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EVALUATION OF THE CURRENT STATE OF AQUATIC ECOSYSTEMS AND THE PROBLEMS OF THE PROTECTION OF BIOLOGICAL RESOURCES DURING DEVELOPMENT OF KRUZENSHTERNSKOYE GCF

The results of studies of the current state of freshwater ecosystems and their biotic components in the western part of the Yamal Peninsula are presented in the article. Based on the evaluation of the structure of communities of phytoplankton, zooplankton, benthos, and whitefishes, the range of problems related to the protection of biological resources during the development of the Kruzenshternskoye gas field is defined. The data on species composition and quantitative indicators of hydrobionts of different types of waterbodies and watercourses in the lower reaches of the Mordyyakha and Naduyyakha Rivers basins is the basis for environmental monitoring of water objects during development and exploitation of the Kruzenshternskoye gas field.

Estimation of the fish fauna state and their food base in the territory of the Kruzenshternskoye GCF according to the monitoring program is present. The river delta zones are the most important feeding areas of the salmonid and whitefishes valuable fish species in the territory of Kruzenshternskoye GCF. In cases where water bodies and watercourses are not completely demolished for the construction of GCF facilities, changes of quantitative and qualitative characteristics of communities of hydrobionts after the end of operations are reversible. River ecosystems are restored within a shorter period of time in comparison to lacustrine ones.

Proposals for the protection of fisheries resources and monitoring of aquatic ecosystems on the basis of comprehensive studies are reported. Recommendations on reducing the anthropogenic impact on aquatic ecosystems in the development period are present. The results of the investigation were used in the development of the environmental protection part of the Kruzenshternskoye deposit project. Anthropogenic disturbances present now on the gas deposit territory of Kruzenshternskoye does not influence the aquatic ecosystems.

Keywords: Kruzenshternskoye gas condensate field, aquatic ecosystems, zooplankton, phytoplankton, zoobenthos, ichthyofauna, whitefishes, human impact

Introduction

Yamal is one of the most important strategic oil and gas-bearing regions of Russia. Commercial development of Yamal fields and adjacent water areas is essential for the growth of oil extraction and natural gas production in Russia. Further economic development of the country is associated with this region.

The active development of the Far North territories may have negative consequences. First, it concerns the delicate equilibrium of northern ecosystems. Under the conditions of active human impact in the exploration, development, and exploitation of oil and gas fields, a threat of downsizing and disappearance of many flora and fauna species may arise. The reduction of habitat areas, disturbance of migration routes of animals and of their vital habitats is possible.

In the assessment systems of the ecological state of ecosystems and of the monitoring methodology in many European countries, there is a transition from physical and chemical to biological control based on the study of structural and functional organization of various biotic components.

An important goal in the development and exploitation of gas fields is to minimize the negative impact on aquatic ecosystems. To reach this goal, first, it is necessary to identify the background state of ecosystems in the areas of development of the future fields prior to the start of work; second, to develop a set of recommendations to minimize the negative human impact on the biota; and third, to perform regular monitoring of the hydrobionts and fish population condition throughout all stages of development and exploitation.

In the neighboring areas to the Kruzenshternskoye field territory, at the early stages of the Bovanenkovo field development, a negative effect on aquatic ecosystems has been shown [1], which mainly resulted in pollution, isolation, or destruction of flood waters and in a significant decrease in the number of fish due to poaching. Currently, the development of the Kruzenshternskoye field has not

