Community-based resource management in the Arctic: transformation caused by the changing environment

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Abstract. The article outlines structural changes in the current environmental management and availability of biological resources for three Arctic indigenous communities are located in Yamal-Nenets Autonomous district (YaNAO), Nenets Autonomous district (NAO), and Canadian ethnic province Nunavut in conditions of extractive industry development and climate change. Special attention is given to factors leading transformation of quality of life of Nenets and Inuit are based on natural resources, playing a vital role for human habitats and supporting ecosystem services. Indigenous carry out a community-based natural resource management relating to their traditional way of life. This management is viewed as an effective tool supporting the Arctic biodiversity. Also it provides access to natural resources for present and growing generations both. Based on field research, statistical information, materials on environment transformation during on-going development of mineral and fuel deposits, reports on changing natural and climatic features, and on interview of a wide range of members of indigenous communities author indicates a modern picture of availability of biological resources for native peoples, reveals sustainability of the Arctic environment to technogenic impact and changing climate, proposes measures aimed at Nenets and Inuit livelihood protection, and at transfer of traditional land-based skills to future Northern generations.

1. Introduction
The Northern regions of Russia and Canada are the significant reserves of the Arctic part of the biosphere, supporting natural-resource potential and environmental functions at the local, regional, and global level [2]. During thousands of years, ecological and resources niches arose on these territories and they have been still providing environmental balance and supporting livelihood for native peoples, rare species of animals, and plants [15]. The Arctic has sufficient natural conditions for traditional hunting, fishing, and economic activities, and also it is a place for occurrence of unique culture of indigenous peoples living on the North. In the article Yamal-Nenets Autonomous district (YaNAO), Nenets Autonomous district (NAO), and Canadian ethnic province Nunavut are viewed as a native home for indigenous peoples, who creates the original system of environmental management and has culture is maximally adapted to the Northern conditions (a number of residents, who indicated the nationality of Nenets is 29,772 in YaNO and 7,504 in NAO, Inuit in Nunavut – 38,234) [4].

Most part of these regions is located beyond the Arctic Circle, in the permafrost zone. The regions under consideration include polar deserts, polar mountain arctic deserts, mountain tundra, arctic tundra, northern tundra, southern tundra, forest-tundra and taiga (northern and middle). Natural conditions and climatic features of the studied territories are similar due to geographical position. According to meteorological databases, climate in the Arctic regions is warming faster, than the global
average (from 1980 to 2015 the global temperature rose by 0.85°C, in the Arctic zone growth reached 1.5°C). A mean temperature in July about +12°C (sometimes it reaches +30°C), a mean temperature in January is -16°C (the minimum winter temperature down to -57°C), winter lasts about 8 month. Indigenous are adapted to such climatic features and carry out traditional way of life.

The main economic activity in the studied regions is mineral and hydrocarbon mining. YaNAO is the most important region for natural gas and oil extraction (14.5% of all Russian oil reserves). 136 reserves are located within the district (62 oil, 6 oil and gas, 59 oil- and gas-condensate, 9 gas and oil), 37 hydrocarbon deposits are active. NAO has 90 hydrocarbon deposits (78 oil, 6 oil and gas condensate, 4 gas-condensate, 1 gas and oil, 1 gas field are discovered). All reserves are located compact and are opened to international and domestic sale markets. Canadian Arctic has reserves of 75 billion cubic meters of gas and 31 million barrels of oil [16]. In Nunavut province exploratory drilling revealed recoverable hydrocarbon deposits, but these stocks are not enough for commercial development. Mineral extraction in Nunavut is based on open-pit mining of gold ore deposit, iron ore, zinc, copper, silver, uranium. According to Organization of the Petroleum Exporting Countries [16], by 2040 energy demand will be 40-60% higher than in 2010 and large proportion of oil and gas production will take place at the Arctic deposits. Extraction of hydrocarbon resources is connected with development of infrastructure facilities (storage stations, terminals, storage spaces, ways of transportation, and pipeline systems). These objects cause degradation of all components of ecosystems and harm the environment, restricting resource availability (fish, meat, berries, and herbs) for native population and negatively affecting their health, in particular by accumulation of persistent organic pollutants in resources. Chemical footprint is found on the Arctic landscapes where indigenous peoples live and on reindeer lichen-cover pastures. Pastures become contaminated and unsuitable for reindeer grazing. Arctic peoples risk receiving contaminants (brominated flame retardants, fluorinated chemicals) from traditional food [11]. Extraction of mineral deposits in Nunavut is developed by open-pit mining, which leads to appearance of landslides, ravines, anthropogenic forms of relief, terricons, and dumps. Land cover is completely destroyed, biological resources are polluted. Expansion of oil and gas activities in YaNAO and NAO increases areas of violated lands up to 5% per 25 years [15]. Extractive industry also affects way of biota migration. Pipelines block passes of migration for deer.

