# DEVELOPMENT OF THE UK-RUSSIA ARCTIC RESEARCH AND COLLABORATION NETWORK

ARKHANGELSK, 2018

UArctic

САФУ

NORTHERN (ARCTIC) FEDERAL UNIVERSITY

# Development of the UK-Russia Arctic Research and Collaboration Network

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This volume presents the proceedings of the international conference, organized on March 1–3, 2018 by the UArctic Research Office at the Northern (Arctic) Federal University in Arkhangelsk. This conference was the concluding event in a round of joint workshops within the project «Development of the UK-Russia Arctic Research and Collaboration Network”, uniting British, Russian and international scholars on interdisciplinary arctic research. The project was funded by the Foreign & Commonwealth Office and the UK Embassy in Russia within the UK-Russia Year of Science and Education 2017.

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## UArctic Facilitates UK–Russia Collaboration in Arctic Research

In 2017–2018, within the UK–Russia Year of Science and Education, the UArctic Research Office at the Northern (Arctic) Federal University implemented the project "Development of the UK–Russia Arctic Research and Collaboration Network". Funded by the United Kingdom's Foreign and Commonwealth Office, the project aimed to provide opportunities for advanced discussions on Arctic research agenda and further collaboration prospects between Russian and British scientists, including activities within UArctic.

Within the framework of this project, research seminars were run both in the UK and Russia, hosted by the University of Aberdeen, the Scott Polar Research Institute and the Northern (Arctic) Federal University. The seminars became a meeting place for one hundred Arctic scientists from 45 Russian and British institutions to share knowledge on coastal and marine biology, Arctic ecosystems, environmental and social impact assessment, climate change, mitigation and adaptation strategies, rural health and wellbeing in the North, new healthcare technologies, coastal archaeology, and indigenous peoples' livelihoods and cultures.

The project was unique in terms of its geographical scope. Research results have been presented by scientists from many UK institutions and from different regions and field sites of Russia, including Far Eastern Russia, Eastern and Western Siberia, Ural, and North-West Russia. The meetings also included discussions on circumpolar mobility, teacher education, Arctic science data analytics, the role of science diplomacy in the Arctic, and reflections on scientific challenges from the perspective of national Arctic strategies of the Russian Federation and the UK.

We also realized how important it was to promote knowledge of Arctic science and international cooperation in the region among the youth, and this was the aim of the workshop "Researcher Connect" held in cooperation with the British Council. The intensive three-day training program was an excellent opportunity for young scholars from Russian UArctic member institutions to improve their skills on science communication and academic writing.

The UK–Russia project aimed at and successfully created networks between both researchers and institutions. Concrete outcomes include, for instance, a formal Memorandum of Understanding between NArFU and the University of Aberdeen; a Researcher Links workshop grant for "Archaeology and Cultural Geography of Arctic and Subarctic Coastal Regions" (NArFU, Durham University); and collaboration on oil spills, seminars and a joint publication (NArFU, University of Aberdeen).

Another result of the project was a conference proceedings volume prepared by the UArctic Research Office as a follow up of the final conference held in Arkhangelsk in March 2018. This volume includes articles by Russian and British conference participants presenting various aspects of current Arctic research. In the first chapter articles about climate change and its impact on Arctic ecosystems, as well as about existing experience and research methods in this field can be found. The second chapter examines issues related to traditional population and indigenous peoples living in the Arctic and subarctic zones. All articles are published in Russian and English.

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Part 1.

# Sustainability of Arctic ecosystems to climatic and anthropogenic loads

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# 20 years of climate change research in the Arctic: Have we made progress?

Climate change has been identified as one of the biggest threats facing humanity this century[1,2]. This is particularly the case in the Arctic, which for several decades has been undergoing transformative change in climatic conditions[3-11]. These documented changes are having implications for the ~4 million people who live in the Arctic. Indigenous peoples, in particular – estimated at 400,000 to 1.3m Arctic inhabitants – have been identified as highly vulnerable to the effects of climate change, and reported to be its first human victims[9,12-17]. Models indicate that climate change will continue to be amplified in the Arctic[9], with negative impacts on food systems, health, infrastructure, and economies projected[3,7,9,18]. Climate change will also bring opportunities associated with new shipping routes, lengthening of marine transportation seasons, and enhanced access to oil, gas and mineral resources[7,19-21].

As climate change has become a major societal concern, there has been a rapid increase in research focusing on documenting impacts, understanding what make human systems vulnerable or resilient, and identifying adaptation options. The Arctic has been in the vanguard of such developments, with some regions becoming ‘hotspots’ for climate change research, driven by large multi-year research programs and expanding funding for Arctic research[22-24]. For example, a search in Web of Knowledge reveals 10,757 articles published between 1997 and 2017 to have a focus on Arctic climate change (topic search for *Arctic AND climate change) – accounting for 4.5% of global publications on climate change–with the number of publications increasing each year (Figure 1).

With this increasing publishing effort comes the question, are we making progress in understanding? This paper examines this question by drawing upon my engagement in human dimensions of Arctic climate change research since the early 2000s, including leading a number of systematic reviews documenting the state of knowledge in the field[22,25-35], lead authorship roles on Arctic-focused climate change assessments (e.g. by Arctic Council[36] and Canadian Government[37]) which involved critically appraising the state of knowledge, and involvement at a research management level in large projects (e.g. ArcticNet). It focuses at the circumpolar level, and conceptualizes "progress" as composed of both whether research is advancing fundamental scientific knowledge *and* addressing key needs to inform decision making processes[38]. Progress is examined in four areas.

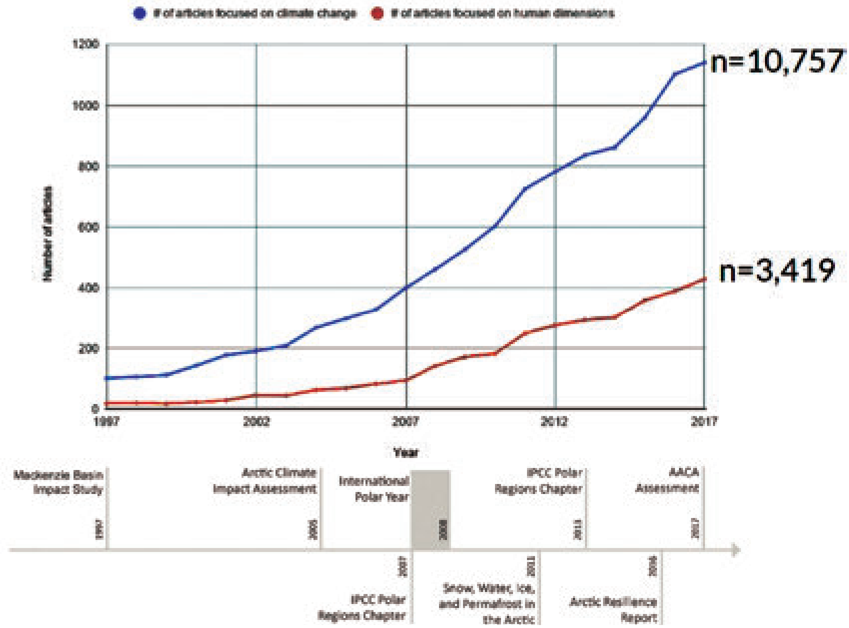


**Figure 1:** Number of peer reviewed articles focusing on Arctic climate change (n=10,757) (Search in Web of Knowledge under "Topic" *Arctic AND climate change), and those focusing specifically on the human dimensions (n=3,419) (topic search for *Arctic AND climate change AND vulnerability OR resilience OR adaptation OR impacts)

**Do we know how the climate is changing?**

The majority of research on Arctic climate change focuses on documenting how the Arctic climate is changing and projecting future impacts. For example, of the 10,757 articles in Web of Knowledge in Figure 1,68% have such a focus. Regional trends are well documented, including a circumpolar warming trend of 1.9 °C which has been documented over the last 30 years[31], a rate more than double the global average. In some regions, warming has exceeded 4 °C[39,40]. The extent of temperature change observed in the Arctic already is thus similar to projections of warming globally by the end of the 21st century[31,41]. Precipitation and storm intensity has been documented to be increasing in many regions: in Canada, for example, an increase in annual precipitation has been documented for 1950–2010 at virtually all northern coastal sites, along with an increase in the ratio of snow to rain[42,43]. Warming is projected to continue under all climate change scenarios, and is expected to be greatest in winter and least in summer[3]. Under the IPCC high-emission scenario (RCP8.5), a temperature increase in excess of 8 °C is projected during winter for 2081–2100, while the low-emission scenario (RCP2.6) projects a winter temperature increase of 2.4 °C.

Despite significant progress in understanding, key gaps remain in understanding how the climate is changing. At a local level, for example, limited data availability constrains understanding of how the climate is changing in particular locations, which is ultimately where such information is needed for guiding decision making and planning. While in the North American Arctic, Indigenous and local knowledge have been used to provide a rich and detailed picture on local changes in climate and fill in gaps in instrumental data, such knowledge has been underutilized in a European and Russian Arctic[44]. Moreover, while regional climate models are increasingly offering greater precision at regional scales and accommodating more parameters, significant uncertainties and knowledge gaps remain[26]. Model disagreements arise from uncertainty about greenhouse gas emissions, parameterization of physical processes, model structure variance (e.g. resolution, constants), absence of long-term reliable data on local climatic conditions, while uncertainties associated with modeling increase dramatically at local scales[36,45]. Precipitation in particular is poorly modeled in models, which continue to offer wide confidence intervals. While some of these challenges of projecting future climate can be overcome with scientific advancements, some degree of uncertainty is inevitable in modeling future climate.

**Do we know the impacts climate change is having?**

Research documenting climate change impacts is also well-represented in the literature, primarily based on studies in the natural sciences but with some work also drawing upon Indigenous and local knowledge. Biophysical impacts are well documented. Sea ice extent in the Arctic Ocean has decreased in all months and virtually all regions over the last 30 years, averaging a 13.7% loss per decade relative to the 1981–2010 average, and accompanied by a 75% loss in ice volume since the 1980s[46,48]. These trends are expected to continue or accelerate [3,48], with some models projecting almost complete loss of summer ice cover before mid-century, although if global temperatures are stabilized at 1.5 °C the probability of an ice free summer Arctic is significantly reduced[49,50]. Across the Arctic, sea, lake, and river ice is freezing up later in the year and breaking up earlier. In northern Canada for example, the ice free open-water period is increasing by 3.2–12.0 days per decade, with freeze up delays and in some cases melt seasons that are more than a month longer than they were previously[26]. Sea ice decline has had major impacts on marine and terrestrial ecological dynamics, with impacts of a changing climate already documented to be affecting the health, abundance, and migration timing of a variety of wildlife species[3,18,51,52]. Even if nations manage to limit warming to the ambitious 2 °C global target committed in the Paris Agreement, increased instances of storm surge, and extreme weather events are still anticipated along with later ice freeze up, earlier break up, a longer ice free open water season, and more dynamic and thinner ice[48,53-55]

There are a growing number of sectoral studies examining the impacts climate change is having on human systems. Changing weather conditions and ice dynamics, for example, are increasing the difficulties of transportation where semi-permanent trails on frozen lakes, rivers, and the ocean are widely used[56-60], compromising the operating period and safety of winter roads[61-63], with reduced ice extent and thickness also increasing opportunities for commercial shipping in the Arctic Ocean (e.g. Northern Sea Route, Northwest Passage) [19,61,64]. Most work on Arctic transportation has focused on shipping, with little research focusing on the use of semi-permanent trails between communities, air travel, and use of inland waterways on large rivers and lakes.

Declining access and availability of wildlife species have been observed to be compromising food security with Indigenous food systems and culture closely linked to the consumption of traditional foods[7,10,51,65-70]. Research focused on food security implications of climate change is well developed in the North American Arctic, but remains understudied in other northern regions. Thawing permafrost, coastal erosion, sea level rise, and increasing storminess are also affecting infrastructure and fisheries, with evidence that the frequency and intensity of storms in the Arctic is increasing[71-75]. Warming temperatures are altering the prevalence and incidence of waterborne, foodborne, zoonotic and vector-borne diseases, and affecting economic sectors[3,9,65,76-82], although research examining what climate change means for health are nascent. Sectoral studies mostly examine present day vulnerabilities, although some work has started to use participatory scenario planning approaches to examine what future impacts might mean at a community scale[25]. The cumulative effects of multiple changes and what they mean for human systems is largely unexplored.

**Do we know what makes human systems vulnerable or resilient?**

As our understanding of how the Arctic climate is changing has increased, studies have begun to investigate what makes certain regions, communities, households and individuals more or less susceptible to harm. Some studies use concepts from a '*vulnerability framing*'[57,83-86], and others from a '*resilience framing*'[87-91]. Such work has increased our understanding of how climate change affects society, illustrating that the impacts of climate change are determined as much by human factors as they are the nature of climate change per se[31,86,92-94], with examples of both resilient (e.g. Indigenous resource use) and vulnerable systems (e.g. forestry) profiled in the literature. Indeed, in many instances, climate change is not the main driver of change but rather one among multiple interacting factors[36]. Despite our growing understanding, however, knowledge on what makes human systems vulnerable or resilient remains incomplete, and we only have a general understanding of the factors creating vulnerability and underpinning resilience. Key gaps in the literature include:

***Understanding on the processes and conditions creating climate vulnerability remains limited.*** Thus we know that the climate is changing and that adaptive learning has historically underpinned adaptation to past climatic change[95-97] but we don't know how or how fast adaptive learning takes place; we know that communities are adapting to climate change[98] but have little understanding of how much disturbance can be adapted to[99,100]; we know that the cumulative effects of non-climatic factors (e.g. resource development, shipping, globalization, demographic shifts, societal change, institutions) will determine vulnerability to climate change[31,86,92-94], but have little understanding of how and for whom; and we know that there are likely time-lags and thresholds of adaptive response but our knowledge of them is limited.

***The nature of climatic conditions that present risks/opportunities have not been fully characterized***. We know that changing sea ice and weather conditions, more common natural hazard occurrence, and ecological regime shifts are affecting Arctic communities, but our understanding of how vulnerability relates to the nature of change (e.g. timing, magnitude, frequency, duration, intensity) is limited, rarely quantified, and typically assessed based on studies that overlook Indigenous and local knowledge.

***Our knowledge on the response of communities to climate change remains static.*** Vulnerability resides in the condition and operation of coupled human-environment systems. These dynamic interactions are poorly understood and are not captured in current work. For instance, coping mechanisms regularly described as indicative of adaptive capacity in the Arctic (e.g. species switching, resource use flexibility of Indigenous communities) may increase long term vulnerability through system response to change over time[101-103] or may transmit risk to other communities, regions, or future generations.

These fundamental gaps limit our understanding of how climate change might affect Arctic societies. For example, Indigenous populations are often described as vulnerable, yet equally there are reasons to believe they may be highly adaptable, offering insights globally for processes affecting climate vulnerability. And if non-climatic drivers are the main determinants of vulnerability, even in-light of transformative climate change observed in the circumpolar north, then this would shift debates on how to respond to climate change. The scholarship is inconclusive on these big questions in the Arctic.

Gaps in understanding stem from conceptual and methodological shortcomings. Natural sciences dominate Arctic research[23]; for example, of the 3,419 articles documented in Web of Knowledge to focus on impacts, adaptation, vulnerability, or resilience in the Arctic, under 6% are classified as from the social sciences or humanities. This work provides critical information on climate impacts, but overlooks the complex interactions between climate and society that determines vulnerability and resilience to climate change. On the other hand there is a small scholarship examining what makes certain regions and communities more or less susceptible to harm[22,72]. Conducted mostly by social scientists and humanities researchers, this work typically utilizes qualitative methods and case study research to examine how climate change is experienced and responded to in the context of local livelihoods. This has generated important information, but we only have a general understanding of the factors creating or moderating vulnerability, and knowledge on the evolution and dynamics of vulnerability over time is unknown[104]. Research is also temporally discrete, typically spanning no more than two years[105,106]. This is appropriate for baseline work but is unlikely to capture the dynamic nature of how human systems experience and respond to change[9,101,107-111], or provide a basis for integrating Indigenous and local knowledge and science which depends on long-term relationships[112]. Long-term monitoring of vulnerability processes is needed but largely absent[106], contrasting to well-developing monitoring systems focused on tracking changes in climatic variables.

**Do we know how to adapt?**

Climate change adaptation can be defined as "*the process of adjustment to actual or expected climate and its effects, in order to either lessen or avoid harm or exploit beneficial opportunities*"[41]. Adaptation encompasses a variety of strategies, actions, and behaviors that make households, communities, and societies more resilient to climate change, and may target reducing sensitivity to climate change impacts, and/or focus on strengthening adaptive capacity to manage and take advantage of change. A number of Arctic regions have demonstrated leadership on adaptation[10,28,36,113], and there is evidence that autonomous and planned adaptation is underway[98]. At the circumpolar level, for instance, adaptation has emerged as a key component in activities of the Arctic Council (e.g. Adaptation Actions for a Changing Arctic assessment). Research has documented a variety of potential adaptation options across regions and sectors, some focusing on responding directly to climate change impacts (e.g. investing in coastal protection measures, relocating critical infrastructure, hazard mapping, retrofitting older infrastructure), others focusing on underlying social-economic-political factors that lead to climate vulnerability.

Despite growing understanding of adaptation needs and opportunities, key gaps are evident, with adaptation a relatively recent focus in the scholarship and one for which the least amount of research exists. Understanding the potential impacts of climate change and determinants of adaptation is important for adaptation, yet as noted above there are significant gaps in both these areas. Approaches for planning for change in the context of uncertainty, including mainstreaming, low/no regrets planning, adaptive management, and adaptation pathways, offer opportunities to advance on adaptation in-light of significant uncertainty, but have not been widely draw upon[36]. Moreover, few studies actually evaluate adaptation options, or provide guidance on how to rank and prioritize options, with work typically identifying a wish list of potential options, thus limiting uptake by decision makers; there is absence of work documenting if and how adaptation is taking place; and it is unclear if adaptations that are taking place are focusing on the main risks posed by climate change. While these gaps are evident across the Arctic, there is a particular dearth of academic literature on adaptation in the Russian Arctic.

**Conclusion**

Our knowledge and understanding of Arctic climate change has expanded rapidly over the last decade, evident in a rapidly expanding body of scholarship. Yet, as I argue in this paper, there are many gaps in understanding, with uneven progress across the four areas focused on. Of particular concern is that many of these gaps are persistent, in that an absence of research from the social sciences and humanities is evident across scholarship over the last 20 years. And while interdisciplinarity and the engagement of multiple knowledge systems (Indigenous and local knowledge, science) are increasingly being promoted as necessary for identifying and characterizing how climate change interacts with society[114-117], efforts to undertake this remain limited. These shortcomings have been identified in major scientific assessments (e.g. IPCC, Arctic Council) as 'grand challenges', and reflect the difficulties of conducting interdisciplinary cross-cultural research. Working with Indigenous knowledge, for example, requires researchers to move outside the bounds of traditional academic research, and to be open to new ways of seeing and doing[29,112,114]. Such work is high risk as it involves navigating worldviews, cultures, and customs quite different than researchers are used to[29], requires stable long term funding necessary to build trust, and requires researchers to take on multiple roles in communities that are often not recognized in academic reward structures. This type of research is essential, however, if we are to understand the key drivers of change in the Arctic both today and in the future.

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## Late glacial and early holocene – the time of the climatic optimum on the islands of the Kara Sea region

The evolution of the natural environment during the late Pleistocene and the Holocene transpired differently in different parts of the Arctic. Ice sheets in the western part of the Arctic had a cooling effect on the surrounding territories, resulting in the late onset of the thermal maximum in those areas – at the end of the middle Holocene. In the eastern plains of the Arctic, which did not witness wide-spread glaciation, the thermal maximum occurred early – beginning at the end of the Pleistocene.

We conducted our research on the Belyi Island. Modern soils as well as paleopeat horizons have been sampled for radiocarbon dating. Among the obtained radiocarbon dates, 14–9 kyr-old samples prevail. This fact points the processes of intensive peat accumulation occurring as early as the end of MIS-2. This observation is further confirmed by the paleobotanical analysis of paleopeat deposits. We have encountered macrobotanical remains of willow and birch, as well as pollen of such plant groups, which are absent in the modern tundra.

The development of the natural environment of the Kara region at the end of the Pleistocene underwent significant changes. The reasons for this were fluctuations in climate and ocean level. A specific feature of climate change in Siberia, compared with the European part of Russia, was the onset of a thermal maximum at the beginning of the Holocene and a decrease in temperatures in the Middle Holocene (Khotinsky, 1977). Unlike the north of Europe and North America, there was no cooling effect of Scandinavian and Laurentian ice sheets.

Studies of Holocene sediments in the Kara region are presented singly (Vasilchuk et al, 1983; Tarasov et al, 1995; Stein et al, 2004; Slagoda et al, 2014.). Of great interest are the studies of buried peat deposits found on Sverdrup Island (Tarasov et al., 1995). According to radiocarbon dating, the accumulation of peat began in the Allerød, about 12,000 BP (14,000 cal BP), but in the Holocene, about 9,500 BP (10,500 cal BP), it stopped. The reason for the early start of peat formation and its accumulation without interruption during the Younger Dryas was the specific history of the climate of the coastal regions of the Arctic, namely, the warm early Holocene and cooling in the Middle Holocene (Tarasov et al., 1995).

Detailed paleo-soil research on the Belyi island began 5 years ago. To date, radiocarbon dates have been obtained from different parts of the Belyi Island (Artemyeva et al., 2016, Alexandrovskiy et al., 2017; Baranskaya, Romanenko 2017), and the palynological composition of buried peat has been studied. This allows us to characterize the history of the formation of deposits (and soils) of the island in the late Pleistocene and Holocene.

Belyi Island is located to the north of the Yamal Peninsula (73°15'00''N, 70°50'00''E) in the Kara Sea (fig. 1). While the island is of substantial size (50x40 km), it has low altitude (not exceeding 10 m a.s.l.). The surface of the island can be classified as a low plain that was formed in the marine depositional environment. Sediments that form drainage divides mostly consist of sands that have different genesis. These sediments date to Late Pleistocene. Throughout the island, there are many thermokarst lakes and round-shaped depressions. The river network mainly consists of small watercourses with poorly defined valleys that are often waterlogged. The watercourses flow in different directions and flow into the Kara Sea or its bays. Belyi Island is located within the Atlantic district of the Arctic climate belt. The climate of the island is characterized by especially long harsh winters that are associated with severe storms and frequent blizzards. The warm period lasts only 55–70 days per year. The average yearly temperatures are negative – -10°C – -12°C. Precipitation is low, less than 300 mm per year. However, flat physical landscape and permafrost result in the island being covered with bogs (Abakumov et al. 2017).

