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The first data on beetles (Coleoptera) of the High Arctic Shokalsky Island (Kara Sea)

Первые сведения о жуках (Coleoptera) высокоарктического острова Шокальского (Карское море)

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KEY WORDS: Coleoptera, taxonomic diversity, geographical range, tundra, arctic species, flight capability, age of fauna

КЛЮЧЕВЫЕ СЛОВА: Coleoptera, таксономическое разнообразие, ареал, тундра, арктический вид, способность к полету, возраст фауны

SUMMARY. The beetle fauna of the Shokalsky Island (Kara Sea) was surveyed. The island is situated at 73°N in the extreme North of the West Siberian sector of the Arctic. Thirteen beetle species from six families were recorded (Staphylinidae, 5 species; Dytiscidae, 3; Carabidae, 2; Helophoridae, 1; Silphidae, 1; Chrysomelidae, 1). The set of families recorded on Shokalsky is similar to those known from other sectors of the High Arctic. At species level the fauna of Shokalsky is most similar to that of the northern Taymyr Peninsula. Staphylinids dominate in almost all studied biotopes, both in abundance and species diversity. Arctic and arctic-boreal-montane species constitute 77% of the total fauna indicating that most species are specialized cryophiles. Flight capability is reduced in seven out of thirteen recorded species, and three species (*Pterostichus pinguedineus* (Esch., 1823), *Micralymma dicksoni* (Mäklin, 1878), *Chrysolina septentrionalis* (Mén., 1851)) are completely wingless. Dominance of flightless species in the fauna suggests their continuous presence in the island at least since the late Pleistocene.

РЕЗЮМЕ. На о-ве Шокальского (Карское море), расположенном на северном пределе западно-сибирского сектора Арктики (73°N), обнаружено 13 видов жесткокрылых из 6 семейств (Staphylinidae, 5; Dytiscidae, 3; Carabidae, 2; Helophoridae, 1; Silphidae, 1; Chrysomelidae, 1). Набор семейств соответствует таковым в других секторах Высокой Арктики, а видовой состав наиболее сходен со списками жуков северного Таймыра. Жуки-стафилины доминируют почти во всех изученных биотопах как по числу видов, так и по обилию. Почти 80% фауны составляют криобионтные виды — арктические и аркто-борео-монтанные. У 7 из 13 найденных видов способность к полёту ограничена, а три вида – *Pterostichus pinguedineus* (Esch., 1823), *Micralymma dicksoni* (Mäklin, 1878) и *Chrysolina septentrionalis* (Mén., 1851) — полностью бескрылы. Такая особенность фауны свидетельствует о ее преемственном развитии по крайней мере с конца плейстоцена.

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Introduction

Coleoptera are the largest insect order with about 387,000 described species [Ślipiński et al., 2011] belonging to 166 families [Lawrence, Newton, 1995]. The diversity of Coleoptera is unevenly distributed across the latitudinal gradient, and drops sharply at high latitudes [Danks, 1990; Chernov, 2002]. The arctic beetle fauna totals up to 700–750 species belonging to 24 families [Chernov *et al*., 2014]. Only 14% of Canadian beetle families were recorded north of the tree line [Danks, Foottit, 1989]. The Coleoptera species list for the High Arctic (the area encompassing both the subzone of arctic tundra and the polar desert zone) includes only about 70 species from ten families and this set of families is rather stable in different sectors of the Arctic [Chernov, Makarova, 2008].

Information about beetles of the High Arctic is scarce [see references in Chernov, Makarova, 2008] and only few species have been recorded in polar deserts [Makarova *et al*., 2007]. In arctic conditions, parts of dead beetle exoskeletons are often well preserved and can be used for species identification, making beetles an ideal group for detecting changes in the environment, both long [Ashworth, 2001; Kuzmina, 2017] and short [Coope, 1987] term, by comparing present and past beetle faunas. This approach is possible only if there are a sufficient number of reference points with well documented present day fauna. Arctic climate is changing particularly fast [IPCC, 2014] and this is another reason why it is important to inventory and analyze the contemporary beetle fauna in the extreme North of West Siberia. Few comprehensive species lists are available for local faunas across the Arctic and the northern-most published list for a local West Siberian fauna comes from a locality at the boundary between the arctic and typical tundra in the Venuyeuoyakhe River basin in the northern Yamal Peninsula at 71°04′N 72°20′E [Ryabitsev, 1997]. This is some 200 km south of the area described in present study.

In summer of 2016, two members of the scientific expedition of the Gydanskiy State Nature Reserve, Mikhail S. Bizin and Anna A. Nekhaeva made the first survey of arthropods of the Shokalsky Island, Kara Sea, located next to the northern tip of the Gydan Peninsula. Until now, only the bird and mammal fauna of the island have been documented [Kalyakin *et al*., 1999; Gorchakovskiy, 2015a, b; Dubrovsky, 2016; Dubrovsky *et al*., 2016]. The goal of present study is to describe the beetle fauna of the Shokalsky Island and compare it to other High Arctic faunas.

Materials and methods

Study area

Islands of the Kara Sea represent the remnants of the alluvial and lake plain that existed at the end of late Pleistocene and was subsequently destroyed by the rising sea [Kalyakin *et al*., 1999]. The Shokalsky Island is small, 30 km x 20 km, and located east of the Gulf of Ob mouth (Fig. 1), 5 km north of the Yavay Peninsula, the north-western part of the Gydan Peninsula, and separated from the continent by the narrow (5–9 km) and shallow (0.5–6 m) Gydan Strait. The island is composed of sands and surrounded by a shallow sea with pronounced tides. The island terrain is mostly smooth or with flat hills cut throughout by a network of brooks. Most of the island is a coastal terrace with elevation not exceeding 4–7 m (10.1 m is the maximum) [Kalyakin *et al*., 1999].

