Reactions of shorebirds and passerines to human development in the Russian Arctic under the influence of strict conservation measures

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Abstract
Anthropogenic impact on nesting waders and passerine birds in the Arctic in surroundings of the industrial complex Sabetta, Yamal Peninsula, Russia was studied. A lot of factors associated with human development may affect nesting birds. The human-subsidized predation is considered to be the most significant. Anthropogenic food sources are usually present in human-transformed habitats, as well as additional dens and perch sites. This leads to a higher press of predation. In Sabetta, there are specific conditions causing artificially-limited predation and human-induced disturbance. Finding a large number of nests in close proximity to industrial infrastructure we have suggested that waders (order Charadriiformes) and passerine (order Passeriformes) birds may be tolerant to an urbanized landscape. In the studied industrial habitat, they probably do not reduce the nesting density, thanks to particular advantages of such habitats (drainability and variety of shelters). To test this hypothesis, we performed an analysis of the relationship between the nesting density of the 8 most abundant species of waders and passerines in relation to the degree of habitat transformation. Statistical analysis was carried out using the GLM module of Statsoft Statistica 10. We found a positive relation between nesting density of the Ringed Plover (*Charadrius hiaticula*) and Snow bunting (*Plectrophenax nivalis*) and the degree of transformation. Habitat transformation did not significantly affect the White wagtail (*Motacilla alba*) and Red-throated pipit (*Anthus cervinus*). The Lapland longspur (*Calcarius lapponicus*) showed a clear decrease of the nest density in transformed habitats. Last but not least, the Little stint (*Calidris minuta*), Temminck's stint (*C. temminckii*) and Red-necked phalarope (*Phalaropus lobatus*) completely ignored only artificial habitats, whereas in partially transformed habitats, their mean nesting density was similar to undisturbed natural areas.

Key words: Arctic, shorebirds, urbanization, nature conservation, anthropogenic habitat

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Introduction

Arctic environment is currently changing under the influence of ongoing climate change, increased grazing pressure and the growth of human activities (Sokolov et al. 2012, Bråthen et al. 2007, Post and Pedersen 2008, Henden et al. 2013, Tape et al. 2006). Such changes have an impact of particular polar ecosystems and the animals inhabiting them. The consequences of the anthropogenic disturbances for the nesting birds are of great concern to the environmentalists (Carney and Sydeman 1999). Urbanization effect is considered as one of the strongest for polar environment resulting in very intense pressure on terrestrial ecosystems of the cryolithozone. Anthropogenic development could reduce reproduction success, bird abundance and species diversity (Baynard et al. 2017, Giese 1996, Marzluff et al. 2001, Liebezeit et al. 2009, Cardilini et al. 2013). Industrial activities can directly or indirectly affect nesting birds through such phenomena as *e.g.* loss and fragmentation of natural habitats, soil erosion, ground surface deterioration (Peter et al. 2008), changes in hydrology and water preferential flow (Bring et al. 2016), traffic noise, dust contamination of the surroundings of linear constructions, various effects of mining (noise, dust, land consumption in complex), as well as increasing in abundance of human-subsidized predators (Liebezeit et al. 2009, Forbes et al. 2004, Meixell and Flint 2017). Nest predation, in turn, is considered one of the most significant factors, regulating population growth for many species (Liebezeit et al. 2009, George 1987, Troy 2000). Habitat fragmentation may indirectly contribute to increased predator pressure, since it has been observed that the diversity and abundance of predators are higher at the habitat edges (Ries et al. 2004). Predation especially affects ground-nesting birds (*e.g.* Dowling and Weston 1999, Dowding and Murphy 2001, Boland 2004) which are also highly susceptible to human disturbance (Mallory 2016, Carney and Sydeman 1999). It is known that the disturbance caused by the movement of vehicles has less harmful effect on nesting birds than visiting nesting sites by the observer (Meixell and Flint 2017). In this regard, the impact of industrial activity on the reproduction of birds in the Arctic can be minimized using methods that limit direct human contact with birds (Meixell and Flint 2017). Nevertheless, birds do not always perceive human activity as something negative. The reaction can be weak or even positive, because an individual has already got used to it (Hans-Ulrich et al. 2007, Liddle 1997). In animals, habitat selection depends on the availability of food resources, predator pressure, human disturbance, and population density (McLoughlin et al. 2010, Christie et al. 2017). Industrial development in the Arctic transforms the environment and changes habitat characteristics. The transformation also leads to creation of new habitats that can be used by breeding birds. In this regard, it is important to understand how different species of ground-nesting birds in the Arctic react to the emergence of human-transformed habitats. Therefore, understanding the patterns of habitat selection is extremely important for developing measures to mitigate the negative impact of human industrial and urbanization activity in the tundra terrestrial environment.

In our study, the communities of ground-nesting birds have been monitored in the vicinity of Sabetta settlement, the Yamal Peninsula, Russia for three years (2015-2017). In the study area, there is a liquefied natural gas plant, the seaport and the worker's settlement. The area is located in the northeastern part of the Yamal Peninsula, on the coast of the Ob Bay of the Kara Sea. The construction of the industrial complex began in 2011. At the time of completion of the study, the number of people living and working in Sabetta reached 8000 people. Prior to the construction, the main type of human activity in the study area was reindeer herding. After the start of the construction, the following environmental protection measures were observed: 1) banning vehicles from entering the tundra and off-road traffic; 2) the prohibition of walking anywhere excepting the construction sites, roads and pathways; 3) the prohibition of hunting, fishing and picking berries; 4) the prohibition of grazing herds of domestic reindeers; 5) the prohibition of waste storage outside specially designed containers; 6) the prohibition of keeping pets and feeding Arctic foxes (*Alopex lagopus*); 7) the regulation of the number of Arctic foxes in March prior to the beginning of the bird breeding season. Special security service is constantly monitoring the implementation of these provisions, and fines are imposed on violators. Thanks to these activities a number of negative anthropogenic effects such as human disturbance or breeding of the subsidized predators have been practically reduced to zero. A strict protection regime has turned most of the tundra sites in this area into mini-reserves which are spared from two major ecological risks of the Yamal tundra: reindeer's overgrazing (Kryazhimskii et al. 2011) and predation of the Arctic foxes. The latter are usually gathering around villages searching for the food wastes. Arctic fox predation is recognized as the main factor influencing the breeding population of waders in the Russian Arctic (Summers and Underhill 1987).