Several types of geomorphic surfaces can be distinguished: marine terraces, their slopes, lacustrine depressions, riverine floodplains, and coastal marshes. Sedge–moss–cotton grass tundra communities predominate on elevated sites of marine terraces. In the depressions, they are replaced by sedge–sphagnum bogs. Dwarf shrub–sedge–lichen–moss communities are developed on drained slopes of the terraces. Forb–sedge and sedge–moss mires occupy waterlogged river valleys and lacustrine depressions. Low coastal marshes are covered by sedge–grass–moss communities. In general, forb–sedge–moss vegetation predominates on the island (Moskovchenko et al. 2017).

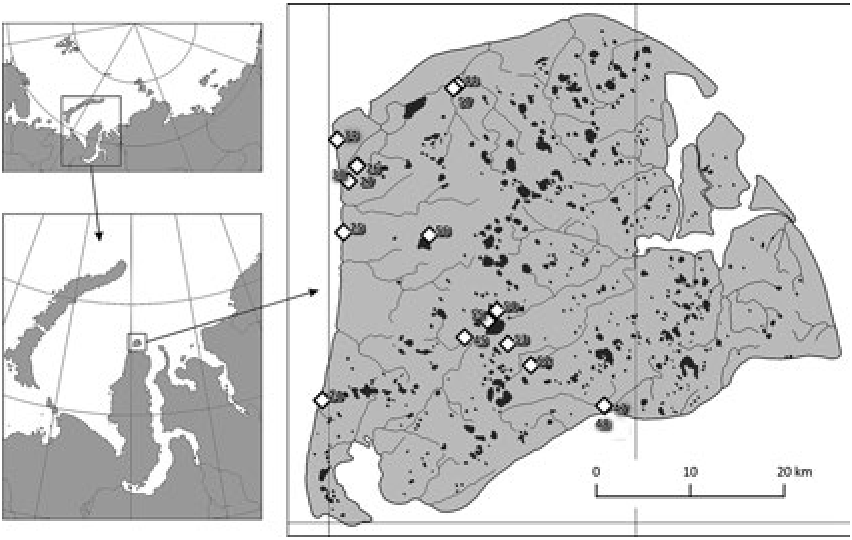


**Figure 1.** Belyi Island. Location of sites

We have conducted research across practically the entire island. Modern soils and well as paleopeat horizons have been sampled for radiocarbon dating. Among the obtained radiocarbon dates (more than 40), 14–9 kyr-old samples prevail. This fact points the processes of intensive peat accumulation occurring as early as the end of MIS-2 (fig. 2).

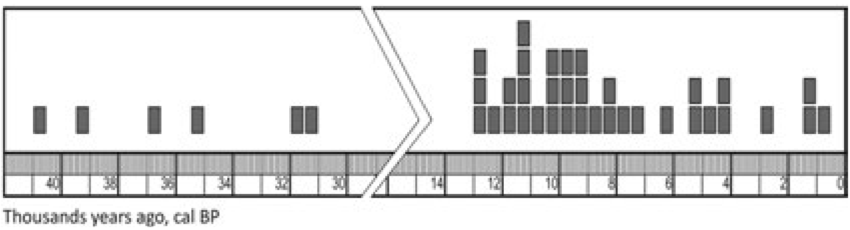


**Figure 2.** Distribution of radiocarbon dates along a time scale

Based on the data obtained, we carried out a periodization of the history of the island over the past 40,000 years.

1. Kargin thermochron, MIS 3, >28000 14C age, cal BP. Climate warming, sea level close to present, peats formed and got buried under the aeoloan sands.

2. Sartan cryochron, LGM, MIS 2, 28000–14000 14C age, cal BP. Deep sea regression (up to -120 m), reduction of the Arctic Ocean's area, formation of aeolian sands.

3. Allerod-early Holocene, MIS 1, 14000–9000 14C age, cal BP. Sea level at -80 – -20 m, thermal maximum, active formation and burial of peat as a result of various processes.

4. Middle and late Holocene, MIS 1, 9000–3500 14C age, cal BP. Climate cooling; high sea level, at times higher than in the present; localized peat burial processes.

5. Present period, MIS 1, <3500 14C age, cal BP. Further cooling; aeolian accumulation in the coastal zone during the last 1500 years.

In the proposed periodization, MIS 1 distinguishes two main stages: (1) the thermal maximum 13 (14) – 9 cal BP and (2) the cooling period of climate 9-0 cal BP. Cooling in the Younger Dryas (YD) was significantly weaker than in the Middle Holocene. The formation of peat in YD was not interrupted, but went with the same intensity as in the early Holocene.

This observation is further confirmed by the paleobotanical analysis of paleopeat deposits. We have encountered macrobotanical remains of willow and birch, as well as pollen of such plant groups as Umbelliferae, Chenopodioideae, Cichorioideae, Artemisia spp., which are absent in the modern tundra. In fact, the closest areas where they grow presently are located more than 500 km to the south of the research zone.

Thus, the paleoarchives of Belyi Island indicate that plants preferring warmer climate conditions (warmer than the current climate on the island) were present in the research area as early as the end of the Pleistocene – beginning of Holocene. These findings confirm the early onset of the HTM in the research zone, as well as challenge the notion of a continuous ice sheet covering the Kara Sea during MIS-2.

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# Geo-Informational assessment of the high-latitude Arctic natural complexes' resistance to anthropogenic and recreational impacts

A natural site of outstanding cultural value, Cape Flora is situated in the south of the Franz Joseph Land, constituting the area of the Russian Arctic National Park. Exposed to more than a century-long anthropogenic impact, not only has Cape Flora witnessed a series of Arctic landmark discoveries, it witnessed its ecosystems receiving a tangible anthropogenic effect. The current trends in anthropogenic impact relate to the increasing load from recreation and transportation, endangering the area's ecological services and loss of biodiversity and historical attractions.

A series of geo-informational and research expeditions were launched in order to assess the scale of anthropogenic impact and its trends that are directly linked with recreational load. They involved three stages – preliminary tabletop analysis, field investigations, and final office processing.

At the pre-field investigation stage, the authors have developed a tentative map of the area's natural complexes, that relies on the outcomes of landscape feature deciphering, as well as on multi-spectral, super high precision satellite images. The latter were received from GeoEye, particularly the image from September 18, 2012, with resolution of 0.5 m per pixel. The process of deciphering the contours of Cape Flora's natural complexes focused on such features as soil types; soil humidity levels; displacement of phonological features of the vegetation growing on slopes varying in layout and gradient. The detected manifestations of the current and relic exogenic processes – namely, frost splitting, solifluction, and soil heaving – received descriptions and classification. Concurrently, the vegetation communities discovered to be present within the zones of exogenic processes, were analyzed for boundaries and attributed to relevant types.

The field investigations were designed to verify the contours plotted on the tentative map and what they contained. At this stage, the degree of detail of the typology used in developing the legend, was estimated. Also, the field investigations enabled the evaluation of phonological delay that had affected the evolution of the vegetation growing on various terrain components, and of the background ecosystems and their counterparts experiencing recreational impacts of various degree. The identified interrelations between the vegetation and the terrain, humidity levels, and microclimate were carefully structured and made basis for a series of thematic maps. The authors were performing the field investigations as part of the Russian Arctic National Park's team. The lasted from 6 July to 24 July 2017 and took place on Northbrook Isle, 'Cape Flora' station.

At the final office processing stage, the image deciphering materials verified during the field investigations were used as a basis for the digital collection of maps encompassing all of Cape Flora's natural monuments. This collection features the maps unveiling, among others, "Slope Phenomena", "Intensity of Linear Erosion Processes", "Disturbance in Soil Freezing Pattern", "Intensity of Gravitational Processes Occurring on Slopes and Nivation Niches and Benches".

Any description of a northern ecosystem can be said to defy identification of one single factor which would be dominant to the key features of each particular ecosystem. Northern ecosystems tend to evolve under the influence of several closely related factors of microclimatic, hydrological and edaphic nature, as well as sets of erosion- and slope-related and cryogenic processes. Our analysis of the conditions under which the currently occurring exogenic processes influence the structural composition of Northbrook's ecosystems, has enabled differentiation between five major factors whose combinations define man-made impact susceptibility levels.

For each of the factors we defined separate principles for image deciphering and field verification.

Special attention was paid to the principles of mapping the Arctic vegetation communities' resilience capacity. Alongside with the conventional set of factors indicative of the resilience levels, we considered such aspects as prevalence of various life forms within vegetation communities, and vegetation cover formation patterns. When it comes to the resilience of ecosystem's bio bone components, a special role is played by grassy turf and vegetable layers of the Arctic soils. The signs of degradation discovered in the grassy turf, as well as its decreasing role in stabilizing the slope and cryogenic phenomena, have formed basis for mapping the resilience levels in the digital collection of maps titled "The Natural Complexes of Cape Flora". The databases used in developing this collection governed the elaboration of the recreation impacts resilience criteria for the entire spectrum of Cape Flora's ecosystems.

The process of mapping the integral risks for Cape Flora's ecosystems was preceded by expert evaluation of the potential negative trends in anthropogenic load. Based on our benchmarking study of the original vegetation communities and their counterparts that are or were under anthropogenic load, we have arrived at three-level risk scales. Risk maps were developed for each of the negative trends by way of assigning the contours on "The Natural Complexes of Cape Flora" risk scores. Risks total were recalculated to 100%. A total of 6 integral risk percentage maps were built.

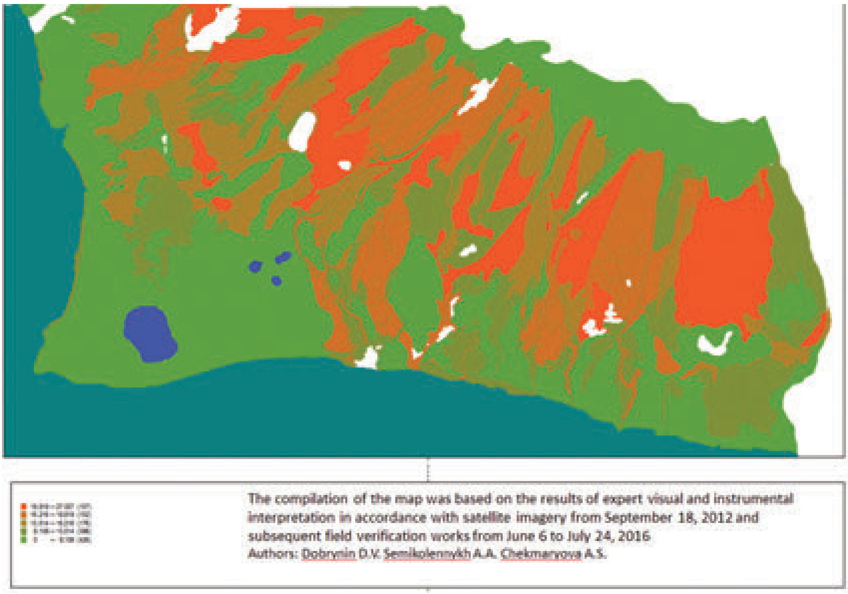


**Figure 1.** Cape Flora, Franz Joseph Land: Negative risk trends map

**Risk score tables for various phenomena and processes.**

*Evolution of slope processes.*

| | | |
|---|---|---|
| 3 | Solifluction most intense, step-wise | !!! |
| 2 | Solifluction slow | !! |
| 1 | Slopes with potential solifluction hazard | ! |
| 0 | Zero solifluction | |

*Disturbance in soil freezing pattern.*

| | | |
|---|---|---|
| 2 | Frost splitting active, frost humps manifest | !! |
| 1 | Heaving patches forming | ! |
| 0 | No soil heaving | |

*Gravitational processes occurring in nivation niches.*

| | | |
|---|---|---|
| 2 | Excessively water-logged section within melting snowfields | !! |
| 1 | A set of gravitational processes occurring in snow-free nivation niches | ! |
| 0 | Zero impact | |

*Evolution of linear erosion processes.*

| | | |
|---|---|---|
| 3 | High likelihood of erosion processes activation in combination with abrasion within steep sections of the shores | !!! |
| 3 | High likelihood of linear erosion on the sides of older and relatively stable cuttings | !!! |
| 3 | Major active downward cuttings | !!! |
| 2 | Dense network of minor cuttings | !! |
| 1 | Cuttings sporadical but actively forming | ! |
| 0 | Zero erosion | |

*Degradation of grassy turf and its decreasing role in slope processes stabilization. Classification of the vegetable layers and related vegetation.*

| | | |
|---|---|---|
| 3 | Damp peat soil | !!! |
| 3 | Exposed mineral surface formed by loose soils | !!! |
| 2 | Loose mineral soils with sod tussock grasslands | !! |
| 1 | Dry, solid peat soils with moss communities and sporadic sod grasses | ! |
| 0 | Loose mineral soils with forming dense sod grasses community | |
| 0 | Rocky soils with sporadic petrophytes | |
| 3 | Hydrophyte communities | !!! |

Also, our analysis involved ranging the threats being faced by Cape Flora's natural complexes. In addition to the integrated risk map, in place is the collection of maps that feature the risk levels from each of the threats, the risk types and distribution patterns. The proposed methodology might be used in assessing and benchmarking the local sites within the Arctic areas.

The developed maps offer evidence-based information that can be used as guidance for banning, partially or completely, tourism in the area in question or for laying travel routes with regard to natural complexes' resilience capacity.

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# The role of science, technology and engineering in the regulation of Arctic oil spills: an interdisciplinary approach

## 1. Introduction

According to an assessment of Arctic petroleum resources by the US Geological Survey, more than 400 onshore fields have extracted 40 billion barrels (bbl) of oil, 1136 trillion cubic feet (Tcf) of gas and 8 billion bbl natural gas liquids to date[1]. A further assessment of the offshore Arctic geology concludes that approximately 30% of the world's undiscovered gas and 13% of undiscovered oil lies in primarily on the Arctic continental shelf in less than 500m of water[2], of which the lion's share is located in the seas of the Euro-Barents Arctic[3]. To date, most of the exploitation of offshore Arctic oil and gas has occurred in the Euro-Barents Region, and includes the Norwegian fields Goliat and Snøhvit, and the Russian Yamal and Prirazlomnoye developments. There are a number of other fields in the area that are slated for development, especially the giant Shtokman Field, as well as highly prospective new areas, including the Fedinsky High straddling the Norway-Russia Maritime Border.

Given the huge petroleum resources in the area, the increased level of exploitation of petroleum, and the risk and consequences of an oil spill associated with such activities, it is critical that the oil spill prevention, preparedness and response (OSPPR) framework considers not only legal regulation, but also incorporates the necessary interdisciplinary knowledge and linkages. Adopting this regulatory framework will ensure best practice in regulating OSPPR. Therefore, this paper examines two main



[1] Donald Gautier et. al., 'Assessment of Undiscovered Oil and Gas in the Arctic' (2009) 324 *Science* 1175–1179, 1175.

[2] This means that estimates of undiscovered, technically recoverable oil and gas in the Arctic are approximately 90 billion bbl oil, 1670 Tcf gas and 44 billion bbl of natural gas liquids. See Gaultier, Ibid.

[3] The Euro-Barents Arctic is the area of Norway and Russia, and includes the Barents Sea, Kara Sea, and the White Sea.

issues. Firstly, it provides an overview of sources of oil spills in the Arctic, and the legal framework relating to spills from petroleum activities. Secondly, it provides a brief overview of the interdisciplinary issues to be considered when seeking to regulate extraction activities in the Arctic to prevent and respond to oil spills.

**2. Sources of oil spills in the Arctic**

The two main sources of oils spill in the Arctic marine environment is that of petroleum platforms and ships as illustrated in figure 1 below:

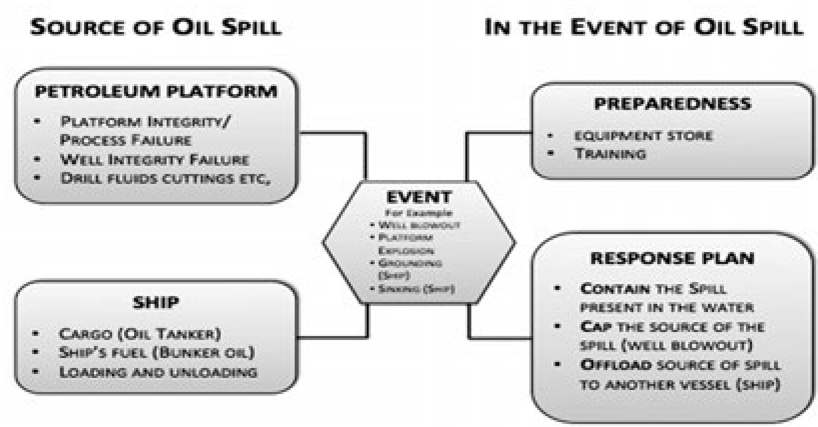


**Figure 1.** Oil Spill sources and events (Source: Compiled by Author)

***2.1 Petroleum Platforms and Facilities (PPF)***

When undertaking petroleum exploitation, there are several possible sources of oil pollution. In particular, there are three main sources of oil spill: well blowouts and associated hydrocarbon release; platform failure; and operational discharges. Of these, operational discharges such as drill fluids and cuttings contribute a small volume oil spill in the environment. A major contributor is that of well blowouts, with platform incidents also contrbuting to oil spills.

*2.1.1 Well Blowouts*

When undertaking drilling operations, a well blowout (also known as loss of well control/integrity) is a source of oil pollution. Such loss of control can range from minimal, causing a minor oil spill, to major well blowouts that have resulted in huge oil spills with enormous environmental and social consequences.

In the period that offshore oil production has occurred, there have been four incidents of note that have had a major impact on the law regulating oil spills from well blowouts. The first was the 1977 *Ekofisk* Bravo well blowout, which occurred during maintenance work on a production well located in the North Sea[4]. The uncontrolled blowout and oil spill continued for seven days until the well was killed[5]. The second spill of significance, and the second worst in terms of volume spilled, was the Ixtoc 1 well blowout and oil spill that occurred on 3 June 1979 when an exploratory well being drilled by the Semi-submersible drilling rig the Sedco 135-F, was being drilled in the Bay of Campeche in the Gulf of Mexico in 50m of water[6]. The well was capped some ten months later on 23 March 1980, with 140 million gallons of oil spilling into the Gulf of Mexico[7].

The third oil spill of significance was the Montara Blowout and oil spill ('Montara') on 21 August 2009[8]. It occurred in a remote area north-west off the Western Australian coast, approximately 690km from Darwin. The spill continued until 3 November 2009 (a total of 74 days), when a relief well capped the leaking well. Approximately 14,000 gallons of oil leaked daily, with a total of approximately 1.5 million gallons (over 44,000 barrels) of oil leaked from the well.[9] Although the Mon-

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[4] Petroleum Safety Authority, Norway, *Safety – Status and Signals, 2012–13: Ekofisk Bravo, (1977)* (2013) http://www.ptil.no/articles-in-safety-status-and-signals-2012-2013/ekofisk-bravo-1977-article9121-1095.html accessed 11 March 2017.

[5] A well kill refers to placing well mud of sufficient density to stop the flow of hydrocarbons from a well. See Schlumberger *Oilfield Glossary* http://www.glossary.oilfield.slb.com/Terms/k/kill.aspx accessed 25 March 2017.

[6] Bureau of Land Management and ERCO, *Ixtoc oil spill assessment: final report executive summary* (1982) http://invertebrates.si.edu/boem/reports/IXTOC_exec.pdf

[7] Ibid.

[8] All other major oil spills in Australia have been the result of ship-sourced pollution. For details of all major oil spills in Australia's waters in the last thirty years, refer to Australian Maritime Safety Authority, *Major Oil Spills in Australia* (2009) <http://www.amsa.gov.au/Marine_Environment_Protection/Major_Oil_Spills_in_Australia/> at 21 April 2010.

[9] Australian Maritime Safety Authority, *Major Oil Spill: Montara Well Head Platform* (2009) Australian Maritime Safety Authority, *Major Oil Spill: Montara Well Head Platform* (2009) http://www.amsa.gov.au/Marine_Environment_Protection/Major_Oil_Spills_in_Australia/Montara_Wellhead/index.asp> at 14 April 2017.

tara incident resulted in no deaths on the oil platform, and minimal environmental impact in Australian waters[10], one of the significant issues relating to this blowout and subsequent oil spill was the length of time required to cap the well.

The fourth, and perhaps most internationally well-known incident is the well blowout on the Deepwater Horizon (DWH) drilling rig and subsequent oil spill in the Gulf of Mexico on 20 April 2010 at the BP operated Macondo Prospect. Following a loss of well integrity, there was an explosion on the Deepwater Horizon drilling rig, causing the death of eleven rig workers and rupturing the riser at the seabed. The well was capped 87 days later on 15 July 2010, resulting in a spill of approximately 134 million gallons of oil[11].

*2.1.2 Platform Failure*

The Piper Alpha platform disaster in the British Sector of the North Sea, which occurred on 6 July 1988 as a consequence of a series of events, was in part attributable to poor decision-making and human error. An explosion engulfed the platform in a catastrophic fire, causing the death of 165 men on board the platform, and two rescue crew members[12]. This event, seen as a failure of technical and organisational factors[13], highlighted the need for robust processes and systems, which has developed into process safety, a disciplined framework for managing the integrity of operating systems and processes that work worth hazardous

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[10] The spill did not reach the Australian coastline due to its distance from the Australian coast, nor were there any discernable impacts on wildlife. However, there have been numerous allegations from West Timor fisherman of impact on fisheries and sea weed farming, leading to a class action brought by West Timorese fishermen. See Gabrielle Dunlevy, 'Indonesian seaweed farmers to file $200m class action over Timor Sea oil spill' (2016) *The Guardian*, https://www.theguardian.com/world/2016/aug/02/indonesia-seaweed-farmers-class-action-timor-sea-montara-oil-spill-2009-australia at 15 April 2017.

[11] An estimation of the amount of oil released varies. For this chapter the estimation from the *Smithsonian National Museum of Natural History Ocean Portal* has been selected due to independence of source. See http://ocean.si.edu/gulf-oil-spill accessed 22 March 2017.

[12] Lord Cullen, *The Public Inquiry into the Piper Alpha Disaster, Vols. 1and 2* (Report to Parliament by the Secretary of State for Energy by Command of Her Majesty, November 1990).

[13] M Elisabeth Paté-Cornell, 'Learning from the Piper Alpha accident: a post-mortem analysis of technical and organisational factors' (1993) 13 (2) *Risk Analysis*, 215–232.

substances such as oil and gas[14]. Whilst the Piper Alpha disaster is synonymous with a failure of process safety, it also was a source of an oil spill as a result of the platform fire and damage to the subsea production wells stemming from destruction of the platform, causing a significant oil spill lasting several weeks. Given the enormity of the loss of life on the Piper Alpha, scant attention has been paid to the oil spill aspects of the disaster. Although a rare occurrence, failures in process safety leading to platform fires and damage to wells has the potential to be a source of offshore oil spills.

