Anthropogenic Impacts on Habitat Structure and Species Richness in the West Siberian Arctic

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Abstract—Intensive technogenous invasion in the West Siberian Arctic during the last two decades in connection with gas and oil exploration, along with the constant growth of domestic reindeer herds, has caused dramatic changes in arctic ecosystems. Loss of biodiversity on the species level has not yet been documented in the region on a whole, but changes in ecosystems in intensively exploited areas are obvious. The absence of some plant species and the disappearance of rare bird species surrounding the Bovanenkovo Gas Field in central Yamal is likely the result of technogenous destruction of their habitats. Length of recovery for different habitats varies greatly. Only about 40 percent of local flora can colonize anthropogenic habitats. Habitats such as well-drained southern slopes occupied by herbaceous meadows, willow copses in the flood plains, coastal marshes, and isolated outposts of trees contain the largest amount of rare species. These are mainly relics of the past, while at the same time are the most vulnerable to disturbance. They should be of special concern. Nature reserves in the region are not representative enough and are not practical in function.

Introduction

Different sectors of the Arctic vary in terms of geological history, formation of biota, and land-use history. The Yamal-Gydan region (namely Yamal, Gydansky, and Tazovsky Peninsulas) is one of the most inaccessible and sparsely inhabited parts of the Arctic. It spreads northward from the Polar Circle for more than 750 km (466 miles). The total area of the three Peninsulas is about 235,000 km^2 (90,734 miles^2). Compared to other sectors of the Russian Arctic, the Western Siberian North has remained untouched by industry until quite recently. Ignoring the extreme fragility and slow regeneration of these ecosystems, along with specific cryological conditions, has led to extensive destruction of plant cover during a short period.

The West Siberian sector of the Arctic is a low plain with flat or gentle rolling relief, and numerous lakes and rivers. It lacks many types of habitats present in other sectors of the Arctic. An absence of exposed bedrock and the presence of a thick layer of Quaternary deposits (clay, clayey and sandy grounds) are typical for this sector. Construction work here is difficult due to fine-grained sediments, high (up to 70 percent) ground ice content, presence of ice wedges and lenses (Sisko 1977). Anthropogenic and natural disturbances of insulating plant and peat cover trigger natural exogenic processes and cause intensive thermodenudation. Ice-rich, steep banks of Baidaratskaya Bay are destroyed and retreat up to 5 m (16.4 ft) per year (Tummel and Zotova 1996). The climate is rather severe, with average July temperatures varying from 11 °C (51.8 °F) in the southern hypoarctic tundra to 5 °C (41 °F) in the arctic tundra subzone, and average January temperature changes in longitudinal direction from –23 °C (–9.4 °F) in the west to –28 °C (–18.4 °F) in the east (Sisko 1977). Climatic conditions make revegetation of disturbed sites very slow. There are also widespread acidic soils and swampy areas.

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History of Traditional Land Use

The ancient hunters of marine mammals and wild reindeer appeared in this region more than 2,000 years ago. In the 10th to 12th centuries A.D., they were replaced by ancestors of modern Nenets—Samodian Tribes of the Altay-Sayan origin. As a result, sledge reindeer husbandry became the main occupation, and hunting and fishing lost their primary importance (Krupnik 1989).

The first Russian pioneers also appeared in the Siberian North in the 11th to 13th centuries. In the 13th to 16th centuries, colonization of the Arctic coast and exploration of the Northern Sea Route began. Since the 15th century, there was a trade route from Baidaratskaya Bay to Obskaya Bay through central Yamal. Some intensification of hunting occurred after Russian tradesmen and hunters came into the area, but on a whole, human influence was very limited. The effect of domestic reindeer at that stage was not destructive due to the relatively small size of the herds (less than 100 animals) and rather long period of circulation. Rapid growth in the number of domestic reindeer started near the end of the 18th century (Krupnik 1989). By the beginning of the 20th century, the total number of domestic reindeer in the region (including forest-tundra) reached 247,000 head (Zhitkov 1913). Corresponding changes in plant cover and productivity occurred (Govorukhin 1933; Zhitkov 1913). The negative effect of the traditional economy on northern ecosystems is also connected with cutting of trees for firewood and tools during nomadic migrations, which caused a gradual retreat of the tree line to the south in regions with reindeer husbandry (Krjuchkov 1994). In Yamal, we found old larch stumps (*Larix sibirica L.*) almost 100 km (62 miles) to the north of the modern tree line. In the Gydansky Peninsula, we observed changes in drainage and swamp development in habitats where alder or willow shrubs were cut down for wood. But on a whole, traditional knowledge let people live in harmony with nature for centuries.