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Translation

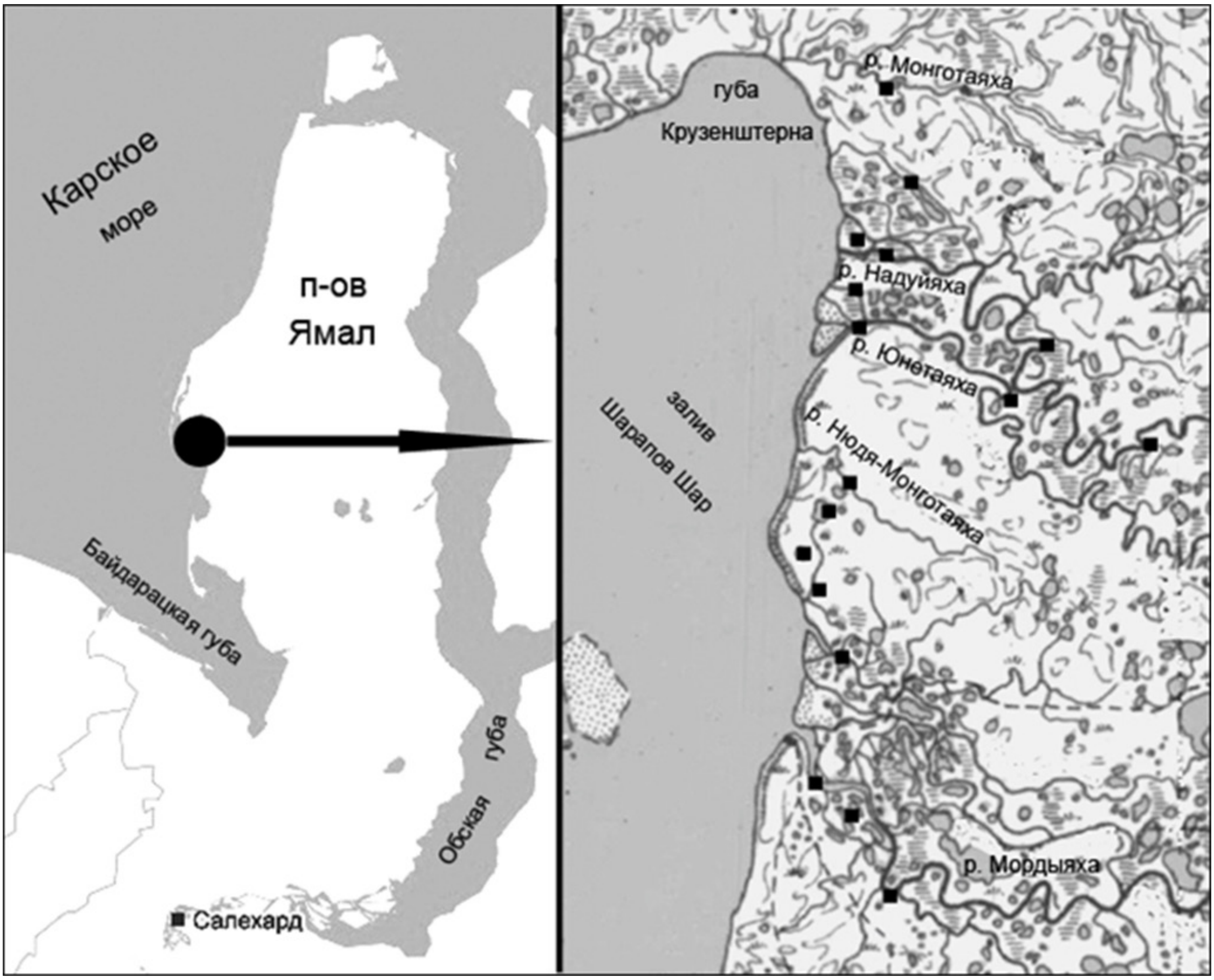
yet started, but the human impact is already present due to transportation of goods from the Kara Sea coast to the Bovanenkovo field by water and land transport and to reindeer herding.

The purpose of this study was to assess the state of ichthyofauna, phytoplankton, zooplankton, and zoobenthos in the water bodies and watercourses of the coastal territory of the Kruzenshternskoye field prior to its development, to define the fishery value of rivers and lakes, and to assess the possible impact on aquatic organisms of operations performed in the development and exploitation of the field.

The study was performed in the framework of the Presidium of RAS Project No. 31 The Role of Space in the Modernization of Russia: Natural and Socioeconomic Potential.

Assessment of the state of hydrobionts was made based on the IPAE UB RAS field research conducted in 2013 using the partially published materials of the years of 1990–1995 [1]. The collection of hydrobiological and ichthyologic samples was performed in different types of waterbodies in the lower reaches of the Mordyyakha and Naduyyakha Rivers basins: N 70° 27´ 00.4˝ E 67° 20´16.2˝ and N 70° 45´ 31.7˝ E 67° 27´ 05.3˝ (Fig.).