### *2.2 Ships*

Ships provide two sources of oil spills. The first source is that of oil tankers, the large ships which transport oil from the place of production to that of consumption. During the last fifty years, since the grounding and subsequent spill from the Torrey Canyon in 1967 there have been numerous oil spills from tankers that have caused severe environmental pollution. The cargos that have been lost as a result of oil spills have been staggering, ranging from 10-88 million gallons of oil.

Although tanker accidents are the largest source of ship-based oil spills other ships, usually cargo ships, also contribute to marine oil spills though the release of bunker (fuel) oil. Most often such accidents are groundings (such as the Shen Neng 1 which grounded on the Great Barrier Reef), collision, or mechanical damage/failure. Whilst the contribution of these types of incidents is much less than that of tankers, they are nonetheless a source of oil spill, since they often occur near shore, in ports or near loading facilities.

## 3. Regulating Arctic oil spills

The legal regime regulating oil spills depends on three things: prevention, planning (also known as preparedness) and response. Together this regime is known as PPR, and the role of each component is illustrated in figure 2 below.

Prevention is a proactive action that is designed to ensure that an oil spill does not occur in the first place. Such legal requirements to prevent an oil spill from occurring in shipping include the use of pilots on ships in hazardous waters and the requirement for a double hull on oil tankers. For petroleum facilities, such preventative legal requirements include risk reduction for platforms and use of standards for the integrity of

[14] Bob Skelton, *Process Safety Analysis: an Introduction* (1997) Institute of Chemical Engineers.

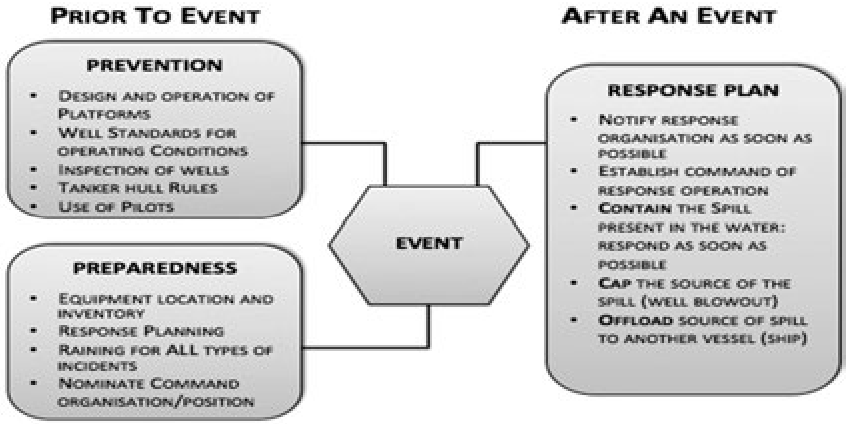


**Figure 2.** Oil Spill prevention, preparedness and response
(Source: Compiled by Author)

wells. Responding to oil spills requires two primary actions: containing the oil that is spilling into the marine environment, and controlling the source of the oil spill.

Controlling the source of the spill varies greatly with the type of oil spill. With tanker accidents, history demonstrates that often there is little opportunity to remove the cargo. However, once a ship has discharged its cargo of oil, there is nothing left to spill. However, this is evidentially not the case with oil spills from oil platforms due to well blowouts. If a well blows out, particularly if it is a high-pressure well (particularly due to depth of the well), the well will continue to spill oil until it is capped[15].

The international legal regime governing oil spills needs to ensure that it adequately addresses all the issues that may arise with regard to oil spills. There are several international instruments related to oil spill prevention, preparedness and response, and two worthy of mention: the *United Nations Convention on the Law of the Sea* (UNCLOS) *and the*

[15] As demonstrated in section 2.1 above, the Ixtos 1 and DWH well blowouts contributed over 130 million gallons of oil, and would have continued to keep leading but for the wellbeing capped. The concern with spills from oil wells is the amount of time it takes to cap a well. Both the Montara and DWH blowouts took over two months to cap, with the Ixtos 1 well taking almost ten months to cap. It is this delay in capping a well, and the continuous, infinite source of oil that makes platform spills the gravest source of oil spills.

*International Convention on Oil Pollution Preparedness, Response and Cooperation* (OPRC).

Article 193 of UNCLOS confers on States a general right to develop their natural resources, including petroleum resources. As a specific source of marine pollution, oil spills are not articulated or regulated under UNCLOS, although a number of articles impose obligations in relation to marine pollution. Article 192 imposes a general obligation to protect and preserve the marine environment. Article 194 imposes the obligation on a State to implement measures to prevent, reduce and control marine pollution from *any source*, including the use of best practicable means at their disposal to[16], 'ensure that activities under their jurisdiction or control are so conducted as not to cause damage by pollution to other States and their environment, and that pollution arising from incidents or activities under their jurisdiction or control does not spread beyond the areas where they exercise sovereign rights'[17].

The OPRC was motivated by the Torrey Canyon oil spill off the West Coast of the UK, and provides an international law regime underpinning for the obligations articulated in UNCLOS. The OPRC provides an international framework to prepare for and respond to major oil pollution incidents[18], and to facilitate international co-operation and mutual assistance. It applies to any vessels of any type operating in the marine environment as well as any fixed or floating offshore installation or structure engaged in oil and gas activities[19]. *The additional Protocol on Preparedness, Response and Co-operation to Pollution Incidents by Hazardous and Noxious Substances, 2000* (the 'Protocol') extends this international legal framework to encompass marine pollution incidents involving hazardous and noxious substances.

Aside from the hard law instruments outlined above, the Arctic Council, has developed its second binding agreement – the *Agreement on Cooperation on Marine Oil Pollution Preparedness and Response in the Arctic 2013* (the 'Agreement'), which was signed by the eight Arctic ministers in 2013[20]. Although normally a soft law body (where Agree-

[16] Article 194 (1) of UNCLOS. Italics added by author.
[17] UNCLOS, article 194 (2).
[18] OPRC article 1.
[19] OPRC article 2.
[20] The Members of the Arctic Council are Canada, Denmark, Finland, Iceland, Norway, Russia, Sweden and the USA, as well as six Permanent Participants, organisations representing the Arctic indigenous peoples.

ments between member parties are not binding), the Arctic Council has made an exception by entering into a biding agreement for marine oil pollution.

A unifying feature of these international instruments is the reliance states enacting national domestic legislation to implement the requirements for OSPPR. Therefore, the main instrument implementing OSPPR is found within each Arctic state's national petroleum regulation framework. Considerations for the national legal framework include the following:

- Is the legal framework prescriptive or rule based? Does it have Arctic-specific rules?
- Does the framework utilise risk assessment or prescribe set requirements for HSE?
- Does the law underpin, or is it the umbrella?

**4. The role of science, technology and engineering in preventing oil spills**

*Engineering*

One of the critical issues relating to the prevention of well blowouts is the engineering standard associated with the regulation of well integrity – does the legal framework require the use of best practice or mere 'good oilfield practice' for the integrity of wells? This includes analysis of the type of engineering standards for wells: are they prescriptive industry standards[21], or more holistic national requirements?[22] Furthermore, such engineering requirements are likely to alter in the Arctic compared to other exploration and production areas due to the impact of temperature and ice on materials.

*Geosciences/reservoir engineering*

The importance of geosciences and reservoir engineering in exploration cannot be understated. It is critical that reservoir modeling (including stratigraphic sequences, pressure, temperature, well placement, etc) are taken into consideration, particularly in the oil exploration phase, to ensure that exploration wells are correctly placed and constructed to take into account pressure and temperature of geology.

*Psychology*

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[21] Such as API Standard 65 Part 2 *(Isolating potential Flow Zones During Well Construction)*.

[22] Such as NORSOK DS-010 on *Well integrity in Drilling and Well Operations*.

The psychology and organisational culture/behaviour of an organisation, particularly in relation to health safety and environment, is critical in oil spill prevention and response. Investigation into the conduct of BP in the aftermath of *Deepwater Horizon* demonstrated failings in the organisational culture and attitude towards safety[23].

**5. The role of science, technology and engineering in oil spill preparedness and response**

*Logistics and planning*

The remote location of the Arctic and the poor infrastructure of the region means that any coordinated preparation and response to oil spills requires logistics and planning. Considerations include:

- Where will oil spill response materials be sited?
- What organisation and level will be responsible for coordinating and leading response? Will it be national, regional or local? Will it be private companies or government?
- What sort of training and preparation will be undertaken for oil spill response? Will it be for small or major incidents?
- How will extra/necessary materials be moved to needed site? How will this differ in different seasons? For instance, if a capping stack is required to effect a well kill, which organisation will organize? What logistics will be required – how will it be flown in, what airport, and how will it be transported to site?

*GIS*

The modeling and prediction of the spread of oil spills is essential in order to firstly predict how oil will move, and also to muster and coordinate response. Therefore, it is essential that GIS is available to regulators and coordinators to enable predictions of oil spill scenarios for planning purposes, and, should there be a spill, available to assist in the mapping and prediction of spill location.

*Political Science and International Relations*

The establishment and continuation of cooperative arrangements between governments is essential for the management of Arctic petroleum activities, especially in the Euro-Barents Region, where there is likely to be joint development of petroleum resources between Russia and Norway. Such activities will require delicate negotiation and mutual deci-

[23] See Andrew Hopkins, *Disastrous Decisions: the Human and Organisational Causes of the Gulf of Mexico Blowout* (2012); Tom Bergin, Spills and Spin: The Inside Story of BP (2012).

sion-making, built on trust and knowledge. Furthermore, should an oil spill occur, and with it trans-boundary pollution, international relations and politics will be essential to maintain cordiality between the nations affected and maintain cooperative arrangements – regional agreements for materials?

*Science*

Responses to an oil spill include three main methods: physical (boom and skim); chemical (the use of dispersants); or natural (utilising nature to breakdown the oil). The regulation of the implementation of these responses in the Arctic depends on the physical environment, which requires the input of scientific knowledge regarding the physical environment, the action of chemicals in that environment, and the behaviour of oil in climatic conditions. Without such knowledge, the regulation of oil spill prevention and response will be impossible. Therefore, States must take a precautionary and scientifically informed approach to deploying oil spill response regulation and policy.

*Engineering*

One of the greatest difficulties with a well blowout is capping a well. This raises many engineering questions: what is the best approach to capping a well? What materials are required? What design is likely to be suited to the cold environ where methane hydrate formation is a problem? Such questions need to be addressed from an engineering standpoint in order to be able to formulate oil spill response regulation.

**6. Conclusion**

When seeking to regulate oil exploitation in the arctic, it is essential to understand the role that other disciplines play. Even though the law provides both the umbrella and the foundation for OSPPR, it cannot possibly effectively and comprehensively regulate without the input of other disciplines. There is a need for a multi-disciplinary assessment that includes natural sciences, social sciences and engineering to ensure that the Arctic natural environment is protected from the impacts and effects of oil and gas exploration and production.

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## Cycling of highly toxic organic contaminants in Arctic trophic chains

Polychlorinated biphenyls (PCBs) are organochlorine chemicals which industrial production was started in 1929 in USA. Since 1929 they have been massively produced for a numerous amount of purposes, for electrical capacitors and transformers, paints, hydraulic liquids, as well as for agricultural needs as various pesticides.

PCB is a biphenyl derivative, with chlorine atoms substitution. Hypothetically PCB derivatives count up to 209 individual substances, depending on amount of substituted chlorine atoms and their positions in the molecule. Thus, chemical and physical properties of the molecule will be various. Biphenyl congeners with few chlorine atoms are more soluble in water and volatile, thus easily penetrating cell membranes. While PCB with many chlorine atoms are rather stable in biodegradable processes and hardly accumulating in cells. Meta- and parachlorine byphenyls have properties from dioxin-like chemicals, while orthoclorine congeners do not (Carpenter, 2006). Dioxin-like and non-dioxin like congeners have a harmful effect on exposed organisms, just their mechanisms of action are different, thus, they have different target organs and systems (DeCaprio, 2005). Dioxins and dioxin-like congeners affect organisms on cell and molecular levels, affecting cytochromes (Bandiera, 2001), which are part of oxidative metabolic pathways, damaging liver, disrupting endocrine and immune systems (Fitzgerald, 2005), other body organs, skin, reproductive organs and many others.

Possible PCBs exposure for human is through inhalation, skin absorption and feeding. Inhalation of PCBs is mostly dangerous for people, living nearby contaminated areas (Baibergenova, 2003; Kudyakov, 2004). In case of PCBs inhalation, there are low-chlorinated congeners, which are more volatile, but as well, quickly degraded by body (Liebl, 2004). Skin absorptions are obvious for the people who are dealing with PCBs without protection facilities. Ingestion is a leading way of PCBs exposure for people, particularly with fatty tissues of commercial animals (Hennig, 2004). Due to solubility of PCBs in fat, they are trapped by fat cells and accumulate in the organism of fishes, birds, mammals. Thus, a person consuming exposed animal tissue becomes a part of the trophic chain and bioaccumulates PCBs in the body. A man accumulates PCBs during his life, magnifying its amount and, as a consequence, decreasing his welfare and health. A woman has the same accumulation and magnification mechanisms, but she could pass PCBs further to her newborns by breastfeeding, decreasing her own PCBs concentration, and placing her newborns at a risk of being exposed at early days of the life.

Cycling of highly toxic contaminants is relevant not just for Arctic inhabitants, but for Earth inhabitants. Generally speaking, trophic chains have no limits in amount of participants and geography, thus, potentially any person could become a part of a trophic chain where highly toxic pollutants occur. Commercial species of birds or fatty fishes could be exposed to areas with residual PCB contamination in Europe (Seveso explosion in Italy in 1976), Asia (Bhopala in India in 1984) or the US (Monsanto catastrophe in 1929–1971) etc. during migrations. Migratory pathways usually cover vast territories of different countries and continents. Although, industrial PCB production has been prohibited in 2001 (Stockholm convention), consequences from big leakages and even catastrophes are not fully estimated worldwide. It is important to monitor commercial animal pathways and control chemical background of PCBs globally, as its transfer has transboarding character.

Figure 1 represents analysis of migratory pathways of several commercial bird species (Taiga Bean Goose, Greater White-fronted goose, Lesser white-fronted goose, Barnacle goose, Tundra swan, Long-tailed duck), which meat and, sometimes eggs, are consumed by indigenous people of the Russian Arctic. The Taiga Bean-Goose (Anser fabalis) and Greater White-fronted goose (Anser albifrons) are herbivorous fully migratory species which migratory pathways lay in the high Arctic region. In winter time they fly to Europe for feeding, particularly to Germany and the Netherlands. The Lesser white-fronted goose (Anser erythropus) is a herbivorous species, breeds in the northern Russian regions, on the Taimyr Peninsula, to the East – Yamal and Gydan peninsulas. During winter season Lesser white-fronted goose feeds around the Black and Caspian Seas. The Barnacle goose (Branta leucopsis) has breeding period while it stays in the Arctic tundra and flies for winter to the Netherlands and the north of Germany. (Kear, 2005; Johnsgard, 1978; Pesyakova, 2018). Eggs of the Tundra swan (Cygnus columbianus columbianus) and the Long-tailed duck (Clangula hyemalis) are a part of the Arctic indigenous peoples' rations, mostly during spring time. The Tundra swan and the

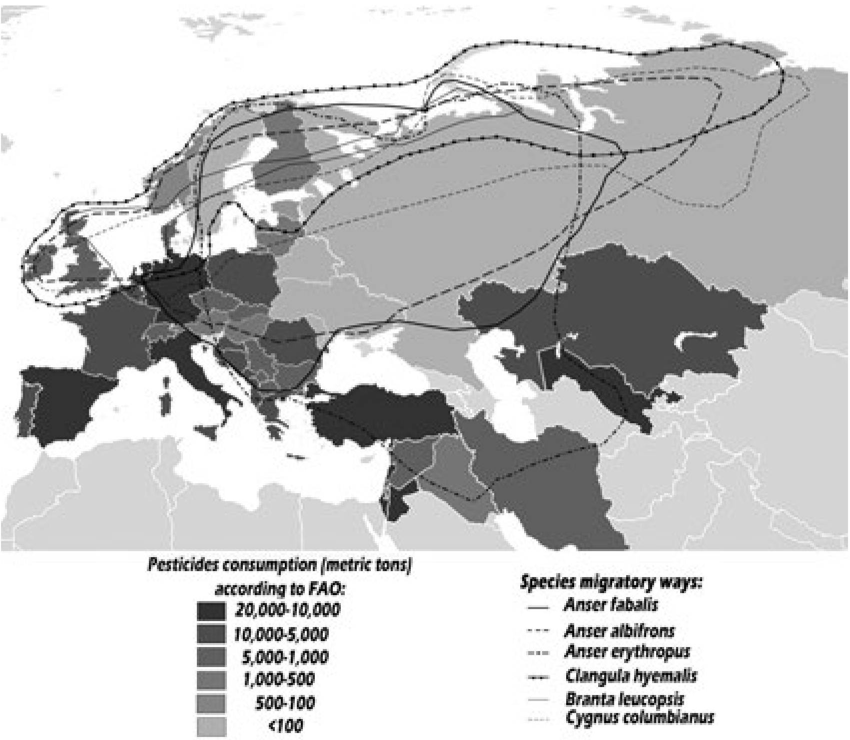


**Figure 1.** Migratory birds' pathways and pesticides consumption according to the Food and Agriculture Organization of the United Nations (Pesyakova, 2018)

Long-tailed ducks have preferably marine based feedstock (crustaceans, molluscs, marine invertebrates, fish, amphipods and polycheate worms), thus, they are accumulating and biomagnifying PCBs, obtained through marine foods. The Long-tailed duck (Clangula hyemalis) breeds in the North of Russia, and spends winters mainly in Germany, Lithuania and Sweden. The Tundra swan (Cygnus columbianus columbianus) spends winters mostly in the Netherlands and the United Kingdom (Kear, 2005; Johnsgard, 1978; Pesyakova, 2018).

Commercial bird species is a prospective source of PCBs in trans-boarding transfer through trophic chains. Birds could bring highly toxic organic contaminants from agricultural territories, exposed to pesticides, from industrial territories, where PCB production was located, areas exposed due to catastrophes and leakages.

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## Three-spined stickleback as an indicator species in high-latitude marine ecosystems

Global changes in the biosphere are associated with the increasing anthropogenic impact and climate change. High latitude ecosystems are particularly vulnerable, as organisms here often live near the limit of their physiological capacity, when any additional stress can unbalance the populations and a whole ecosystem. At the same time, any favorable change of environment may cause quick population growth. Thus, it is very important to monitor such ecosystems, which allows to identify changes already happened and to make predictions for further trends. Such monitoring requires significant resources; thus, it is advisable to focus on the most informative species, based on their role in the ecosystem. One of such species is three-spined stickleback *Gasterosteus aculeatus*. Below, we discuss advantages of this species as an indicator for monitoring of marine high-latitude ecosystems, mostly based on our studies in the White Sea.

*Responsiveness to climate changes.* The analysis of historical sources shows that stickleback experienced large-scale fluctuations in its abundance during the last century (Lajus et al., 2013). It was very abundant from the 1920s to 1960s, but declined dramatically in the next decade and sustained very low numbers until the late 1990s. Since that time, the population quickly expanded, and now is close to its historical maximum. Field studies performed from 2007 to 2016 showed, that abundance of stickleback is significantly correlated with the local air winter temperature. The decrease of winter temperature causes decrease of stickleback population next year (T.S. Ivanova, M.V. Ivanov, D.L. Lajus, unpublished data). Likely, mortality of stickleback increases during longer winters. Responsiveness of stickleback to climate change is also supported by its appearance in freshwater of Svalbard recorded in the early 2000s (Svenning et al., 2015). This is significantly much farther north than the known distribution range of this species, spreading up to the southern part of the Novaya Zemlia Archipelago. This finding may mean expanding of their distribution range, likely caused by warming.

*High abundance.* The extensive beach seine surveys around the White Sea in 2010–2011 allowed to estimate the total abundance of stickleback. This was possible because all mature fish come to spawn in the sublittoral zone. We also considered the age structure of the population. According to our estimates, there are almost a billion of three-spined sticklebacks in the White Sea, and about 60% of that number is in the Kandalaksha Bay. This is more than the number of herrings, although total biomass of herring is higher because they are larger (Ivanova et al., 2016). It is important to notice, that according to our monitoring in the Kandalaksha Bay, the abundance of stickleback in 2011 was several times lower than in previous or consequent years, probably due to cold winter in 2010. This may mean that usual number of sticklebacks in the White Sea is even higher. However, even in 2010–2011, they comprised about 95% of the fish number caught in summer period within the 30-m near-shore zone. Even assuming that catchability of other fish species can be lower than stickleback for different reasons, these data show a strong dominance of stickleback in the present-day fish community of the White Sea.

*The "wasp waist" of the ecosystem.* The lower (phytoplankton and zooplankton) and higher (predatory fish and birds) trophic levels of marine coastal ecosystems are usually more diverse, in terms of species richness than the intermediate (small pelagic fish) level. Because of that, these ecosystems are usually said to have a "wasp waist" (Cury et al., 2000). Therefore, a few species of small pelagic fish forming this "wasp waist" control most of the energy flow in the ecosystem. Because of that, while selecting indicator species for monitoring of the ecosystem, it is most reasonable to use the "wasp waist" species. In the White Sea, the "wasp waist" is represented by herring and three-spined stickleback. About ten fish species prey on adults, juveniles or eggs of stickleback, and for four species such as the European sculpin *Myoxocephalus scorpius*, the Fourhourn sculpin *Tryglopsis quadricornis*, the Atlantic cod *Gadus morhua* and the Saffron cod or navaga *Eleginus nawaga,* stickleback represents a key food item (Bakhvalova et al., 2016, 2017). Birds such as terns and seagulls, also actively prey on stickleback. Sticklebacks are euryphagous and, in the inshore zone, feed on plankton, benthos, their own eggs and larvae (Demchuk at al., 2015, in press). The White Sea stickleback also forms other important biotic relationships with seagrass during the spawning period (Rybkina et al., 2017), and with various parasites (Rybkina et al., 2016).

*One of the most studied fish species.* Three-spined stickleback is a very popular object of studies in evolutionary biology, population genetics, ethology. Researchers extensively studied its antipredator adaptations, host-parasite interactions, sensory physiology, reproductive physiology, and endocrinology. This is due to their high phenotypic plasticity and adaptability in nature, and easiness of cultivation in capture. This species is often referred to as a model and sometimes is even called "supermodel" (Gibson, 2005; Barber and Nettleship, 2010). A large amount of diverse information on stickleback definitely facilitates its use as an indicator species. In the White Sea, in addition to the research cited above, we perform investigations of the lipid and fatty acid composition which could be an informative indicator of the population status (Murzina et al., 2017), age, size and sex structure (Golovin et al., 2015, 2017) and morphological variation (Dorgham et al., in press).