In our study, we found a large number of nests in close proximity to infrastructure. Therefore, we hypothesized that in the context of effective conservation measures, small ground-nesting bird species (waders and passerines) may be tolerant to an urbanized landscape and not reduce the nesting density in the vicinity of human infrastructure. Thus, the aim of this study was to test the hypothesis of possible tolerance of nesting small bird species to urbanization under specific conditions of strict environmental measures. We have defined the following objectives: 1) to explore breeding habitat selection for several most common species of waders and passerines; 2) to analyze the relationship of nest density depending on the degree of habitat transformation by anthropogenic activity.

Methods

Study area

The study area is located in the vicinity of Sabetta settlement (Northeast of the Yamal Peninsula, Russia, 71°15'N, 72°3'E), in the valleys of the Sabetayakha, Salyamlekabtambada-Yakha, and the Nyaruyaha rivers and adjoins the Ob Bay area (*see* Fig. 1). The site is characterized by an extremely developed network of rivers and streams, as well as a huge number of small floodplain and thermokarst lakes. The area is located in the Arctic tundra near the southern border of its distribution (Matveyeva 1998, Sochava and Gorodok 1956).

Most of the area is occupied by sedge-moss bogs, lichen-moss and sedge-moss tundra. Lichens are limited in growth by the overgrazing by domestic reindeers that had been performed there long before the gas field site was established. Thickets of shrubs are completely absent.

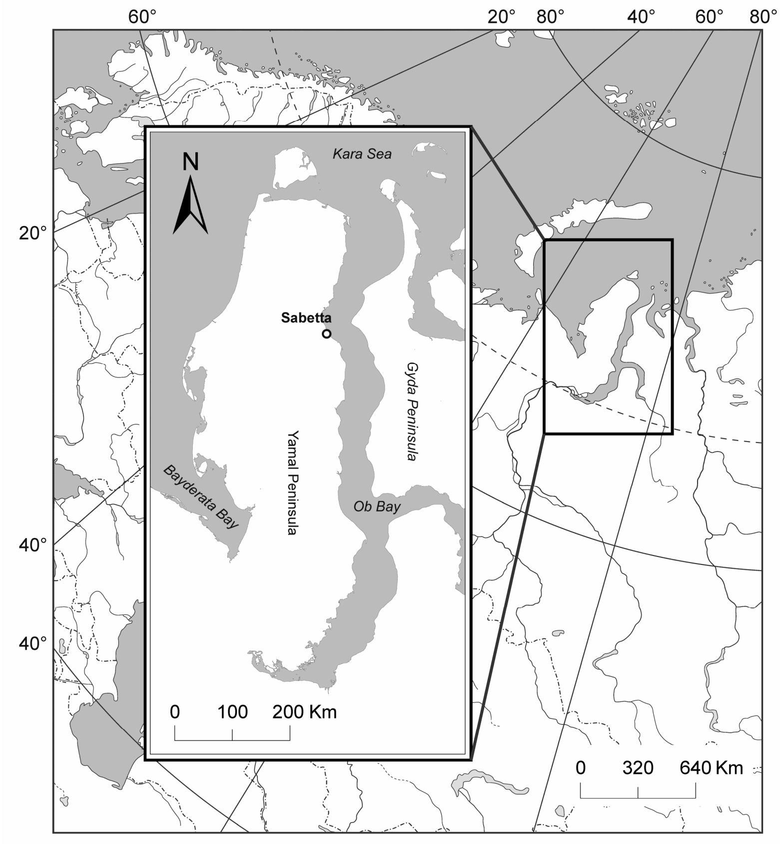


Fig. 1. The location of the study area.

There are only rare single willows in river valleys. Investigated natural landscapes is typical by overmoisted flat plain with evident features of increased hydromorphizm. Soils in the natural landscapes are presented mainly by Cryosols and Cryometamorphic soil with evident features of stagnification. Average thickness of the active layer is about 1.0-1.5 meters. Natural soil were normally clyely textured. Anthropogenic soils of the artificial heaps were sandy textured and consisted mainly of few undeveloped horizons. These soils are known as Arenosols or Entisols with low degree of alteration of soil mineral matrix during pedogenesis. These soils are more drained and demonstrate less redoximorphic features than natural ones. Therefore, antropogenic effects on soil texture results in a decrease in hydromorphizsm and an increase of the draining ability of soils.

Complexes of dwelling and industrial buildings and a road network are located in the study area. This could be classified as example of urbanization on the territory of arctic terrestrial environment. All facilities are located on the sand mounds with a height of about two meters. In general, the anthropogenic infrastructure covers 25% of the study area (Fig. 3).