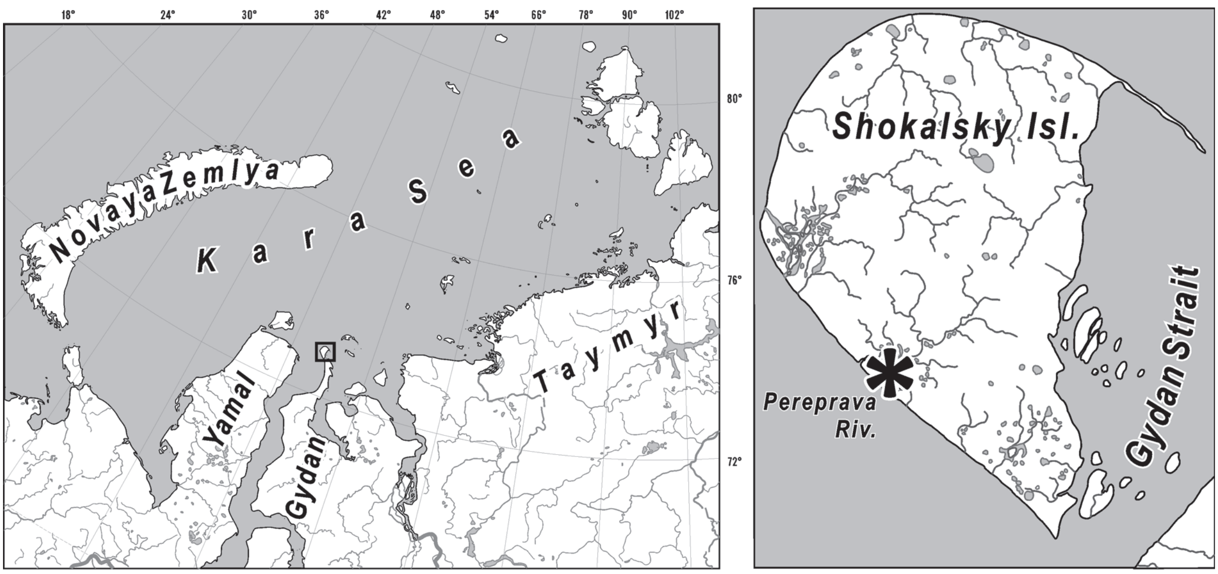
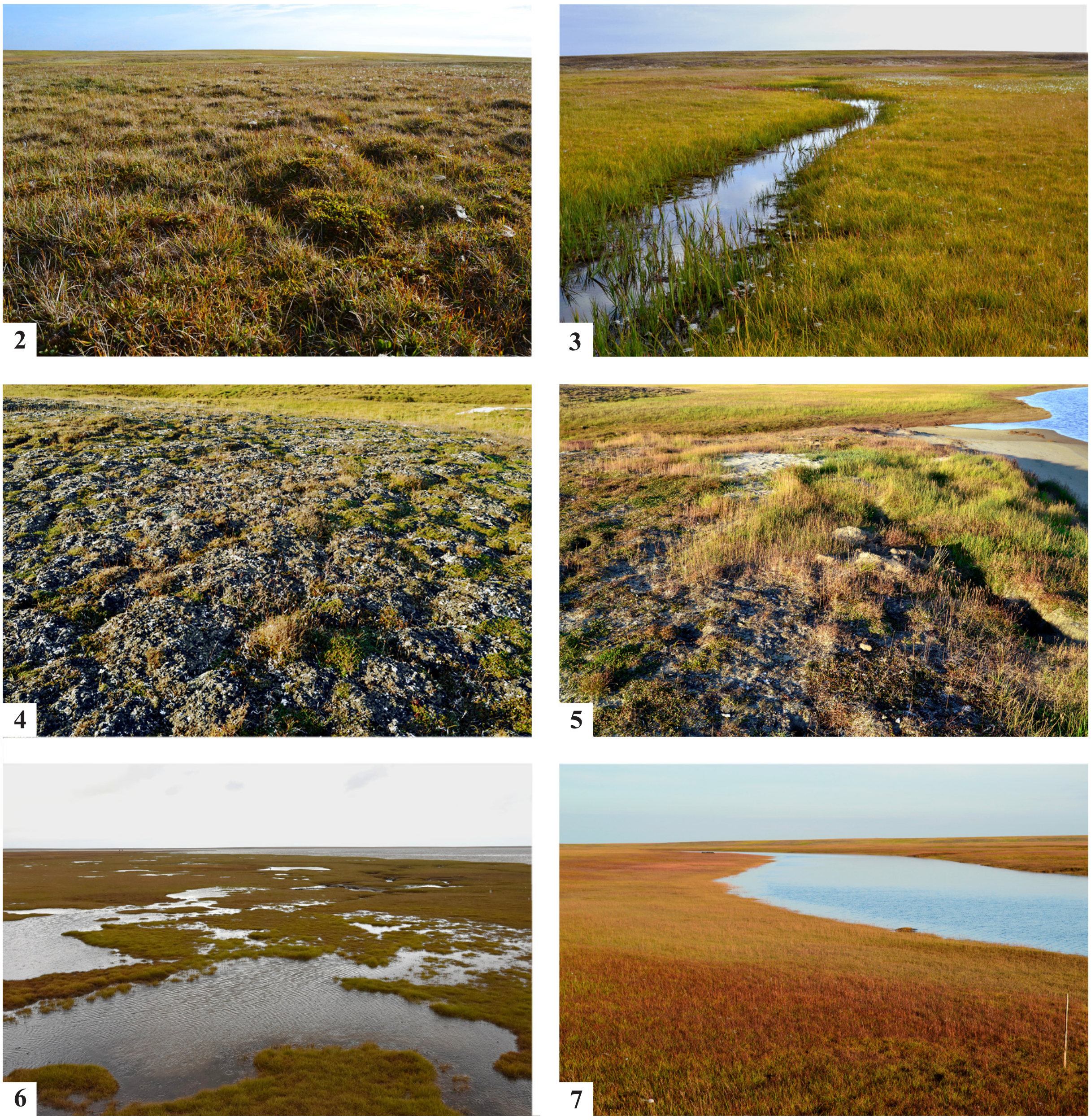


Fig. 1. Schematic map of the Kara Sea region, the extreme north of West Siberia. Study area is indicated with an asterisk.