*A practical object for research*. It is crucially important for ecosystem studies that abundance of stickleback is relatively easy to assess. The reliable abundance assessment for most fish species is possible only with trawling, which requires significant resources. Operating a small beach seine to study stickleback can be done by two persons only, and estimates are usually rather accurate. Stickleback tolerates well various manipulations, for instance, tagging, survives in aquaria – both adults and juveniles. They are inshore in summer during their most important stages of the life cycle, it corresponds well with the schedule of university students, which makes stickleback a very convenient object not only for research but also for teaching purposes. Adults, juveniles and eggs are easy to catch in any amount during summer. At the same time, we do not know so far where in the White Sea stickleback spends winter when it is absent in the inshore zone.

Therefore, in many aspects, the three-spined stickleback is a promising candidate species for monitoring ecosystem of the White Sea, being a massive fish well integrated into the ecosystem and sensitive to climate changes. Likely, stickleback goes currently through its historical maximum, similar to what was observed in the early 1930s. The decrease of temperature resulted in a long-term depression of stickleback population during 1960–1990s. It is unclear how the stickleback population will respond if no decrease of temperature will occur in the nearest future, but in any case, changes in their population will reflect and maybe cause changes in the whole ecosystem. Currently, stickleback is not very numerous in other parts of the Arctic, but the White Sea case shows that this species has a high potential for quick population growth with warming. Thus, the quick growth of stickleback population may also happen in other parts of the Arctic.

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# Ecotoxicological study of the pulp and paper wastewater effluents' influence on ichthyofauna

All transformations in aquatic ecosystems are caused by two large-scale factors: natural-climatic (natural-historical process) and anthropogenic, caused by human economic activity. In our time, succession changes in water ecosystems are determined by the impact of man-made factors (Novoselov, 2000). At the same time, timber processing complexes (mainly pulp and paper industry) occupy the third place in terms of the amount of wastewater generated as a result of their production activities. Wastewaters contain both organic and inorganic components (lignins, tannins, chlorine derivatives, etc.). Before wastewater discharge, the main contaminants must be removed or their quantity reduced, so it undergoes a number of purification procedures, including mechanical, physical, chemical and microbiological treatment. Imperfections of treatment facilities at enterprises can lead to leakage of contaminants. Such leaks can provide a negative impact on the environment, especially when contaminated wastewater enters natural water ecosystems. Some of the hypothetical risks include: reduction of the species diversity of the ichthyofauna (decrease in the number of fish species) and loss of their fodder base (change in the qualitative and quantitative characteristics of aquatic invertebrates); growth of unwanted bacteria that can absorb oxygen and reduce its content in water, which can lead to oxygen starvation of fish; reduced visibility due to the reduced transparency of water; accumulation of micro- and toxic elements in fish tissues, which can be transferred with food chains to humans; physiological changes at individual level within the species; and, finally, genetic changes affecting the immune system of fish organisms and metabolic connections.

In the middle of the XIX century there was a need to study the effect of industrial wastewater poisons on fish. To date, there is a voluminous list of publications, including studies of heavy metals, their salts, acids, alkalis, organic compounds, various kinds of insecticides and herbicides, and the combined effect of poisons (synergism and antagonism) (Lukyanenko, 1967). Despite the huge amount of experimental data, it is a problem to study the effect of industrial wastewater poisons due to inadequate theoretical and methodical knowledge both in the Russian Federation and abroad, because of the incorrect formulation of ecotoxicological experiment, the lack of generally accepted principles how to conduct it, ignoring various factors that may affect the result of the analysis, the lack of uniformity in the definition of the toxicity criteria, errors in the interpretation of the results, and wrong statistical analysis.

The "fish test" analysis is based on the establishment of acute and chronic concentration of a harmful substance, using fish as the object of the experiment. In laboratory studies, *Danio rerio* is used as a model fish organism. It is a freshwater radiate fish of the C*yprinidae* family. The advantage of this species is that they are suitable for studies in juvenile and adult life period, for studying any body system, and are also suitable for the effective modeling of human diseases and pathophysiology (Carvan, et al. 2005). *Danio rerio* has historically been used to study the teratogenic effects of toxicants and the mechanisms, which regulate cellular responses. In laboratory experiments, *Danio rerio* breeds easily, reaches the juvenile stage within several weeks, and becomes mature in 3–4 months; produces a large number of eggs that are easy to manipulate and study at different stages of development; they are easy to keep in the laboratory. Dave and his colleagues noted that *Danio rerio*, in comparison with *Daphnia* and *Salmo gairdneri*, was the most suitable organism for toxicological studies (Dave, 1981). Braunbeck noted during his studies with atrazine that *Danio rerio* was least sensitive to it with prolonged exposure, and therefore more suitable for a chronic experiment (Braunbeck, 1992). Mizzel and Romig concluded that *Danio rerio* embryos were extremely effective in researching the effects of both a single chemical and a mixture of toxicants; and are also susceptible even to low concentrations of pollutants in water (Mizzel and Romig, 1997). The waste water of the pulp and paper industry is a complex component mixture represented by various groups of chemical compounds. Their composition can vary greatly between plants. Basically, wastewater is a highly concentrated liquid with COD within 0.5–115 g/l (Wang, 2005). The main reason for such an interval of COD values is that different types of wood are used, as well as various conditions for the production of pulp and paper.

To date, more than 250 different substances have been identified in the wastewater of the pulp and paper industry (Khan, 2011). They consist of various kinds of tannins, stilbenes, phenols, dioxins, chlorides, pyranes, phenols and sulfur-containing compounds (Ali, 2001). Effluents from pulp bleaching are rich in toxic substances such as adsorbed organic halogens, chlorinated organic compounds, phenols, dioxins or furans.

Thus, the results of the "fish test" analysis will expand knowledge of the toxicity of sewage sludge materials in the pulp and paper industry to *Danio rerio*, make it possible to predict the physiological and genetic effects of ecotoxicants on the ichthyofauna of aquatic systems located near the pulp and paper mills.

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## The influence of climatic changes on phenological phases of plants in Barguzinsky Nature Reserve

The study of the environment and its separate elements is one of the most important tasks of botany and its section – phenology. As a famous botanist Alexander Shennikov said, "Any more or less profound study of vegetation should be started or accompanied by phenological observations. The characteristic of cenosis is incomplete without phenology. It is deprived of illumination of the important property of cenosis – its rhythm".

Long-term, continuous observations of the state of nature including phenological monitoring have been conducted in nature reserves in our country.

The Barguzinsky State Nature Biosphere Reserve, which celebrated its 100th anniversary last year, is located on the north-eastern shore of Lake Baikal and occupies the middle part of the western slope of the Barguzinsky Range. It is presently managed by the Federal state budget institution "Zapovednoe Podlemorye".

In the Barguzinsky Nature Reserve the regular observations have begun since the late thirties. The most complete data were obtained in the second half of the 20th century. Currently, the Nature Reserve has the data from the continuous series of observations which lasted for 45–30 years.

Phytophenological observations in the Nature Reserve are conducted on permanent and temporary routes and on five (5) permanent sample plots near the settlement Davsha.

Phenological observations conducted in the Reserve are based on the method of I.N. Beideman (1974). For phenological observations 81 species of higher plants including 7 species of forest-forming were selected. Phenological observations are carried out for 5 phenological stages, 22 phenomena. Plants` seasonal stages of development are registered: swelling and opening of the buds, unfolding of leaves, blooming (beginning and end), ripening of fruit and seeds, autumn colouring of leaves, leaf fall. The results of phenological observations are presented in the Chronicles of nature in the corresponding table.

At 5 stationary plots the state of plant populations is assessed depending on climatic changes and other environmental factors. The air temperature and the total sum of precipitation are registered on the meteorological station "Davsha" and by thermographs (recently thermochrones) on permanent plots.

The phases "blooming" and "fruiting" have been chosen to determine important phenological phases of the seed productivity. To characterize the temperature-humidity regime of the phenological plots, the aridity index has been summarized by years on each plot. To determine the most humid and dry periods, the aridity index for every ten-day period on the plots has been summarized by years.

The diagram of air temperatures and precipitation is constructed according to A. Gossen's method. The months are laid on the abscissa axis, and monthly average air temperatures and precipitation in the ratio of 1:2 (i.e. 10˚ corresponds to 20 mm of precipitation.) are laid on the ordinate axis. When the precipitation curve is below the air temperature curve on a climatic chart, it defines the arid period, unfavorable for the growth and development of plants.

The data have been processed using the «Statistica» program in which Spearman correlation coefficient has been calculated.

To analyse the influence of weather conditions on plants vegetation the aridity index has been chosen. This index is a generalized characteristic of aridity, it was derived by Marton: $I = P / (T + 10)$, where P is the annual amount of precipitation, mm; T – the annual temperature in degrees. The higher the aridity index is, the more humid the climate is. The aridity index is determined on each plot every ten-day period. Its dynamics reflects the trend of climate warming and desiccation.

Climatic indicators on phenological plots with identical values of precipitation differ in the thermal regime. This is due to the mesorelief of the Davshe Bay area. According to the aridity index the warmest and driest plots are plots 4 and 5 (fig.1.). Plot № 4 is located in the meadow with a thermal spring, Plot № 5 is located on the slope of the southern exposition of the fire-site with a rare forest. Plot № 3 is in the mouth of the Davshe river. It is the "coldest" plot. The highest index of aridity is registered there.

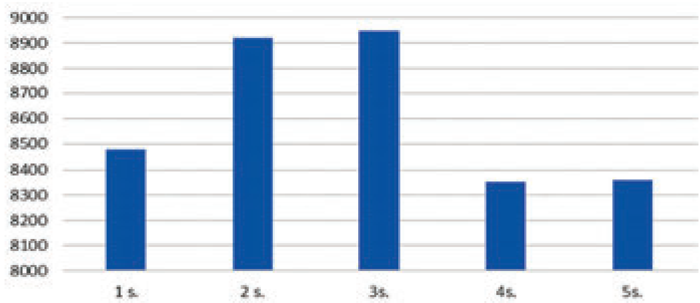


**Figure 1.** Index of aridity on phenological plots (amount by years 1988–2015)

In this regard, phenological indicators of the same species differ on different plots. For example, in 2013 the phenological phases of red bilberry were observed earlier on plots №№ 4; 5; 1 consecutively, and on colder plots №№ 2 and 3 they were observed 5–10 days later (fig.2). Thus, according to the aridity index it is possible to learn the relative terms of the onset of phenological phases and their deviation from long-term average indices.

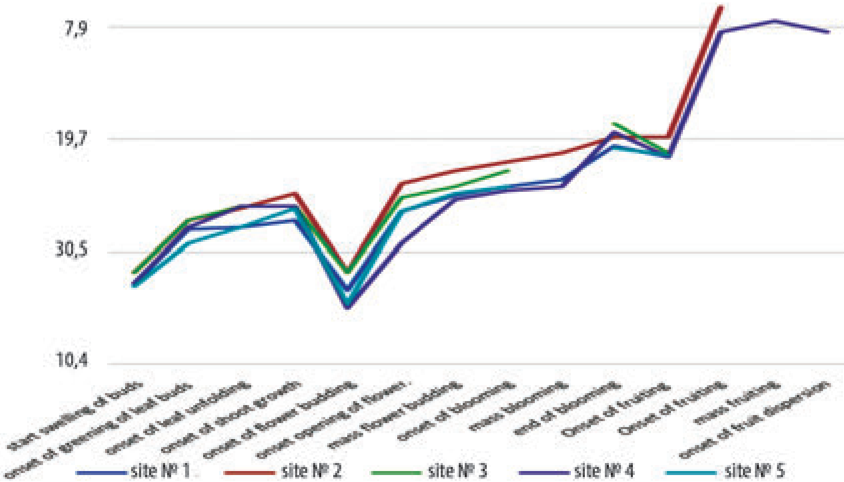


**Figure 2.** The phenology of Vaccinium vitis-idaea L.
on phenological plots in 2013

The most humid period on the plots is the last ten-day period of May (Fig.3). The driest month is July in the middle ten-day period of which both high temperatures and low precipitation are observed.

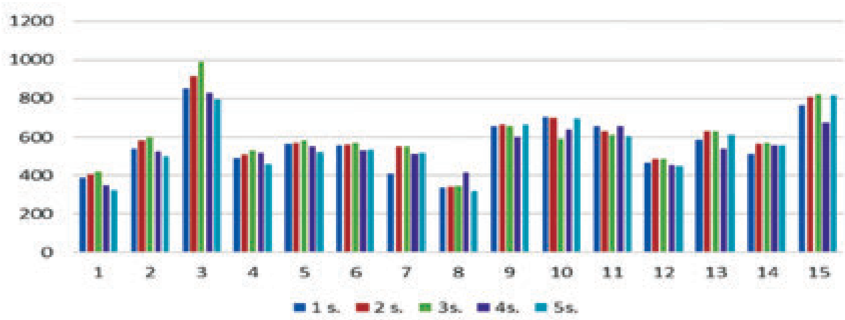


**Figure 3.** The index of aridity on phenological plots for ten-days period (May - September), total by year (1998–2015)

To study the dependence of the rhythm of plant development on environmental factors (temperature, precipitation), blooming and fruiting curves are plotted on the graph of air temperatures and precipitation in the Chronicles of nature. To illustrate that, we present the materials of the Chronicles of nature for 2012 (fig.4).

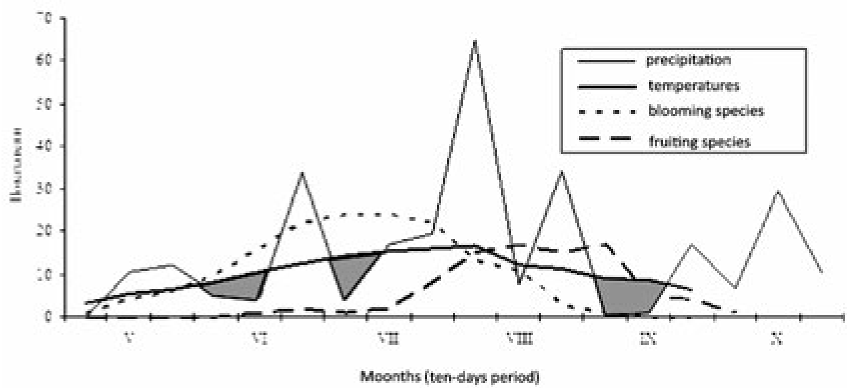


**Figure 4.** Blooming and fruiting of species at plot No. 4 in 2012

Three distinct peaks of the precipitation maximum have been recorded on the chart during the vegetation period: the end of June, the first ten-day period of August, the end of August and one smoothed peak at the beginning of the vegetation period in the middle-end of May. The temperature curve has no peaks and smoothly reaches its maximum in the last ten-day period of July- at the beginning of August. After heavy precipitation a droughty period usually began which was accompanied by temperature increase, and this contributed to abundant blooming and fruiting on all plots. The greatest number of blooming plant species is observed in the beginning and in the middle of July. During this period, the average daily temperatures are rather high, and the soil moisture accumulates due to precipitation in the end of June. In the diagram the blooming curves correlate with the temperature curve and show no expressed peaks. The blooming peak comes after a period of sufficient moisture. Fruiting curves in 2012 are also marked by no clearly expressed peaks.

The blooming and fruiting curves show the dependency of fruiting and blooming on temperature and precipitation: the generative functions of the plant are most active at maximum temperatures after a period of high precipitation, when enough moisture accumulates in the soil.

Statistical data which are based on the aridity index and the number of fruiting and blooming species on plots during 1998–2015 confirm the conclusions from the visual analysis of the charts. A reliable correlation of the aridity index with the year shows negative connections with values from -0.23 to -0.36. This confirms the trend towards climate aridization which was identified earlier by other methods. In this case, the negative connections of the year with fruiting are revealed (from -0.51 to -0.67) which indicates a decrease in fruiting of the observed species.

A reliable correlation of blooming and fruiting species with the aridity index was revealed only in four cases. During these periods, a mass blooming and fruiting of most species is observed.

However, in the analysis with a shift in the term of the phenological phase relative to the term of the registration of the aridity index, the connections are noted on all plots and in all ten-day periods of observation of the phenological phase of mass fruiting and blooming (Tabl. 1, 2).

*Table №1.*

**The Spearman correlation coefficient with the displacement of the aridity indices and the number of blooming species on the phenological plots (1998–2015, 1–15 ten days periods from May to September)**

| Displacement/ № plot | plot №1 | plot №2 | plot №3 | plot №4 | plot №5 |
|---|---|---|---|---|---|
| Displacement for 1 ten-days period (the ten-days period of the aridity index is indicated) | | -0,496947 ($3^{rd}$ ten-days period) | 0,655220 ($7^{th}$ ten-days period) | 0,600324 (6 ten-days periods) | |

*Tab. №1*

| Displacement/ № plot | plot №1 | plot №2 | plot №3 | plot №4 | plot №5 |
|---|---|---|---|---|---|
| Displacement for 2 ten-days periods | | | | | 0,495071 (5th ten-days period) |
| Displacement for 3 ten-days periods | | 0,484011 (2nd ten-days period) | | | 0,537851 (8th ten-days periods) |
| Displacement for 4 ten-days periods | | | 0,567600 (3rd ten-days period) | | 0,480766 (3rd ten-days periods) |

At the shift for 1 ten-day period, the negative connections were revealed on plot № 2: at a high aridity index in 3 ten-day period, the number of blooming species decreases in the first ten-day period of June. On plots №№ 3 and 4, the connections are positive. This is obviously due to the fact that the plot № 2 is located in the forest with a high level of shading, which additionally increases the high aridity index at the end of May and slows down the onset of blooming in the next ten-day period. On the plot № 3 hygrophilous species begin mass blooming after the first ten-day period of July with a high level of aridity index. In the situation of a rather open plot № 4 with a high level of aridity index in the last ten-day period of June, favorable conditions for blooming appear in the next ten-day period. The high aridity index of the second ten-day period of June leads to an increase in the number of blooming species in the first ten-day period of July on the phenological plot № 5.

The analysis of the onset of phenological phases when the number of blooming species is shifted from the ten-day period of the aridity index for 3 ten-day periods shows the correlation on the plot №№2,5. With a high aridity index in the middle of May and in the middle of June, there will be more blooming species on the plot №2. On the plot № 5, the high aridity index in the middle of July will cause a high blooming activity in the middle of August.

The shift for 4 ten-day periods shows the dependence of blooming in the first ten-day period of July on the high moisture content in the end of May on plots №№ 3 and 5.

*Table №2.*

**The Spearman correlation coefficient with the displacement of the aridity indices and the number of fruiting species on the phenological plots (1998–2015, 1–15 ten days periods from May to September)**

| Displacement/ № site | 1 site | 2 site | 3 site | 4 site | 5 site |
|---|---|---|---|---|---|
| Displacement for 1 ten-days period (the ten-days period of the aridity index is indicated) | 0,524661 (9th ten-days period) | 0,575657 (12th ten-days period) | 0,555347 (9th ten-days period) 0,563115 (12th ten-days period) | | 0,588427 (9th ten-days period) |
| Displacement for 2 ten-days periods | | 0,552916 (9th ten-days period) | | | |
| Displacement for 3 ten-days periods | | 0,472736 (9th ten-days period) | 0,515731 (9th ten-days period) | 0,621439 (9th ten-days period) | -0,599562 (11th ten-days period) |
| Displacement for 4 ten-days periods | | | | | 0,500813 (8th ten-days period) |

The correlation analysis with the shift of the terms of the phenological phase "fruiting" relative to the registration of the terms of the aridity index gives more reliable results, especially with the shift for 1 and 3 ten-day periods. At the same time, there is a positive correlation on all plots and at all times except the plot №5. Here, with an increase of the aridity index in the middle of August, the number of fruiting species decreases in the middle of September. Obviously, additional moistening or lowering temperatures at the end of summer does not contribute to abundant fruiting at the end of the vegetation season.

*Conclusions.*

The aridity index values can be used to provide objective characterization of biotopes and to predict the seed productivity of plants. Blooming and fruiting occur in 1–3 ten-day periods after a time marked by a high aridity index. The negative trend of the aridity index confirms the tendency for the climate aridization in the Barguzinsky Nature Reserve.

A negative trend between the year and the number of fruiting species demonstrates a decrease in fruiting of the observed species, which confirms the positive connections between the aridity index and the number of fruiting species.

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## Seasonal changes in soil $CO_2$ emission: modeling of seasonal changes in middle taiga forests in Siberia

The soil is a major biospheric reservoir for carbon (C), containing globally twice as much C as the atmosphere and three times as much as vegetation. In order to accurately estimate C budgets in target ecosystems, we must be able to account for spatial variation in soil respiration on regional and local scale. Existing models are inadequate to explain the spatial variations of soil respiration between sites. Therefore, it is necessary to incorporate both temporal and spatial variation of soil respiration into the model in order to scale-up the chamber measurements of soil respiration to ecosystem level. In our research we present a model which combines the meteorological parameters of the whole area and local specific features of each ecosystem (forest type).

Soil carbon is one of the main components of the global carbon balance, accounting for about 25% of the amount of global $CO_2$ exchange (Buchmann, 2000; Schlesinger et al., 2000).

One of the key questions to be addressed is the future dynamics of the large amount of C that is currently stored in soil organic matter. The efflux of soil carbon is highly sensitive to changes in surface temperature and relatively small changes in surface temperature may have a major influence on the magnitude of soil efflux. The potential increase in $CO_2$ release from the soil caused by future temperature increase may enhance the atmospheric $CO_2$ concentration growth and global change (Fang, Moncrieff, 2001).

Flux measurements in Europe show that boreal forests are weaker storage areas for atmospheric $CO_2$ per unit than forests further south (Valentini et al., 2000), mainly as a result of high soil respiration in relation to net photosynthesis (Janssens et al., 2001).

In case of the future global warming, the soil respiration speed will increase and is likely to mediate progressively lower rates of carbon sequestration (Raich and Schlesinger, 1992; Davidson et al., 2000). Despite its obvious importance to carbon cycle processes, soil respiration has proven to be extremely difficult to quantify in an accurate manner. Like many other soil processes, respiration exhibits high levels of spatial heterogeneity, especially across small spatial scales, and can be highly variable on diurnal, seasonal and interannual time scales (Law et al., 1999; Buchmann, 2000; Xu and Qi, 2001).

Large-scale models typically use soil temperature (Buchmann, 2000), soil moisture (Davidson et al., 2000) as well as their interaction (Lee et al., 2002) for large-scale soil respiration estimates.

However, they are unable to explain the spatial variations of soil respiration within a site and between sites (Xu and Qi, 2001). The spatial upscaling of soil respiration from field measurements to ecosystem levels will be biased without studying its spatial variation (Tang and Baldocchi, 2005). Therefore, it is necessary to incorporate both temporal and spatial variation of soil respiration into the model in order to scale-up the chamber measurements of soil respiration to ecosystem level (Han et al., 2007).