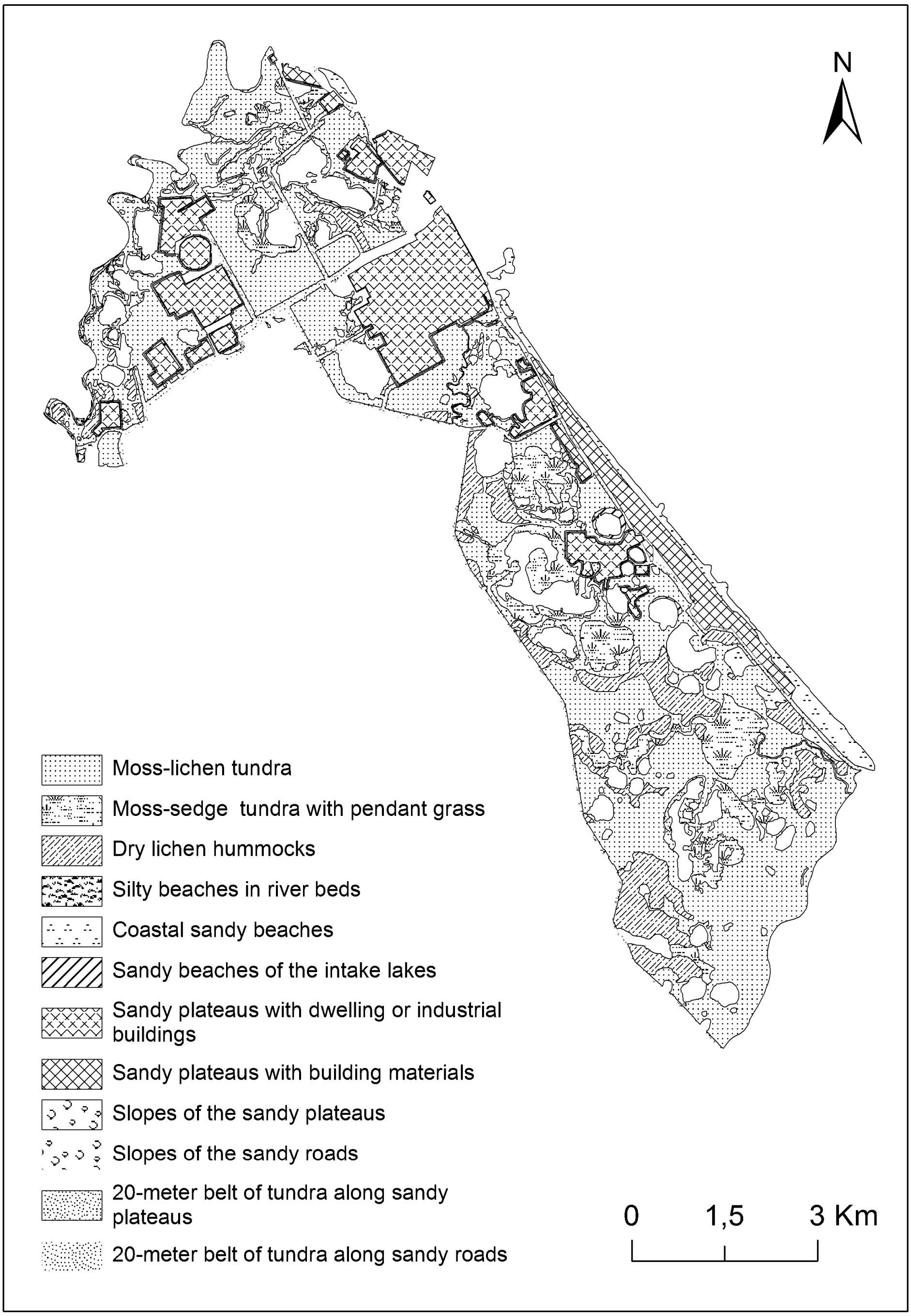


Fig. 2. The map of the study area.

During the bird breeding season, several species of predators are present in the vicinity of Sabetta. They are Arctic fox (*Vulpes lagopus*), stoat (*Mustela erminea*), Snowy owl (*Nyctea scandiaca*), Rough-legged buzzard (*Buteo lagopus*), Glaucous gull (*Larus hyperboreus*), Heuglin's gull (*Larus fuscus heuglini*), and three species of skuas (*Stercorarius longicaudus, Stercorarius parasiticus*, and *Stercorarius pomarinus*). As previously mentioned, strict conservation measures do not allow these species to receive any benefit from the human neighborhood with the possible exception of additional perches and densites. For example, Arctic foxes breed annually in the iron pipes which were left after construction.

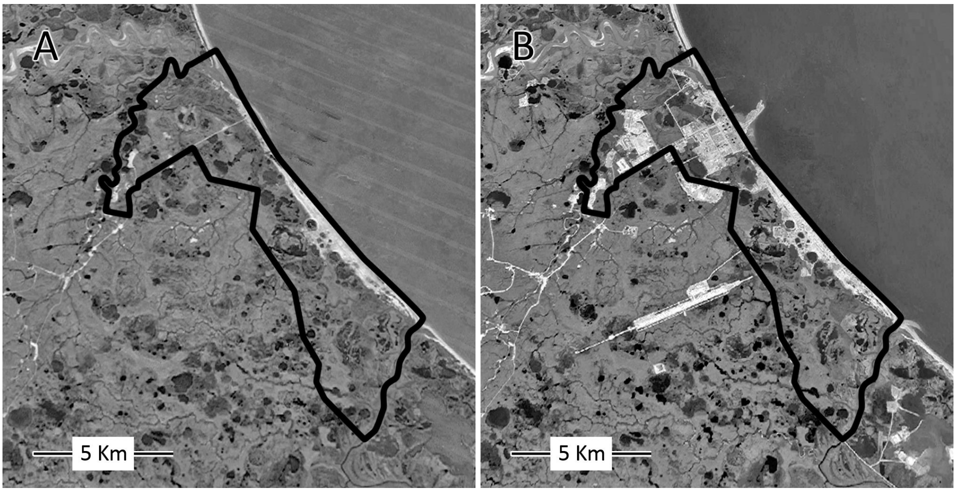


Fig. 3. Satellite images before and after the construction of the industrial complex. (A) Google Earth Image Landsat / Copernicus, 2009. (B) Google Earth Image Landsat / Copernicus, 2016. The black line indicates the study area.