Published data on the development of plankto- and benthocenoses in the tidal zones of Yamal rivers featuring with special conditions is extremely limited, so our research makes up for the gap to some extent.



Карское море—the Kara Sea
п-ов Ямал—Yamal
Байдарацкая губа—Baydarata Bay
Обская губа—the Gulf of Ob
Салехард—Salekhard
Губа Крузенштерна—Guba Kruzenshterna
Залив Шарапов Шар—the Sharapov Shar Gulf
***Fig.** Schematic map of hydgobiological sampling (■ means sites of sampling)*

The Kruzenshternskoye gas condensate field is located in the western part of the middle of Yamal. The Mordyyakha River originates from the Yambu-to lake and its confluence with the Kara Sea forms a delta. The river is 300 km long; its basin area is 8,530 km2. The Naduyyakha River is 271 km long and the catchment area of 2,890 km^2. The river flows down from the central Yamal watershed hill and empties into the Gulf of Sharapov Shar. The rivers have complex deltas and are subject to tidal and wind-driven waves over a large area (60–70 km). The rivers and lakes are of atmospheric-derived nourishment and surface flow, the runoff coefficient is 0.8. The hydrochemical composition of the water in the rivers is soft and brackish. The highest water flow is observed in the floodwater, the lowest, in the winter low water period. The main phase of the water regime is the spring tide in June–July. The rise of the water level in high water reaches the absolute mark of 5 m. The summer–autumn low water is characterized by low water and lasts until September. Rivers freeze at the beginning of October. The maximum thickness of the ice reaches 1.7 m (March–April). The average duration of complete freezing is 250 days. [2] Ice drift starts in the second half of June. Water flow in winter is virtually zero due to the termination of groundwater flow and freezing of riffles.

In the coastal part of the Kruzenshternskoye field, the main areas used by fish during feeding and migration include rivers, canals, and related shallows. Most of the existing lakes are shallow and frozen through; therefore, they are not significant for fisheries. Rivers are the main migration routes in the seasonal distribution of fish for a more efficient use of feed resources and avoiding the adverse effects of external factors (such as suffocation).

Results and Discussion

Phytoplankton. Phytoplankton—the primary link of energy flows, autochthonous organic matter producer, and an important agent of self-purification and photosynthetic water aeration —is of great importance in the functioning of aquatic ecosystems. Phytoplankton is widely used for bioindication of the ecological condition of water bodies in Europe. Plankton algae are representative biological indicators of water quality able to react to the slightest changes in the ecosystem not detected by other research methods. Any changes to the characteristics of the main primary producer have a direct impact on the formation of energy flows and all subsequent links in the food chain.

Phytoplankton meets the essential requirements to bioindicators: it is characterized by high taxonomic and ecological diversity, it is widespread in water bodies of different types, and its structural and functional characteristics are closely linked to environmental factors. Phytoplankton is also one of the biological elements of the assessment of the environmental state of water bodies under the Water Framework Directive 2000/60/EC.

The algae flora of the examined rivers, canals, and lakes includes 213 species, varieties, and forms of 8 divisions: *Cyanophyta*, *Bacillariophyta*, *Chlorophyta*, *Chrysophyta*, *Cryptophyta*, *Dinophyta*, *Xanthophyta*, and *Euglenophyta*. The basis of the species list consists of diatom (49.8%), green (26.3%) and blue-green (12.7%) algae. A high percentage of few species genera is revealed as a part of phytoplankton, which is typical of high latitude algoflora [3, 4].

152 species and intraspecific taxa are found in rivers, 56 ones in canals. Species diversity is defined by diatoms and green chlorococcales. Brackish-water species of *Nitzschia* algae and *Gyrosigma scalproides (Rabenhorst) Cleve* can be found. In the canals, the abundance of phytoplankton varies from 844 to 3,970 thousand cells per liter; its biomass varies from 208 mg/m^3 to 334 mg/m^3. In the rivers, the algae biomass varies more widely: (56–478) mg/m^3, abundance changes from 3,012 to 6,616 thousand cells per liter. Almost in all watercourses, quantitative indicators of algocenoses are defined by blue-green and small-celled green algae. The leading role in the establishment of the phytoplankton abundance is played by blue-green algae (52.7%–87.0% of the total population). Usually, *Aphanocapsa holsatica (Lemm.) Cronb. et Komarek* is predominant. The proportion of diatoms in the total biomass averages 17%–20%, reaching 40% in some cases. High levels of empty diatom flaps are characteristic of all watercourses.