The main goals of this work were (a) to estimate the dynamic of soil $CO_2$ emission during snow-free season (June – September) for different forest types; (b) to detect the impact of climatic variables (soil temperature and SWC) to soil $CO_2$ efflux; (c) to model the seasonal soil $CO_2$ efflux for each forest type.

The study area was located in the south of the Turukhansky district of the Krasnoyarsky Region (60 ° N, 90 ° E), within the Ket-Symskaya lowland. The main factor in the distribution of plant communities in the region was the groundwater level which determined the degree of moisture and habitat differentiation of moisture on the relief elements.

The climate is continental. According to the agro-climatic zoning, it is a moderately cold area with adequate moisture: the sum of temperatures above 10 °C is 800–1200 °C. The average annual temperature is -3.7 °C. The average minimum temperature is -48 °C, the average maximum temperature is 31 °C. Absolute minimum temperature is -54 °C, the absolute maximum temperature is 36 °C. The amplitude of the oscillations of the average monthly temperature is 41.9 °C. The average annual relative humidity is 76%. The amount of precipitation is 590 mm per year (Forest ecosystems, 2002).

Soil respiration measurements were carried out during the snow-free seasons (June – September) during five years – 2012, 2013, 2015, 2016 and 2017. The measurements sites were located in the different forest types: lichen pine forest, feathermoss pine forest, and mixed forest. The plots were located at a distance of 50 m.

At the each sample plot, plastic collars of 20 cm diameter were installed in spring of 2012 prior to taking measurements. For measuring the soil CO2 efflux, we used automated soil CO2 flux system based on the infrared gas analyzer LI-COR – LI-8100A (Li-cor Biogeosciences Inc., USA). At the time of the soil respiration measurement, soil temperature was measured adjacent to each plastic collar using Soil Temperature Probe Type E (Omega, USA) in the three depths – 5, 10, 15 cm. These depths were characterized by the maximum activity of soil microorganisms and plant activities (root respiration) so that we could see how these processes were related and identify their impact on the soil CO2 efflux. Volumetric soil moisture measured by the Theta Probe Model ML2 (Delta T Devices Ltd., UK). For measurements in the areas with plant ground cover, it was necessary to install moisture meter directly on the soil surface and remove ground cover from measuring area. Detailed measurement procedure is described in our earlier paper (Makhnykina et al., 2016).

The data collected with LI-8100A was stored on a memory device with an internal Compact Flash (CF) card. For the analysis and processing of the results we used LI8100_win-4.0.0 Original Software.

In addition to the obtained data, we carried out statistical analysis which revealed the dependencies and correlations between the individual components of soil respiration and some environmental factors (pressure, temperature and moisture).

## Change in meteorological conditions

All the seasons considered differed in meteorological conditions. If we only take into account the total amount of precipitation for 3 years – 2012, 2013 and 2016 – their values for these seasons were approximately on the same level and averaged 147 ± 2 mm. The most humid season is the season of 2015, the amount of precipitation in it exceeds previous data more than twice. It was accompanied by heavy rains, which made this factor prevailing in comparison with other external factors for this season. The final season of measurements in

2017 is the closest to the average in terms of precipitation. We have radically different seasons in terms of moisture conditions, which allow to trace the influence of external factors on the amount of $CO_2$ emission from the soil with a high probability (Fig. 1).

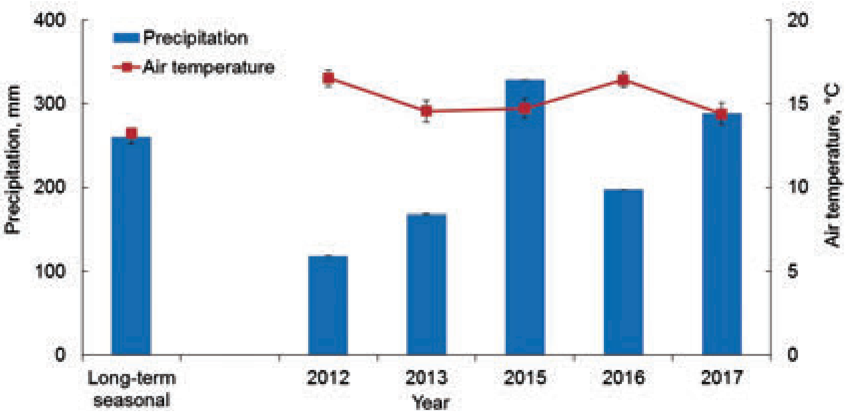


**Figure 1.** Meteorological characteristics of the growing season (June-September) for a 5-year period of observations of measurements in comparison with the long-term mean seasonal values. Data presents mean for season with st. errors

The air temperature for 5 seasons of measurements did not suffer significant changes. The highest average seasonal temperatures were in the 2012 and 2016 seasons – 16.5 ° C, which is 3 ° C above average for four months. The air temperature in 2013, 2015 and 2017 was approximately the same and was 14.5 ± 0.1 ° C. The temperature data for all seasons allow to track what changes occur to the soil temperature, in comparison with the air temperature for areas with different types of ground cover.

The meteorological conditions of each season influence soil conditions. The dynamics of soil temperatures for each season and within each season varies for different sites and it can be traced for all five years of measurements (Fig. 2). The minimum soil temperatures are noted in the feathermoss pine forest, with a thick litter layer, which acts as a barrier to the change in microclimatic soil conditions. Due to this mechanism, both the soil temperature and moisture in this forest type are minimally varied during the season. The lichen pine forest is more exposed to the temperature factor. In arid seasons – 2012 and 2013 – the soil temperature in the first two months of measurements in 2 times higher than in the feathermoss pine forest. In the mixed forest, a similar dynamics of soil temperature were observed, but the value is less, in comparison with lichen pine forest. This is due to the high crown closeness in this area and the presence of a fairly powerful litter layer, which, just like in the feathermoss pine forest, inhibits changes in soil temperature following a change in air temperature.

Within the season there is a constant dynamics of soil temperature. The maximum values are often in July. The exception is the season of 2013, when the maximum temperatures were recorded in August.

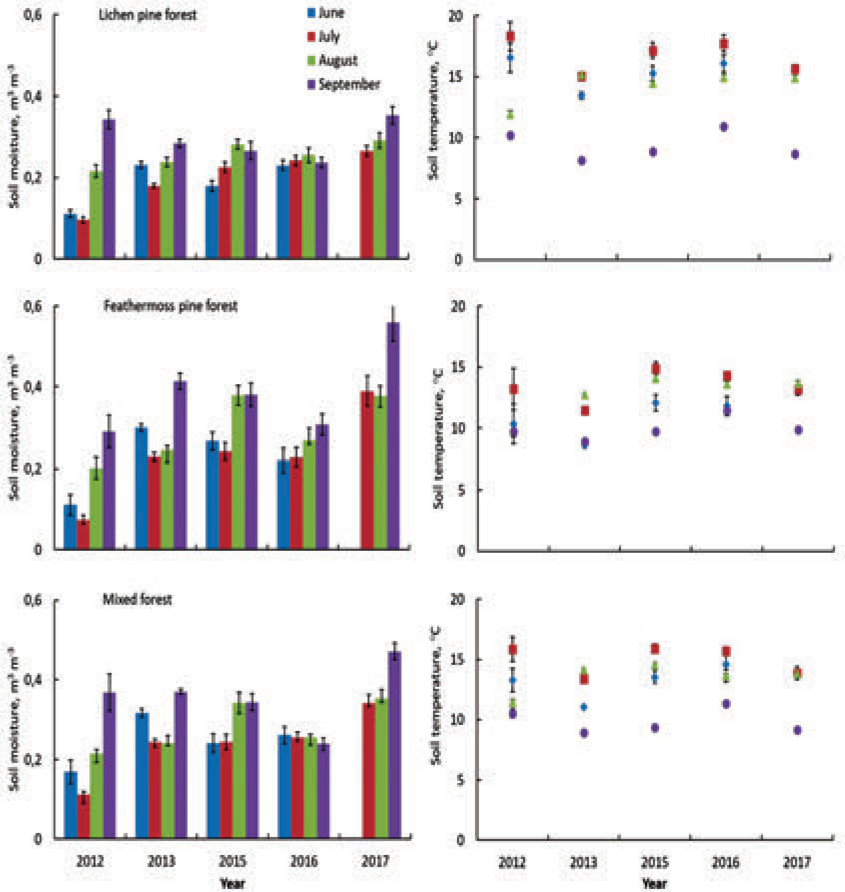


**Figure 2.** Soil moisture and temperature soil during the growing season for 5 years of measurements for sites: lichen pine, feathermoss pine forest, mixed forest. Data presents mean for month with st. errors

All types of sites are formed on sandy podzols with a comparatively low moisture capacity. The lichen pine with a weak organic horizon is characterized by the minimum values of soil moisture, since the lichen cover does not retain moisture and it quickly penetrates the soil profile. In the feathermoss pine forest the thickness of the organic horizon is somewhat larger, but the main difference is in the powerful litter layer, which has a water-retaining function. This condition led to an increase in soil moisture by 1.2 times compared with lichen pine. The biggest differences are observed in seasons with normal and increased moisture. The mixed type of forest in its ground cover combines both separate types of lichens and mosses, so the soil moisture in this forest is intermediate compared to the two groups described earlier. The distribution of precipitation during the season is similar for all forest types. The maximum amount of precipitation falls on the second half-end of the season.

**Seasonal dynamics of soil $CO_2$ emission**

The dynamics of soil $CO_2$ effluxes during the season varies slightly, and basically the maximum flows fall to the middle of the season (late July – early August). In arid years (2012 and 2013), fluxes in all forest types were low and were limited by high temperatures (Fig. 3). Fluctuations during the season in these years were practically not observed, the $CO_2$ fluxes throughout the season were at the same level, and only in the second half of the season (in August) there was a small increase in the soil $CO_2$ effluxes. A large amount of precipitation during the season of 2015 stimulated the development of emission processes, and the maximum values of fluxes in this season were recorded in the lichen pine forest and mixed forest.

The lichen pine forest shows the maximum fluxes only in the growing season with increased precipitation – 2015. The maximum fluxes recorded during this season averaged 5.3 μmol $CO_2$ $m^{-2}$ $s^{-1}$, and during peak periods (the second half of July to the beginning of August) increased to 9.8 μmol $CO_2$ $m^{-2}$ $s^{-1}$. This feature allows to talk about the stability of this forest type despite significant differences in temperatures and precipitation over the season. Average $CO_2$ fluxes during the growing season are 2.9 μmol $CO_2$ $m^{-2}$ $s^{-1}$.

The mixed forest, like the lichen pine forest, quite clearly responds to the increase in the amount of precipitation by the growth of soil $CO_2$ emission. Maximum fluxes and their fluctuations are noted for the season of 2015, the middle of the growing season. The average $CO_2$ fluxes for the season were quite different from the other types of sites and

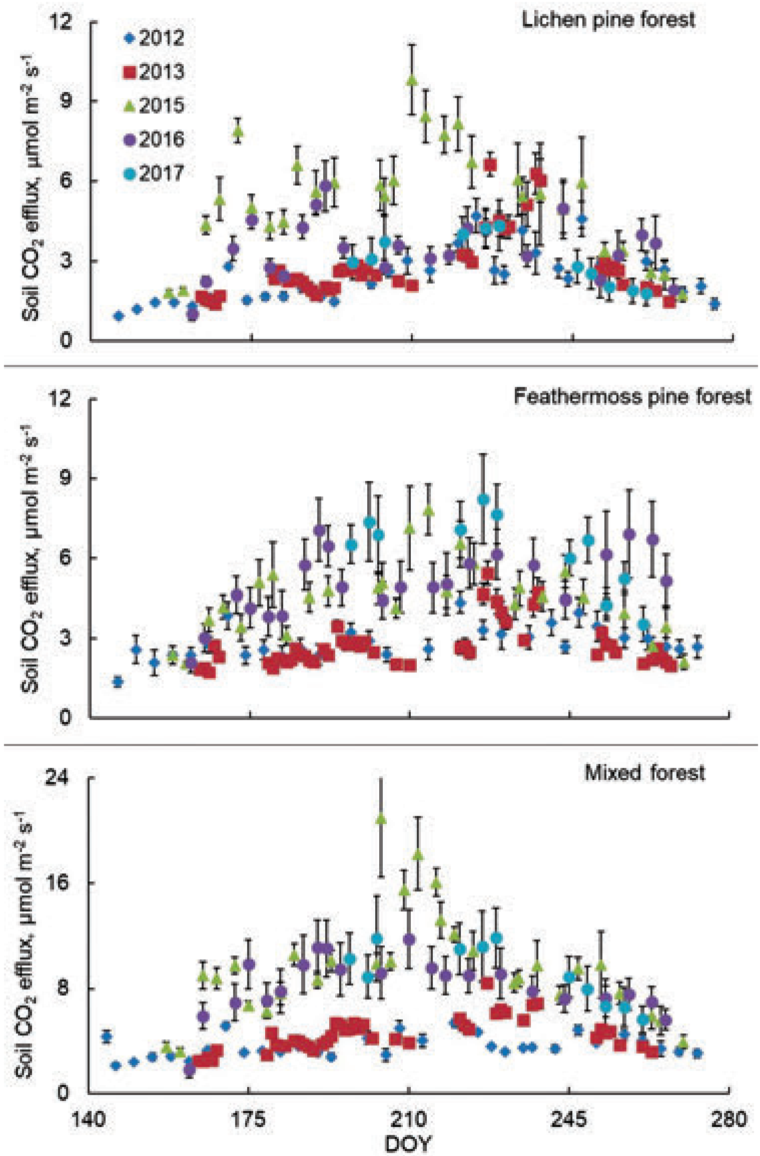


**Figure 3.** Seasonal dynamics of soil $CO_2$ effluxes for different sites for five years of measurements: lichen pine forest, feathermoss pine forest, mixed forest. Data presents mean for day with st. errors

amounted to 9.7 μmol $CO_2$ $m^{-2}$ $s^{-1}$, on certain days the flux reached 20.1 μmol $CO_2$ $m^{-2}$ $s^{-1}$. The minimum flows occur immediately for two seasons – 2012 and 2013 – the fluxes averaged 3.7 and 4.5 μmol $CO_2$ $m^{-2}$ $s^{-1}$, respectively. The season of 2016, as well as 2017, for the mixed forest, is characterized by high fluxes, but without apparent clear dynamics during the season.

The feathermoss pine forest is the most moistened of the three areas examined. This factor had a direct effect on the magnitude and intraseasonal dynamics of the $CO_2$ fluxes. All measurement seasons can be divided into two groups according to the amount of $CO_2$ fluxes: a group with low and medium – up to 5 μmol $CO_2$ $m^{-2}$ $s^{-1}$ and high fluxes – up to 10 μmol $CO_2$ $m^{-2}$ $s^{-1}$. The first group includes two seasons in 2012 and 2013, an average of 2.9 and 2.7 μmol $CO_2$ $m^{-2}$ $s^{-1}$, respectively, for the season. The second group includes just three seasons – 2015, 2016 and 2017 – in them the $CO_2$ fluxes were 1.7 ± 0.2 times higher than in the first group. For the two previously considered sites, the wettest season of 2015 led to a significant increase in $CO_2$ flows. In the feathermoss pine forest this trend was not observed because this type of forest is able to maintain soil moisture at a high level for a long period of time.

**Modeling of seasonal dynamics of soil $CO_2$ emission**

To simulate the seasonal soil $CO_2$ emission we modified the classical exponential model for $CO_2$ emission (Xu and Qi, 2001; Davidson and Janssens, 2006) by adding the environmental factor that affects the magnitude of the seasonal flux dynamics-soil moisture.

In general, the equation for calculating the seasonal soil $CO_2$ emission was:

$$E = E_0 * (b_0 + b * SWC) * e \wedge (a * Ts), \text{ where}$$

$E_0$, $b_0$, b and a – calculated parameters, Ts – soil temperature, SWC – soil moisture, E – value of soil $CO_2$ emission. The calculation of $CO_2$ emissions used the least squares method, which allowed calculating the model parameters on the basis of experimental data with a minimum error.

The comparative analysis was carried out for two seasons, differing in the degree of moistening – the 2013 and 2015 seasons (Fig. 4), for each forest type. The simulated fluxes allowed to reliably estimate the change in soil $CO_2$ emission during the season, it is possible to distinguish the soil $CO_2$ emission change and single out peaks. Moreover, it is important to note that taking into account the influence of soil moisture in the

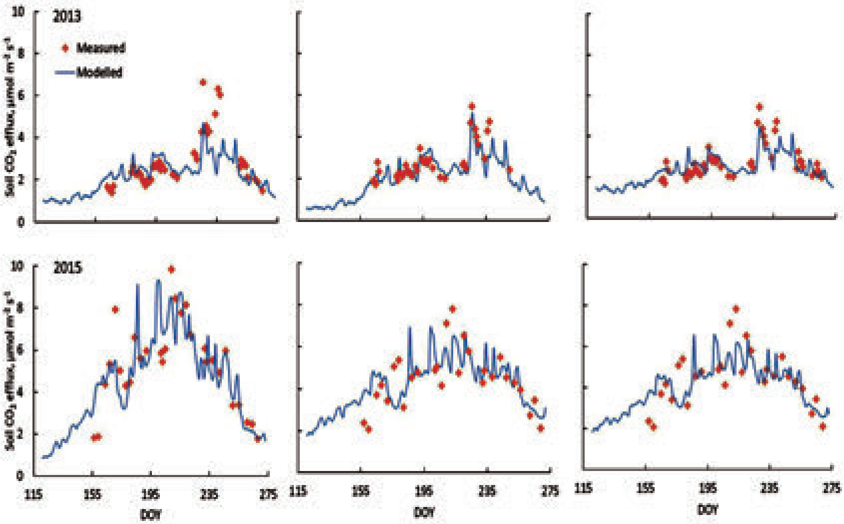


**Figure 4.** Comparison of the modeled fluxes with measured for two years of measurements in three sites:
a) lichen pine forest; b) feathermoss pine forest; c) mixed forest

model makes it possible to compare the seasons, which differ drastically in terms of the amount of moisture.

## Conclusion

Changes in the meteorological conditions of a current season directly control the soil conditions of forest area. Specific features of feathermoss pine forest can modify the unfavorable meteorological conditions and maintain the soil meteorological condition almost at the same level for drought or moist seasons.

The mixed forest made the biggest input to the seasonal soil $CO_2$ emission. Lichen pine forest does not have a thick litter layer and reacts rapidly to the changes especially in the moisture conditions. Feathermoss pine forest is the most resistant to the changes of meteorological conditions during the season.

Our model includes specific features for each forest type and can provide the most probable information about the changes there. This model allowed to estimate the intraseasonal dynamics of soil $CO_2$ emission for different forest types with a high reliability.

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Part 2

# Anthropology in the North: traditional population in urban and rural areas

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# Reading the ethnographic past in the present: Waldemar Jochelson and *The Yukaghir*

*The Yukaghir and Yukaghirized Tungus* by Waldemar Jochelson (Vladimir Il'ich Iokhel'son) (1855–1933) is one of those rare books in the history of anthropology: a study of a people so little known or understood, achieved on such a grand scale and in such a comprehensive manner, that it has become a definitive work on the subject. The Memoir was one of the last pieces of the Jesup North Pacific Expedition – possibly the largest anthropological collecting enterprise ever undertaken – directed by Franz Boas, known as the father of American anthropology, for the American Museum of Natural History in New York. Begun in 1897, the expedition covered both sides of the North Pacific region in North America and northeastern Asia, collecting material from indigenous peoples from interior British Columbia in Canada to the Lena River valley in Sakha-Yakutia (Boas 1905, 1898–1930; Kendall, Mathé, and Miller 1997).

This collection was made at the turn of the 20th century, a time when most western scientists did not expect indigenous cultures and peoples to survive much longer. The Yukaghir, a people living in the tundra and taiga of northeastern Siberia, were one of the smallest numbered peoples in the entire region and in the Jesup North Pacific Expedition. At the time of Jochelson's field work there were only about 200 Yukaghir people alive.

Jochelson's monograph was published in three parts over a period of more than two dozen years. The writing was interrupted by various difficulties, including the Russian revolution and Jochelson's opportunity to complete Boas' grand vision of a North Pacific culture area by making an expedition to the Aleutian Islands. Boas was torn between supporting Jochelson's fulfillment of his own broader research agenda and finishing the Memoir series for the museum, both of which were needed for closure of the original project. Some twenty years passed between the publication of Part I and Part III of Jochelson's magisterial ethnography.

This was slow science. And even though it was still being finished after the Soviet era had begun, when drastic changes were taking place in the lives of the Yukaghir people, it was written mainly in the present tense – a present tense which mostly refers to the years of Jochelson's exile and expedition field work, the late 19th and early 20th centuries. When we read the ethnographic past in the present tense a century later, in an account written during a period of more than two decades, how should we interpret it?

On the second page of his Memoir, Jochelson introduced the Yukaghir as a tribe "insignificant and having no future." And yet they are still there. The Yukaghiric languages were once widely spoken throughout a vast range: across Chukotka and parts of the modern-day Sakha Republic and northern Magadan Oblast; from west to east, from the Ural Mountains to the Yenisei River; and from north to south reaching from the Arctic Circle to the southern Altai taiga. They numbered perhaps 10,000 to 20,000 people at the beginning of the 17th century. Other peoples in the area called the Milky Way "Yukaghir fire", because the stars in the sky resembled the many campfires of the Yukaghir at night. The Yukaghir's catastrophic population decline occurred throughout the 19th century, mainly due to epidemics, outmarriage, extreme climatic conditions, deprivation, famine, and being merged with other groups.

The Yukaghir are in fact two interrelated peoples, the reindeer Yukaghir or tundra Yukaghir (Wadul) and the taiga Yukaghir (Odul). The two dialects of the Yukaghir language are so different that they are almost mutually unintelligible. The classification of the language has long been a subject of debate among anthropologists and linguists. It was originally classified as an isolated Paleosibiric remnant unrelated to neighboring languages, but modern linguists have reconsidered this and are starting to look at it as related to the Uralic language family, probably by way of Mongolia and Manchuria.

Among the pictures and artifacts in the museum's collection are letters and maps written in signs on birch bark. Some were love letters, including at least one describing Jochelson himself. Others depicted forests, lakes, and river crossings. Paleolinguists have hypothesized that these are remnants of an ancient language, but once thought no one was left alive who could read them. During my field work at the end of the 20th century, though, a few elders could still read them. Among the functions of this kind of writing were counting time and predicting the return of a hunting party according to the phases of the moon. Along the rivers of Kolyma the time a journey takes is thus reckoned in distance, which is to say that distances are also expressed in terms of time, as Jochelson remarked.