Bird surveys

We study how selected species of birds react to the emergence of new types of anthropogenic landscape in the Arctic. During the three years of research, 474 nests of 9 shorebird species and 420 nests of 8 passerine species were recorded while 2630 hectares of the territory and 12 habitat types of both natural and artificial origin were investigated. The following bird species were included in the analysis: Ringed plover (*Charadrius hiaticula*), Little stint (*Calidris minuta*), Temminck's stint (*Calidris temminckii*), Red-necked phalarope (*Phalaropus lobatus*), White wagtail (*Motacilla alba*), Red-throated pipit (*Anthus cervinus*), Snow bunting (*Plectrophenax nivalis*), and Lapland longspur (*Calcarius lapponicus*). These are the most widespread breeding species of waders and passerines in the area. Nest counts were carried out for three years, from 2015 to 2017, during the breeding season by the same observer (Kouzov S.A.) using the territory mapping method (Gregory et al. 2004, Bibby et al. 2000). The method was chosen because of the absolute openness of the territory, absence of bushes, and low density of breeding birds. In such circumstances, it is not difficult to trace the territorial behavior of birds and detect the nest. The study area was examined by the observer three times per season by a zigzag route with an interval of 100 m. Due to the large area, each survey was conducted for several days. In 2015 the counts were carried out on July 4-8, 13-16 and July 17-20. In 2016 – July 6-10, 14-17 and 19-21; in 2017 – July 5-9, 13-16 and 18-23. Meeting birds with territorial behavior, the observer looked for the nest then returning to the former route. Since the territorial mapping method was combined with the direct search for nests, three visits were enough to reveal most of the breeding pairs, given the ease of detection in the open landscape. The study area is replete with a large number of lakes so the route changed, passing along the shore. Observations were made in the morning or evening hours in accordance with the morning and evening peaks activity. In bad weather conditions, observations were not made. The coordinates of the detected nests were recorded using a GPS. We did not mark nests for fear of attracting predators. If a bird with territorial behavior was present, but the nest could not be found, the coordinates of the bird's location were recorded. Subsequently, the registered points were plotted on the map in the ArcMap 10.0, where the boundaries between territorial areas were determined. Nests density was calculated as the number of nests per 1 hectare. The areas of habitat patches were calculated using high resolution georeferenced Google satellite images, obtained with the SAS. Planet program. On the basis of these satellite images we have built a vector map of habitat patches in ArcMap 10.0 (Fig. 2).

Statistical analyses

The analysis was carried out for 12 types of habitats: 1) moss-sedge tundra with the areas of the Pendant grass (*Arctophila fulva*) (24 patches), 2) moss-lichen tundra (12 patches), 3) dry lichen hummocks (17 patches), 4) coastal sandy beaches with sedge hillocks (6 patches), 5) silty beaches in river beds (16 patches), 6) sandy plateaus with dwelling or industrial buildings (21 patches), 7) sandy plateaus with building materials (4 patches), 8) slopes of the sandy plateaus (17 patches), 9) slopes of the sandy roads (11 patches), 10) 20-meter belt of tundra along sandy plateaus (17 patches), 11) 20-meter belt of tundra along sandy roads (11 patches), 12) sandy beaches of the intake lakes with low water levels (7 patches). All patches had different areas. Three years of research did not differ much in weather conditions (high summer temperatures), the number of lemmings (it was rather low), and abundance of nesting birds (it was stable). Since the same areas of the territory were observed for 3 years and these years were similar, the ANOVA Repeated Measures module was used in the Statistica 10.0 ([1] - Statsoft 2012). The densities of nests in 2015, 2016 and 2017 acted as repeated measurements of the dependent variable. The habitat type acted as an independent categorical predictor. In this way, the relationship of the species with the habitat type was studied (Fig. 2). Furthermore, all the patches were divided into three categories: natural habitats, partially transformed habitats, and artificial habitats (Table 1). The natural habitats included moss-sedge tundra, moss-lichen tundra, dry lichen hummocks, coastal sandy beaches with sedge hillocks, silty beaches in the river beds.

Artificial habitats included sandy plateaus with a dwelling or industrial buildings, sandy plateaus with building materials, slopes of the plateaus, and slopes of the roads. The 20-meter belt of tundra along plateaus and roads, as well as sandy beaches on the shores of the intake lakes, were classified as partially transformed habitats. They were attributed to the partially transformed habitats since the old overgrowing ruts of the tracked vehicles remained there, and the soils changed under the influence of sand flung from the mounds.

Group	N	Median	Mean	SD
Natural habitats	75	9.53	23.12	45.47
Partially transformed habitats	35	2.72	6.57	11.79
Artificial habitats	53	2.66	12.50	34.06

Table 1. The average area of the patches, hectares. *Notes*: N – number, SD – standard deviation.