74 species and intraspecific taxa belonging to 6 divisions are found in lakes. The structure of phytoplanktocenoses is usually defined by blue-greens with the proportion in the total number and biomass of 70%–84% and 79%–95%, respectively. In the floodwaters of river estuaries, the leading role in the formation of biomass is played by green chlorococcales *Planktonema lauterbornii Schmidle* (88.3%). The abundance of plankton algae varied from 1,868 to 7,489 thousand cells per liter, the biomass varied from 0.06 mg/m^3 to 5.16 mg/m^3.

Translation

The studies provided the first background material on the structure and development of phytoplankton in water bodies and watercourses at the gas field area. The algae flora is characterized by considerable species richness.

Most of the identified species are common in the water bodies of different types on the Yamal Peninsula [5-8]. Blue-green, green, and yellow-green algae are represented mainly by planktonic freshwater species. Among the diatoms, the main core is made up by the inhabitants of the littoral zone, bottom, and fouling. Species diversity of phytoplankton increases in the row of lakes – canals – rivers. The level of quantitative development of algocenoses in the lakes is higher than in the rivers and canals.

Zooplankton. The zooplankton community is an important link of aquatic ecosystems. Its significance in energy transformation, biotic circulation in water bodies, in self-purification, and in the formation of natural water quality is very high. The indicator role of crustaceans and rotifers is to determine the extent of the water body saprobity and its trophic type. Analysis of qualitative and quantitative characteristics of planktocenoses allows clearly enough identifying contaminated waters and their areas and providing a comparative assessment of the level of pollution in time and space. Changes in the zooplankton structure are an important indicator of changes in the habitat that is used for monitoring the quality of water, eutrophication, acidification, and toxification of aquatic ecosystems. In addition, zooplankton is used in the evaluation of fishery water bodies, as zooplankton organisms form the basis of plankton-eating fish diets. In the waters of Yamal, zooplankton is consumed by peled, whitefish, and larvae of most fish species.

Studies of the Yamal zooplankton fauna started in 1908 [9, 10]. Later, with different frequency and detail, many researchers examined zooplankton of various reservoirs and streams of the middle and southern parts of the peninsula, and the data collected before 1995 is summarized in monographs [1, 11]; the data obtained in recent years is presented in separate articles [12 15].

48 species of zooplankton have been identified within the territory of Kruzenshternskoye GCF as well as the taxa of higher rank (order *Harpactiformes*, genera *Eurytemora* and *Acartia*), which make up one third of the currently known ones in the Yamal Peninsula. Rotifers were of the greatest diversity (28 species), cladocerans were of the smallest diversity (8 species).

7 cladocerans species, 14 species, and three taxa of higher rank of the copepod species and 21 species of rotifers were found in the area watercourses. 9 to 18 species were found in a particular watercourse. In watercourses exposed to tidal phenomena, including the canals (distributaries) of the delta areas of Mordyyakha and Naduyyakha Rivers, "estuarine" species (*Podon leuckarti (Sars), Limnocalanus grimaldii (Guerne), Eurytemora gracilcauda Akatova, E. raboti Richard, E. tolli Rylov, Leptodiaptomus angustilobus Sars, Keratella cruciformis wirketissi Kuticova, Notholca caudata Carlin*) and even marine species (juvenile Acartia sp.) were found along with the typical representatives of freshwater zooplankton. The incidence and abundance of the representatives of these groups are often low. Acartia sp. juveniles stand out for these indicators (23.6% of the number and 74.5% of the biomass of all zooplankton organisms in the main Naduyyakha River canal) like *K. cruciformis wirketissi Kutikova, N. caudata Carlin*, and *E. raboti Richard* in a smaller extent. The abundance and biomass of zooplankton organisms vary widely in watercourses. It is maximal in the Mongotayakha river (1,772.08 thousand specimens per sq. m and 2.591 g/m^3) due to the development of rotifers *Keratella quadrata (Müller)* (73.1% of the total population and 30.0% of the total biomass of zooplankton), one of the most common and numerous Yamal species. In other watercourses, zooplankton abundance was significantly lower and ranged from 183.93 to 22.21 thousand specimens per sq. m; the biomass was from 0.280 g/m^3 to 0.097 g/m^3. Copepods, primarily their various age juveniles, are predominant in most watercourses (up to 71.8% of the total population and up to 66.5% of the total biomass), rotifers are less common (up to 73.5% of the total population and up to 30.0% of the total biomass).