Rane Willerslev (2007) opines that the Yukaghirs have been romanticized as a primitive remote people and something of an icon of the small-numbered peoples of the north, based largely on travelers' impressions and most of all on Jochelson's Memoir. He notes the paradox of such representations: they are portrayed as sad but cheerful, poor but rich in emotional feeling. As a small tribe, they inhabit some of the harshest terrain in the world but escaped some of the harshest Soviet-era policies, particularly the worst of the anti-shaman campaigns. None of their shamans were killed, but they were threatened and repressed. When the post-Soviet era began, many people said there were no shamans left. Actually there were some, but they weren't revealing themselves. By the end of the 1990s a few had revealed themselves to outside researchers but not to their neighbors, following a tradition of secrecy and respect for the dangerous power of the spirits. One shaman said he would give me information, but only if I agreed not to share it with the local community. If I brought it to Europe or America that was fine, he said, because then it would be science. He decided what to reveal by negotiating with the spirits ahead of time.

Jochelson was sometimes criticized for creating a canonic ethnographic representation of shamanism while maintaining that he himself had met very few shamans. However, some shamans were only revealed to him as shamans after their death. The authorial voice in the Memoir is unmistakably his, but Boas' editorial hand remains in the background of the work, in the granular level of detail, careful framing of theories, and most of all an emphasis on pre-contact traditions. Boas instructed his field workers to screen out modern adaptations and present an image of the pre-contact past. The traditions were already fading at the time that they were being collected and written about.

In the early 1990s, for the first time in their history, the Yukaghir held a gathering of all the Wadul and Odul clans to plan their future. The main concerns that emerged were land and language. Without these, many of those present felt they would no longer be a distinct people. The numbers of native language speakers have drastically declined since then. 2002 Russian census figures listed about 200 native speakers; by 2009 this number had fallen to 55 or 60. Linguists have recently declared the language moribund.

Yet while the elders who both lived through and outlived collectivization, the ones Nikolai Vakhtin (1991) calls the rupture generation, told their stories and sang their songs for outside researchers, their children and grandchildren listened. There will come a time when the Soviet era passes out of living memory. Nevertheless, as folklorist Ludmilla Zhukhova (1996), who worked with the Yukaghir for many years, has said: “The old people are dying, but new old people are growing.”

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# Indigenous minorities of the northern areas of Western Siberia in the context of the industrial development of the region

With industrial development onset traditional lifestyle of indigenous peoples in the North underwent a series of changes. The recent modernization has altered the region, forcing the Khants, the Mansis, and the Nenets to search for a new place in the industrially advanced North.

Obviously, indigenous small-numbered peoples and their lifestyle could not fit easily into Europe-oriented standards, with their sedentarisation, industry-triggered goods/money relationships, and civilized utilities.

The national policy aimed at integration of indigenous small-numbered peoples into a new context mainly focused on ways to intensify specific northern agriculture and economy. It seeked mechanization and automation, and, consequently, every possible reduction of human labour. It was believed that exposure of indigenous communities in the North to novel machinery, alongside with increased performance and mechanization, would foster a switch to modern economy, enriching indigenous communities' material and spiritual culture.

As a consequence, the Khants, the Mansis and the Nenets, who had been practicing a communal approach to nature management for centuries, were turned into state workers. There were some social and economic reasons for it: all small-sized, unprofitable collective farms had to be closed down; state workers became entitled to guaranteed wages (higher than in the collective farms) and social benefits (leave allowance, retiring pension). The emerging state-owned farms offered better commodities and food products, but on the other hand all these changes led to farms being amalgamated and communities relocated, which, in turn, caused devastation across vast territories. Another consequence was desolation of significant fishing grounds, fishermen detachment from traditional wild capture grounds and use of expeditionary fishing methods. Unable to continue fishing in their original grounds, indigenous fishermen had to spend months away from their families, often having very low social and living standards.

Measures to maintain the indigenous communities' traditional trades and practices were often sporadic and lacked comprehensive vision. In the Yamal-Nenets District, they came down to the following: "Designed to avoid the need for recruitment, converting collective farms into state-owned ones aims to engage in fishing and fish processing the local indigenous communities (especially their female population). This aim has not yet been attained and it won't be, unless we offer women an ample amount of day care centers."

Fishing was not the only industry affected in the early 1960s by the situation as negative as this. Hunting, which constituted the core of Siberia's indigenous peoples' economy was affected too.

To give you an example, we cite here the Memorandum "Concerning the Current Status of the Khants Inhabiting Shuryshkarsky District in the Yamal-Nenets National District, Tyumen Region", prepared by Z.P. Sokolova:

"In this district, as elsewhere in this region, hunting industry has very poor progress…

<…> Nobody seems to care about dwindling numbers of hunters and hunting grounds. After the indigenous communities had been moved to bigger settlements, some of hunting grounds remain completely abandoned <…> The area is badly lacking experienced hunters. Only few of the Soviet party leaders are hunters themselves, their expertise mainly being fishing and agriculture. Therefore, they underestimate the importance of hunting as an industry" [Sokolova, 2015].

Situation in indigenous communities didn't improve after new USSR and RSFSR constitutions were adopted in 1977 and 1978. According to these documents, northern national districts were to be reorganized into autonomous districts. Administrations of newly established autonomous districts were to be regulated by the USSR Law "On Duties and Powers of Krai, Regional Councils of People's Deputies, and of Councils of People's Deputies for Autonomous Areas and Autonomous Districts", enacted on 25 June 1980.

Local authorities in autonomous districts enjoyed a very limited scope of powers and were completely subordinate to regional authorities and ministries. In particular, as was noted by the experts, "northern economies were largely inhibited by the fact that their product markets were regulated by organizations reporting to upper standing authorities for agriculture, not to the local ones <…> All funds allocated for the purposes of scheduled, social and economic growth in indigenous people's resettlement areas, were sent to regional or krai (area) authorities, while autonomous districts enjoyed only subsidies meant to cover expenditures sustained by state-owned farms. Northern farms were denied their right to re-distribute capital investment according to their needs. Nor were they free to promote their manufacturing and product markets."

In established and later reorganized state-owned and collective farms, indigenous communities were supposed to become the main driving force. But, due to low wages, they displayed very little interest in enhancing their performance, so the farms had, in the long run, proved poorly performing.

The lack of production culture was also underlined by N.V. Lukina when she was conducting research in the Alexandrovsky District of the Tomsk Region:

"The oil field development that we have witnessed here over the last few years, has caused some members of indigenous communities to become industrial workers. At the same time, the majority of working Khants continue practicing their traditional trades, often taking leave from their work to go fishing or trapping and balancing their old and new occupations. Notably, the Khants who seem to underestimate the importance of being continuously employed by one single employer, see this balance to be a natural thing" [Lukina, 1973].

When it comes to the extent to which the indigenous residents were involved in the sectors of economy, it should be noted that according to the Surgut District Council of People's Deputies, "as by 1 June 1978, ca. 900 indigenous residents were employed by manufacturing sector, ca. 150 by the local fish farm, ca. 600 by game wardens cooperative, more than 50 by service sector; more than 20 by agricultural sector; ca. 10 by local industries and forest harvesting, and ca. 10 by oil industry."

The above data demonstrates that the majority of indigenous residents stayed true, in one way or another, to their traditional trades, i.e. hunting and fishing. According to the Surgut District Council of People's Deputies, "out of more than 2,500 indigenous residents, ca. 1,700 are settled … ca. 1,000 are nomads subsisting on hunting fur animals, upland fowl, wild hooved animals, fish from local water bodies, and wild-growing plants."

The performance data of Surgut Game Wardens Cooperative indicates that "the total number of employed indigenous residents is 603. 374 of them are involved in fishing and hunting, 127 in collection and processing of wild-growing plants, 8 in reindeer herding, and 79 in forest harvesting, transportation and related operations".

Generally, over the period from 1975 to 1985, the share of indigenous employees in Surgut District increased by 25 %. According to the archived information, majority of them were employed by fishing- or hunting-related industries, which, however, suffered an acute staffing shortage. The performance data of Surgut Game Wardens Cooperative indicates that "even though the headquarters and remote premises of the game warden cooperatives look sufficiently manned with managers and experts, most of them stay for a year or less. Many managers are unaware of the local way of life and working standards among the indigenous communities, and therefore do not seem to be in full command of the situation, at least at the beginning of their work. It's natural that in the absence of a director decision-making is poor or none."

No less problematic was the housing issue. In the early 1960s, Shuryshkarsky District, Yamal-Nenets Area alone built for its indigenous residents 1,300 houses costing RUR 1.4 million. However, the Khants, the Mansis, and the Nenets tended to live in tents they normally put up close to where they worked. This led to the prevalence of a welfare mentality in the working settlements, which was related to the community leaders' excessive care for the indigenous residents who, on their part, demonstrated little observance of hygiene and sanitation.

Another social consequence of the industrial development in the northern areas of Western Siberia relates to the contruction of oil and gas pipelines. It forced indigenous communities to leave their habitual places of abode. While actively constructing pipelines, the then existing All-Union Association TyumenGazProm did not provide for any funds to build new housing for the Khants and Mansis.

Moreover, forcing on the indigenous communities the settled way of life often broke cultural ties within them. After training at special boarding schools, indigenous children would return home with no skills of maintaining the traditional lifestyle in taiga and tundra areas. As a result, as is evidenced by research teams, "there has appeared a generation gap, and the cultural practices ceased to be passed onto younger generations. Children ceased to speak their native language. With the loss of smaller indigenous villages, triggered by the resettlement process, indigenous culture started to sink into oblivion. That portion of the indigenous population that had moved to the amalgamated settlements (with rural councils, collective and state-owned farms), lost all contact with the aboriginal economy which by that time had started to fade into obscurity as well."

As can be seen from the above, despite all measures undertaken by the government, the efforts to integrate indigenous communities into the process of industrial development have proved futile. Aimed at reforming their traditional lifestyle, they led to nothing but worsening the well-being of the indigenous communities and, ultimately, negative social impacts.

The large-scale oil and gas development projects have triggered a gradual curtailing of indigenous occupations, causing communities to migrate to bigger settlements, leaving their original habitats with only a few hunters and fishermen, and generating a dependent population as the former fishermen and hunters were forced to seek another source of income.

Yu. Slezkin notes that “over the period from 1959 to 1979, the number of aboriginal northerners engaged in unskilled, menial work (cleaners, loaders, watchmen), had increased from 13% to 30%. In oil- and gas-rich autonomous districts of Khanty-Mansy and Yamal-Nenets, this increase could be as high as 30% or 60% (even 90% in some state-owned farms).” Especially wild was this trend in places to which the indigenous communities were forced to relocate. Z.P. Sokolova, for instance, argues that “one such place could provide jobs to not more than a third of its inhabitants (the rest of them were employed as managers and auxiliary personnel with very modest duties).”

Let us dwell on the causes of the above challenges in more detail.

The first cause to be mentioned is what A.I. Pika defines as “the policy (to be more exact, the lack of any knowledge-based, target policy) that existed for indigenous communities.” Instead of decreasing the indigenous residents’ self-sufficiency, such policy should have targeted “the gradual curtailing of the non-proftable industries that the northern areas were completely alien to, such as dairy farming, Arctic pig breeding, among others. Instead, the policy should have tried to introduce and facilitate family businesses to promote reindeer husbandry, tenancy agreements, and other forms of cooperation.”

Another cause was the excessive paternalism displayed by the Soviet government. According to V.N. Skalon, “the Soviet power treated the aboriginals the way a first-time mother cat treats her knewly born kitten, safeguarding and hiding it in every corner she can find until it dies of overprotection… Imposing on indigenous communities the settled way of life and attempting to overcome nomadism, the governmental edicts of the 1950s echoed a way too much partenalistic attitude.

Such policy was bound to fail also because of its mechanisms. As was rightly noted by Yu.G. Rychkov, “the most paradoxical thing about this tragedy is that it was paved with good intentions, it was created by a powerful government that was, however, ignorant of historical and ecological consequences of its deed, the government that attemped to make its nation happy without asking for its vision of happiness first, the government that opted for administrative enforcement as a way to assure better living for a civilization it knew very little of.”

Ultimately, for indigenous peoples of the North industrial development created more loss than gain. There was a price to pay for this exposure to the industrial progress: the loss of vernacular culture, the large-scale pollution, and the reduction of the tribal grounds were all it had led to.

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# Ethical principle and criteria of geocultural approach in defining the Arctic zone of the Russian Federation

The Decree of the President of the Russian Federation (May 2, 2014 "On land territories of the Arctic Zone of the Russian Federation") defined the boundaries and the list of the land territories in the Arctic, outlining the territory of the Arctic zone. The strategy for social and economic development of the Arctic zone was adopted by the Russian government on April 21, 2014. The Strategy for the development of the Arctic zone of the Russian Federation and national security for the period until 2020 is aimed at implementing a set of tasks. The financial and economic mechanism of this implementation is focused mainly on the needs of the Northern Sea Route, oil and gas extraction on the continental shelf, and national security. This approach reveals a purely consumer attitude to the resources of the Arctic, exposing the meagerness of the social content in the new version of the Strategy. That is declared clearly in the 146 "anchor projects" of the eight key areas development programs – social dimension projects represent less than 1%.

Local population and indigenous peoples view the current definition of the boundaries of the Arctic zone of the Russian Federation and the strategy for its development as a violation of the ethical principle of mutual understanding and assistance, a disregard for the very existence of the indigenous population, a disregard for the geocultural and ethno-cultural experience that helped autochthons of high latitudes to survive over centuries and live full creative lives.

Ignoring and suppressing the autochthon experience in the development of the Arctic territories is one of the most enduring traditions in the methodological and humanitarian provision of the modern Arctic policy, devoid of ethical principles inherited from the very beginning of the so-called discovery of new lands beyond the Ural mountains. These lands were viewed as terra incognita, undeveloped territories, although many pioneers survived thanks to the help and culture of indigenous ethnic communities living in the Arctic since times immemorial. According to the colonial policy, local ethnic groups could be considered a component part of local natural resources.

Nowadays there are active discussions on the legitimization of various aspects of Arctic governance. There are three approaches to defining the boundaries of the Arctic zone of the Russian Federation.

The first one is the **thalassocratic approach** which focuses on the resources of the Arctic Ocean and its coastal territories. Consequently, it does not take into consideration the socio-economic and cultural development of the indigenous people living far from the ocean. The Decree of the President of the Russian Federation (May 2, 2014, N 296) "On land territories of the Arctic zone of the Russian Federation", issued in order to implement the Fundamentals of the state policy of the Russian Federation in the Arctic, was prepared in accordance with the thalassocratic approach. In the Annex to the Decree there is a list of the land territories of the Russian Arctic zone adjacent to the Arctic Ocean. The meagerness of this approach seems obvious, that is why every territory should be considered before including it to the Arctic zone. President Putin said: "The Arctic is the most important region that will ensure the future of Russia. The strength and power of Russia will grow in the Arctic region (June 15, 2017)". On December 9, 2017, he outlined the historical perspective: "... Russia will grow in the Arctic in this century and in the next". Due to the tasks set the boundaries of the Arctic zone are expanding: thus, the Belomorsky, Loukh and Kemsky regions of Karelia are included in the Arctic zone of the Russian Federation by the Decree of the President (June 26, 2017), although these regions do not have direct access to the Arctic Ocean.

The second approach – **tellurocratic** – defines the Arctic as a territory situated to the north of the Arctic Circle. This approach was accepted by the Government of the Sakha Republic (Yakutia). According to the Decree No. 521 of the Government of the Republic of Sakha (Yakutia) adopted on December 2, 1995, 12 *ulus* or *regions* (administrative subdivisions), constitute the Arctic zone of the Republic: Abyyskiy, Allaikhovskiy, Anabarskiy, Bulunskiy, Verkhoyanskiy, Zhiganskiy, Momskiy, Nizhnekolymskiy, Olenekskiy, Srednekolymskiy, Ust-Yanskiy, Eveno-Bytantaiskiy. The Decree No. 464, adopted on September 29, 2011, added Verkhnekolymskiy ulus to the list above.

**We suggest a third approach: to introduce a notion of a "continental Arctic",** thus expanding the term "continental shelf of the Arctic". To define the boundaries of the Arctic according to this approach, it is necessary to apply geocultural and ethno-cultural criteria, which take into account indigenous culture, developed in harsh conditions of cold air and cryolithic zone. There is a land Arctic, and there is a continental Arctic, where Arctic peoples have lived since ancient times and have created an extreme culture of life support. To define it, we need a multi-faceted approach based on the methodology of organicism, which allows to integrate both natural and social aspects of life in the Arctic.

This approach is supported by the scientific community that considers the Arctic a special region with a vulnerable ecosystem, where indigenous peoples of the North are engaged in traditional economic activities, and their alive culture, and sometimes their lives are threatened by unresolved problems of the Arctic region. Today, many stakeholders understand that applying only one criterion (geographical or naturalistic) is not enough. Interdisciplinary, interdepartmental scientific approaches are actively developing. They focus on the convergence of the natural-science and socio-humanitarian directions. One of the most important arguments is the dialogue between researcher and the researched, and adjustment of decisions being made to the interests of local communities via discussing them with authorized representatives of these communities.

Based on the study of opinions of the Arctic residents, we have developed seven geocultural and ethno-cultural criteria for defining the boundaries of the Russian Arctic zone. On February 6, 2017 the residents of the coldest region of Eurasia – the Oymyakonsky ulus of the Republic of Sakha (Yakutia) addressed the Government with a request to include the Oymyakonsky ulus in the list of the Arctic territories. This request emphasizes that "The community of the Oymyakonsky ulus and scientists agree that including the ulus into the list of the Arctic territories will be a fair and just decision and will help to reach a decent quality of life and stop people from leaving the Pole of Cold. We consider our proposal to be fair and worthy of a positive decision".

The population of the Oymyakonsky ulus has always tried to build a decent life in conditions of "double cold" (extremely low temperatures and permafrost). There are areas of compact settlement of small indigenous groups, which are engaged in traditional economic activities (mainly reindeer breeding and native cattle and horses' breeding). According to the law of the Republic of Sakha (Yakutia) "On the list of small indigenous groups of the North and the areas of their compact settlement" (10.07.2003), this list includes the settlements of Tomtor II of the Borogonsky *nasleg* (agricultural community), Orto Balagan and Yuchugei of the Oymyakonsky ulus. The river Indigirka, running through the entire territory of the ulus, flows into the Arctic Ocean.

Over the past 20 years, the Oymyakonsky ulus has seen a threefold decrease in population. The main reason for this is the negative migration balance. Compared with the data of the Russian Census 1989, population of the ulus has decreased by 80% and counts up to 6.3 thousand people now.

The arguments for the inclusion of the Oymyakonsky ulus in the Arctic zone were put into the reports and recommendations of the Russian Scientific Conference ”Oymyakon – A Pole of Cold” dedicated to the 125th anniversary of the birth of S.V. Obruchev (September 22–25, 2016, Tomtor, Oymyakonsky ulus, Republic of Sakha (Yakutia)), a round table discussion “Nature and people of the Pole of Cold” (March 25, 2017, Tomtor, Oymyakonsky ulus). On the 30$^{th}$ of November, 2017 when the temperature outdoors was 56 degrees below zero, another round table discussion took place in the Oymyakon settlement. Among the participants were the senior executives of the Russian Geographical Society and the leading experts in social issues and cryology in the Arctic. The participants adopted recommendations to include the Oymyakonsky ulus in the list of the Russian Arctic zone territories. December 15, 2017, an interdisciplinary scientific round table discussion was held as a part of the Days of Yakutia in Moscow. The topic was “Cold and Civilization”. The participants of this discussion supported the proposals of the scientific community and the initiative of the Oymyakonsky ulus residents to include this ulus in the Arctic zone of the Russian Federation.

In fact, Yakutia, where the Arctic culture has developed since ancient times as the frontier of national security in the northeast of the Russian Federation, like no other deserves recognition as the Arctic zone of Russia. Yakutsk is rightly declared the cultural capital of the Arctic.

Below, we briefly outline the geocultural and ethnocultural criteria which we have developed for defining the territory of the Arctic zone of the Russian Federation.

**The first criterion is the length of residence on the given territory.** The geographic image of the Arctic has specific features in the perception of the indigenous peoples and the newly-arrived population. Russians do not have a mental map of Russia, which includes the lands beyond the Urals. For indigenous peoples, the Arctic represents their territory of development, where they have lived since Paleolithic Period, their pain and hope for a decent development in the modern world.

**The second criterion is the structuredness of space.** The Arctic space is characterized by low permeability, inaccessibility, availability of autonomous resources in the form of indigenous cultures. The theory of terra incognita has cost many lives of brave pioneers. Their weak point was neglecting the geocultural knowledge, skills and spiritual values of the creators of the Arctic circumpolar civilization. This gap continues to prevail in the minds of many leaders, ruling the Arctic territories from afar, and people who spend only a short period their lives in the Arctic.

**The third criterion is the presence of a cultural nucleus.** The Arctic was developed not by the "doomed aborigines" and not by the representatives of "backward civilizations", but by the bearers of the cultural nucleus, which possesses impressive stability and continuity to the ancient cultures of the Northeast Asia. The migration routes were established by Homo mobilus – a nomad with an absolute will for reclamation of space. According to A.Toynbee, "the challenge of the hard environment" was accepted by the Arctic aborigines as a "nomandism principle" – the conservation of movement law, because only by moving one can stay alive in the harsh conditions of the Arctic. Continuous nomadism has led to the reclamation of vast territories of the circumpolar Arctic and has created a united culture. At present, recognition, acknowledgement, restoration, preservation and revival of the Arctic aborigines' cultural unity is becoming an interesting humanitarian and political issue of our time, the issue of the supranational pan-Arctic cooperation.

**The fourth criterion is the maturity of the regional identity.** In recent years, the notions such as "Arctic identity", "the world of the Arctic resident" have occupied an important place in the assessment of social and cultural development in the Arctic. The Arctic identity as a manifestation of self-identification of residents in different regions of the circumpolar world has specific local features.

**The fifth criterion is the existence of shared spiritual and cultural values.** The socio-psychological rules of coexistence, shaped by harsh conditions of the Arctic, have created shared spiritual and cultural values that can form the basis for the future integral socio-cultural system. The sociocode of the Arctic civilization consists of a system of three leading values:

- Control over one's own destiny;
- Cultural integrity, manifested in belonging to a viable local culture;
- Regard for nature, manifested in co-evolution with the traditional habitat.

**The sixth criterion is a culture of dignity.** The life of an Arctic resident in his perception is not a survival, but a full life, forming a culture of dignity. The culture of dignity also extends to relations with nature, as evidenced by a set of rites, customs, rituals, aimed at establishing relationships with natural phenomena, spirits, animals, typical for the traditional way of life. The culture of dignity forms a free and responsible person, capable of a secure independence, which is extremely important for autonomous life in the Arctic.