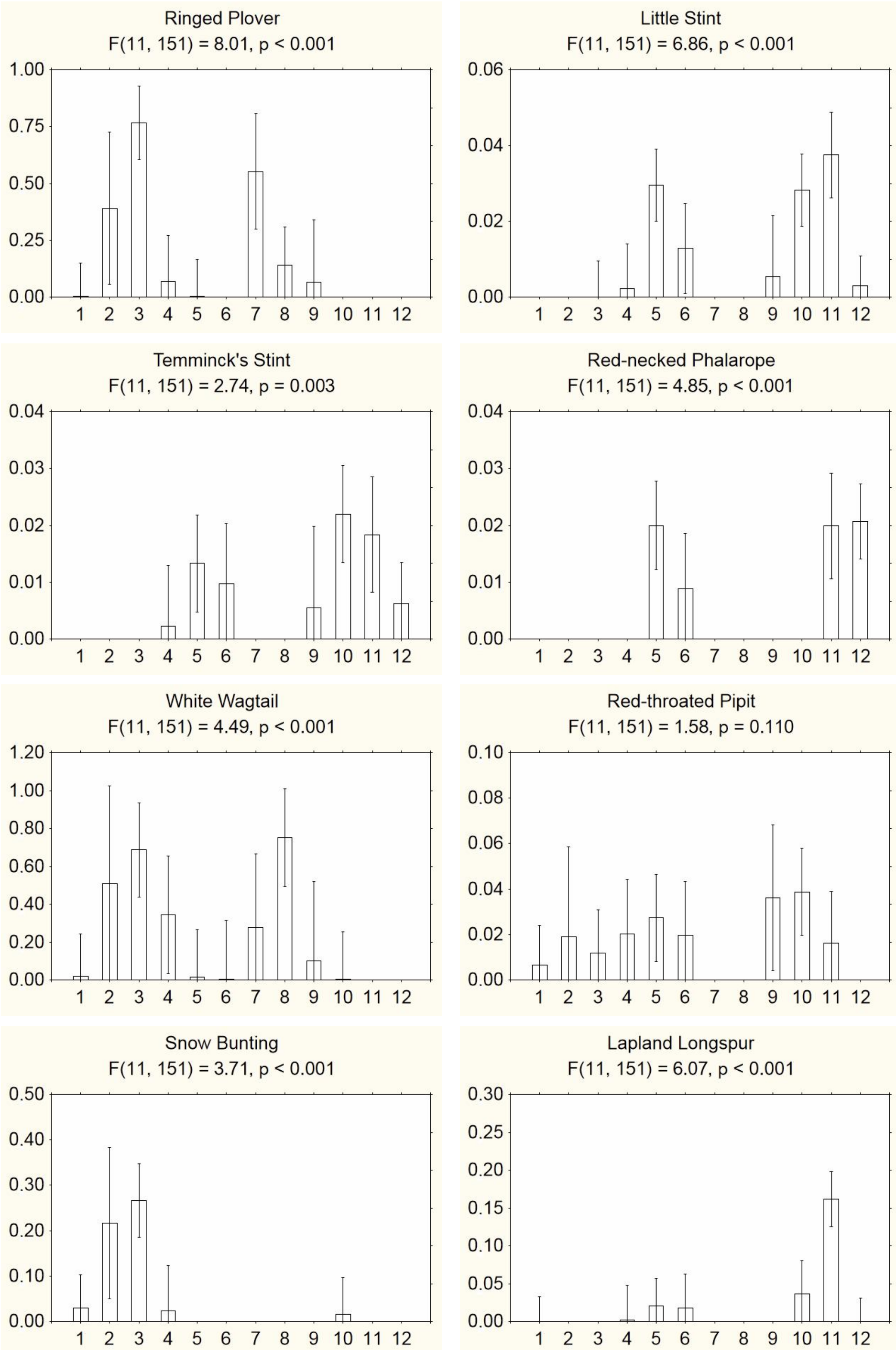
The relationship between the density of nesting birds and the degree of habitat transformation was analyzed using the GLM module in the Statsoft (Statistica 10). Since the habitat area in fragmented landscapes had a positive effect on the abundance and density of birds (Henden et al. 2013, Rosenzweig 1995, Fahrig 2003), we included patch area in the model as a continuous predictor. The degree of anthropogenic transformation acted as a categorical factor, and the values of the species density in 2015, 2016 and 2017 acted as a dependent variable with three repeated measurements (within effects). The categorical predictor assumed three values: natural habitats, partially transformed habitats, and artificial habitats. Results were considered statistically significant with $p <= 0.05$.

Results

Within the three years of bird observation, 141 nests of the Ringed plover, 83 nests of the Little stint, 61 nests of the Temminck's stint, 104 nests of the Red-necked phalarope, 181 nests of the White Wagtail, 62 nests of the Red-throated Pipit, 68 nests of Snow buntings and 75 nests of Lapland longspur were found. In addition to the most widespread species, the Grey plover (*Pluvialis squatarola)*, the Wood sandpiper (*Tringa glareola)*, the Dunlin (*Calidris alpina)*, the Pectoral sandpiper (*Calidris melanotos)*, the Ruff (*Philomachus pugnax)*, the Citrine wagtail (*Motacilla citreola)*, the Meadow pipit (*Anthus pratensis)*, the Wheatear (*Oenanthe oenanthe)* and the Little bunting (*Emberiza pusilla)* breed in the study area.

We used a one-way ANOVA (Repeated Measures) to examine differences in density of the eight bird species in relation to the habitat type. According to the results of the analysis, Ringed plovers preferred to nest on the anthropogenic sandy plateaus and their slopes, as well as on the sandy beaches of intake lakes, *i.e.* mainly in the anthropogenic landscape. More rarely, they chose slopes of the roads, as well as coastal sandy beaches and silty beaches in river beds ($F(11, 151) = 8.01$, $p < 0.001$; Fig. 4).

Fig. 4. ►►Least square means of the nests densities in different types of habitats. Vertical bars denote 0.95 confidence intervals. The y-axes show the mean density of the nests, and the x-axes show the habitat type: 1) sandy plateaus with dwelling or industrial buildings, 2) sandy plateaus with building materials, 3) slopes of the plateaus, 4) slopes of the roads, 5) 20-meter belt of tundra along sandy plateaus, 6) 20-meter belt of tundra along the roads, 7) sandy beaches of the intake lakes, 8) silty beaches in river beds, 9) coastal sandy beaches, 10) dry lichen hummocks, 11) moss-lichen tundra, 12) moss-sedge tundra.


Ringed Plover
F(11, 151) = 8.01, p < 0.001
Little Stint
F(11, 151) = 6.86, p < 0.001
Temminck's Stint
F(11, 151) = 2.74, p = 0.003
Red-necked Phalarope
F(11, 151) = 4.85, p < 0.001
White Wagtail
F(11, 151) = 4.49, p < 0.001
Red-throated Pipit
F(11, 151) = 1.58, p = 0.110
Snow Bunting
F(11, 151) = 3.71, p < 0.001
Lapland Longspur
F(11, 151) = 6.07, p < 0.001
1 2 3 4 5 6 7 8 9 10 11 12

The Little stint significantly preferred moss-lichen tundra and dry lichen hummocks, but it also nested in 20-meter belt along the roads and plateaus ($F(11, 151) = 6.86$, $p < 0.001$), as well as the Temminck's stint ($F(11, 151) = 2.74$, $p = 0.03$). The Red-necked phalarope nested mainly in the moss-sedge and moss-lichen tundra, but it was also found in 20-meter belt of transformed landscape ($F(11, 151) = 4.85$, $p < 0.001$).

The nests of the White wagtail could be observed almost everywhere both in anthropogenic and in natural habitats with sandy substrates, such as beaches, slopes, and plateaus ($F(11, 151) = 4.49$, $p < 0.001$). The Red-throated pipit also nested in a wide variety of habitats with the exception of the very wet areas and beaches, the differences in the nesting density were not significant ($F(11, 151) = 1.58$, $p = 0.11$). The Snow bunting preferred exclusively anthropogenic landscapes (sandy plateaus and their slopes), rarely appearing on the dry lichen hummocks in the tundra ($F(11, 151) = 3.71$, $p < 0.001$). In contrast, the Lapland longspur nested in the untransformed tundra, however not neglecting 20-meter belt along anthropogenic plateaus and roads ($F(11, 151) = 6.07$, $p < 0.001$; Fig. 4).