Рис. 1. Схематическая карта региона Карского моря, крайний север Западной Сибири. Звездочкой отмечен район работ.

The island has Arctic climate, severe and humid, due to oceanic influence. During the last decade the mean annual temperature at the nearest observation point, Popov Weather Station (Belyy Island, northern Yamal Peninsula), was –8.7 °C, the mean temperature of July was 5.8 °C, and that of January was about –20 °C. Annual precipitation is just below 300 mm, with about 50% as rain. Relative air humidity is high, almost 90% on average [Weather Archive…, 2015]. Frost free period does not exceed two months, and the depth of seasonally thawed layer is about 0.8–1.2 m. The dominant soil types are Reductaquic Turbic Cryosols and Histic Reductaquic Turbic Cryosols [Kalyakin *et al*., 1999; classification by IUSS Working Group WRB, 2015].

Like northern part of the Gydan Peninsula, the Shokalsky Island is located within Yamal-Gydan subprovince of the European-West Siberian province of the Arctic floristic region [Yurtsev *et al*., 1978]. The vascular plant flora includes 99 species [Rebristaya, 2002]. Presently, about 350 individuals of wild reindeer live on the island [Gorchakovskiy, 2015a].



Figs 2–7. Typical biotopes studied: 2 — sedge-mossy hummocky tundra; 3 — cotton-grass bog; 4 — *Dryas* tundra; 5 — polar fox hill; 6 — low coastal marsh; 7 — geese molt site, bank of the Pereprava River (Shokalsky Island, Kara Sea, August 2016).

Рис. 2–7. Изученные типичные биотопы: 2 — осоково-моховая бугорковая тундра; 3 — пушицевое болото; 4 — дриадовая тундра; 5 — песцовое норовище; 6 — низкий приморский марш; 7 — гусиный линник на берегу р. Переправа (о-в Шокальского, Карское море, август 2016 г.).

Sampling

Terrestrial and aquatic beetles were collected in August 1–23, 2016 in the south-western part of the island near the Pereprava River mouth (72°58 N, 74°27 E), both manually and by traps (Table 1, Figs 2–7). Altogether thirty samples of soil or sifted litter were taken in different biotopes (Table 1) in 25 x 25 cm plots, up to 3–5 cm deep. Specimens were extracted from the samples manually, fixed in 75% ethanol for several hours and then transferred to 96% ethanol (Staphylinidae) or placed on cotton layers (all other families). The survey included also 650 trap-days for pitfall traps and 30 trap-days for bottle traps. A total of 357 adult beetles and 16 larvae were collected (currently deposited at the Department of Zoology and Ecology, Moscow Pedagogical State University, Russia and in the Natural History Museum, University of Oslo, Norway).

Statistical analysis

To compare beetle faunas of different High Arctic regions, we compiled species lists using earlier published data [Chernov, Makarova, 2008]. Faunal similarity between regions was estimated in PAST [Hammer *et al*., 2017] using Kulczynski index for qualitative (presence/absence) data. General geographical distribution of species was compiled mainly from Löbl and Smetana, [2004], Makarov *et al*. [2013], and Nilsson & Hajek [2017].

Table 1. Characteristics of the studied biotopes in the lower course of the Pereprava River, Shokalsky Island.
Таблица 1. Характеристика изученных биотопов (нижнее течение р. Переправа, о-в Шокальского).

Biotope	Landscape position	Coordinates	Dominant plant species	Collecting methods	
				PF	SS
Cotton-grass bog	Flat gulley of spring between gentle hills	72°56'04"N 74°18'38"E	*Eriophorum scheuchzeri, Carex concolor, Arctophila fulva, Hierochloë pauciflora, Poa* sp., *Aulacomnium turgidum, Rhizomnium* sp., *Dicranum* sp., *Sphagnum* sp.	160	–
Sedge-mossy-hummocky tundra (zonal community)	Gentle slope of hill, 700 m from the sea	72°56'07"N 74°18'34"E	*Carex arctisibirica, Salix polaris, Dryas punctata, Poa alpigena, Luzula confusa, Aulacomnium turgidum, A. palustre, Dicranum* sp., *Polytrichum* sp., *Hylocomium splendens, Cladonia* spp., *Peltigera rufescens*	176	4
Dryas tundra	Upper slope of the river valley, 15 m from the river	72°56'37"N 74°26'33"E	*Salix nummularia, Dryas punctata, Vaccinium vitis-idaea, Alopecurus alpinus, Aulacomnium turgidum, Hylocomium splendens, Racomitrium lanuginosum, Dicranum* sp., *Polytrichum* sp., *Cetraria islandica, Flavocetraria cuculata, Sphaerophorus globosus, Cladonia* spp., *Ochrolechia* sp., *Parmelia* sp., *Pertusaria* sp.	60	4
Polar fox hill	Upper slope of the river bank, 5 m from the river	72°56'37"N 74°26'33"E	*Salix nummularia, Poa alpigena, Alopecurus alpinus, Festuca* sp., *Racomitrium lanuginosum, Dicranum* sp., *Polytrichum* sp., *Cetrariella delisei, Sphaerophorus globosus, Parmelia* spp., *Bryocaulon divergens, Stereocaulon* sp.	97	4
Lower coastal marsh	Flat seashore in river delta	72°55'16"N 74°20'23"E	*Puccinellia phryganodes, Carex subspatacea, Stellaria humifusa*	24	6
Upper coastal marsh			*Deschampsia borealis, Poa* sp., *Dicranum* sp.	133	8
Geese molt site	Low bank of the river, 5 km from the mouth	72°56'22"N 74°24'13"E	*Phippsia algida*, *Festuca* sp., *Dicranum* sp.	–	4
Brook and shallow lakes in a bog	Bog in gulley	72°56'04"N 74°18'38"E	*Carex concolor*	30*	–

NOTES. PF — number of trap-days by pitfalls, SS — number of soil samples (25 x 25 cm) taken, * — bottle traps.
ПРИМЕЧАНИЕ. PF — число ловушко-суток, ловчие банки; SS — число взятых почвенных проб (25 x 25 см), * — водные ловушки.

