill [1]. The tidal inhabited zone shrinks in that case in several times. The most important part of the ecological littoral complexes (Du Rietz-Mokiewsky complexes) fall out, and pseudolittoral migratory complex, or movable coenoclement (synoecium s.l.) happens to occur.

## III ■ AFTER THE IMPROVEMENT OF TPS WORK

Some positive changes took place after relative improvement of TPS work according to the project. The drastic freshening factor had been eliminated though the ice-sheet area did not decreased and was not winter severity dependent. Planktonic community did not already differ much from the outer one by its species composition and periods of development, the forms of estuarine complex developed mainly in the upper part of the inlet. The littoral zoobenthic communities have begun their gradual formations within new boundaries. Three main species occured on rocks and boulders : *Mytilus edulis, Semibalanus balanoides, Littorina littorea* ; some other invertebrates happened to occur at low tide levels. The *Mytilus edulis* aggregations have almost completely overlapped the sites settled by *Macoma balthica* on the tide flats, and also the most part of the former sites dwelled by *Chironomus salinarius* which had been replaced by marine species (*Macoma*, etc...). Species diversity of polychaetes increased significantly, barnacles are extensively distributed on stone embedded area of the watten. Mass development of alga *Chorda filum* was noted in upper sublittoral. In some invertebrate species (for instance, *Asterias rubens, Strongylocentrotus droebachiensis*) fluctuations took place followed by outbreaks of population abundance.

Three years after the recovery processes in the ecosystems, the TPS was transferred to be operational in the regime of idle water-letting as the more favorable one for sea biota of its basin. The vertical distribution boundaries of few mass species on the littoral zone have stabilized after two-years working of the station in this regime. The succession of benthic communities has almost completed on the tide flat. The number of benthic species there reached 25, their biomass increased (mainly due to mussels) up to 2-3.4 kg per sq.m in low littoral zone, and up to 0.1-0.9 kg per sq.m in the upper one. The main pycnocline happens at maximum depth of 18-19 m in summer in the wide middle part of the inlet, in the inland upper it usually occurs at 7-9 m. The aeration of deep waters have improved in the depression of the inlet's mid part, hydrogen sulphide was not more found out amid the bottom waters and sediments ; zoobenthic communities, mainly polychaetes, recover. The dominant species is *Ammotrypane aulogaster*, the biomass of benthos is up to 20-30 g per sq.m. The hydrogen sulphide happens to occur in summer deeper than 30 m in the water and 20 m in the bottom sediments in the inland upper part only.

The overall number of macrophyte species reached its initial number 33. Though *Fucus vesiculosus* has become an habitual species in lower part of the intertidal (beside the inner part of the inlet), it is distributed very sparsely — the highly productive macrophytes belt in the intertidal does not recover. It is caused by irregular long-term mean sea level fluctuations in the basin, by amplitude comparable with its decreased semi-diurnal tides. Only mud- and sand-dwelling species, the forms being tolerant to long-term exposure or capable of movement can survive in the upper part of the new intertidal zone.

## REFERENCE

[1] SEMENOV V.N. — Ecosystem alterations influenced by the tidal power plant on the coast of the Barents Sea. 26 EMBS, 17-21 Sept. 1991. Progr. and Abstr. Middelburg, The Netherlands, 1991, pp. 111-113.

* N.D.L.R. : en Allemand dans le texte.