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Research Article

Methodology for a local fauna study of ground beetles (Coleoptera, Carabidae) in the forest-tundra zone of the Polar Urals, Russia

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Abstract

An important step in research planning is the choice of methodology. This is especially important for territories which are difficult to access such as in the Arctic, where successive repetitions of field works require significant resources. The methodology utilizing the local fauna has been used over the past twenty years. It provides comparable data on the structure of fauna and species richness for different territories. The purpose of the present study was to assess the “local fauna method” with respect to fauna studies of ground beetles in the Arctic forest-tundra zone. The research was conducted from June 18 2017 to August 30 2017 within the Polar Urals (10 km from the Harp settlement in the Yamalo-Nenets Autonomous Okrug, which is a state of Russia). Carabids were sampled by using pitfall traps on 20 sites. This article will also include the results of our previous research concerning the structure of some local faunas from the forest-tundra zone of Nenets Autonomous Okrug (settlements Nes’, Oma, Khorey-Ver). The results of this study demonstrate the following: 1) the local fauna of the Polar Urals has 85 species of ground beetles from 25 genera, which is 77% of species lists of carabids for a 70-year period of research within the Polar Urals; 2) the local fauna of the Polar Urals has 29% similarity of list species with local faunas from the European part of the Arctic, with similar compositions of zoogeographical groups and life forms; 3) in one research period there was 90% detection of carabids species in the forest-tundra local fauna using the sampling method of pitfall traps within a period of 40 days, conducted at 15 sites, with the predominance of southern types of plant communities (meadows, forests).

Keywords

ground beetles, Coleoptera (Carabidae), local fauna, forest-tundra, Arctic.

Introduction

Studies of ground beetle faunas (Coleoptera, Carabidae) in the Polar Urals have been systematically conducted over the last 60 years (Stebaev 1959, Olshvang 1980, Korobeinikov 1984, Zinovyev and Olshvang 2003, Uzhakina and Dolgin 2007). At the same time, ground beetle species from different geographic locations in Polar Urals range from 26 to 110 species (Stebaev 1959; Olshvang, 1980, Lomakin and Zinoviev 1997, Kozyrev et al. 2018). This is due to the different approaches to material collecting, the number of study sites and the research periods. Collected data characterize the species richness of ground beetles of the Polar Urals area in general but this is not applicable to comparative analysis due to its methodological heterogeneity.

In recent years the local fauna concept has been used in faunistic research (Penev 1996, Bolotov and Danilevich 2005, Filippov 2008, Makarov and Matalin 2009, Kolosova and Potapov 2010, Tatarinov and Kulakova 2010). The term "local flora" was proposed by Tolmachev (Tolmachev 1931) and this was later borrowed by Chernov (Chernov 1975) in zoological studies in the form of "local fauna". Penev (Penev 1996) clarified this concept for a zoological approach as in a territory of 100 km^2 in a certain biome. Using the local fauna approach it is possible to obtain comparable data on species richness and fauna structures of soil invertebrates with the determination of the maximum species compositions for a certain territory. This method was used for studying ground beetle local fauna of semi-deserts in the Volga Region (Makarov and Matalin 2009) and the European sector of the Russian Arctic (Filippov and Shuvalov 2005, Filippov 2008, Markov 2011, Zubriy and Filippov 2015). The main aim of the present research was to study the ground beetle local fauna of the Polar Urals forest-tundra zone and to estimate the effectiveness of species richness determination.

Materials and methods

Local fauna field works of ground beetles from the Polar Urals forest-tundra zone were conducted at a distance of 10 km from Kharp settlement (Yamalo-Nenets Autonomous Okrug, Russia) from 18 June 2017 to 30 August 2017 (see Fig. 1). Within 20 model sites, the main types of plant communities were selected: gramineous-herb meadows, upland sphagnous, sedge and dwarf birch bogs, moss-lichen and shrub tundras, and also larch forests, spruce forests and alder forests (see Table 1).

Ground beetles were collected using pitfall traps (Heydemann, 1956) – 500 ml plastic cups with a trap hole diameter of 93 mm. In each site 10–25 traps were installed in parallel lines with a distance of 10 m between traps and lines. For fixing insects 4% formaldehyde solution was used. The material was sampled from the traps once every ten days. Carabids near water bodies were collected using the exhaustion trapping method. As result, 375 traps were installed for a total of 24,852 trap-days and 6,409 specimens of imago were sampled (see Table 1).