Results and discussion

Taxonomy and species diversity

The total of 357 collected adult beetle specimens includes thirteen species (Table 2) representing six families as follows: Staphylinidae (5 species), Dytiscidae (3), Carabidae (2), Helophoridae (1), Silphidae (1), and Chrysomelidae (1). The number of species and the family set are typical for the arctic tundra subzone (Tables 2–4), but the Shokalsky fauna is more diverse than those of polar deserts [Chernov, Makarova, 2008]. Genus *Helophorus* Fabricius, 1775 has been recorded so far north only once, on the Yuzhnyi Island of the Novaya Zemlya Archipelago, at 73° N [Münster, 1925]. Silphids are recorded in the High Arctic for the first time.

Table 2. Beetle species found on the Shokalsky Island, their biotope and geographic characteristics.
Таблица 2. Виды жуков, найденные на о-ве Шокальского, и характеристика их биотопического распределения и ареалов.

Beetle taxa	**Flight capability**	**Bog**	**Sedge-mossy tundra**	***Dryas* tundra**	**Polar fox hill**	**Coastal marsh**		**Geese molt site**	**Range type**	
						Low	**High**		**Lon**	**Lat**
Carabidae										
Notiophilus aquaticus (L., 1758)	+				+				H	Pz
Pterostichus pinguedineus (Esch., 1823)	−		+	+	+				H	ABM
Dytiscidae										
Agabus moestus (Curtis, 1835)	±	+	+						H	A
Hydroporus erytrocephalus (L., 1758)	±	+					+		P	Pz
Hydroporus morio Aubé, 1838	±		+				+		H	AT
Helophoridae										
Helophorus sibiricus Motsch., 1860	+	+							H	ABM
Staphylinidae										
Boreophilia subplana (J.Sahlberg, 1880)	+		+						H	A
Micralymma dicksoni (Mäklin, 1878)	–		+	+	+	+			P	A
Olophrum boreale (Paykull, 1792)	+	+			+				H	ABM
Olophrum latum Mäklin, 1853	+	+			+	+		+	H	ABM
Tachinus arcticus (Motsch., 1860)	+	+	+	+	+	+			P	A
Silphidae										
Thanatophilus ?lapponicus (Herbst, 1793)*	+				+				H	ABM
Chrysomelidae										
Chrysolina septentrionalis (Mén., 1851)	–	+	+				+		H	A

NOTES. Flight capability: “+” — species capable of flying, “±” — dimorphic species (some specimens with fully developed wings, some with reduced wings and/or wing muscles), “–“ — wings and/or wing muscles always reduced. Range types: Lon (longitudinal characteristic) — H, Holarctic; P, Palaearctic; Lat (latitudinal characteristic) — A, arctic; B, boreal; M, montane, south of boreal zone; T, temperate; Pz, polyzonal. * — only larvae available.

ПРИМЕЧАНИЕ. Способность к полету: “+” — летающий вид, “±” — диморфный вид (у части экземпляров задние крылья полностью развиты, у части задние крылья и/или крыловые мышцы редуцированы), “–“ — задние крылья и/или крыловые мышцы всегда редуцированы. Типы ареалов: Lon (долготная характеристика) — H, голарктический; P, палеарктический; Lat (широтная характеристика) — A, арктический; B, бореальный; M, встречается в горах к югу от бореальной зоны; T, температный; Pz, полизональный. * — найдены только личинки.

As in other arctic regions [see references in Chernov, Makarova, 2008], Staphylinidae, the largest family of insects [Irmler *et al*., 2018], are the most diverse beetle family on Shokalsky. The five recorded species belong to three subfamilies, Omaliinae, Tachyporinae and Aleocharinae, forming the typical High Arctic set with prevalence of Omaliinae (3 species) [Chernov *et al*., 2014].

Single specimens of coccinellids (*Calvia quatuordecimguttata* (Linnaeus, 1758) and *Adalia bipunctata frigida* (Schneider, 1792)), and also dytiscid *Colymbetes dolabratus* (Paykull, 1798), all found dead in seaweed on the beach, should probably be treated as non-native to Shokalsky. The northernmost known record of the latter species in West Siberia is in the northern Yamal Peninsula, some 200 km south of Shokalsky [Ryabitsev, 1997]. The two mentioned species of coccinellids have not been recorded in West Siberia north of 69° N [Zinovyev, Olshvang, 2003].

Based on ratios among families, the structure of the terrestrial beetle fauna of Shokalsky is most similar to those of the Severnyi Island of the Novaya Zemlya Archipelago [Økland, 1928] and north-western Taymyr Peninsula [Khruleva, 1999]. Dytiscidae of Shokalsky are much less diverse than on Vaygach Island (69°49′ N), where sampling of similar intensity resulted in 9 species [Prokin *et al*., 2017].

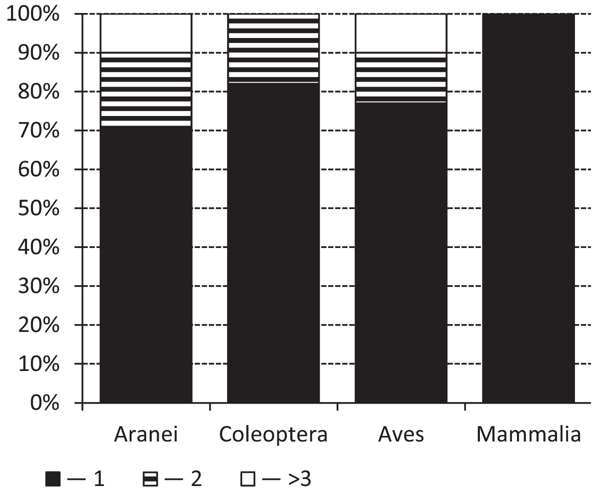


Fig. 8. Proportions of genera represented in the Shokalsky fauna by one (1), two (2), and three or more (>3) species in major animal taxa, based on Kalyakin *et al*., 1999; Gorchakovskiy, 2015a, b; Dubrovsky, 2016; Dubrovsky *et al*., 2016; Nekhaeva, 2018 and our own data.