In 1949, a decision was made by the Soviet Government to put an end to the nomadic way of life (Decree of Council of Ministers of Russian Federation No. 595 of 26.07.1949). It resulted in reorganization of collective farms into state farms and redistribution of pastures. Traditional ways of nomadic migrations were changed. At the same time, the number of reindeer steadily increased, especially in the last two decades, mainly due to the growth of private herds. In Yamal, the number of domestic reindeer from 1976 to 1980 was 131,600 head, including 50,700 privately owned animals, whereas from 1990 to 1995 it reached 177,400 head, including 97,200 privately owned (Korytin and others 1995a). This amount exceeds twice the potential reindeer carrying capacity of summer, and especially winter, pastures (Bykova 1995). This situation led to overgrazing, trampling, exhaustion, and delichenization of pastures, and changes in the structure of plant cover. In southern and central Yamal and Tazovsky, lichen-dominated tundras have been replaced by moss-dominated tundras with increased portions of grasses (Khitun 1997). More than 50,000 km^2 (19,305 $miles^2$) of lichen pastures were destroyed in southern and central Yamal by the 1990s (Bykova 1995). The situation is worsened by the withdrawal of lands by the gas and oil industry. The Bovanenkovo Gas Field in central Yamal occupies 151,000 ha (370,658 acres), 127,000 ha (313,824 acres) of which were pastures once belonging to the Yarsalinsky State Farm (Korytin and others 1995a). Another traditional branch of the economy—hunting—has almost lost its importance nowadays due to a decrease in game population and low state prices, whereas fishing remains important—almost one-third of the world's white fish catch is supplied by this region (Korytin and others 1995a). Several fish-processing factories are located in southern Yamal.

Effect of Gas and Oil Exploration on Natural Ecosystems

In the 1930s, industrial exploration started in different parts of the Russian Arctic, but Western Siberia remained almost intact until the 1970s. Due to an intensive geological survey, more than 20 important hydrocarbon layers were found in the area, mainly in Yamal and Tazovsky, and some infrastructure was built (fig. 1). Development of the Yamal gas fields, containing about 10 trillion m^3 of gas reserves (Korytin and others 1995a), is planned for the near future. Already the disturbed areas have reached 0.14 percent of the total area in Yamal, and in Tazovsky where

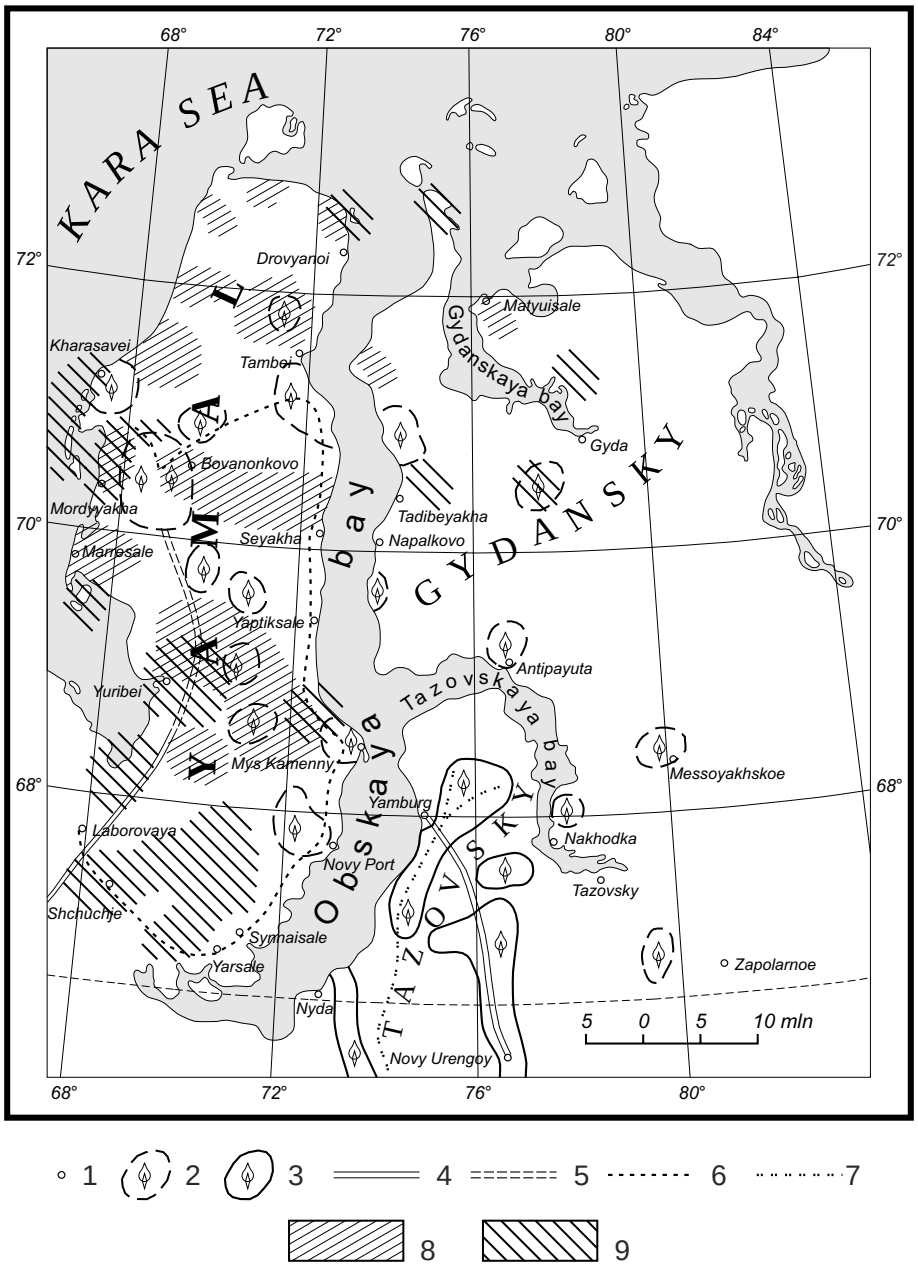

Figure 1—Industrial land use and localities of wildlife concentration in the West Siberian Arctic.