The list of Russian ground beetles (Makarov et al. 2016) and the Catalogue of Palaearctic ground beetles (Löbl and Löbl 2017) were used for taxonomic classification.

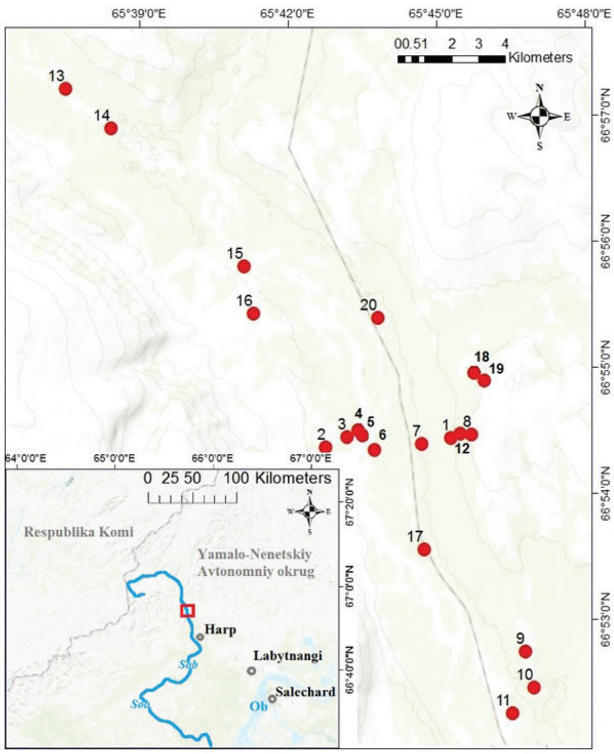


Fig. 1. Study sites (see Table 1 for numbers of sampling sites)

Table 1. Sampling sites in the Polar Urals

No.	Site	Pitfall traps (number)	Pitfall trap-days	Imago specimens (number)
1	Sphagnum-ledum bog	20	1,350	196
2	Meadow grass	20	1,469	303
3	Green-mossy bog with dwarf birch	20	1,364	372
4	Forest glade	10	699	145
5	Meadow grass	20	1,418	364
6	Meadow grass	10	679	321
7	Birch-fir forest	20	1,370	949
8	Moss-shrub tundra	20	1,270	443
9	Rocky moss-lichen tundra with larch	20	1,400	27
10	Fir-wood ledum-green-mossy	20	1,420	140
11	Rocky moss-shrub tundra	20	1,420	153
12	Thickets of alders with grass	20	1,341	318
13	Meadow grass	20	1,380	608
14	Larch forest with moss and shrubs	20	1,331	139
15	Meadow grass	15	1,035	891
16	Moss-lichen-shrub tundra	20	1,380	198
17	Sphagnum-ledum bog with dwarf birch	20	1,311	208
18	Moss-ledum bog	20	1,216	47
19	Rocky moss-shrub tundra	20	1,216	420
20	Grass bog	20	698	38
	by exhauster (waterside sites)			129
Total:		**375**	**24,852**	**6,409**

Information about ground beetles of Fennoscandia was used for fauna the zoogeographical analysis (Lindroth 1992). Carabid habitat preferences in the tundra zone were determined by using the authors' own data and also by using published data (Lindroth 1992, Dudko et al. 2010, Khobrakova et al. 2014). Categorization of the species in respect of their life forms was made according to the classification of Sharova (1981).

For determining the full species richness in the forest-tundra zone of the Polar Urals, field work periods and the number of sites in different habitat types were estimated by using the authors' own previous data on local faunas in the European Arctic sector (see Table 2).

Carabid species similarity among local faunas of the North Europe and Polar Urals was assessed by using the Jaccard index in a dendrogram of cluster analysis via the simple average link algorithm in the BioDiversityPro software (McAleece et al. 1997). Species accumulation curves were estimated as a function of research periods, number of sample sites and habitat types of local fauna of the forest-tundra zone of the northern part of Europe and the Polar Urals. The species richness cumulate rates for local fauna and different communities were estimated by rarefaction procedure in the EstimateS software version 9.1.0 (Colwell 2013). The Akaike Information Criterion (AIC) was applied to a selection of models and describes the forecast trend lines for new species appearance with an increase in samples (Hammer 2015).