Рис. 8. Доли родов, представленных в фауне о-ва Шокальского разным числом видов, в крупных группах животных. Источники: Калякин и др., 1999; Gorchakovskiy, 2015a, b; Dubrovsky, 2016; Dubrovsky *et al*., 2016; Nekhaeva, 2018 и собственные данные.

Table 3. Structure of beetle assemblages in different biotopes of the Shokalsky Island.
Таблица 3. Структура сообществ жуков в различных биотопах о-ва Шокальского.

Species / Method	Bog	Sedge-mossy-tundra		*Dryas* tundra		Polar fox hill		Coastal marshes		Geese molt site	Total, ind.*
	PF	PF	SS	PF	SS	PF	SS	PF	SS	SS	
Tachinus arcticus	8.1	35.2	0.8	10.0	–	2.1	–	0.9	0.7	–	121
Olophrum latum	1.3	–	–	–	–	13.4	–	16.0	3.1	0.5	99
Micralymma dicksoni	–	9.7	2.3	5.0	0.3	1.0	0.3	–	0.6	–	47
Pterostichus pinguedineus	–	5.1	–	10.0	–	5.2	–	–	–	–	47
Agabus moestus	8.8	0.6	–	–	–	–	–	–	–	–	18
Olophrum boreale	5.0	–	–	–	–	1.0	–	–	–	–	9
Hydroporus morio	–	0.6	–	–	–	–	–	1.2	–	–	5
Hydroporus erytrocephalus	0.6	–	–	–	–	–	–	3.6	–	–	4
Chrysolina septentrionalis	0.6	0.6	–	–	–	–	–	–	–	–	4
Thanatophilus ?lapponicus	–	–	–	–	–	2.0	–				2
Helophorus sibiricus	0.6	–	–	–	–	–	–	–	–	–	1
Notiophilus aquaticus	–	–	–	–	–	1.0	–	–	–	–	1
Boreophilia subplana	–	–	–	–	–	–	–	–	–	–	1
Staphylinidae, larvae	1.3	–	–	–	–	–	–	11.3	–	0.5	14

NOTES. PF — species activity (dynamic density) assessed by pitfall traps, number of specimens per 100 trap-days; SS — species density in soil samples (25 x 25 cm) including sifted samples, number of specimens per sample; * — the total number of collected specimens, including those collected manually or with cylinder traps for lemmings.

ПРИМЕЧАНИЕ. PF — уловистость по данным почвенных ловушек, экз./100 ловушко-суток; SS — плотность по данным разборки почвенных проб (25 x 25 см), в том числе просеянных через энтомологическое сито, экз./проба; * — общее число экземпляров, в том числе собранных вручную и ловчими цилиндрами для учета леммингов.

The beetle fauna of Shokalsky is the northernmost among the described faunas of West Siberia. Prior to our study the northernmost described beetle fauna of West Siberia was that of the environs of Venuyeuo (71°04′ N, 72°20′ E) in the northern Yamal Peninsula [Ryabitsev, 1997].

Most genera (82%) and half of the families in the Shokalsky fauna are represented by a single species, confirming the opinion that the Far North beetle fauna is taxonomically fragmented [Chernov, Matveyeva, 1979]. Other groups of animals (Fig. 8), particularly mammals, demonstrate the same pattern [Kalyakin *et al*., 1999; Gorchakovskiy, 2015a; Dubrovsky, 2016].

Geographical structure of the fauna and its similarity

The majority of recorded species (Table 2) are typical elements of the arctic fauna, widely distributed in tundra of the Holarctic (10 species) or Palaearctic (3 species) regions. Absence of species with longitudinally narrow ranges (European, Siberian, etc.) possibly reflects the general trend of circumpolar distribution common in species of the northern Holarctic [Danks, 1981]. Specialized cryophilous species represent 77% of the Shokalsky fauna: five species have arctic-boreal-montane ranges (i.e. in addition to tundra and taiga zones, they inhabit mountainous areas in more southern zones), and five species are strictly arctic.

Table 4. Species diversity, family composition, and species flight capability in beetle faunas of some tundra regions of the High Arctic.

Таблица 4. Видовое разнообразие, набор семейств и способность к полету видов в тундровых фаунах жуков Высокой Арктики.

Acronym	Island/Region	Latitude, °N	July mean temperature °C[1)]	Number of species[2)]	Number of species, by family	Sources of species records	Flight capabilities, percentage of species in the fauna*		
							+	±	–
GRE	N Greenland	69.0–83.0	+4.8	7(7)	Ca(1), Dy(2), St(2), By(1), Cc(1)	Böcher, 1988	57	29	14
SPI	Spitsbergen, Svalbard	76.6–80.1	+6.3	14(13)	Ca(1), St(7), By(1), Cr(2), An(1), La(1), Cu(1)	Coulson, 2013; Coulson et al., 2014	77	15	8
NNZ	Severnyi Island, Novaya Zemlya	73.2–77.0	+4.0	12(10)	Ca(2), St(8), Ch(2)	Jacobson, 1898; Münster, 1925; Økland, 1928	50	10	40
SHO	Shokalsky Island, Kara Sea	73.0	+5.8	13(13)	Ca(2), Dy(3), He(1), St(5), Si(1), Ch(1)	New data	46	31	23
NT1	Meduza Bay, NW Taimyr	73.4	+5.0	17(16)	Ca(3), Dy(1), St(9), Ch(2), Cu(2)	Khruleva, 1999; Chernov, Makarova, 2008	20	20	60
NT2	Uboynaya River (lower reaches), NW Taimyr	73.6	+4.5	14(13)	Ca(5), St(5), Ch(3), Cu(1)	Chernov, Makarova, 2008	8	15	77
NT3	M.Pronchishcheva Bay, NE Taimyr	75.9	+4.0	9(9)	Ca(3), St(3), Ch(3)	Chernov, Makarova, 2008	11	11	78
ALA	Cape Barrow, Alaska	71.2	+3.8	15(12)	Ca(4), Dy(1), St(6), Ch(4)	References in Chernov, Makarova, 2008	0	17	83

ABBREVIATIONS: Ca — Carabidae, Dy — Dytiscidae, He — Helophoridae, St — Staphylinidae, Si — Silphidae, By — Byrrhidae, Cr — Cryptophagidae, La — Latridiidae, An — Anthicidae, Ch — Chrysomelidae, Cu — Curculionidae, Cc — Coccinellidae.