Legend: 1 = permanent settlements and trading posts; 2 = gas fields under geological prospecting (compiled from Bykova 1995); 3 = gas fields under exploitation; 4 = railroad under exploitation; 5 = rails under construction; 6 = winter roads; 7 = pipeline under exploitation; 8 = places of increased abundance of polar fox dens (compiled from Korytin and others 1995; our data for Gydansky); 9 = territories of concentration of rare bird species (compiled from: Ryabitzev 1993; Zhukov 1998; our personal observations for Gydansky).

the Yamburg Gas Field is under exploitation, this figure has reached 1.5 percent (Bykova 1995) and is estimated at 6,000 to 7,000 km^2 (2,300 to 2,700 miles^2) in the region (Krjuchkov 1994). A lack of appropriate machinery and advanced technologies, plus environmental unawareness, were the reasons that the West Siberian Arctic appeared at the edge of ecological catastrophe (Forbes 1999; Khitun 1997). Newcomers did not know local conditions, were not aware of traditional and natural values, and intended to leave these places in the near future. Hence, their behavior included: uncontrolled use of heavy tracked vehicles (officially forbidden in the summertime since 1989, but there have been numerous violations until recently); barbarian recreational hunting and fishing without recognition of breeding or spawning periods; spreading of rubbish all over; conflicts with indigenous population; and an increase in anthropoecological tension.

The main types of disturbances connected with industrial activities in the West Siberian Arctic are offroad vehicle movement, winter roads, exploratory drilling, sand excavation, pipeline and railway construction, temporary camps, settlements, and gas-condensing complexes (Khitun 1997). During the last few years due to the

difficult financial situation of the country, construction work in Yamal was "frozen" or went on slowly, but now several international projects to exploit Yamal's gas and to construct several pipelines are being discussed (Forbes 1999). A new wave of intensive technogenous impacts may reach Yamal again soon.

Habitat Diversity and Stability to Mechanical Impact

Due to its relief and geology, the West Siberian Arctic lacks many habitats, nevertheless we distinguish there 23 habitat types (Khitun and Rebristaya 1998). They differ by species richness, area, and resistance to mechanical impact (Rebristaya and others 1993). Interfluve plateaus; convex, slightly elevated surfaces on river terraces; shallow depressions between hills; long, gentle foothills; and lake depressions with tundra communities are relatively stable to anthropogenic impact and have potential for self-recovery. Gentle slopes with low shrub-dominated tundra, wet meadows and bogs in flood plains, and polygonal bog complexes are weakly resistant to impact, but have a relatively high potential for self-recovery. Convex marginal parts of hilltops (especially on sands); mineral mounds; steep, sandy, short slopes; steep, well-drained slopes of hills; high riverbanks; deep ravines; and high shrub thickets on the slopes are unstable and dangerous for exploitation, with the possibility of escalation of erosion and denudation.

Responses of Plant Communities to Disturbance and Rate of Recovery

The natural ability of different plant communities to recover after one to several passages of tracked vehicles was studied in the surroundings of the Bovanenkovo Gas Field in central Yamal 6 years after the impact occurred (Khitun 1997; Rebristaya and others 1993). Responses of plant communities depended on moisture conditions and intensity of impact (fig. 2). Mesic tundra was rather tolerant from one to three passes of a tracked vehicle, whereas in sedge wet meadows, sphagnum bogs, and willow copses, plant cover was severely disturbed even after one passage. Wetlands had rather high restoration ability due to the abundance of plants with high regeneration potential (rhizomatous, with dormant buds and fast-growing shoots), and after 5 to 6 years may even have a higher total cover due to increased sedge cover. No community can survive numerous passages.

The most dramatic effect was on shrub-dominant vegetation. Multiple passage tracks were colonized with horsetail (*Equisetum arvense*), alpine meadow bistort (*Polygonum viviparum*), sedge (*Carex concolor*), and willow (*Salix glauca and S. lanata*) shoots. Mosses from adjacent natural communities (*Drepanocladus uncinatus, Plagiomnium medium, Aulacomnium palustre*, and *A. turgidum*) spread along with pioneer mosses (*Ditrichum cylindricum, Anisothecium vaginale*, and *Bryum* sp.). If wet peat is exposed, horsetail, Arctic dock (*Rumex arctica*), bluegrass (*Poa alpigena),* bulblet saxifraga (*Saxifraga cernua),* tall Jacob's ladder (*Polemonium acutiflorum),* frigid coltsfoot *(Petasites frigidus), Stellaria crassifolia*, and later cloudberry (*Rubus chamaemorus)* are successful colonizers.