Table 2. Local faunas of the Nenets Autonomous Area

Settlement	Research period (ten-day periods)	Number of sites, n	Number of species: pitfall traps/total, s	Number of carabids individuals, n
Nes	27 Jun – 23 Aug 2002 (5)	8	74/74	7,728
Oma	3 Jun – 1 Sep 2008 (7)	12	63/80	6,361
Khorey-Ver	12 Jun – 22 Aug 2013 (6)	6	50/50	1388

Results

For ground beetle local fauna of Polar Urals forest-tundra zone, 85 species from 25 genera were established (see Table 3). The taxonomic structure demonstrated the highest participation of genera representatives: *Pterostichus* (15 species), *Bembidion* (12 species), *Amara* (11 species) and *Agonum* (8 species).

The carabid species belonged to 4 zoogeographical categories. The greatest presence was exemplified by Palearctic species - 56.5%; the Northern Holarctic faunal type accounted for 31.8%; the Euro-Siberian faunal type accounted for 8.2%; and the European faunal type accounted for 3.5% (see Table 3).

Representatives of the class Zoophagous predominated in imago life forms of ground beetle species – 78.8% (see Table 4).

The life forms of the ground beetle species in this study belonged to 12 groups. Most of the zoophages belonged to the subclass Stratobios: surface and litter-dwelling stratobionts (30.5%), litter-dwelling stratobionts (17.6%). Among the mixophytophagous species, the haploid geohortobionts predominated (12.9%).

On a dendrogram of species similarity, the Polar Urals carabid cluster has relatively low association (29.3%) with North Europe local faunas of the forest-tundra zone (see Fig. 2). The local faunas of

Table 3. List of Carabidae beetles, established for Polar Urals local fauna

No.	Species	[1]Zoogeographical groups	[2]Life forms of imago	Number of specimens
1	*Trachypachus zetterstedtii* (Gyllenhal, 1827)*	PAL	1.1.1	1
2	*Pelophila borealis* (Paykull, 1790)	HOL	1.2.1	5
3	*Leistus terminatus* (Hellwig in Panzer, 1793)	PAL	1.2.2	1
4	*Nebria rufescens* (Ström, 1768)	HOL	1.2.1	6
5	*N. nivalis* (Paykull, 1790)	PAL	1.2.1	1
6	*Notiophilus aquaticus* (Linnaeus, 1758)	HOL	1.2.1	99
7	*N. biguttatus* (Fabricius, 1779)	E-SI	1.2.1	10
8	*N. reitteri* (Späth, 1899)	PAL	1.2.1	48
9	*Carabus nitens* (Linnaeus, 1758)	EUR	1.1.1	22
10	*C. truncaticollis* (Eschscholtz, 1833)	HOL	1.1.1	57
11	*C. henningi* (Fischer von Waldheim, 1817)	PAL	1.1.1	32
12	*C. odoratus* (Motschulsky, 1844)	PAL	1.1.1	81
13	*Cychrus caraboides* (Linnaeus, 1758)	EUR	1.1.1	7
14	*Diacheila arctica* (Gyllenhal, 1810)	HOL	1.1.1	3
15	*Diacheila polita* (Faldermann, 1835)	PAL	1.1.1	169
16	*Blethisa multipunctata* (Linnaeus, 1758)	HOL	1.2.1	17
17	*B. catenaria* (Brown, 1944)	HOL	1.2.1	1
18	*Elaphrus angusticollis* (R.F. Sahlberg, 1844)	E-SI	1.2.1	21
19	*E. lapponicus* (Gyllenhal, 1810)	PAL	1.2.1	33
20	*Loricera pilicornis* (Fabricius, 1775)	HOL	1.2.1	29
21	*Clivina fossor* (Linnaeus, 1758)	HOL	1.3.1	20
22	*Dyschiriodes globosus* (Herbst, 1783)	PAL	1.3.1	6
23	*D. melancholicus* (Putzeys 1866)	PAL	1.3.1	1
24	*D. nigricornis* (Motschulsky, 1844)	PAL	1.3.1	2
25	*D. neresheimeri* (H. Wagner, 1915)	E-SI	1.3.1	1
26	*Miscodera arctica* (Paykull, 1798)	HOL	1.2.3	18
27	*Bembidion properans* (Stephens, 1829)	PAL	1.2.1	50
28	*B. bipunctatum* (Linnaeus, 1761)	PAL	1.2.1	9
29	*B. transparens* (Gebler, 1829)	PAL	1.2.1	2
30	*B. quadrimaculatum* (Linnaeus, 1761)	HOL	1.2.1	86
31	*B. fellmanni* (Mannerheim, 1823)	PAL	1.2.1	15
32	*B. andreae* (Fabricius, 1787)	PAL	1.2.1	1
33	*B. saxatile* Gyllenhal, 1827)	PAL	1.2.1	27