1) The highest value for the region is given.

2) Number of species with known flight capability is given in parentheses.

* Species flight capability is classified in three categories as in Table 2.

СОКРАЩЕНИЯ: Ca — Carabidae, Dy — Dytiscidae, He — Helophoridae, St — Staphylinidae, Si — Silphidae, By — Byrrhidae, Cr — Cryptophagidae, La — Latridiidae, An — Anthicidae, Ch — Chrysomelidae, Cu — Curculionidae, Cc — Coccinellidae.

1) Приведены наибольшие значения для региона.

2) В скобках указано число видов, для которых известна способность или неспособность к полету.

* Способность вида к полету как в Таблице 2.

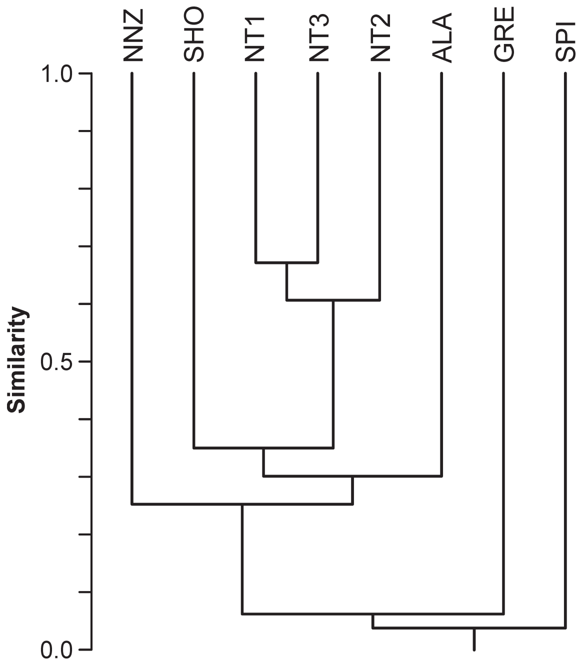


Fig. 9. Dendrogram of faunistic similarity among beetle faunas of some High Arctic tundra regions (based on data from Appendix; Kulczynski index). Acronym as in Table 2.

Рис. 9. Дендрограмма фаунистического сходства колеоптерофаун тундровых районов Высокой Арктики (по данным Приложения; индекс Кульчинского). Сокращения как в Табл. 2.

The vascular plant flora and vertebrate fauna of Shokalsky are also composed of primarily arctic species [Kalyakin *et al*., 1999; Rebristaya, 2002; Gorchakovskiy, 2015b; Dubrovsky *et al*., 2016].

Based on our newly obtained data and published information, we compared the beetle fauna of Shokalsky with those of other High Arctic tundra regions (Appendix). A dendrogram based on Kulczynski index illustrates similarity among the compared faunas (Fig. 9). All three regional northern Taymyr faunas are similar and cluster together (Kulczynski index >60%). The Shokalsky fauna is most similar to the Taymyr cluster of faunas taken together, but the similarity is low (35%), just barely higher than with the fauna of Barrow, northern Alaska. Similarity of the five mentioned faunas with that of Novaya Zemlya is even lower (24%). Still, the youngest (in geological sense) faunas of the Spitsbergen Archipelago and northern Greenland differ from the rest much more. Thus, the circumpolar High Arctic beetle fauna is very heterogeneous in species composition.

Assemblages

In most biotopes, from 3 to 7 beetle species were recorded (Table 3). Only the geese molt site, a eutrophic and trampled area (Fig. 7), appeared to be a "beetle desert". Costal saline marshes (Fig. 6) were populated by non-specialists, i.e. no halophilous species were found. Larvae of the carrion beetle *Thanatophilus* were collected only in pitfall traps placed at the polar fox hill (Fig. 5).

In terms of abundance, rove beetles prevailed in all studied biotopes (Table 3). Their share accounts for 78% of all the collected beetle specimens. The highest numbers of staphylinid specimens collected by traps was recorded in the zonal community of sedge-mossy-hummocky tundra, 45 individuals per 100 trap-days (in other biotopes, excluding the geese molt site, only 14–18 individuals per 100 trap-days).

Some species, such as *Pterostichus pinguedineus* and *Micralymma dicksoni,* were more numerous in well drained biotopes whereas *Agabus moestus* and *Olophrum boreale* preferred humid biotopes. The most abundant species, *Tachinus arcticus* and *Olophrum latum*, were abundant in different and even contrasting biotopes.

Preference of *M. dicksoni* for relatively warm drained biotopes becomes far more pronounced northward, in the Severnaya Zemlya Archipelago (polar desert zone), where this species is restricted to dry sites with the longest growing season [Makarova *et al*., 2007].

A typical tundra inhabitant, *T. arcticus* is in general common in the northern Yamal Peninsula [Zinovyev *et al*., 2001]. It is also typical of arctic tundra in the northern Taymyr Peninsula [Chernov, 1978]. However, this species is absent from the rather well studied southern part of Yamal [Zinovyev, Olshvang, 2003]. In this connection, it is very interesting to note that *T. arcticus* occured in the southern Yamal during the last cold stage of Holocene, in Sub-boreal time, 2000–3000 years ago [Zinovyev *et al*., 2001].