Lake zooplankton of the area is represented by 27 species of crustaceans and rotifers, among which the bulk is constituted of the most widespread and numerous Yamal species (e.g., *Kellicottia longispina (Kellicott), Keratella quadrata (Müller), K. cochlearis (Gosse) Chydorus sphaericus (O.F. Müller), Bosmina longirostris (O.F. Müller), and B. longispina Leydig*). The "estuarine" species (*N. caudata Carlin, L. grimaldii (Guerne)* and *E. tolli Rylov)* are found in the samples rarely and sporadically. Lake zooplankton communities vary in their structural organization considerably: the species composition of lake zooplankton in the laida mouth of the Naduyyakha river was limited to three species but was richer in other lakes (10 to 18 species); similarity indices of lake zooplankton species did not exceed 20%;

Shannon-Weaver species diversity index (biomass) at the laida was 0.0016 for lake bioplankton and varied from 1.0799 to 2.6310 for the zooplankton of other lakes; the total number of zooplankton differed 8.2 times, was 42.03 thousand specimens per sq. m in the lake at laida, and reached 189.06–346.30 thousand specimens per sq. m in other lakes; the difference in the biomass of communities was still significant, 382.3 times as determined by high biomass in the lake at laida (82.204 g/m^3) and relatively low biomass in other lakes ((0.215–2.187) g/m^3); the ratio of *Crustacea* and *Rotifera* biomass was significant (108.0–115.8); rotifers were not found in the lake at laida; the average individual weight of zooplankton organisms in the lake at laida was high (1.960 mg) and varied widely but was low in other lakes ((0.001–0.116) mg); the proportion of the dominant in terms of abundance in the lake at laida was 96.6% and lower in other lakes ((41.0–43.4)%), in the biomass, it was 99.9% and (96.0–76.1)%, respectively. The data presented shows that the environmental conditions are extreme for the development of a highly organized zooplankton community in the lake located in the intertidal zone at laida, the Naduyyakha river floodplain, so a single species of *Daphnia middendorffiana Fischer* is prosperous and forms high biomass due to the high weight of individuals. High zooplankton biomass has been observed earlier in individual lakes in Yamal, but it was due to the development of "large" species under the influence of human activities. [13] The qualitative composition and quantitative development of zooplankton of other lakes is close to the zooplankton of the middle of Yamal.

Thus, the preliminary studies of zooplankton fauna within the territory of Kruzenshternskoye GCF have shown that it is rich (50 species and 3 taxa of the above species rank) and makes up one third of currently known Yamal copepod and rotifer zooplankton species [1, 11]. The highest species richness is characteristic of rotifers, 28 species. Cladocerans form the poorest in the species groups (9 species). Inhabiting species differ in their biology, ecology, occurrence, and significance in ecosystems. Typical freshwater species of crustaceans and rotifers found within the territory have been previously known in Yamal.

The impact of tidal phenomena affected not only the species composition of the zooplankton fauna of the territory (8 brackish and one marine species found) but also the formation of zooplankton communities with low levels of organization in some lakes at large river estuarine areas laida, thus forming favorable conditions for the development of one particular species, *D. middendorffiana Fischer* in this case.

In terms of quantitative development and ratio of the main groups, the zooplankton of most water bodies and watercourses is close to the zooplankton of similar water bodies and watercourses of the middle of Yamal and, according to the classification [16], characterizes the water bodies and watercourses as low-feed and—less common—as close to medium-feed for plankton-eating organisms. The lake at laida where a very high biomass of zooplankton was found, and others similar lakes belong to the ones with no fish and are of no fishery value.

Zoobenthos. Benthic invertebrates play an important role in the transformation of matter and energy both within aquatic ecosystems and between the latter and the terrestrial ecosystems. Participating in the formation of qualitative and quantitative diversity of aquatic biota, zoobenthos organisms are important components in the diet of commercial fish species. Many of them are the intermediate hosts of fish, bird, and mammal parasites.