Furthermore, we built general linear models to explain the density of nests by using two variables: patch area and the degree of anthropogenic transformation. Estimated parameters for the models implies that the area does not matter, while degree of anthropogenic transformation was highly significant factor explaining the nesting density of six of the eight species (Table 2).

The average nesting density of the Ringed plover and the Snow bunting was minimal in the natural habitat areas and maximal in anthropogenic areas (Fig. 5). The Little stint and Temminck's stint preferred to nest in natural and partially transformed habitats, almost completely ignoring the artificial ones. The Red-necked phalarope behaved in a similar way. The average nesting density of the Lapland longspur consistently decreased as the degree of habitat transformation increased (Fig. 5). The nesting densities of the White wagtail, and the Red-throated pipit were not significantly related to the degree of habitat transformation (Table 2).

In total, 24% of waders and 54% of passerines nested in the artificial habitats, 13% of waders and 11% of passerines nested in partially transformed habitats, 62% of waders and 36% of passerines nested in natural habitats. Among the 12 types of habitats, we observed relatively high nest density at the slopes of the plateaus (1.49 nests per hectare), silty beaches in the river beds (0.80) and sandy beaches of the intake lakes (1.17) (Table 3). The lowest density was observed on the plateaus with a dwelling or industrial buildings (0.04), as well as in moss-sedge tundra (0.04). Species richness estimated as the number of nesting species was relatively high in the 20-meter belt of tundra along the roads and plateaus (8 and 7 species, respectively), and in lichen (7), moss-lichen (8), and moss-sedge tundra (7). The poorest in terms of the number of nesting species were silty beaches in the river beds (2) and sandy beaches of the intake lakes (1).

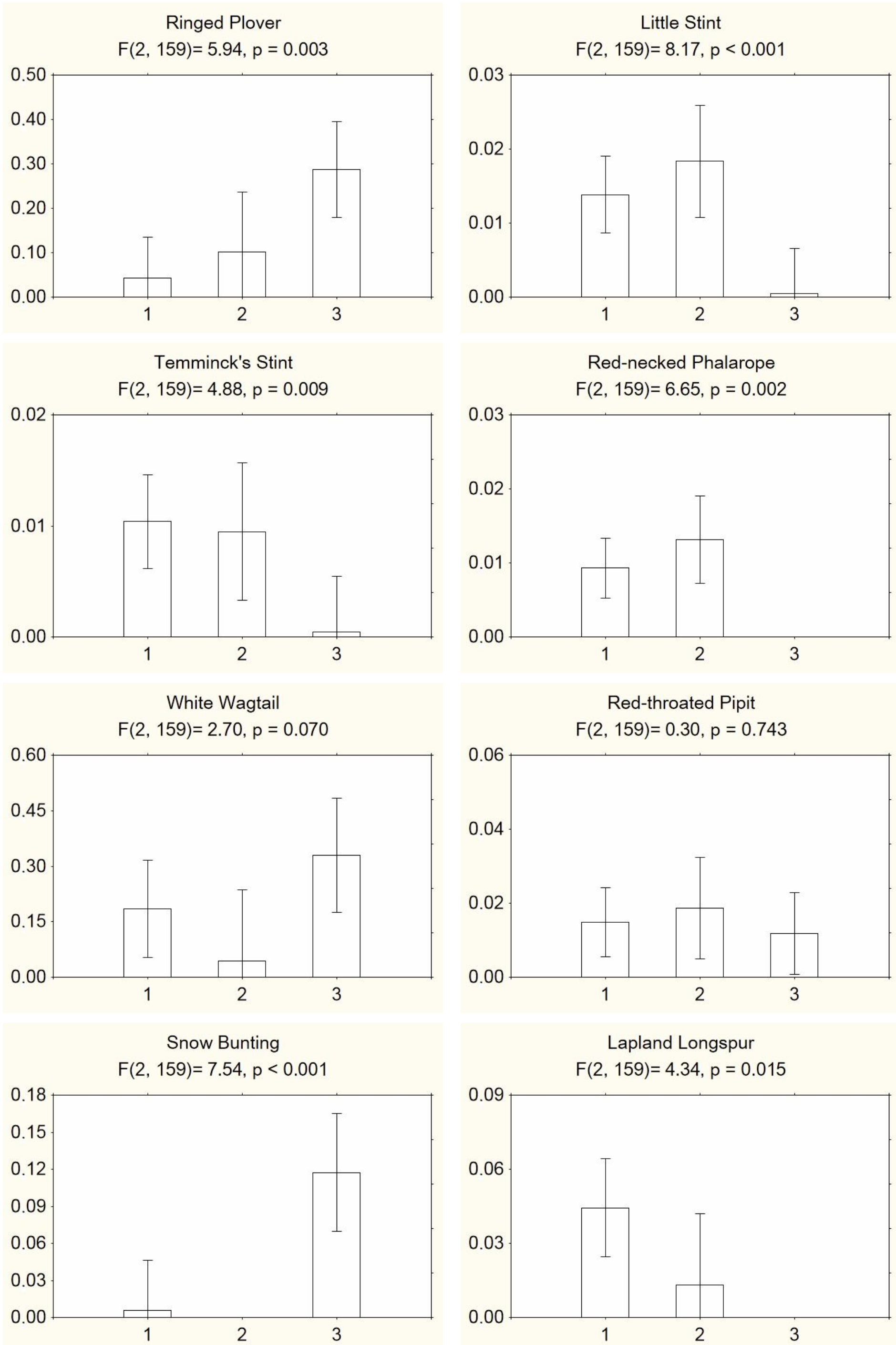


Fig. 5. Average nesting densities in the habitats with varying degree of anthropogenic transformation. Vertical bars denote 0.95 confidence intervals. 1 – natural habitats, 2 – partially transformed habitats, 3 – artificial habitats.