Flight capabilities

Flight capabilities are limited in 7 out of 13 recorded species (Table 2). All individuals are absolutely wingless in *P. pinguedineus, M. dicksoni,* and *Chrysolina septentrionalis*. In all recorded dytiscid species and in *Notiophilus aquaticus*, facultative reduction of wings (brachyptery) and/or reduction of wing musculature are known [Eriksson, 1972; Lindroth, 1992; Larson *et al*., 2000; etc.]. Flight suppression saves resources, such as energy and body volume, that are significant for reproduction and development [Roff, 1990]. In cold conditions the necessity to save energy results in prevalence of wingless and dimorphic species [Ås, 1984; Roff, 1990; Chernov, Makarova, 2008]. Percentage of non-flying beetles generally increases northwards [Lindroth, 1957; Downes, 1965] and the well-established arctic beetle faunas comprise mainly brachypterous or dimorphic species [see references in Chernov, Makarova, 2008]. On the contrary, young migratory faunas in the High Arctic consist mainly of well dispersing species, usually capable of flying (Fig. 10).

Although during the last glacial maximum the present day Shokalsky Island was a part of the continent [Rekant, Vasiliev, 2011], at the end of late Pleistocene the sea level in this region was 5–6 m higher than today [Slagoda *et al*., 2014], i.e. most of today's island (with its elevation of 4–7 m) must have been submerged. Similar fluctuations of sea level occured multiple times during the Holocene [Makarov, Trunin, 2016]. Therefore, presence of wingless beetle species on the island indirectly indicates that at least a part of it was continuously exposed since the late Pleistocene.

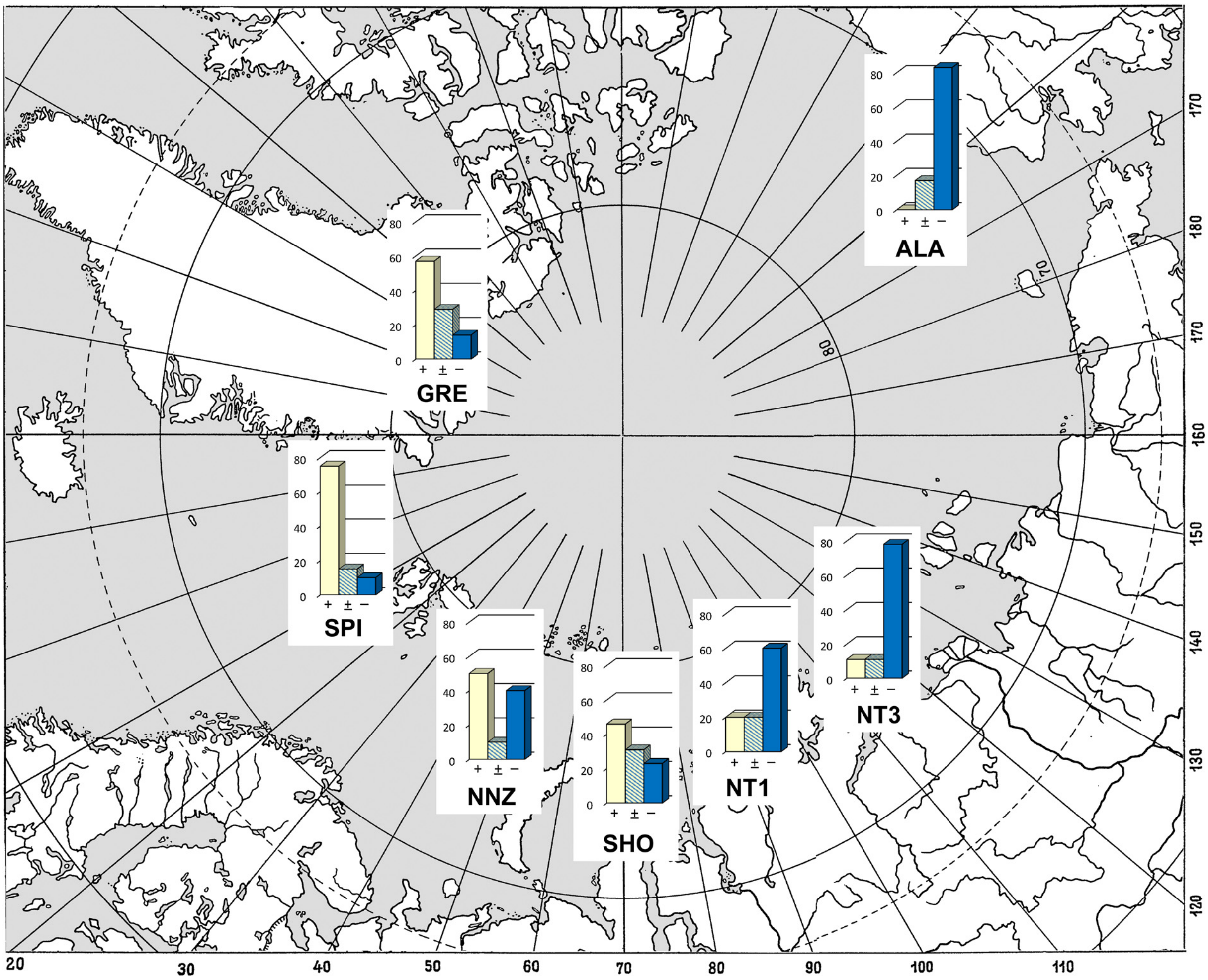


Fig. 10. Species flight capability in local beetle faunas in different sectors of the High Arctic (based on data from Table 4). Acronyms of islands and regions as in Table 4. Species flight capability is classified in three categories as in Table 2 (+, +, –).

Рис. 10. Способность к полету видов в локальных фаунах жуков в различных секторах Высокой Арктики (по данным Таблицы 4). Сокращения названий островов и регионов как в Таблице 4. Способность вида к полету как в Таблице 2 (+, +, –).

Conclusion

The beetle fauna of the Shokalsky Island is mainly composed of specialized cryophilous species (arctic and arctic-boreal-montane). A relative ease of beetle sampling, availability of data about local beetle faunas across the Yamal Peninsula and adjacent regions [Ryabitsev, 1997; Zinovyev, Olshvang, 2003; Andreyeva, Petrov, 2004], particularly along latitudinal transect [Lomakin, Zinovyev, 1997; Kozyrev *et al*., 2018], observed differences among local faunas and good preservation of beetles as subfossils, suggest that beetles are a very promising group for monitoring of environmental changes in the Far North.