Zoobenthos communities are a convenient object for the observation of anthropogenic changes, dynamics of self-purification processes, and the evolution of aquatic ecosystems. Species composition and quantitative characteristics of benthic invertebrate communities are good (and in some cases, the only hydrobiological indicators of contamination of the soil and the bottom water layer) and widely used in various systems of bioindication and hydrobiological monitoring of the state of aquatic ecosystems.

As part of the benthic fauna of watercourses and bodies within the territory of the Kruzenshternskoye GCF, 29 species and taxa of higher rank were identified, which is less than 10% of the total number of zoobenthos species found in water bodies of different types in the middle Yamal [11, 17]. The representatives of polychaetes, oligochaetes, mollusks, amphipods, aquatic beetles, caddisflies, limoniids, ateritsids, and chironomids have been found. Larvae of aquatic insects—82.1% of the total number of species—are the most diverse organisms. In terms of the number of taxa, chironomids represented by 19 species and forms are predominant. The group of "constant" organisms (incidence of 50% or more) is represented by 5 species: *Chironomus anthracinus (Zetterstedt), C. muratensis (Ryser,* *Scholl et Wuelker), Procladius choreus (Meigen), Tanytarsus pallidicornis (Walker),* and *Atherix ibis (Fabricius)*.

19 invertebrate taxa were observed in rivers and canals. Quantitative indicators of zoobenthocenoses are defined by chironomids: (97.4–100.0)% of the total number and 84.3% of zoobenthos biomass. Pelophylax *C. anthracinus* larvae are predominant. The leading role in zoobenthocenoses in the estuary river areas is played by the brackish water polychaete *Marenzelleria arctia (Chamberlin)*. The abundance and biomass of zoobenthos varies widely from 780 to 10,452 specimens per sq. m and from 2.09 g/m^2 to 14.014 g/m^2. The average values were 4,542 specimens per sq. m and 5.732 g/m^2. The maximum values were observed at silted habitats of estuarine canals flowing from the lakes.

The lake bottom fauna is represented by 18 taxa of invertebrates. The examined lakes belong to the reservoirs of the chironomid type. The structure of zoobenthos is defined by chironomids, the proportion of which in the formation of the total abundance and biomass is 74.4–100.0 and (63.8–100)%, respectively. The predominant group of organisms in terms of biomass includes *Chironomus* larvae, 59.0-98.7% of the total benthos biomass. Oligochaetes play a significant role in benthic communities. The abundance of hydrobionts varies insignificantly from 1,174 to 1,860 specimens per sq. m. The biomass varies to a greater extent from 1.53 g/m2 to 10.29 g/m2. The maximum level of the quantitative zoobenthos development is recorded in floodplain lakes located at the intertidal zone laidas (the lake at the mouth of the Naduyyakha River). The amount of biomass characterizes them as high-feed for benthophagous fish water reservoirs [16].

In general, most of the benthic invertebrate fauna consists of Holarctic and Palearctic species widespread at Yamal. There are the representatives of the relict crustaceans fauna of *Mysis relicta Loven, Saduria entomon (Linnaeus), Gammaracanthus lacustris Sars,* and *Monoporeia affinis (Lindström)* inhabiting the lakes of Karelia, Finland, Sweden and the estuaries of the White Sea and the Siberian coast of the Arctic Ocean. The quantitative characteristics of zoobenthos are comparable to those given in publications for different types of watercourses and water reservoirs of the Yamal Peninsula [11, 14, 15, 17, 18].

Ichthyofauna. Ichthyofauna of reservoirs and watercourses within the territory of the Kruzenshternskoye field is represented by 14 species belonging to 9 families. The largest number of species (five) is characteristic of the whitefish family [1, 11, 19-21].

Fish populations are represented by marine, migratory, and freshwater species. The latter include nonmigratory fish that do not migrate distantly (nine-spined stickleback) and semi-migratory fish migrating within the river basin (whitefish, peled, vendace, humpback whitefish, broad whitefish, burbot vulgare). Migratory fish migrate from sea to the rivers to reproduce (salmon, Asian smelt, cisco). Marine fish live mainly in the Gulf of Sharapov Shar but are also found in salty areas downstream (navaga, fourhorn poacher, Arctic flounder, Czech-Pechora herring).