Zonal dwarf-birch-willow-graminoid-lichen-moss communities on the interfluve plateaus do not resist numerous passages of heavy vehicles and recover slowly. After 5 years, less than 5 percent of the track was revegetated by reed-grass (*Calamagrostis holmii* and *C. lapponica),* foxtail *(Alopecurus alpinus),* hairgrass (*Deschampsia glauca*), and *Carex arctisibirica*. On an abandoned (20 years prior to our survey) transportation corridor with altered drainage, cottongrass dominated the community, with *Carex arctisibirica*, foxtail, bluegrass, Arctic dock, alpine meadow bistort, and willows making up a total projective cover of up to 100 percent. Frost-boiled tundra with prostrate dwarf-shrubs on the plateau edge was the most resistant, but when finally disturbed, especially if the tractor made a turn, practically no revegetation was noticed due to the dryness of the substrata. Similar responses were found on steep slopes with dwarf-birch-grass-moss tundra where the native vegetation was totally damaged. Deflation was recorded in these two habitat types. Recovery in such habitats takes dozens of years.

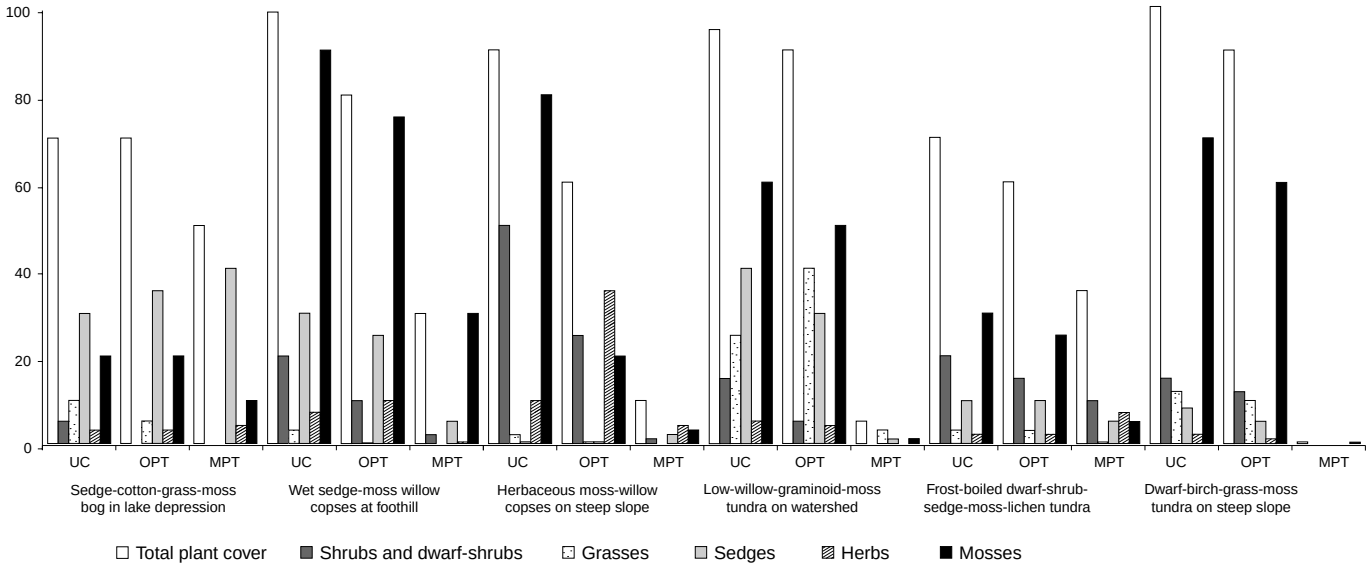

Figure 2—Responses of different plant communities along a mezotopographic gradient to disturbances of different intensity in central Yamal: UC = undisturbed community (control); OPT = one-pass track; MPT = multiple-pass track. Observations were made 5 to 7 years after impact.

Restoration Potential of Yamal's Flora

Recovery after anthropogenic disturbance in the West Siberian sector of the Arctic is at the expense of local flora. Sixty species (about 40 percent of local flora) were found to colonize disturbed sites in central Yamal, and 76 species (41 percent of local flora) in the surroundings of the Yamburg Gas Field on the Tazovsky Peninsula (Khitun 1997). In the eastern part of the Arctic, such sets of species are more diverse: 125 in the surroundings of Vorkuta (Druzhinina and Zharkova 1979) and 169 in the coastal part of Bolshezemelskaya tundra between the settlements of Indiga and Amderma (Gruzdev 1990). According to the scale proposed by Yurtsev and Korobkov (1979), only 8 percent of local flora in central Yamal belongs to the group of active colonizers, which is half that in the surroundings of Vorkuta (Druzhinina and Zharkova 1979). The majority of species found in disturbed sites plays a very small role in site recovery.

Sets of species colonizing natural and anthropogenic disturbances are very similar, and arctic (*sensu* geographic element) species prevail in them. Disturbances resulting in partial or complete destruction of the organic layer changes soil pH from strongly acidic to almost neutral, and mineralization of the substrata causes edaphic conditions more favorable for the arctic species. In this sector, they even spread to the south by anthropogenic disturbances: Arctic camomile (*Tripleurospermum hookeri)* in the south of Yamal can be found only in transportation corridors. Boreal elements play important roles in the flora on a whole, but compared to the European sector of the Arctic, where the phenomenon of borealization was discovered (Gruzdev 1990), in Yamal and Tazovsky the increase of boreal species was not significant in disturbed habitats.