Numerous evidences show the fragility of the Arctic landscapes to technogenic pressure and low recovery rates after such impact owing to climatic features [1], [7], [12]. Restoration of violated lands is a long process due to low sustainability of the Arctic landscapes to technogenic pressure and it can take 10-15 years [1]. In-shore hydrocarbon extraction has a negative effect on aquatic biological recourses. Extraction and transportation of oil affect marine species - beluga whales, harbor seals, seabirds. These species can be contaminated by polychlorophenyls. In case of regional warming, landscapes changes rapidly – during the last 30 years zone is covered by grasses and bushes with high capacity is increased by 15% (capacity reaches 1-3 ton per ha in the arctic tundra, 3-5 ton per ha in the forest-tundra). This process is called “greening” [15], it changes zonal characteristics of the Arctic: areas are suitable for biota habitats (habitats for polar fox, reindeer, blue hare, snowy owl, and marine mammals - narwhals) are relocated. Native fauna are forced to remove to territories are placed far from the areas, where indigenous are hunting and fishing. Abundance of species is available for hunting is decreasing. Some boreal predators (brown bear, lynx) are going closer to indigenous’ settlements. There is a danger of people to meet predators coming from southern latitudes.

Industrial development of mineral resources, oil, and gas deposits in the Arctic regions in changing climatic conditions [3], [6], [15] has dramatic effects on biodiversity, ecological situation in settlements of indigenous communities, and transforms the way of life are carried out by native peoples [5], [7], [8]. The influence of extractive industry on the nature leads to biological resources shortage and restricts its availability for marine fishing, hunting, and wild plants harvesting. Economic activity in condition of changing climate has a large-scale effect on traditional environmental management in Nunavut and in Russian local settlements in YaNAO and NAO. Necessity of ecosystem-oriented management of the Arctic environment is arising for these regions. In this context
revealing factors limiting access of indigenous communities to biological resources and studying of mining impact on areas, where native peoples live, have the major meaning on the way to sustainable development of the Arctic.

The goal of the research is to reveal the specifics of traditional community-based resource management in YaNAO and NAO and Nunavut, as well as to assess the impact of extraction industry expansion and regional climate changes on biodiversity and current ecological situation. Some results were reported at the 5th International Scientific Conference “Arctic: history and modernity”.

Inuit and Nenets’s culture are adapted to the environmental management. It is a key part for survival of these peoples. Studying of links are formed between traditional way of life, nature, biological resources, and economic activities we can reveal strong and weak sides of sustainable development of these Arctic territories facing changing environment and technogenic pressure. The major scientific task of the research is to analyze how to save Inuit and Nenets traditional knowledge for the future indigenous generations in condition of resources development and current environmental-climatic changes.