According to the state standards, all whitefish and salmon are considered particularly valuable species in terms of their commercial value.[1] These species represent 50% of the fish fauna of the territory.

One species of fish listed in the Red Book of YaNAO inhabits the study area—it is whitefish belonging to the Mordyyakha River population. This species belongs to the second category, its population is steadily declining, and with the further exposure to the factors that reduce the species abundance, it may move into the category of endangered species in a short time. Overfishing, construction of gas condensate fields resulting in contamination and elimination of floodwaters are the limiting factors and causes of degradation of the species.

Until 2010, the category of rare and endangered species inhabiting KGCF and listed in the Red Book of YaNAO included Arctic char (semi-migratory form), but currently the species has been unreasonably excluded from the Red Book.

The species composition and distribution of fish in the lower reaches of the Mordyyakha and Naduyyakha Rivers are determined by the natural migration of fish populations, by the dynamics of the level of hydraulicity and salinity in the intertidal zone, by the influence of rundown and piled-up winds, ice conditions, and water flow in the rivers. Whitefish, broad whitefish, vendace, and smelt feed primarily in the areas of river deltas. Cisco and navaga migrate to the lower reaches of rivers in winter, and smelt migrates there for reproduction in spring, during the rise of the water.

[1] Indicators of the state and the rules of taxation of fishery water bodies: GOST 17.1.2.04-77. Moscow: Publishing House of Standards (1987): 17 p.

As a result of the development of the fields in 2005, broad whitefish and Arctic char almost disappeared in the lower river reaches, whitefish, humpback whitefish, and peled became rare species. The abundance of vendace and smelt that were numerous in the 90-s of the last century was reduced dramatically despite the fact that their populations were less affected by fishing, and that due to their expanded reproductive area compared with broad whitefish and humpback whitefish (which reproduce only in the riverbed), they can recover their population quicker. Cisco, navaga, and fourhorn poacher—species that enter the internal waters of the Kara Sea—were affected to a lesser extent. The age structure of populations had changed in most species of valuable fish: there had occurred the reduction of age series and rejuvenation [14, 22].

By 2009, positive changes have occurred in the ichthyofauna structure. Measures to protect the fish population, introduction of the whitefish populations in the Red Book of YaNAO, along with the introduction of elementary discipline for the personnel of construction sites have significantly reduced the extent of poaching. Due to this, the fish populations, especially the whitefish and broad whitefish ones, began to gradually recover. By 2013, their abundance in the lower reaches of the Mordyyakha River approached the levels of 1990, and whitefish appeared in the Naduyyakha River where it had not been previously found.

Impact on hydrobionts. The construction of gas fields results in a breach of historical biotic and abiotic components of aquatic ecosystems. Any economic activity in the river valleys results in the disturbances of the vegetative ground cover with a sharp increase in erosion, in flushing solids in water bodies, increased water turbidity, and changes in sediment accumulation processes [23-29]. The release of erosion material into rivers and canals continues after cessation of operations as well.

The main source of water pollution during the construction work and the development of gas fields on the background of changes of hydrological and hydrochemical regimes is the release of fine mineral suspension into water accompanied by sedimentation of bottom soils. The content of suspended solids in fish water bodies shall not be greater than 25 mg/l. Water turbidity shall not exceed the background by more than 0.25 mg/l in the water bodies where the fish spawn, in other water bodies, by 0.75 mg/l.[2] At the natural concentration of mineral suspensions of more than 30 mg/l, their increase within 5% of baseline values is permissible [30].

Construction of crossings over watercourses is accompanied by an increase in water turbidity and formation of not typical of tundra rivers and lakes habitats, thus resulting in the inhibition of hydrobionts and deterioration of fish reproduction conditions. Large floodplain areas used by fish for feeding are used for construction. Increased turbidity leads to substantial alterations in the structure of hydrobiotic communities [31-35]. Fish that can move actively migrate from the areas of increased turbidity. Under short-term operations, this results in a reduction in their numbers within the polygon areas. With many years of large-scale impact of turbidity, the reduction in fish abundance is accompanied by changes in their distribution in water reservoirs, habitat areas of the most valuable commercial species are reduced, their abundance is reduced as well, and their place in the ichthyocomplex is gradually occupied by less valuable short-cycle species.