**The seventh criterion is a combination of nature conservation and the value of human life.** The ethics and aesthetics of the peoples of the Arctic are based on the understanding of a place a human being occupies in the biosphere, the ethnosphere, the sociosphere, the noosphere and the cosmosphere, and are manifested in the following activities of indigenous peoples:

- Traditional knowledge of the lanscape;
- Attunement to the space;
- Following the rhytms of nature;
- Spiritual connection with the original habitat;
- Energoinformational knowledge and values;
- Phenomenon of a travelling settlement;
- Phenomenon of a spiritual bond with one's birthplace.

**Conclusion**

The above-mentioned geocultural and ethno-cultural values of indigenous peoples of the Arctic fill the legal term "unity and integrity of natural and economic complexes" with humanitarian meaning, and justify special conditions of economic activities and environmental safety in the context of global climate change in the Arctic and development of the offshore and coastal deposits. The aim of these special conditions is to increase the role of the local indigenous population in the co-management of the Arctic development, in the protection of the environment, in the use of natural resources and in pursuing sustainable livelihoods of people in the Arctic.

The ethical principle and the geocultural and ethno-cultural criteria allow us to define the Arctic as an integral complex of the ocean-land and the original birthplace of the circumpolar Arctic civilization culture.

It is important to understand the interrelationships of the following connections:

- Nature and civilization;
- Resources of the planet and modern ecogenic processes;
- Culturological turn in the global civilization space and changing climate conditions.

The introduction of the "continental Arctic" concept will allow to resolve the existing contradiction between the legal provision, management and industrial development of the Russian Arctic zone on the one hand, and the expectations of the indigenous groups on the other hand.

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# Elderly families as the basis of traditions and stability of the indigenous peoples of the North (on the example of the Republic of Sakha (Yakutia)

The increase in the number of older persons worldwide is becoming a global trend. Thus, according to demographic forecasts of Russian scientists, by 2026 the older generation in Russia will be 26.4%. The trend of increasing the proportion of older persons in the total population of the Earth continues. According to experts, by 2050, the proportion of older persons will be 22% of the total population in the world.

In the current demographic situation, it is important to study older families as a primary group, which actively influences the preservation of the traditional way of life of indigenous peoples. The study of elderly families in the Republic of Sakha (Yakutia) has not previously been conducted, especially in the aspect of indigenous families.

What are the statistics on elderly families of indigenous minorities in the north of Yakutia? What is the composition of the family, how many generations continue to live together? What is the mechanism of traditions and customs reproduction in the modern family? In our opinion, families of the elderly are the basis of stability for their ethnic group.

The study of family and marriage history among the Evens of Yakutia shows that the Even family has passed several stages in its historical development, each of those reflecting the processes of socio-economic relations development.

Among Evens, constantly moving with herds of deer, a settlement was not of a permanent character. They lived in nomadic camps, which united several related and unrelated families. Nomadic camps as ordered systems played a huge role in the preservation of the Evens as an ethnic group.

Changes in the socio-economic life in the early twentieth century were increasing until the outbreak and decomposition of a large patriarchal family of the Evens. As shown by archival materials from the end of the XIX – beginning of the XX cc. the dominant form of the family among the Evens was a small individual family with an average number of 3-6 members, composed of two generations, based on private ownership and individual consumption. Less common was a large family with an average of 8–14 people.

The quantitative ratio of large and small families differed in the considered period in different generic groups of the Evens of Yakutia. In the nomadic Even society a large patriarchal family normally did not share one yurt, but had several yurts due to the nature of nomadic life. [Nikolaev, 1964, p. 39]

At the beginning of the twentieth century, according to ethnographer U.G. Popova, a typical Even family consisted of a married couple with children, who lived in their own home, separate from their parents, and moved from place to place with a community of neighbors and distant relatives. [Popova, 1981, p. 140].

Form, structure and size of the Even the family of the late XIX – early XX century depended mostly on climatic conditions and were associated with membership in a particular social group.

The size of the family depended directly on its material well-being: the wealthier the family was, the stronger the economy was, the larger was the family itself.

The shape and size of a family are closely related to its structural features, i.e. the related composition of families. Even families consisted of several generations of blood relatives on the ascending and descending lines: two generations (parents and children) in a nuclear family and three or more generations (old parents, their married sons and grandchildren, and sometimes great-grandchildren) in an extended family. Some families included uncles or aunts of the patriarch or his wife, unmarried relatives or cousins, nieces and nephews.

The above makes it possible to conclude that the Evens had both family forms – the extended and the nuclear. When changing one form of the family (patriarchal extended) to another (nuclear), the decisive factor was the development of the forms of ownership (from communal to private), closely related to the nature of economy developing from natural to money.

Thus, having subsistence production, the large patriarchal family consisting of several married couples with their offspring (nuclear families) prevailed. Along with the development of money economy, the patriarchal family went into decay.

The predominant family form among the Evens of the late XIX – early XX centuries was a nuclear family with an average number of 3-6 people. A characteristic feature of the traditional Even family was that subsistence production prevailed, thus making a family an important economic unit of the society in the harsh climate of the North.

In the Republic of Sakha (Yakutia), 5 districts are included in the list of the Arctic regions, while 20 districts are considered to be areas of the Even settlement.

According to research data, the number of families in these areas in 2002 reached 21 520, and in 2010 – 19 940, i.e. decreased by 7.3%. The greatest reduction was registered in the Nizhnekolymskiy (23.0%), Verkhnekolymskiy (15.0%), Ust-yansky (15.2%) districts. Only Zhigansky (+1.2%) and Eveno-Bytantayskiy (+5,5%) districts had a somewhat positive trend. Actually, there were no changes only in Srednekolymsky district (+0,1%)[1].

According to the Russian Census of 2002, the biggest percent in the distribution of households by number of members in all Arctic areas, with the exception of the Anabar district, belonged to families consisting of two people. Moreover, in areas such as Verkhnekolymskiy and Nizhnekolymskiy districts the proportion of households of this size has already exceeded 40%. One third of the families of the Abyisky, Srednekolymsky, Verkhoyansky, and Momsky districts also consisted of two people families. In 2010, this trend has somewhat flattened, yet still the proportion remains at a high level.

[1] Report on the research work on the topic "Assessment, the main trends in the natural and socio-economic status, human potential of the Arctic economic zone of the Republic of Sakha (Yakutia)". Section 2. Assessment of the current state of human potential of the Arctic economic zone of the Republic of Sakha (Yakutia). 2.2.3. Marriage and family relations in the Arctic zone. 2.2.3.1 Features and trends of the family structure of the population. Sukneva S.A., Barashkova A.S.

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# Siberian river as an event-driven corridor: hidden from the eyes and transparent practices and messages

This article is dedicated to an unusual "character", which is neither a community or a group, united by close ties, nor a complicated personality. The main character of this article is the river Ob. I suggest to view the Middle Ob, which connects settlements and towns of the Tomsk region, as a special tool used by the local residents and visitors to conceal certain facts and declare others. (Fig. 1)

**Figure 1.** A cutbank, formed by landslide

Can a river be a subject of a socio-anthropological research? It would be more accurate to say that in this case the river is viewed not just as an environment, environmental characteristic or a factor influencing local communities, but occupies an intermediate position between the status of an actor having its own will, and the status of a substance or a special phenomenon.

It does not act, but it is managed by actions or events, transmits meanings, signals, saves information and destroys it, unites people, proposes alternative ways of moving, and creates barriers by separating the inhabitants of one settlement from another on the other bank. A member of a community catching sterlet for a living is constantly balancing between the danger of being caught by a water bailiff and the problem of losing touch with his rivals and allies in case of an emergency.

The inevitability and determination with which it is interwoven in many life scenarios of local residents, creates expectations on their side and allows to make the river perform certain functions. However, this process is not easy: on the one hand, we see disruptions in scenarios due to collisions of interests of different participants of this “river dialogue”, who understand the river and work with it and its surrounding space in different ways. On the other hand, these failures are connected to the life cycle of the river, early floods, water level changes and a permanent process of change the river bed is undergoing. (Fig 2).

**Figure 2.** An alluvian island

For example, I cannot decisively call the following phenomenon purely natural: after 40–50 years of active functioning of quays located in the coastal zone of a settlement, the river changes its watercourse, turning a deep area of the riverbed into a narrow armlet, unsuitable for large scale boat traffic. This can be explained by improperly conducted dredging operations, and by the fact that sand and gravel mixture is extracted from the bottom of the Ob with the help of dredgers. (Fig 3). The knowledge of the dynamic and spatial characteristics of the river used by the local residents, who, over decades, have created their own life support system relying on what they know, brings no results but high risks and significant losses. At this moment, the change of the main watercourse becomes a social event, not simply a natural one.

**Figure 3.** A dredger

However, if the change of the watercourse is a long process, which can be called a macro-process in social dimension, we can witness other processes on an everyday micro-scale. This article focuses on various interactions, including different types of actors. In one case it can be an interaction between people and small groups *via* the river; in other cases we can witness interactions which lead to consolidation of people *against* the river and its dynamic characteristics. Apart from this we can consider actions performed *together* with the river or supported by the river, and, finally, those special life situations, when the river *reacts to* the impact.

I would like to single out one of the significant examples, related neither to fishing nor to economic activities, but to the phenomenon of a death of a community member. And here the river acts, on the one hand, as a way to save lives during certain seasons and provide medical assistance to residents of remote settlements, where overland transportation would be dangerous for the patient. On the other hand, the off-season river conditions contribute to the effect of isolation and affect not only the living, but the dead as well. Living far from towns, where examination and autopsy are available, families cannot bury their dead members before the river freezes up and an ice bridge is formed, or before the river is clear from ice. Thus the funeral rite remains unfinished, creating a tangible tension in the community at a symbolic level. It is interesting to note that in the biographical interviews of the local residents the river is much less frequently viewed as a source of danger than as the cause of rupture of the social infrastructure, affecting everyday culture and the key rites of passage.

One more important aspect is related to the river as an event-driven corridor and, on the other hand, a corridor dictating certain features of life in the local communities. The first example is a warning system. To keep the location of traps and wicks in secret, fishermen wait until dark, fearing the members of the local community not as much as strangers from other microregions, who can pass the information to regulatory bodies in order to get indulgence for themselves. However, conspiratorial practices are combined with close and constant connections of fishermen – phone meetings, roll calls, placemarks.

First of all, the "river telegraph" becomes relevant when a water bailiff starts policing the river. Given the speed of his boat and the direction of the current the locals are capable of converting the distance into hours left before he arrives at their settlement. When the bailiff passes certain sections, fishermen put temporary marks and pass this information to the next observation point by phone. Thus, having calculated the time of his arrival to the next kilometer or to the next settlement, and not seeing him there at the set time, the residents can guess the reason of him being delayed between the marked observation points.

To be invisible and at the same time to be able to ask for help in case of an emergency situation – this is a difficult task a water bailiff faces while being on duty.

In this case, the properties of the river are manifested, first of all, in its surface. The assessment of its state (calm, storm) makes it possible to calculate the running characteristics of the boat much more accurately than in case of an overland transportation.

On the other hand, the properties of the water surface as a substance can play a cruel joke on fishermen. Indeed, "nothing can be hidden on the river", everything becomes known at the villages along the river, faster than inside one large settlement. This is true not only in case of any personal secrets of a community member. The river can hide or "betray" a fisherman and help the water bailiff trying take him in the act of committing a crime.

The river resonates, the river gives out hidden sounds. The boat engine sound is heard from afar. The direction, speed, type of engine, potential owner of the boat – all this can be defined thanks to good sound conduction. In the night, when becoming invisible is most relevant, sound becomes the only source of information. In case of a water bailiff chasing a fisherman, you can be quick and own a good boat engine. But the point is that you do not hear well because of the engine and can not assess the situation and locate your opponent because of darkness. (Fig 4). To hear and locate him, you need to stop. A static subject on the river sees the picture clearly as in the daytime, but is not able to catch up or to outrun anyone.

**Figure 4.** A water bailiff retrieves an illegally installed trap from the bottom of the river

The third story is connected with various fishermen claiming certain areas and sections of the river, which are considered to be most productive and rich in rare fish species. When fishing nets are installed openly, a fishing permit is placed above the surface of the water, and thus the right is assigned to a person or a crew. Only in case of expiration of time limits or violation of standards, the license can be terminated. Traps hidden on the bottom, can be found either by catching while checking his traps at night or by trawling. (Fig. 5) In this case, if the fishing gear that operates mainly at medium depth and closer to the surface of the river, touches the bottom, two types of fishing and two crews or fishermen can be in conflict. This can result in cutting the rope of the trap by the competitor who discovered it.

Each of the types of fishing has its advantages. To use nets means to control the state of the fishing gear constantly, to react to any damage instantly, and to leave no traces in the river itself. Using traps allows to elongate the operation and to have more time for other economic activities.

**Figure 5.** A local resident is checking a trap in daylight

Despite the unofficial ethical code, the danger associated with river fishing can come not only from the monitoring bodies, but also from fellow villagers or residents of another village who specialize in other types of fishing and can steal both tackle and catch.

But there is also a third party – the river that can damage traps, wicks (Fig. 6) or cone-shaped fish traps due to the passage of driftwood downstream. In summer, a dynamic river bed makes it difficult to find the points where fishing tools are placed. This happens due to the migration of sandy islands, which shift their coastline downstream in one or two years, and the trees growing on them are absorbed by the current. Therefore, sometimes even a detailed geolocation, which the fisherman himself calculates, does not allow him to find the gear in the place where he has left it. (Fig. 7).

**Figure 6.** Checking the wicks for sterlet

**Figure 7.** A sandy island, annually growing due to incaving and collapse of the bank

The river is a zone of constant displacements and shifts, which each time produce different consequences for interested parties. For example, a case which happened during the night check of traps, turned out to be a chain of failures and misfortunes, and allowed me to find out new details of the organization of the fishing process. One of the informant's traps was cut in half, and this complicated the retrieving. One end was crushed by a snag and covered by ooze.

The drag cable broke. A spare drag was in the boat. However, strong current made the drag cable wind on the motor screw and the fisherman had to cut the cable, leaving the second drag on the bottom. The fisherman went to the mouth of a river which flows into Ob in order to get a third drag out of his hiding place. Thus, another rule has worked, which is sometimes used by rivals: if you want to find out what is hidden "on the ground" or on the "surface" – break something under water.

Many questions remain about the role of the river in the transformation of the social space of the partially isolated coastal communities. In this paper, we have described only several examples of the river existing as a special phenomenon, which, in our opinion, has not only natural but also a socially-generative character.

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# Northern labyrinths and petroglyphs – ancient instruments of navigation and markers of uniform cultural space

The article highlights the instrumental (navigational) functions of the ancient objects of the cultural heritage in the Arctic. The objects of research were stone labyrinths and petroglyphs located on the coasts of the White Sea. The authors suggest newly developed methods of research: the calculation of the calendar properties of objects on the basis of the trigonometric function; the algorithm for creation and usage of petroglyphs by analogy with the work of the sun clock-calendars; a comparative analysis of the signs of culture and semiotics of light (graphs of the gnomon's shadow and the form of instruments).

Geographical studies of ancient cultural heritage sites are aimed at revealing their rational functions in the territorial system. Spatial approach and reliance on the fundamental laws of nature and society allow geography to integrate a wide range of disciplines, including: geoarchaeology, evolutionary geography, paleoecology, archeology, anthropology, ethnography, metrology.

The aim of the research is to consider the technologies of navigation (orientation and movement) in the context of exploration of geographical space (physical and essential). Possibilities of navigation in the North in prehistoric time are visually shown by the White Sea petroglyphs (age 4-6 thousand years) – boats that can accommodate up to 20 people, scenes of marine fishing. The lack of landscape landmarks in the open sea involves the use of astronomical objects, while polar days and white nights contribute to the development of the orientation by the Sun (Fig. 1).

The research is based on the theory of reflection, the system approach, the scientific provisions of V.I. Paranin, developed within historical geography (the role of the solar-oriented practices in the organization of

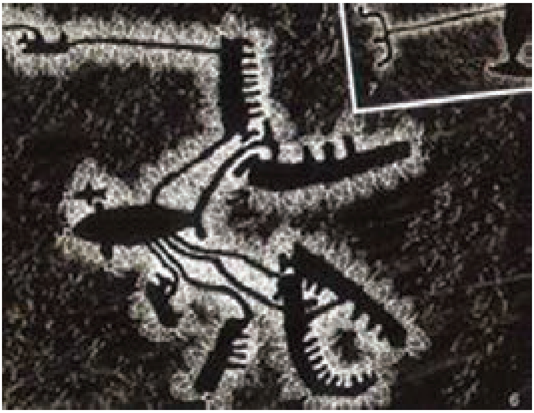


**Figure 1.** Petroglyphs of the White Sea. Trace drawing by N. Lobanova

territorial systems, and others). The results are broadly congruent with the conclusions made by B.A. Frolov on the subject of the Stone Age art rational value and the concept of the “anthropology of movement” developed by A.V. Golovnev [Paranin, 1990, 1998; Frolov, 1992; Golovnev, 2009; Paranina, Paranin, 2009; Paranina, Paranin, 2016, 2017a].

The objects of research conducted by the authors in years 2009-2017 in the North and North-West of Russia, were stone labyrinths, petroglyphs and sacred stones. During these studies the researchers used standard geographic methods of measurement and observation of landscape analysis; they used maps of different scale, remote sensing data, as well as models of natural and climatic settings for the time of creation of the studied objects (Mesoholocene). To reconstruct the algorithms for creating and instrumental use of the studied objects, the researchers used the oldest angle gage – a gnomon of the sun clock-calendars. To calculate the shadow charts, we used the basic trigonometric function and the astrocalculator [Paranina, 2011, 2014].

***The stone labyrinths*** are typical for the North of Europe (Fig. 2**).** The shadow of the gnomon explains the primary navigational purpose of the White Sea labyrinths, some of which were created during the period of the climatic optimum in Holocene (synchronous to petroglyphs). All elements of the labyrinth can perform calendar functions: the diameters of the arcs indicate the positions of the noonday shadow of the gnomon, corresponding to the movement of the Sun during the year; the radial marking (entrance, ends of spirals) fixes the boundaries of the astronomical seasons of the year along the azimuths of the shadow at sunrise / sunset. The largest number of instrumental functions is performed by a coiled-coil labyrinth oriented along the meridian. The variety of patterns of labyrinths can be explained by the influence of a complex of factors such as: geographical latitude, shape of the horizon, astronomical situation, specifics of the phenological cycle, economic tasks and cultural traditions at the time of creation [Paranin, Paranin, 2009; Paranina, Paranin, 2014].

**Figure 2.** A coiled-coil labyrinth, the Oleshin Island, Kuzov Arch. Photo by S. Golubev

***The method for calculation of the solar labyrinth-calendar*** (or another rhythmically constructed structure *oriented along a geographic meridian*) is the solution of an equation based on a trigonometric identity (H = tg α · A).

The solution of this equation allows to find the height and the location of the gnomon, the noonday shadow of which changes within a certain range during the year (for example, it coincides with the diameters of the inner and the outer arcs of the labyrinth). Both parts of the equation give one result – the height of the gnomon, and describe the interrelation between the angle of the sun α and the length of the shadow *A*: the left in summer, the right in winter. We have added an allowance *x* to the distances measured from the central point to the outermost arcs of the labyrinth (in this example – 1 m and 5.5 m) to define its position more precisely:

$$\text{tg } 48{,}47\ (1 + x) = \text{tg } 4{,}97\ (5{,}5 + x) \qquad (1)$$

The solution of this equation allows to find all the main dimensions by calculating the allowance *x*, added to the distances to the provisional center:

$$1{,}13\ (1 + x) = 0{,}09\ (5{,}5 + x)$$
$$1{,}13 + 1{,}13\ x = 0{,}5 + 0{,}09\ x$$
$$1{,}13\ x - 0{,}09\ x = 0{,}5 - 1{,}13$$
$$1{,}04\ x = -\ 0{,}63$$
$$x = -\ 0{,}63\ /\ 1{,}04$$
$$x = -\ 0{,}61$$

The correction of the distances to the center is based on the defining of the shadow length for different seasons (м):

$$1 + x = 1 - 0{,}61 = 0{,}39$$
$$5{,}5 + x = 5{,}5 - 0{,}61 = 4{,}89$$

The final solution of the equation (1) gives the height of the gnomon (м):

$$1{,}13 \cdot 0{,}39 = 0{,}09 \cdot 4{,}89$$
$$0{,}44 = 0{,}44$$

Our research on the shores of the White Sea has shown that the Ponoysky labyrinth and the objects of B. Zayatsky Island provide the greatest amount of information since they are symmetrical to the geographic meridian. In most labyrinths one can define safely only the days of the equinox (in Kandalaksha, Krasnaya Luda and on the Oleshin Island). The Umbinsky labyrinth allows to mark the beginning and the end of the summer salmon fishing season (May-August). The main differences in the pattern of labyrinths are related to the lighting regime, especially to the phenomena of polar days and nights. In the Arctic, a classical labyrinth (coiled-coil, seven arcs) undergoes a certain “deformation”: the axis deviates from the meridian, a ring appears in the center, the decorated entrance disappears, and etc. It is important to take into account that the position of the Arctic Circle has been gradually changing during the last 41,000 years (according to the Milankovich cycle).

***The current task of the systemic interdisciplinary studies of the labyrinths in the North of Europe*** *(a significant part of them is located in the Baltic Sea)* is to create a database that will include the following indicators: 1. geographical coordinates of the central points of the labyrinths; 2. true (geographical) azimuths of the entrance, directions to the linear and dot elements of the figure (they fix the azimuths of the sunrises / sunsets in the days of equinoxes and solstices); 3. the value of deviation of the physical horizon from the line of the astronomical horizon (by constructing a circular panorama); 4. age of relief according to paleogeography and archeology; 5. dating of the labyrinths, defined with the help of paleoastronomical calculations; 6. local and regional life sustaining tasks (based on palaeoenvironmental data); 7. analysis of the location of objects in the system of transport communications in different historical epochs. This work will allow to reconstruct the development of navigation technologies, as well as natural conditions and cultural traditions of the territory.

***Petroglyphs.*** The navigation knowledge of ancient Karelians was studied in the twentieth century on the example of the Lake Onega petroglyphs. Out of 1221 local images 184 are solar and lunar signs [Lobanova, 2015]. The azimuths of these signs are related to the astronomically significant azimuths of the Sun and the Moon rising / setting (Ravdonikas, 1978). Researchers suggested an original reconstruction of lines on rocks as extensions of the paths of light observed on the water surface when the Sun crosses the horizon line [Potemkina, 2010]. However, it does not suggest the instruments and actions that ensure an accurate fixation of the directions. The technology developed by the authors of the article suggests installation of a pole in the center or on the edge of the image and observation of how its shadow coincides with the line of a sign or an image on a certain day or hour (instead of observations it is possible to measure the azimuth of the lines and compare it with the results of paleoastronomical calculations). The images of poles put in the soil are found in the compositions of the Onega petroglyphs, but are nowadays interpreted as bird traps, although it is in contradiction with the biology of the harvested species typical for the region (Fig. 3). To draw a sign on the shadow of an object it is convenient to use a rope, which is depicted tied to the poles on petroglyphs [Paranina, Paranin, 2011].