2. Materials and methods
Methodology of the research involves a wide range of mixed scientific and practical approaches, as well as field research, including interview of community’s members of Inuit in the Canadian province Nunavut (in English) and Nenets in YaNAO and NAO (in Russian). Interview was chosen as a common practice for gathering information about quality of life in native communities [3, 5, 7]. During interview 20 questions in the area of transformation of traditional resource management is carried by indigenous and about shortage of biological recourses were asked to native peoples (30 participants of mixed ages in 3 focus-groups). Additional information was gathered directly from reports and scientific publications focusing on community’s adaptation to changing environment, and from databases on social research in the Arctic [2, 3, 4, 5, 7, 13]. During the study author applied methods of ground-based observation of environmental violations and loss of biodiversity due to development of mineral and fuel resources [1, 13], as well as due to climate changes [14]. Methods of collecting statistical and scientific information from open sources, nature research, and rank assessments of environmental sustainability to technogenic violations were used by author in order that determine the degree of the Arctic landscapes sustainability. Meteorological data on current climatic changes over studying territories, availability of biological resources for indigenous, and data on degree of ecological pressure by mining activities were obtained since 1970s. [4, 6, 8, 9, 10, 12, 13, 14, 15]. Extraction of resources and changing climate both are viewed as driving forces of violations of the Arctic landscapes and drivers of restrictions for traditional environmental management [3, 7]. Arctic ecosystems resilience to mining development and to changing climatic values was ranked on the scale from 1 to 8 (1 is the highest, 8 is the lowest resilience). The key ecological violations are related to mining development in the studied regions also were ranked (low, mean, and high degree of violations). All scales/ranks were compared with current research are presented in reports and publications on climate change, as well as with issues on regional strategies on social-economic development of the Arctic [2-5]. Results of the study were compared to quantitative and qualitative information providing by Ministry of Nature of Russian Federation, Intergovernmental Panel on Climate Change (IPCC), the Institute of geography RAS, Federal service Roshydromet, McGill University, and Guelph University (Canada) [3, 4, 6, 8, 9, 10, 12, 14, 15].

3. Results and discussion

3.1. Effects of the extraction industries on the environment
The major environmental violations are currently active in YaNAO, NAO, and Nunavut were ranked by degree of their occurrence in places where indigenous live. The rank was following: melting permafrost (depth of thawing 1.5 m - high, depth of thawing 1 m - mean, depth of thawing 0.5 m -
low), area of sea-ice decrease (30% - high, 15% - mean, 5% - low), area of sub-soil and top-soil destruction (60% - high, 40% - mean, 20% - low), air pollution (60.000 ton / km² per year - high, 59.000 - 35.000 ton / km² per year - mean, 34.000 - 7.000 ton / km² per year - low), area of sea pollution (15% - high, 14 - 5% - mean, 5% - low), area of soil pollution (51% - high, 26 - 50% - mean, 25% - low), area of soil erosion (41% - high, 21 - 40% - mean, 20% - low), area of solifluction occurrence (60% - high, 59 - 30% - mean, 29% - low), ravine occurrence (3 per km² - high, 2.9 - 0.6 per km² - mean, 0.5 per km² - low), area of karst occurrence (20% - high, 29 - 4% - mean, 3% - low), loss of marine resources (25% - high, 15 - 24% - mean, 14% - low), loss of deer pastures (20% - high, 19 - 10% - mean, 9% - low), decrease of hunting areas (25% - high, 15 - 29% - mean, 14% - low), loss of bio capacity (20% - high, 19 - 10% - mean, 9% - low), decrease of herbs, mushrooms, berries areas (40% - high, 39 - 20% - mean, 19% - low), decrease of fishing areas (25% - high, 15 - 24% - mean, 14% - low). Table 1 contains the list of ranked ecological violations and evidences about degree of their occurrence during extraction industry development in YaNAO, NAO, and Nunavut.

**Table 1.** Ecological violations and degrees of their occurrence during extraction industry development in YaNAO, NAO, and Nunavut

| Ecological Violations                           | Degree of Occurrence |
|------------------------------------------------|-----------------------|
| Melting permafrost                              | high                  |
| Decrease of sea-ice area                        | high                  |
| Sub-soil and top-soil shifts                    | mean                  |
| Air pollution                                   | mean                  |
| Sea pollution                                   | high                  |
| Soil pollution                                  | high                  |
| Soil erosion                                    | high                  |
| Solifluction                                    | high                  |
| Ravine occurrence                               | high                  |
| Karst occurrence                                | low                   |
| Loss of marine resources                        | mean                  |
| Loss of deer pastures                           | high                  |
| Decrease of hunting areas                       | high                  |
| Loss of bio capacity                            | mean                  |
| Decrease of areas where herbs, mushrooms, and berries grow | high                  |
| Decrease of fishing areas                       | high                  |
| Access to bioresources to indigenous            | low                   |