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APPENDIX. A list of beetle species in some High Arctic tundra regions [Chernov, Makarova, 2008; new data]
ПРИЛОЖЕНИЕ. Список видов жесткокрылых в тундровых районах Высокой Арктики [по: Chernov, Makarova, 2008; новые данные]

Species, flight capability*	Island/Region**							
	GRE	SPI	NNZ	SHO	NT1	NT2	NT3	ALA
Carabidae								
Notiophilus aquaticus (L., 1758) (±)				+		+		
Bembidion grapii (Gyll., 1827) (±)	+							
Bembidion hastii C. Sahlb., 1827 (+)							+	
Pterostichus (*Cryobius*) *ventricosus* (Esch., 1823) (–)			+				+	
Pterostichus (*Cryobius*) *brevicornis* (Kirby, 1837) (–)					+	+	+	
Pterostichus (*Cryobius*) *pinguedineus* (Esch., 1823) (–)				+	+	+	+	+
Pterostichus (*Cryobius*) *nivalis* (R. Sahlb., 1844) (–)								+
Pterostichus (*Cryobius*) *cf. longipes* (Popp., 1906) (–)							+	
Pterostichus (*Cryobius*) *tareumiut* Ball, 1962 (–)								+
Pterostichus (*Lenapterus*) *agonus* G.Horn, 1880 (–)						+	+	
Curtonotus alpinus (Payk., 1790) (±)			+		+	+	+	+
Amara quenseli (Schönh., 1806) (±)		+						
Amara glacialis (Mnnh., 1853) (+)							+	
Dytiscidae								
Hydroporus morio Aubé, 1838 (±)	+			+				
Hydroporus erytrocephalus (L., 1758) (±)				+				
Agabus moestus (Curtis, 1835) (±)				+	+			+
Colymbetes dolabratus (Payk., 1798) (+)	+							
Helophoridae								
Helophorus sibiricus Motsch., 1860 (+)				+				
Staphylinidae								
Micralymma brevilingue Schiødte, 1845 (–)	+							+
Micralymma dicksoni (Mäklin, 1878) (–)				+	+	+	+	
Micralymma marinum (Strøm, 1783) (–)		+						
Micralymma sp.								+
Phyllodrepa angustata (Mäklin, 1878) (+)			+		+		+	
Coryphiomorphus hyperboreus (Mäklin, 1880) (+)			+					
Coryphiomorphus sp. (?)					+			
Eudectus whitei Sharp, 1871 (+)			+		+			
Olophrum boreale (Payk., 1792) (+)		+		+				

APPENDIX. (continued)
ПРИЛОЖЕНИЕ. (продолжение)

Species, flight capability*	Island/Region**							
	GRE	SPI	NNZ	SHO	NT1	NT2	NT3	ALA
Olophrum latum Mäklin, 1853 (+)				+				
Omalium caesum Grav., 1806 (+)		+						
Eucnecosum brachypterum (Grav., 1802) (±)		+						
Holoboreaphilus nordenskioldi (Mäklin, 1878) (–)			+					+
Tachinus arcticus (Motsch., 1860) (+)				+	+	+	+	
Tachinus brevipennis J. Sahlb., 1880 (–)					+	+	+	+
Tachinus instabilis Mäklin, 1853 (+)								+
Atheta (*Atheta*) *holtedahli* Mnst., 1825 (?)			+					
Atheta (*Alaobia*) *trinotata* (Kr., 1856) (?)			+					
Atheta (s. str.) *graminicola* (Grav., 1806) (+)		+						
Atheta (*Oreostiba*) *lenensis* Popp., 1909 (–)							+	
Atheta (*Boreostiba*) *sibirica* (Mäklin, 1880) (+)			+					
Atheta sp. 1 (?)		+						
Boreophilia subplana (J. Sahlb., 1880) (+)		+		+			+	
Gnypeta brincki Palm, 1966 (?+)					+			
Gnypeta cavicollis J. Sahlb., 1880 (+)	+		+					
Stenus frigidus J. Sahlb., 1880 (–)					+			
Lathrobium poljarne tchernovi Tikh., 1976 (–)					+	+	+	
Staphylinidae gen. sp. (?)						+		+
Silphidae								
Thanatophilus ?lapponicus (Herbst, 1793) (+)				+				
Byrrhidae								
Byrrhus fasciatus (Förster, 1771) (+)	+							
Simplocaria metallica (Sturm, 1807) (+)		+						
Cryptophagidae								
Atomaria atricapilla angulicollis Kangas, 1973 (+)		+						
Atomaria lewisi Reitt., 1877 (+)		+						
Coccinellidae								
Coccinella transversoguttata Fald., 1835 (+)	+							
Latridiidae								
Latridius minutus (L., 1767) (+)		+						
Anthicidae								
Anthicus flavipes (Panz., 1797) (+)		+						
Chrysomelidae								
Chrysolina (*Arctolina*) *septentrionalis* (Mén., 1851) (–)			+	+	+	+	+	+
Chrysolina (*Arctolina*) *subsulcata* (Mnnh., 1853) (–)						+		+
Chrysolina (*Arctolina*) *magniceps* (J. Sahlb., 1887) (–)								+
Chrysolina (*Pleurosticha*) *cavigera* (J. Sahlb., 1887) (–)								+
Hydrothassa hannoverana (F., 1775) (–)			+		+	+	+	
Curculionidae								
Hypera diversipunctata (Schrank, 1798) (±)					+		+	
Hypera ornata (Capiomont, 1868) (–)						+		
Isochnus flagellum (Erics., 1902) (+)		+						
Isochnus arcticus (Korot., 1977) (–)					+		+	

NOTES. * —Flight capability classified in three categories as in Table 2; (?) — no data. Sources: Eriksson, 1972; Chernov, Makarova, 2008; new data; ** — acronyms of islands and regions as in Table 4.

ПРИМЕЧАНИЕ. * — Способность вида к полету как в Таблице 2; (?) — нет сведений. Источники: Eriksson, 1972; Chernov, Makarova, 2008; новые данные; ** — сокращения названий островов и регионов как в Таблице 4.