	SS	df	MS	F statistic	P-value
Ringed plover					
Intercept	10.184	1	10.184	21.388	**< 0.001**
Area	0.746	1	0.746	1.566	0.213
Degree of transformation	5.657	2	2.828	5.940	**0.003**
Error	75.710	159	0.476		
Little stint					
Intercept	0.047	1	0.047	30.899	**< 0.001**
Area	< 0.001	1	< 0.001	0.019	0.892
Degree of transformation	0.025	2	0.012	8.175	**< 0.001**
Error	0.243	159	0.002		
Temminck's stint					
Intercept	0.018	1	0.018	17.929	**< 0.001**
Area	< 0.001	1	< 0.001	0.009	0.925
Degree of transformation	0.010	2	0.005	4.875	**0.009**
Error	0.163	159	0.001		
Red-necked phalarope					
Intercept	0.016	1	0.016	17.639	**< 0.001**
Area	0.003	1	0.003	3.243	0.074
Degree of transformation	0.012	2	0.006	6.664	**0.002**
Error	0.148	159	0.001		
White wagtail					
Intercept	19.138	1	19.138	19.647	**< 0.001**
Area	3.065	1	3.065	3.147	0.078
Degree of transformation	5.259	2	2.630	2.700	0.070
Error	154.887	159	0.974		
Red-throated pipit					
Intercept	0.105	1	0.105	20.941	**< 0.001**
Area	0.004	1	0.004	0.765	0.383
Degree of transformation	0.003	2	0.001	0.298	0.743
Error	0.797	159	0.005		
Snow bunting					
Intercept	0.781	1	0.781	8.363	**0.004**
Area	0.053	1	0.053	0.565	0.453
Degree of transformation	1.408	2	0.704	7.541	**0.001**
Error	14.841	159	0.093		
Lapland longspur					
Intercept	0.207	1	0.207	9.225	**0.003**
Area	0.038	1	0.038	1.720	0.192
Degree of transformation	0.194	2	0.097	4.339	**0.015**
Error	3.560	159	0.022		

	2015		2016		2017		Mean	
	Density	Number of species	Density	Number of species	Density	Number of species	Density	Number of species
Sandy plateaus with a dwelling or industrial buildings	0.04	4	0.04	2	0.04	5	0.04	4
Sandy plateaus with building materials	0.57	4	0.58	4	0.40	3	0.52	4
Slopes of the plateaus	1.59	2	1.53	5	1.35	5	1.49	4
Slopes of the roads	0.42	2	0.55	6	0.48	7	0.48	5
20-meter belt of tundra along the plateaus	0.27	7	0.14	5	0.27	10	0.23	7
20-meter belt of tundra along the roads	0.10	8	0.08	6	0.12	9	0.10	8
Sandy beaches of the intake lakes with low water levels	0.75	1	1.25	1	1.50	2	1.17	1
Moss-sedge tundra with the areas of the Pendant grass	0.04	7	0.05	8	0.04	6	0.04	7
Moss-lichen tundra	0.13	7	0.13	9	0.19	9	0.15	8
Dry lichen hummocks	0.16	5	0.27	8	0.39	8	0.27	7
Coastal sandy beaches with sedge hillocks	0.20	3	0.20	3	0.15	4	0.19	3
Silty beaches in river beds	1.20	2	0.80	2	0.40	2	0.80	2

Table 3. Total nesting density and species richness in the different types of habitats (average number of nests of all species per hectare and number of species, respectively).

Table 2. ◄◄ The results of the GLM showing the influence of the factors on the nesting density of studied species. *Notes*: SS – sum of squares effect, df – degrees of freedom, MS – mean square effect, F statistic – test statistic in F-test , P-value – level of significance.

Discussion

The habitat selection of 8 bird species was analyzed. According to the results of the general linear models (Neter et al. 1996), the infrastructure significantly affects the nesting habitat choice of 6 out of 8 species. The Ringed plover and the Snow bunting actively used the anthropogenically-transformed territories, neglecting natural sites. In the Arctic, the Ringed plover usually nests on sandy and pebble beaches on the seashore, or on silty, sandy and rocky beaches along rivers and lakes (Hayman et al. 1986, del Hoyo et al. 1996, Snow and Perrins 1998, Johnsgard 1981) everywhere preferring a well-drained substrate. In our study, 90% of the Ringed plovers nested in the artificial or partially transformed landscapes, sometimes even not related to water sources such as rivers or lakes. Apparently, the degree of drainage of the anthropogenic soils significantly exceeds the natural counterparts. This data supported by soil hydrological data and well vertical electric resistivity data for central part of Yamal region (Alekseev et al. 2017). This may be one of the reasons for the Ringed plover active nesting in the anthropogenic landscape. Some cases of nesting of the Ringed plover in the 20m belt of tundra near the sandy plateau is quite interesting. Probably, sand fluttering from the mounds creates microhabitats with a suitable substrate where birds nest. As for Snow buntings, these birds often nests near or even inside human settlements (Rising 2016), therefore their commitment to the anthropogenic landscape is quite obvious.

Nest densities of the White wagtail and the Red-throated pipit were not significantly related to the degree of anthropogenic transformation, these species nested in both natural and transformed habitats. It is worth noting, that Red-throated pipit is generalist (Sokolov et al. 2012), therefore they can probably nest in the anthropogenic landscape with minimal human disturbance and limited predation pressure. As for the White wagtail, the facts of its nesting in farmlands, parks, on industrial territories, in the cities are well known (Tyler 2016). The Temminck's stint in Scandinavia nests near fishing huts and houses, as well as on the industrial territories (Ronka 1996), although the natural habitats in the Arctic tundra for it are floodplains and deltas of the rivers (Snow and Perrins 1998). In our study, this species adhered to natural and partially transformed habitats.

The Little stint and the Red-necked phalarope avoided anthropogenic habitats, but the mean nesting densities in natural and partially transformed habitats were similar. The Little stint usually nests on the dry ground near the wetlands (del Hoyo et al. 1996) or in the places where mosses and sedges alternate with hummocks with crowberries (*Empetrum nigrum*, Johnsgard 1981). The areas within the 20-meter belt of tundra along the roads and plateaus are often corresponding well to this description. Old, overgrown with moss and sedge ruts create an uneven landscape, and in these habitats, crowberries grow. Thus, it is quite a suitable biotope for the Little stint. As our observations showed, the birds quickly get used to the noise of the road traffic, and walking people don't disturb them because it is forbidden to go off the roads to the tundra.