The wide personal field research in the studied regions showed that many empty buildings, old fuel tanks and other technogenic garbage are left after the mining activity. Arctic landscapes are being ruined and regeneration is going very slowly. A huge number of tanks with diesel oil and contaminated barrels are abandoned. Oil products fall on land and seas. According to official statistics concerning accidental oil spills in the Arctic, the main accidents occur during transportation and break of pipelines (30% of all accidents) [1]. Chemical pollution destroys soil and vegetation cover, decreases capacity of ecosystems, leads to fire danger, and contaminates rivers. Indigenous try not to gather wild plants and lose skills how to harvest them. Shortage of wild plant resources reaches 75%. Also, development of mineral resources destroys seasonal pastures – places for deer feeding. Besides, on violated lands invasion of alien species reaches 40%. Most of them transfer and accumulate pollutants. It is urgent to eliminate the accumulated environmental damage.

Assessment of environmental violations causing by mining in YaNAO and NAO shows, that the polar deserts zone has the highest resilience to mining, at the same time ecosystems are located in the
European and Siberian tundra and the sub-arctic southern tundra are the most vulnerable to technogenic impact. The pressure of oil and gas extraction industries on different types of the Arctic landscapes in YaNAO and NAO is shown on Figure 1.

![Figure 1. Profile of ecosystem resilience to oil and gas sectors impact in YaNAO and NAO.](image)

Environmental violations causing by open-pit mining and their intensity in Nunavut are shown on Figure 2. Profile of the landscapes resilience to open-pit mining impact in Nunavut is the similar to profile of resilience to oil and gas extraction impact in YaNAO and NAO; however the values are well below.

![Figure 2. Profile of ecosystem resilience to open-pit mining impact in Nunavut.](image)

3.2. Violations on the Arctic indigenous’ territories and transformation of indigenous’ ways of life due to climate change

Based of the personal field research, interview, and data are gathered from scientific reports [4], [6], [10], [12], author comes to conclusion, that the most sustainable ecosystems to climate changes are located in the polar desert zone, at the same time the areas with a low sustainability are placed on the sub-arctic southern zones of tundra, as well as on the European and Siberian tundra. Figure 3 shows author’s results on assessment of the ecosystems resilience of the natural landscapes in YaNAO, NAO, and Nunavut to climate change.
In the context of changing environment in the Arctic it is necessary to assess the influence of climatic phenomena on the ways of life of indigenous peoples. Duration of thaw and amount of precipitation has been rising since 1970s [9]. For the period 1973–2015 in studied regions total duration of thaw (from 12 to 22 days) and rainfall amount rose (from 60 to 120 mm). It leads to decrease of wild berries areas – sources of vitamins and medicinal resources for indigenous. More than half of the interviewed Nenets and Inuit note decrease of cowberry, blueberry, cloudberry, blueberry, currant, and cranberry in everyday meal.

Growth of seasonally thawed layers of the permafrost (1–4 cm / 10 years and 24–26 cm for the period 1999–2015) leads to decreasing of areas covered by lichen. Reindeer have shortage of lichen in feed – source of many anti-inflammatory minerals preventing reindeer diseases. Warming in the Arctic leads to reduction of permafrost zone up to 15-20% and shifts its borders to north-east by 150-200 km. Depth of seasonal thawing rises to 25-50%. These phenomena lead to biodiversity decreasing, bogging, and replacement of tundra to forests. Degradation of the permafrost zone has a harmful effect on the arctic ecosystems. Threats to traditional resource management on Northern territories are rising.

In the winter period fragility of snow restricts access for native peoples to hunting areas. Statistical data for 1984–2015 show reduction of snow cover thickness by 0.3 cm / year. At the same time duration of days with snow cover is decreased from 230–290 days to 210–270 days [3, 10]. Since 2000s terms of the first snow appearance have began later for 10 days in compared with the data of climatic period 1970–2000. Snow texture is getting fragile; use of sledges for moving is getting impossible. Hunting on unstable surface is difficult, native peoples have to use modern vehicles such caterpillar land rovers and quad bikes (70% of Nenets use it). These vehicles affect land cover, accelerate fragmentation of vegetation, destroy subsoils, increase erosion, solifluxion, and ravines. Indigenous lose traditional skills how to move by sledges and to operate of dog-teams. Native peoples can not transfer this knowledge to young generations.