On the Tazovsky Peninsula, the boreal element in local flora on a whole reaches 25 percent, and in the set of species found in anthropogenic habitats it is 18 percent. In central Yamal, it comprises 9 percent, both in local flora and in flora of disturbed habitats. This information is important for planning recultivation work. Numerous experiments failed because the wrong seed mixtures (the same boreal grasses as in less severe climatic conditions in Vorkuta, Bolshezemelskaya tundra) were used. Only local species, mostly representing the arctic element, may hold potential for successful restoration. We suggested different sets of species for restoration on different grounds—sands, loams, and peaty wetlands (Khitun and Rebristaya 1997)— including not only grasses, but different herbs and local willows. The presence of a severe climatic barrier prevents the penetration by weeds. Compared to

the East-European Arctic, sinanthropization, or the spread of adventitious species, has not been recorded in central Yamal. But in the southeast part of the Peninsula, along the railway (fig. 1), dispersion of chickweed (*Stellaria media),* penny-cress *(Thlaspi arvense),* shepherd's rupse *(Capsella bursa-pastoris),* lamb's quarters *(Chenopodium album*), and common knotweed *(Polygonum aviculare)* seems possible, as they are already present in the nearby towns of Labytnangi and Salekhard. Although the number of species in secondary communities increases due to such species, in the long term they may have a negative effect by replacing some native species.

Biodiversity of the West Siberian Arctic

Flora

Species Richness—The territory studied is the Yamal-Gydan subprovince of European-West-Siberian Province of the Arctic floristic region (Yurtsev 1994). It spreads through three botanical-geographic subzones (Yurtsev 1994): southern hypoarctic, northern hypoarctic, and arctic tundra (fig. 3). Floristically, this sector

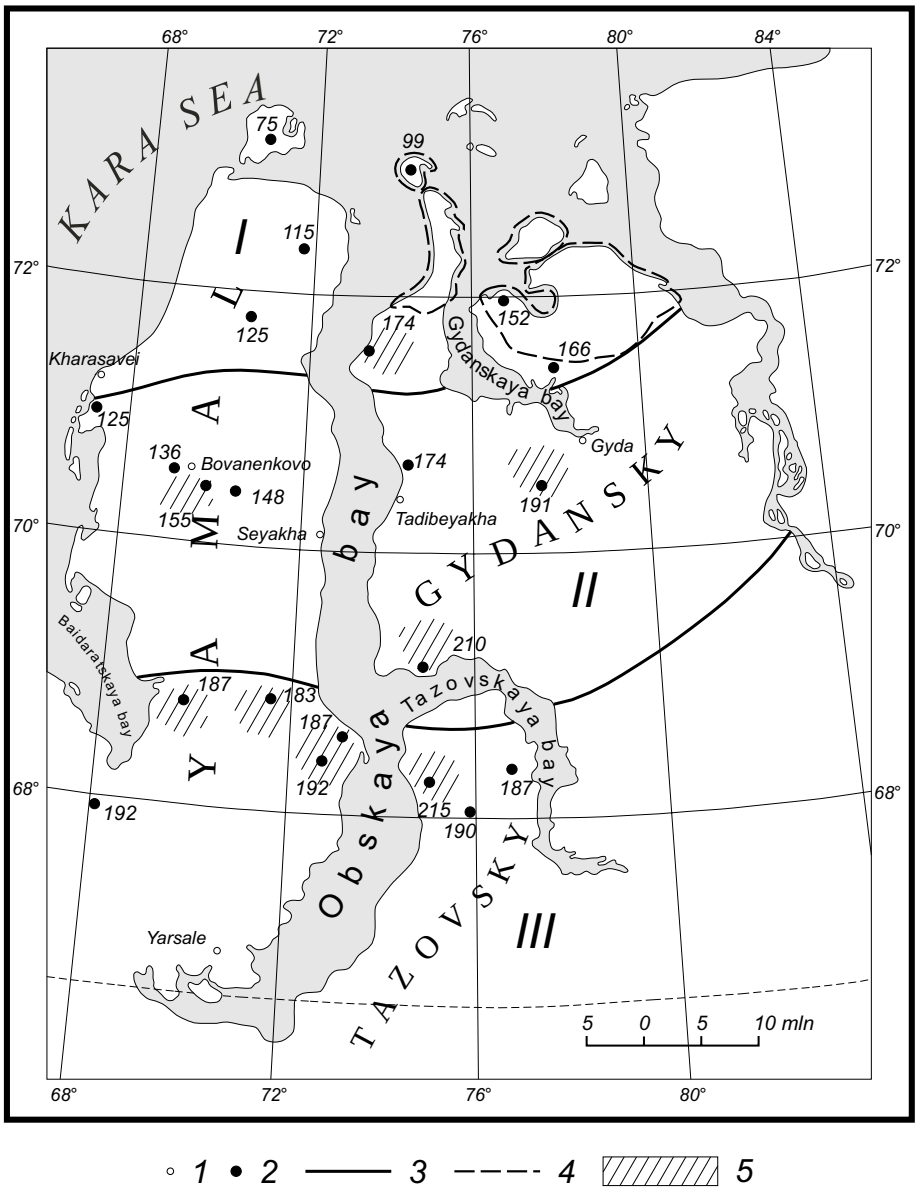

Figure 3—Subzonal division and species richness of local flora in the West Siberian Arctic.