In contrast, the Red-necked phalarope prefers flooded lowlands (Sokolov et al. 2012) or swampy areas overgrown with grass, sedge and moss (Johnsgard 1981, del Hoyo et al. 1996). Within the 20-meter belt along the roads and plateaus, low wet areas were also present. The sites nearby these areas were suitable for nesting of Red-necked phalaropes.

The Lapland longspur preferred to nest in moss-lichen tundra, on dry lichen hummocks, less often in 20-meter belt of tundra along the roads and plateaus, completely ignoring the wet moss-sedge boggy tundra. In Greenland, this species, on the contrary, more often prefers wet boggy areas with crowberries and dwarf birch (*Betula glandulosa*) - Rising and Christie (2016). The differences in habitat preferences of this species in the studied area compared to the tundra of Greenland are probably related to the characteristics of wet habitats. In Sabetta boggy tundra is characterized by smooth microrelief and almost no sedge bumps, which birds usually use for nests. At the same time, this species can nest in a wide range of biotopes of both dry and wet tundra in areas with developed microrelief and hilly landscape. Lapland longspur avoids only rocky, gully and desert sandy areas (Boeme et al. 1998). And the latter is typical for anthropogenic landscapes. Probably for this reason, in our study, the nesting density of the Lapland longspur consistently decreased as the degree of habitat transformation increased.

Many studies showed a positive relationship between habitat area and the abundance and richness of species in fragmented landscapes (Henden et al. 2013, Fahrig 2003, Smith et al. 2011). This phenomenon is explained by the concentration of predators along the habitat edges, and, accordingly, the higher pressure of predation in highly fragmented landscapes, which may contribute to bird concentrations in non-fragmented areas (Henden et al. 2013). However, in our study, none of the eight species showed a significant relationship between the nesting density and the area of the patch. Perhaps, this is due to the measures taken to control population of predators in the Sabetta region. We also believe that in the Yamal peninsula the number of predators in the areas of oil and gas infrastructure, where reindeer herding is prohibited, is lower than in active grazing areas. High deer numbers should lead to higher mortality, and therefore abundant food resources for predators. Probably, Arctic foxes (*Alopex lagopus*) can feed on carrions, which is especially important in conditions of an incredibly high number of domestic reindeers in the Yamal peninsula. Our assumption is consistent with the study in Norway where Red foxes (*Vulpes vulpes*) mostly fed on deer carrions during the low phase of the rodent population cycle (Killengreen et al. 2011).

The Yamal Peninsula is currently experiencing an uncontrolled growth of reindeer herding (Kryazhimskii et al. 2011, Walker et al. 2009). According to the Institute of Plant and Animal Ecology, Ural Branch of the Russian Academy of Sciences, the livestock of domestic reindeer (*Rangifer tarandus*) in 2017 in the Yamalo-Nenets Autonomous District numbered 750 000 individuals, but the pasture capacity is not more than 400 000 individuals (Gileva 2018). According to information from the same source, about 6% of the territory of the peninsula has been turned into sandy areas, and the Yamal peninsula ecosystems are on the verge of an ecological disaster. This information is partially confirmed by our observations during expeditions to the peninsula. The situation with overgrazing in Yamal is unique for the Russian Arctic and can be explained by the geographical shape of the peninsula. It is stretched in the meridional direction and narrow in width. As a result, a huge number of reindeer herds are forced to migrate from South to North and back along the same routes every year. On the Taimyr Peninsula and in the tundra of European Russia herds of domestic deer can annually change the migrations routes and tundra recovers for several years.

Some authors report that grazing of deer reduces the area of bush tundra and reduces the height of bushes, which in turn reduces the species richness of birds (Ims and Henden 2012, den Herder at al. 2008). Reindeer can also be classified as active nest predators, as they eat eggs and small chicks. Banning deer herding on the Sabetta gas field site undoubtedly contributes to the conservation of tundra and the growth of the abundance and species richness of nesting birds, while linear objects (gas pipelines) physically prevent the penetration of herds into the area. As a result, the vegetation of the tundra areas in the vicinity of Sabetta is in a markedly better condition (according to our visual estimates), rather than outside the zone of influence of the industrial complex. Unlike the neighboring territories, there are no degraded desert sandy areas on the hills, and lichens cover a larger area. Oddly enough, on the Yamal peninsula, the territories belonging to the oil and gas industry may become the only well-preserved and suitable for bird nesting in the future, if the regional government still will not take any decisive measures by grazing restriction.

In order to preserve tundra ecosystems, many enterprises of the oil and gas complex use unprecedented measures to protect the territory adjacent to infrastructure facilities. These measures have been applied in Sabetta. Thus, the damage of the ecosystem resulting from the human activities and disturbance is reduced. Reproduction of predators is reduced due to measures for direct control of their numbers, prohibition of animal feeding and storage of food waste in special containers. In such conditions, some bird species can benefit in such anthropogenic territory. For example, good drainage of the substrate or availability of shelters may affect nesting positively. The plateaus with construction materials were found very suitable for nesting of some species in our study. On the one hand, they are rarely visited by people. On the other hand, stacks of building materials provide excellent shelter, especially valuable in arctic tundra with no shrub cover. In our study, we report a lot of White Wagtail, Snow bunting and Red-throated pipit nests in this habitat.

Conclusions

We can conclude that our initial assumptions were confirmed for the Red-throated pipit and White wagtail. The first is a generalist species whereas the second traditionally related to anthropogenic infrastructure. Two more species (the Snow bunting and the Ringed plover) preferred anthropogenic habitats to natural ones. The Lapland longspur showed a clear decrease of the nest density in transformed habitats. As for the remaining three species, they completely ignored only artificial habitats, whereas in partially transformed habitats their mean nesting density was similar to natural areas.

These results demonstrate the importance of exploring species-specific differences in response to human development in Arctic regions. Further research is needed to include more species in order to get more data and a better understanding of how human activity effects on nesting birds in the Arctic tundra.

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