According to J. Ford et al. [3] decreasing of sea ice area (in 50 km along the in-shore zones) leads to relocation of marine mammals habitats. Besides, drifting ice in the Arctic seas restricts hunting and fishing. The distance that hunters and fishers from Nunavut, YaNO, and NAO need to overcome to reach the animals locations is increasing. During interview, Nenets and Inuit claimed that a distance to the habitats of marine animals has increased in 1.2–1.5 times for the last 15 years. Respondents indicated that use of motor boats for fishing is necessary. Sea hunters lose traditional skills how to move by wooden boats, how to create and repair them.

Unpredictability of the weather conditions makes hunting dangerous. Nenets and Inuit hunters are not prepared well for these extreme events. Native peoples in Russia and Canada have to adapt to changing climate: to use only motor boats to reach the habitats of mammals; to plan the time for

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**Figure 3.** Profile of ecosystem resilience to changing climate in YaNAO, NAO, and Nunavut.
hunting carefully; to use heat-saving modern clothes in contrast to traditional fur clothes. Indigenous gradually lose skills how to create traditional fur coat and hunting by traditional way.

A specific of community-based resource management is carried out by native peoples in the YaNAO, NAO, and Nunavut is shown on Figure 4.

Figure 4. A specifics of community-based resource management is carried out by indigenous peoples in YaNAO, NAO, and Nunavut in condition of current climate changes and mining development.

The scheme on Figure 4 is based on current climatic exposures and pressure from resource extraction companies affecting the way of life of indigenous peoples. The central core of the scheme includes the risks for indigenous peoples to lose the traditional knowledge on community-based environmental management during economic development and changing climate. Within the framework of the Arctic strategies governments of Russia and Canada both should support programs directed at involvement of indigenous in economic activities, for example reindeer breeding and wild plant harvesting. Also government of YaNAO is renewing the international project “Children of the Arctic” promoting to comprehensive education of the Russian young indigenous through humanitarian and cultural exchanges with the native peoples in the Canadian Arctic.

4. Conclusions
Indigenous in YaNAO, NAO, and Nunavut have risk to lose survival skills in conditions of on-going environment destruction and climate change. Therefore, understanding risks and offering of measures aimed at communities’ livelihood protection in changing environment can promote to sustainable development of the Arctic and can prevent rapid loss of ecological niches for native peoples, rare species of animals, and plants. Based on conducted research author makes some proposals:

1. Indigenous of the Arctic should be involved in the process of the environmental management on territories of hydrocarbon exploration and mining development. Traditional knowledge and methods on the environmental management are carried out by native peoples can be a good response to minimize effects from technogenic pressure and can support sustainable development of the Arctic
during economic development. Indigenous in Russia could be involved in the national projects, such as “Ecology” and could carry out monitoring of key species on the territories where mining companies conduct and plan activities. The Ministry of Natural Resources is ready to provide a scientific, methodological, and analytical support for this purpose.

2. Expansion of oil and gas activities increases extremely hazardous natural phenomena and changes location of arctic biota. Exploration of hydrocarbons creates a growing risk to biodiversity. The risks of oil spills and pollution during transportation and extraction are rising. Oil and gas companies have to use modern environmental-friendly technologies, aero-monitoring of pipelines, and networks for utilization of associated petroleum gas in order to minimize ecological risks and violations of the Arctic nature. Open-pit mining should be implemented with recultivation works.

3. Development of mineral, oil, and gas resources should be followed with creation of reserve territories for protection of unique biodiversity. Protected territories should be increased (up to 20-30% in each region) and expansion of mining facilities should be restricted.

4. Arctic regions are resource for future generations and these territories are needed in ecological-balanced development. For these regions special programs supporting activities of the indigenous in the environmental management should be developed. In Russia a positive role in such possess can play the Agency for Human Capital Development in the Far East and the North and Arctic Institute providing education in the fields of new industrial technologies development, environmental management, and support of native peoples.

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