Studies of the instrumental functions allow to make significant additions to the interpretation of objects. For example, according to the medieval Christian tradition, the image "Demon" (Onega petroglyphs) shows that the ancient man was afraid of the surrounding nature and asked mercy from some terrible god; the crack in the rock symbolizes the gastrointestinal tract, the sanctuary is organized in order to "feed" the demon [Savvateev, 1983]. However, the spatial analysis of the image shows that the "Demon" and the elongated objects nearby – a staff, birds, animals – all are directed towards the sunrise on the day of *the*


**Figure 3.** Lake Onega petroglyphs, Besov Nos Cape.
Trace drawing by Yu. Savvateev

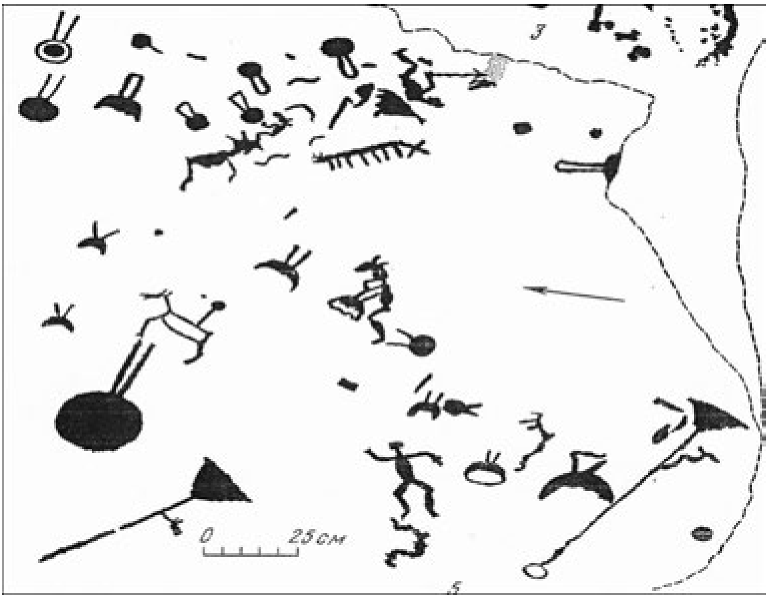
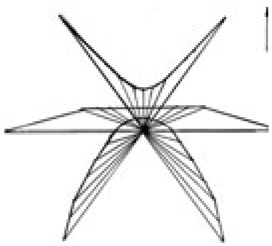



**Figure 4.** Lake Onega petroglyphs, Peri Nos Cape.
Trace drawing by Yu. Savvateev

*summer solstice* (Fig. 4). The image of a fish conveys the shape of the Baltic sturgeon, which goes up the rivers such as Neva, Svir, and further up the rivers flowing into the Onega Lake in June to spawn. Isolated cases happen even today. So the demon can be interpreted as pointing to the place and time of successful fishing.

***Reconstruction of the stages of evolution of astronomical orientation.*** The selected stages differ in the measure of developed geographical space, the nature of tools and the degree of change in the natural substrate [Paranina, 2017]: *the landscape stage* (astronomical instruments – stable natural objects, technologies – foresight, ie watching astronomical objects crossing the horizon line), *the local networks stage* (tools – large artificial objects, technologies – foresight  and backsight), *the regional networks stage* (tool – gnomon, backsight technologies, ie observing the shadow of an object or a focused ray. These technologies are portable and effective), *the historical stage* (the creation of portable navigation tools, the development of modeling), *the modern stage* (new technologies of navigation and communication).

***Semiotics of a solar calendar.*** Studies of petroglyphs have shown that *astronomical (graphic) signs were the first to be drawn on a surface of a stone*. This is congruent with the reconstruction of the information coding algorithm "movement of light – geometric sign – image (artistic interpretation of a sign)"[Paranina, Paranin, 2016]. The shadow chart for one day can be the basis of zoomorphic images: a caudal fin of a fish (shadow lines – rays), wings (lines – feathers), horns (lines – annual increase). Solstices and equinoxes create a geometric basis for radial and triangular solar signs and the six-armed Shiva (symbolizing creation and destruction); more detailed drawing gives an image of the multi-armed Shiva or the shape of the open lotus (lotus is the symbol of the day of the gods, which lasts 1 year). In a year, the shadow covers an area in the form of a labrys (two-sided, two-horned axe) (Fig. 5).



**A – winter solstice:** the shadows are in the northern sector of the area since sunrises/sunsets take place in the southern part of the horizon;

**B – vernal and autumnal equinox:** the shadows form the W-E line;

**C – summer solstice:** the shadows are in the southern part of the area;

**Figure5.** The schemes of shadow-covered areas (the gnomon being the central point).

The sketching of the shadows of T- and L-shaped objects gives solar signs in the form of a swastika and once a day forms a straight line (when installed along the meridian at noon, on a polar day – 2 times a day). In the past, a staff could perform the functions of a gnomon, for example, staffs are found at the Oleneostrovsky (Deer Island) burial grounds in Karelia and Murmansk region, their age varies from 3000 to 10,000 years. The tradition of measuring one's own shadow with footsteps still exists.

*The definition of the boundaries of astronomical seasons* has an important adaptational significance. Solstice days allow to determine climax of warm and cold seasons. The W-E direction allows to define the days of the equinox – the border between the most opposite halves of the year – the warm and the cold. This is especially important in areas with continental and extreme climate (polar and mountainous), since timely actions ensure an adequate human response to a change in natural conditions. It is not by chance that days of the equinoxes and solstices are fixed by holidays in the calendars around the world. *Spatial orientation* ensured use of resources and development of communications, as well as formation of territorial systems [Paranin, Paranin, 2017a].

A necessary consequence of the practice of geographical space-time measuring is the notation system. The signs of astronomical orientation are abstract in form and concrete in content, they link the light signal and the state of the landscape (stimulus and food reinforcement), which can be considered as the basis for the brain building, ie biological adaptation [Paranin, Paranin, 2017b].

**Conclusions**

Studies of the evolution of ancient navigation technologies in the North have shown: 1. orientation by the Sun is convenient during polar days and white nights; 2. the most stable natural material – stone – was used first for making tools, and later the staff and the shadow method appeared; 3. the first simple, abstract signs represent a graphic recording of the cyclic lighting processes and form the basis for the design of artistic images (images and compositions). Thus, Stone Age navigation technologies could use light, staff and stone.

Complex studies of stone labyrinths and petroglyphs can substantially fill the gap in the knowledge about nature and culture of the Arctic in the prehistoric past. This is important for understanding the specifics of the region, its functions in the geocultural space of the Earth, the development of interdisciplinary and intercultural communications, the creation of scientifically based programs for rational recreational nature management and the preservation of cultural heritage.

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## Archaeological research at the Arctic Research Center

The general direction of the research at the archaeology sector of the Arctic Research Center is "The North of Western Siberia: Traditions and Mobility".

The Arctic Research Center in Salekhard since its opening in 2011 has set the task of carrying out complex studies of the territory, including archaeological research. This led to establishing of a long-term target program "Development of research activities in the Yamal-Nenets Autonomous District in the field of archaeology for years 2012–2015" in 2012. The program in a somewhat modified form is still valid under the title "Development of research and technology and innovative activities of the Yamal-Nenets Autonomous District for years 2014–2020". The support of the YNAD government ensured rapid development of archaeological research in the Arctic and Subarctic territories of Western Siberia. It was extremely important since – as joint studies of Russian and foreign specialists show – modern indigenous cultures in the Yamal-Nenets Autonomous District are preserved much better than in other circumpolar areas and countries.

The presence of unique, even by world standards, archaeological sites with a frozen cultural layer, in which practically all objects of material culture, including organic products, are preserved, provides a rich source for studying the history of traditional cultures and the formation of economic, biological and cultural adaptations in the arctic and subarctic environment. This is of exceptional importance not only for the actual Arctic and Subarctic zones, but also for studying ancient cultures of other regions with different landscape and climatic characteristics.

In general, the research allows to throw light on the rich unwritten history of the Yamal-Nenets Autonomous District from antique to modern times. We are studying the development of economic adaptation systems, including the formation of the most ancient system – hunting and fishing economy, which is typical for the population of the northern taiga and tundra even today.

Thus, a clear stratigraphic situation, plentitude of factual material (42000 samples of clay ware fragments alone), and interdisciplinary research of the settlement Gorny Samotnel I (which dates back to the end of the 4th-3rd millennium B.C.) make it possible to consider this settlement as one of the main objects for the reconstruction of economic activities of the local population in the Eneolithic Period.

With the help of geomagnetic sounding, three large houses with farm buildings and pits were found in the settlement. It should be noted that the settlement was of a long-term nature, and was used on a year-round basis.

Fishing was the basic economic activity here, additional sources were hunting, gathering and crafts. The predominant role of fishing is confirmed by remains of fishing nets and accompanying gear – stone plumbs and birch bark floats. The study of the faunal remains has shown that main species of fish were burbot, pike and various fish in the family Salmonidae.

The main hunting tools were bow and arrows. The local population hunted mainly reindeer, elk, waterbirds: geese, swans, Aythya, river ducks, and rodents such as beaver.

Let us note once again the fact that the research at the Gorny Samotnel I settlement allowed to understand when exactly net fishing on large rivers appeared.

During the 2017 field season, a group of researchers focusing on the Eneolithic-Bronze Age worked at the settlement Salekhard 4 located near the city of Salekhard. This settlement was previously dated by the Bronze Age. As a result of the field research it was stated that the settlement functioned during the late Iron Age and is related to the Karym culture of the 4th-6th cc. A.D.  A supposedly male burial dated by the Bronze Age was discovered at the continental level. Accompanying inventory consisted of a ceramic pot, a stone ax and a grindstone.

For the Yamal-Nenets Autonomous District it is extremely important to reconstruct the origins of reindeer herding, initially in its transport form, discovered at Ust-Poluy. Parts of reindeer harness and fragments of sledges found there are two thousand years old. The design of the reindeer harness has not actually changed in the course of time.

The transition to reindeer husbandry of a modern type took place at the turn of the 1st-2nd millennium A.D. and led to many innovative shifts in the economy and social sphere. Simply put, the confrontation between the nomads and the sedentary population begins in the Subpolar and Polar regions, as well as in the southern territories of Russia in this period. The process was accompanied by fortress building, raiding, loots, etc.

Studies of reindeer herding are carried out using the material of the Yamal tundra sites within the framework of international interdisciplinary projects. Cooperation with Professor David Anderson's group from the University of Aberdeen (UK) was particularly fruitful for us. Our colleagues studied the surroundings of the archaeological site Yarte 6 using geoarchaeology methods and lipid biomarkers data, which allowed to locate the reindeer corrals – a procedure impossible if using arhaeological methods only.

The study of the ancient sacral and industrial center of Ust-Poluy (a site located within the city of Salekhard) has become a landmark event for our district. For the first time traces of transport reindeer breeding were found there along with a unique bone-carving art center. Our outstanding modern bone-carvers find the level of ancient mastery unusually high, teachers and their students must have worked there. The findings of year 2016 were very interesting. We had known before that various religious objects in the sanctuary were made from bone, wood and bronze. But in the 2016 season, iron production sites were studied. We studied slags (total mass up to 8 kg) and iron balls together with our colleagues from Tomsk. As a result of this research, Ust-Poluy was named the oldest and most northern iron production center in Northern Eurasia at the turn of the ages.

Over the years, numerous remains of dogs were found here. Our Canadian colleague Robert Losey has counted 115 specimens. According to his conclusion, this is the largest number of dogs found on the archaeological sites of Northern Eurasia. The study of bone remains led to the conclusion that these animals were sacrificed at the sanctuary.

No less significant for our district is the study of the archaeological complex Zelyony Yar. Human remains found there, including mummified ones, make it possible to trace the formation of the anthropological type of the Yamal-Nenets Autonomous District indigenous population, its genetic history, as well as to find out what diseases those people suffered from. During the study of Yarte 6 – a medieval settlement located in the central part of the Yamal Peninsula, coprolites of dogs were found. They were infected with opisthorchiasis. In the opinion of the Institute of Emergency Situations SB RAS, this may serve as an evidence that those dogs were brought from the Ob River, since there is no opisthorchiasis in the rivers and lakes of the Yamal Peninsula. Studies of diseases caused interest in different countries. Thus, researchers from the University of

Seoul came to us to reconstruct the appearance of the boy found in 2015. In 2017, the field research of the cemetery continued. Ten examined burials were attributed to the 13th century A.D. The burial ground gives an opportunity to see the completely different degrees of preservation of burials, from graves without skeletons to relatively well preserved mummified remains.

One of the most important areas of our work was the study of trade relations. Now we can say with certainty that they existed in the large area from the Great Silk Road (beads from Egypt and the Black Sea region found at Ust-Poluy) up to the Northern latitudinal passage, which was used for trade in the Middle Ages, when our region was a supplier of furs. Only medieval society, largely thanks to the trade route “from the Varangians to the Greeks” discovered the exclusive value of furs, which began to symbolize nobility, military prowess and, in general, membership in some elite group. The medieval society worked out etiquette principles according to which fur could be used in apparel, in heraldry in accordance with the hierarchy and tribal or quasi-tribal affiliations.

Walrus and mammoth tusks were exported. The walrus tusk was valued almost as ivory and was paid for in gold. It was used in baculi and scepters, symbolizing the “world tree” – the basis for the divinely instituted order.

Hunting birds like falcons and gyrfalcons were taken to Constantinople and Mecca. They were popular in Egypt and Italy as well.

The imported products included iron goods, fabrics, beads, silver jewelry and costume accessories. Silver vessels could be diplomatic gifts. By the 13th century, our north became a full partner in the Nordic “common market”. We found out that in the Middle Ages, not only the external market was formed with all its attributes such as shopping places, diplomatic gifts, local production, designed for trade, but an internal market as well: production of belts and wooden utensils for regional trade.

In the field season of 2017 our sector carried out work at the medieval settlement Ngarka Yodyotayaha 1, which is located in the south of the Yamal Peninsula. The most important result of this work can be the discovery of an ironmaking industry, the only one found on the whole peninsula dating back to the 9th-12th centuries.

Why is our research important for the District and the Arctic as a whole?

First of all, our research allows us to position the territory of the modern Yamal-Nenets Autonomous District as a region with rich culture and history, in no way inferior to the history and culture of Russia, Scandinavia, Eastern Europe. Thus, it is not merely a raw material colony, but a cultural bridge between the West and the East.

Secondly, our research provides an opportunity to watch the development of indigenous cultures of the Arctic region in the historical perspective from antiquity to the present day and talk about the tradition, including traditional types of farming.

And finally, our research is the opportunity to understand that such "modern" processes as climate change and globalization have been going on for two millennia at least.

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## To relations between cold and civilization based on the „Wissenschaftslehre“ by I.G. Fichte

This article examines the possibility of understanding of the cold as an indispensable attribute of civilization, and a factor of its development. At the same time the author criticizes the common understanding that the cold is a source of suffering, and the North is the place of primitiveness and backwardness. The „Wissenschaftslehre“ method by I.G. Fichte lies at the basis of the idea about collective super-consciousness of Northern residents. There are also characteristics of this super-consciousness given on the base of Russian anthropologists' ideas. According to them, super-consciousness expresses specifically the content of freedom. On the basis of cosmism philosophy conclusions are made about cold as one of the conditions for civilization existence in the genetic sense (without cold the emergence of a civilization would not be possible) and in content sense (cold in a modified form found in modern civilization in a variety of its manifestations). Cold will allow humanity to come to a deeper understanding of itself, and hence – to formation of a more rational social order, corresponding to dignity of every person and of humanity as a whole, i. e., a more civilized society.

In order to develop an adequate theory of the North development, we need to raise a question of its understanding. In the ordinary consciousness the North is associated with cold, and the last – with suffering. There must be all sorts of protection from cold to create an artificial environment in which a low/middle latitudes person would feel comfortable. The North must be reclaimed by rotational method (shift works), and by using robots, which can do heavy and dirty work in cold and mostly dark areas. As for indigenous peoples of the North, they are to be provided with some compensation in the form of promotion and support of their business in tourism and indigenous arts and crafts in order to help them make money and migrate finally to warmer places.

However, such an understanding of the North suffers from one-sidedness. This understanding describes the experience of a southern person, who finds himself in an environment alien to him and cannot fully adapt to it. Meanwhile, German philosophical anthropology pointed out "eccentricity of a man", his ability to change his seemingly unshakable anthropological constants, plasticity and adaptability of mankind. The fact is that all of us besides a physical body have also a consciousness. It is consciousness that can actively influence the corporeality and transform it as a result of purposeful efforts.

At this point, we start to rely on the methodology of I.G. Fichte („Wissenschaftslehre"), according to which our consciousness believes that outer world is a result of the free activity. The opposite of our self is the external world, non-I, which at first glance appears as something that limits the activity of the self. However, a deeper consideration of the problem makes it clear that, in fact, it is the outer world, appearing as a non-I, from which I myself receive a certain impulse to self-realization, to development of all my internal abilities. This impulse does not come even from the world itself, but from others Selves, who influence each other through the medium of the external world, thereby creating a special reality. From isolated self-consciousness, Fichte passes to absolute self-consciousness, which is gradually formed as each self-conscious being begins to fulfill his destiny.

We need a new science about the North, designed to show how the collective consciousness of its inhabitants assumes the content, by which they are able to live in the Arctic, not being in a state of eternal suffering, but, on the contrary, being in harmony with their environment.

First of all, Northerners can be considered to be a kind of nomads, born travelers, for whom the meaning of life is road, development of new lands, who go to places that are perceived as uninhabited, just because there they find freedom they desire. And they do not understand freedom as satisfied physical needs and safety, but as a command of oneself, which ultimately allows them to dominate over others. Nomads feel an irresistible *call*, which they are brave enough to follow. And as they move into unknown lands, such people develop completely different abilities unknown to sedentary inhabitants, and because of this they gradually find equilibrium with the environment at a completely different level. By equilibrium, we mean not at all the dull entropy, but the state of maximum material, energy and information exchanges with the environment that is generated by the concerted, purposeful activity of the entire "wandering" community as a whole.

What specific content of freedom is open to northern people? Here we must disclose the spiritual world of northern people from the standpoint of socio-cultural phenomenology. First of all, northerners live in a harsh environment, but they cannot overcome it individually; therefore, belonging to a viable local cultural community is one of their essential characteristics. People are most likely to survive in the North by organizing some collective forms of activity, and for this it is necessary to form a common symbolic space for collectives of northern inhabitants, which is associated with the sacral sphere. This explains the special authority of people who are gifted in the religious sphere, a special favorable socio-cultural field for the development of such abilities that allow maintaining this common sacred space and spiritual integrity beyond the narrow contents revealed by sensuality: that is, the great social role of people, commonly called "shamans". Sensuality gets its special meaning in the North: cold conditions make it possible to develop eyesight, hearing, refine the sense of touch, get a completely different sense of smell, feel the taste of frosty air in frozen fish and many others. It is well known that such northern inhabitants as Eskimos know hundreds of shades of snow; that darkness of the polar night is also very different, and there are also a number of shades of black that northern people discern; and if aurora lights flare up in the night, a highly sensitive person can in general understand himself as a witness of some cosmic conversation between the Sun and the Earth… Is it possible to regard the cold as a mean to self-realization of a person in special aspects and not as an unambiguous factor of suffering? For example, winter swimming can change the very foundations of corporality (also Russian people have a thousand-year old bathing tradition in the ice-hole on Epiphany night).

Thus, the North is inhabited by people of a special nature who respond to the call of life to reclaim uninhabited spaces and to equip life in new lands. The northern people have a special perception and understanding of freedom, which is expressed in the symbolic universe of a northern community and is realized in various forms of activity, as a result of which a special circumpolar civilization arises. Taking the next step in the analysis, we suggest a point that the development of the North should not continue according to the standard model of creating artificial conditions for people. There is an alternative scenario, which suggests making the essence of the cold a substantial basis for the northern civilization, extracting special energy and information from the cold, reviewing our standard understanding of the cold. In more detail this idea can be clarified by people of the natural-science type of thinking: they easily explain what new unexpected properties materials gain in low-temperature conditions, and how these modified states can be used in practice. The snow itself becomes, under certain conditions, a fine building material, which, oddly enough, will create a warming effect inside the dwelling (so that you can even build a fire there).

But we can further apply the philosophical method and raise the question more radically: is it possible to bring the concepts of cold and civilization so close together that they will express different attributes of a single universal substance? In other words, is the cold inherent to the civilization as its integral characteristic, expressed in withdrawn (transformed) form? Did not the cold serve as the driving force behind the civilization itself?

Of course, the previous global glaciation period played a big role in anthropogenesis and thereby contributed to the transition of mankind to the "Neolithic revolution", and cold still stimulates development of modern civilization. This conclusion is certainly true, but also in a certain sense reduces the level of intellectual abstraction. Here we are striving to finally find a universal concept, the elements of which are cold and civilization together.

The philosophical method („Wissenschaftslehre") by I.G. Fichte, by which we were so far reliably guided, allows us to do this. This universal concept is self-awareness in its universality, that is, the collective super-consciousness of mankind. This concept can be concretized by studying the world as an organic whole, which develops not in itself, but in co-evolution with the human race. This means that the evolution of nature at a certain stage will be possible due to the fact that mankind will begin to consciously guide nature as a whole. An example of such a conscious impact on natural processes can be weather management in the sense of collective efforts to prevent global warming. In this way, we will be able to understand the paradoxical value of the cold so that the world as an organic whole, developing in unity with the realization of spiritual and material destiny of the mankind, be filled up to its universality, and if cold escapes from it, then this universality ceases to exist in this form. The point is that without real comprehension of the cold essence as one of the substantial attributes of the North, mankind can't fully discover the truth about the world in which it exists, realize the content of its self-consciousness and develop those abilities that are necessary to fulfill its mission of conscious leadership of the whole world evolution.

This is how we will understand the connection between cold and civilization. The cold is one of conditions for civilization existence in both the genetic sense (without the cold it wouldn't be possible) and in the content (the cold in a transformed form is contained in modern civilization in its various manifestations, from oil being extracted in cold latitudes to modern cooling chambers, including cosmetology). But more important, the cold will allow humanity to acquire a deeper awareness of itself, and hence – to formation of a more reasonable social system, corresponding to the dignity of each individual and humanity in general, also, a more civilized society ... So, the North through the cold (and not only) can help human civilization to realize the universal values of humanism.