Legend: 1 = settlements; 2 = study sites; arabic figures = number of species in the local flora; 3 = borders of subzones (Yurtsev 1994): I = arctic tundra, II = northern hypoarctic tundra, III = southern hypoarctic tundra; 4 = borders of Gydansky Nature Reserve (from: Kalyakin and others 2000); 5 = areas of concentration of rare relic plant species.

of the Arctic is one of the poorest (Khitun and Rebristaya 1998). There are 405 species of flora in Yamal, with 88 of them found only in the southernmost part of the Peninsula (Rebristaya 1998); flora of the Tazovsky Peninsula—274 species (Rebristaya and others 1989), and in the tundra part of the Gydansky Peninsula (which is still very poorly investigated) about 400 species are found (Khitun 1998). The West Siberian Arctic is characterized by an absence of many species, with disjunction in their ranges. Several arctic-alpine species found in arctic tundras of the Gydansky Peninsula are absent or very rare in Yamal, but they occur in Taymyr and in the Bolshezemelskaya tundra (Khitun and Rebristaya 1998). This reflects both the history of the region and a topography that is a monotonous lowland. Several marine transgressions during the Pleistocene era destroyed vegetation, and the revegetation occurred through migrations (Sisko 1977). Consequently, obligate seashore halophites (*Carex glareosa* and *Carex maritima)* are present in the inner parts of the Peninsulas, and are indicative of exposed salted horizons. Wide distribution of hypoarctic species, as well as some boreal species, was favored by the spread of acidic peat soils, which, in contrast, are not suitable for most arctic species.

The main objects of our investigations in the area are the local floras, in other words, floras of geographic localities with areas about 100 km^2 (39 $miles^2$). Study areas differ in species richness; for example, in Yamal they generally contain fewer species than in Gydan (Khitun and Rebristaya 1998). There is also a clear tendency toward decreased species richness to the north (fig. 3) due to dropping out of boreal and hypoarctic species with little enrichment by the arctic element coming from the east, particularly in Gydan, less in Yamal.

Rare Species—Many rare species in the flora of the West Siberian Arctic are relics of the past: *Saxifraga cespitosa* and *Gastrolychnis apetala*—of the mid-Pleistocene; *Dianthus repens, Carex supina, Koeleria asiatica,* and *Cerastium maximum*—of the late Pleistocene tundra-steppe complex; *Rhodiola quadrifida* and *Saussurea alpina*—periglacial relics of the same age; and amphiatlantic species *Gnaphalium supinum, Epilobium davuricum, Veronica alpina,* and *Sibbaldia procumbens*—relics of the Boreal humid period of the early Holocene. During warm periods of the Holocene, larch (about 8,000 to 9,000 years ago) and birch-spruce (about 5,000 to 7,000 years ago) forests expanded up to 400 km (249 miles) north of the current tree line (Khotinsky 1977). This explains a relatively large portion of the boreal element in the flora of the West Siberian Arctic (Rebristaya and Khitun 1994). Some herbaceous species left after the retreat of the taiga forest and survived in altered climatic conditions—*Linnaea borealis, Orthilia obtusata, Pyrola minor, Trientalis europaea,* and *Adoxa moschatellina*. There are only two neo-endemic species in the flora of the West Siberian Arctic—*Castilleja arctica* and *Pedicularis hyperborea*, and one subendemic—*Crepis nigrescens*. *Castilleja arctica* is included in the Red Data Book of the Russian Federation (1988). Fifteen species are listed in the Red Data Book for the Yamal-Nenetz National District (Dobrinskii 1997), including both endemics. Although this list includes several species rather common to the area, such as *Polemonium boreale, Myosotis asiatica,* and *Parrya nudicaulis*, it does not contain some relics very rare for this region (*Carex holostoma, C. maritima, C. supina, Primula stricta, Erigeron silenifolius,* and *Draba sibirica*) found specifically in one or two localities.

Importance of Habitat Conservation—Most of the species mentioned above as rare are stenotopic and occupy a narrow ecological niche. The main danger for them is disappearance or transformation of their habitats. Warm, steep, well-drained slopes with meadowlike vegetation are shown to contain the greatest number of rare species (Khitun 1998; Khitun and Rebristaya 1998). Foothills with nival conditions and certain mineral enrichment, shrub thickets in flood plains, and coastal marshes also contain many rare species. These habitats occupy a relatively small part of the territory and are spread sparsely. They demand special conservation control, which is absolutely absent now.