Thus, even in the absence of an acute direct exposure to elevated concentrations of mineral suspensions on fish, the fishery value of the rivers in polluted areas is lost. With the reduction in species diversity, a significant reduction of quantitative indicators of phytoplankton, zooplankton, and zoobenthos is observed. The increased degree of dominance of certain species is the evidence on the simplification of the structure of various groups of hydrobionts. A mechanical breach and destruction of benthic habitats, repeated and prolonged excess of the natural rate of turbidity lead to the complete loss of living organisms in the area of construction.

The reduction in the abundance and biomass of zooplankton and zoobenthos, which are the basis of the feed supply for fish, causes adverse changes in the species, dimensional, trophic, and spatial structure of fish populations. As a result of the delivery of suspended solids into water bodies, the following occurs:

— destruction of spawning areas of fish
— reduction of feeding areas
— decrease in fish production of reservoirs
— changes in historical migration routes

[2] Sanitary Rules and Norms for the protection of surface waters against pollution (SanPiN 4630-88). Moscow (1988): 142 p.

— loss of the fish fauna biodiversity

— a significant reduction in fish stock

In cases where water bodies and watercourses are not completely demolished for the construction of GCF facilities, changes of quantitative and qualitative characteristics of communities of hydrobionts after the end of operations are reversible. River ecosystems are restored within more short periods of time compared to lacustrine ones. The recovery period for different groups of aquatic organisms is different. Plankton is restored in the disturbed areas faster than other hydrobionts.

Years of research conducted by the Institute of Plant and Animal Ecology UB RAS demonstrated that in the areas of construction of pipeline crossings fish spawning grounds in the rivers are restored within three years after the completion of work. Communities of aquatic organisms, zoobenthos, in particular, can be restored within a shorter period of time with short-term anthropogenic impact [36-41].

Under large-scale anthropogenic disturbances, and when oil and other toxic substances are released into watercourses, restoration of river biotic ecosystem components takes much longer [42-44].

Conclusion

The Kruzenshternskoye gas condensate field is located in the lower reaches of the Mordyyakha and Naduyyakha Rivers basins in the specially protected area (the Yamal reserve). The Mordyyakha and Naduyyakha Rivers belong to the water bodies of the highest fishery category. The river delta zones are the most important feeding areas of the salmonid and whitefishes valuable fish species in the territory of the Kruzenshternskoye GCF. Human economic activities in such areas can result in the destruction of fish populations in the shortest time.

To preserve fishery resources in the development and exploitation of the Kruzenshternskoye field, the highest requirements must be applied to the protection of water areas where fish spawning grounds are located. Floodwaters, where fish feeds, can be used with certain restrictions regarding water intake, discharge of sewage, and construction in the water protection zone. River estuaries that are the main places of fish feeding and hibernation should be specially protected areas.

In accordance with the environmental legislation, measures for maximum prevention of adverse effects on fish habitat must be provided in the design of objects in the waters or in the coastal area of fishery water bodies. For normal functioning of aquatic ecosystems, the following measures are required:

— Build pipeline crossings over the watercourses, if possible, which will significantly reduce the extent of the negative impact on the feed base and on the migration of fish

— Preserve the natural regime of the water masses flow at floodplain reservoirs during the flood (construction of effective culvert systems)

— Limit the time of work in the waters, in canals, and floodplains during the winter period

— Restrict the areas of water intake end walls placement

— Monitor the water quality of fishery water bodies

— Prohibit fishing for the employees of construction and gas companies in the water bodies and watercourses of the Mordyyakha and Naduyyakha Rivers basins

— Prohibit small boats traffic on the canals of the Mordyyakha delta throughout construction and operation of the Kruzenshternskoye gas condensate field

Currently, the existing preserved and abandoned drill sites in the territory of the Kruzenshternskoye field do not influence the aquatic ecosystems.

The data on the species composition and quantitative developmental characteristics of hydrobionts in different types of water bodies and watercourses in the basins of the lower reaches of the Mordyyakha and Naduyyakha Rivers is the starting point for environmental monitoring of the state of water bodies in the development and exploitation of the Kruzenshternskoye gas field.

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