Deterioration of habitats has led to the disappearance of rare species. Unfortunately, we cannot prove it because no floristic research was done in the Bovanenkovo Gas Field area before its exploration started. However, it is very likely that the absence of some species in the local flora is the result of habitat deterioration. We did not find the 20 species there that are present in the nearby, more or less intact, local flora (Khitun 1997). Many of these species (*Arnica iljinii, Castilleja arctica,*

Linnaea borealis, Draba sibirica, Viola biflora, and *Erigeron eriocalyx*) occur on steep, warm slopes. Many of their possible habitats in Bovanenkovo were deteriorated, both by natural cryogenic landslides and by erosion triggered by anthropogenic mechanical disturbances. This is similar to what we found in the Tazovsky Peninsula. Local flora of the Laiyakha River mouth includes 215 species, whereas 15 km (9 miles) to the south, in heavily disturbed surroundings of the Yamburg settlement, we found only 190 species.

Wildlife

Decrease in Number—Hunting pressure on game animals in the West Siberian Arctic has increased during the last centuries. Reindeer husbandry and the migration of huge herds of domestic reindeer cause disturbance to the natural habitats of some animals and birds. During industrial exploration, deterioration and fragmentation of wildlife habitats caused the migration and disappearance of certain species in some areas, especially in Yamal and Tazovsky. The situation in the Gydansky Peninsula remains satisfactory, as there is no industrial activity at present. Poaching and exploitation are big dangers for wildlife in the areas surveyed. Species diversity has not decreased yet, but the condition and size of populations of some animal and bird species are cause for concern.

Fish—Development of the gas and oil industry in the West Siberian Arctic resulted in pollution of the Ob river embayment and the Kara Sea shelf by oil products and other chemical contaminants, with subsequent detrimental effects on fish catches and destruction of spawning areas (Shishmarev 1988). Populations of gwyniad and surgeon fishes are decreasing because of catching pressure in vicinities of exploration areas. A decrease in number and change in age structure of previously numerous muksun (*Coregonus muksun*) and chir (*Coregonus nasus*) has been recorded in the delta of the Mordyyakha River, clearly connected with exploration of the Bovanenkovo Gas Field (Bogdanov and others 1995). The population of muksun in Mordyyakha is listed in the regional Red Data Book (Dobrinskii 1997).

Mammals—There are 26 species of animals in the West Siberian Arctic, but many of them visit the territory sporadically or are restricted to the southern border. Findings of polar bear skulls at Nenets sacred sites in the north of Yamal give evidence that these animals were fairly numerous in this region (Uspenskii 1983). Currently, they sometimes visit the northern coasts of Yamal and Gydan and the surrounding islands. They have been strictly protected since 1956. Reindeer (*Rangifer tarandus*), polar fox (*Alopex lagopus*), two species of lemmings (*Lemmus sibiricus* and *Dicrostonyx torquatus*), and Middendorf's vole (*Microtus middendorfi*) have been an autochthonous part of the fauna in the region since the Pleistocene. Another important part of the fauna is a group of species with a very broad intrazonal distribution, such as fox (*Vulpes vulpes tobolica*), wolf (*Canis lupus albus*), wolverine (*Gulo gulo*), ermine (*Mustela erminea tobolica*) and weasel (*Mustela nivalis*). The wolf population is controlled by hunting (mainly by Nenets people). The total number of animals does not exceed 500, and their density was reported to be less than one per 1,000 km^2 (386 miles^2) (Bibikov 1994). Wolverines are even less numerous. Red fox, ermine, and otter are mainly restricted to larch forests or high shrub thickets in the flood plains in the south of the Peninsulas and are not numerous. In the period of greatest fur trapping in Yamal, in the 1950s, up to 2,700 pelts of ermine were obtained, but at present the number of this precious animal has declined sharply (Korytin and others 1995b). Forest mammals (brown bear, moose, and hare) penetrate into the southern part of the region.

The domestic reindeer plays the most important role in the functioning of Yamal-Gydan tundra ecosystems and has almost totally replaced its wild relative. Since the 1910s, the southern limit of the distribution of wild reindeer has gradually shifted to the north along with the growth of domestic herds. A population of wild reindeer exists only on Belyi Island and in the northernmost parts of Yamal and Gydansky, with around 1,000 animals (Syroechkovsky and Kuprianov 1995). In the Soviet period, the wild reindeer were referred to as an enemy to reindeer herders and was intensively hunted. The number of wild reindeer rapidly decreased in the region from 8,000 head in the 1930s (Tyulin 1938) to 300 to 400 by the 1970s (Skrobov 1975). It is listed in the regional Red Data Book (Dobrinskii 1997).

Polar fox is the most numerous predator and the most valuable fur-bearing animal in the region. Respectively, it is an object of intensive hunting, both by locals and newcomers. Polar fox is spread all over the region, and the limit of its breeding area is constantly shifting to the north. The breeding area has shifted 140 km (87 miles) compared with its position in the 1930s, possibly reflecting climate warming (Korytin and others 1995b). Den abundance varies from 1.3 to 3.3 per ha (Korytin and others 1995b). Several areas with increased abundance of dens were found in Yamal (fig. 1). There is no such data for Gydansky, but in some of the areas where we made our floristic investigations we also found high den abundance. In Yamal, these areas occupy about 34 percent of the breeding zone, but as the main places of polar fox reproduction, they are very important for the viability of the population. Disturbance of natural conditions in such areas are especially dangerous for the Yamal polar fox population. Unfortunately, the Bovanenkovo Gas Field lies within one of such areas. In the early phases of its intensive development, 13 percent of Arctic fox dens were destroyed by different industrial activities and by uncontrolled offroad movement of tracked vehicles (Dobrinsky and Sosin 1995). The number of polar foxes follows the cyclic fluctuations in the number of their main prey—lemmings. The dynamics of state pelt output in Yamal-Nenetz Autonomous District shows a decline since the mid-1970s. Unfortunately, those figures could not show the complete picture because part of the pelts during the last 20 years have gone to the black market. The absolute peak in the number of polar foxes was in the mid-1950s, when pelt output reached 41,000. The lowest pelt output was in the mid-1920s and in the beginning of the 1980s. In the latter case, it was less than 5,000, but by the begining of the 1990s it increased to 18,000 (Korytin and others 1995b). For the preservation of Yamal's polar fox, a system of strict measures against poaching is absolutely necessary, as well as protection (in terms of prohibiting industrial activity) of the areas with high den abundance.

Birds—More than 180 species of birds are recorded within this sector of the Arctic, but only about 80 species have their nesting areas within the tundra zone (Ryabitzev 1993; Zhukov 1998). Waterfowl are the most numerous. Flood plains with numerous small lakes and shrub thickets are the most species-rich habitats, whereas on watersheds only few bird species occur. There are several rare bird species listed, both in the regional and federal Red Data Books, including: the White-beaked Diver (*Gavia adamsii*), Tundra Swan (*Cygnus bewickii*), Red- breasted Goose (*Branta ruficolis*), and Peregrine Falcon (*Falco peregrinus*). At the end of the 1960s, molting Tundra Swans would concentrate along the west coast of Yamal in the mouths of big rivers (Uspenskii and Kishinskii 1972), but in 1980 along with industrial exploration in those areas, the birds disappeared (Mineev 1987). They probably migrated to more secure places. The White-fronted Goose (*Anser albifrons*) is one of the most common species, with average nest density from 0.05 to 0.4 pairs per km^2 (Ryabitzev 1993), and occupying a wide range of habitats: swampy plains, shrub thickets, ravines, and eroded riverbanks. Though groups of molting geese can be met in different parts of Yamal, their big concentrations have disappeared. The Bovanenkovo Gas Field was one of such places where they used to concentrate (Uspenskii and Kishinskii 1972). The reason for the decrease in number of birds in molting concentrations is probably disturbance by noise of machinery, especially helicopters. Geese are intensively hunted in areas near the settlements. The Red-breasted Goose is endemic to the Sibirian Arctic. Its population in West Siberia is small in number but more or less stable; during the last 20 years it has fluctuated around several hundred pair (Ryabitzev 1993). The birds tend to migrate from Yamal to the more quiet Gydansky (Zhukov 1998). Eroded riverbanks are favorite nesting habitats of these birds. Interestingly, they nest under the patronage of the Peregrine Falcon (Ryabitzev and others 1989). In the 1970s, there were several dozen pairs of Red-breasted Geese and 12 to 15 pairs of Peregrine Falcons breeding in the mouth of the Yuribei River, but by the 1990s the number of geese had decreased three times, probably because of the exploratory drilling in the neighborhood (Ryabitzev and others 1989). One more negative example can be given from the Bovanenkovo Gas Field, where three pairs of Peregrine Falcons were breeding initially, but only one pair was left by the begining of the 1990s.

Nevertheless, the West Siberian Arctic still contains an essential variety and number of ducks, waders, grouse, and small passerines (Ryabitzev 1993). Two species of predators are common over all the area, the rough-legged buzzard and the snowy

owl. Though several bird species are recognized as endangered and are protected, additional measures are necessary for their conservation. First of all there is need for the protection of breeding grounds. There are several areas with increased concentrations of rare birds (fig. 1), including: coastal habitats to the south of Kharasavei; in archipelago Sharapovy koshki; mouths of the Yuribei and Erkutayakha Rivers; the middle reaches of the Yuribei River; basins of the rivers Shchuch'ya; and Khadata, with outposts of forests on flood plains in southern Yamal. An increase in industrial activity and linear constructions connected with gas and oil transportation will become a serious hazard for the ornithofauna of Yamal.

Many areas in Yamal urgently need status as protected areas, but unfortunately nature reserves are absent in the area. A recently organized Gydansky Zapovednik (nature reserve), located in the north of the Gydansky Peninsula (fig. 3), was ratified at a much smaller size than was suggested by scientists (Kalyakin and others 2000), and is not really representative for the area. It is likely that only lands that are not of interest for the gas and oil industry, or for the reindeer herders, will receive protected status. Numerous suggestions regarding giving protected status to certain localities in Yamal remain only on paper.

Conclusions

The situation in the West Siberian Arctic needs permanent attention. Unfortunately, a system of ecological control of human activities (both industrial and recreational), as well as monitoring the state of wildlife populations is not working. Though technogenous impact is concentrated locally, destruction of important habitats affects populations of wildlife over the whole area. Distribution of rare wildlife and plant species should be taken into account when new constructions are planned. Modern maps of their distribution need to be published. The situation with reindeer husbandry also needs some urgent solutions, made in close contact with the Nenets people. The number of reindeer should be decreased.

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