34	*B. prasinum* (Duftschmid, 1812)	PAL	1.2.1	53
35	*B. dauricum* (Motschulsky, 1844)	HOL	1.2.1	18
36	*B. crenulatum* (R.F.Sahlberg, 1844)	PAL	1.2.1	3
37	*B. obscurellum* (Motschulsky, 1844)	HOL	1.2.1	1
38	*B. semipunctatum* (Donovan, 1806)	PAL	1.2.1	1
39	*Patrobus assimilis* (Chaudoir, 1844)	E-SI	1.2.2	19
40	*P. septentrionis* (Dejean, 1828)	HOL	1.2.2	89
41	*Pterostichus nigrita* (Paykull, 1790)	PAL	1.2.3	1
42	*Pt. strenuus* (Panzer, 1797)	PAL	1.2.2	2
43	*Pt. brevicornis* (Kirby, 1837)	HOL	1.2.2	814
44	*Pt. adstrictus* (Eschscholtz, 1823)	HOL	1.2.3	5
45	*Pt. kaninensis* (Poppius, 1906)	EUR	1.2.2	4
46	*Pt. macrothorax* (Poppius, 1906)	PAL	1.2.2	40
47	*Pt. middendorffi* (J.Sahlberg, 1875)	PAL	1.2.2	223
48	*Pt. pinguedineus* (Eschscholtz, 1823	HOL	1.2.2	22
49	*Pt. dilutipes* (Motschulsky, 1844)	PAL	1.2.3	15
50	*Pt. eximius* (A. Morawitz, 1862)	PAL	1.2.3	22
51	*Pt. kokeili* (Poppius, 1907)	E-SI	1.2.3	213
52	*Pt. montanus* (Motschulsky, 1844)	PAL	1.2.3	1199
53	*Pt. haematopus* (Dejean, 1831)	HOL	1.2.2	11
54	*Pt. rubripes* (Motschulsky, 1860)	HOL	1.2.2	185
55	*Pt. vermiculosus* (Menetries, 1851)	HOL	1.2.2	98
56	*Calathus melanocephalus* (Linnaeus, 1758)	PAL	1.2.2	306
57	*C. micropterus* (Duftschmid, 1812)	PAL	1.2.2	11
58	*Agonum dolens* (C.R. Sahlberg, 1827)	PAL	1.2.1	2
59	*A. quinquepunctatum* (Motschulsky, 1844)	PAL	1.2.1	305
60	*A. ericeti* (Panzer, 1809)	PAL	1.2.1	4
61	*A. viduum* (Panzer, 1797)	PAL	1.2.1	2
62	*A. consimile* (Gyllenhal, 1810)	PAL	1.2.1	7
63	*A. fuliginosum* (Panzer, 1809)	E-SI	1.2.1	24
64	*A. gracile* (Sturm, 1824)	PAL	1.2.1	17
65	*A. exaratum* (Mannerheim, 1853)	HOL	1.2.2	5
66	*Amara plebeja* (Gyllenhal, 1810)	PAL	2.1	7
67	*A. bifrons* (Gyllenhal, 1810)	PAL	2.3	110
68	*A. brunnea* (Gyllenhal, 1810)	HOL	2.2	11
69	*A. erratica* (Duftschmid, 1812)	HOL	2.3	9
70	*A. ingenua* (Duftschmid, 1812)	PAL	2.3	14
71	*A. lunicollis* (Schiødte, 1837)	PAL	2.2	21
72	*A. praetermissa* (C.R. Sahlberg, 1827)	PAL	2.2	499
73	*A. quenseli* (Schönherr, 1806)	PAL	2.3	255
74	*A. municipalis* (Duftschmid, 1812)	PAL	2.3	4
75	*A. interstitialis* (Dejean, 1828)	HOL	2.2	3
76	*A. reitteri* (Tschitscherine, 1894	PAL	2.3	1
77	*Curtonotus torridus* (Panzer, 1797)	PAL	2.3	1
78	*C. alpinus* (Paykull, 1790)	PAL	2.3	691
79	*C. hyperboreus* (Dejean, 1831)	HOL	2.3	96
80	*Dicheirotrichus cognatus* (Gyllenhal, 1827)	HOL	2.2	5
81	*D. mannerheimi* (R.F.Sahlberg, 1844)	PAL	2.2	1
82	*Harpalus torridoides* (Reitter, 1900)	E-SI	2.3	5
83	*H. nigritarsus* (C.R.Sahlberg, 1827)	HOL	2.3	48
84	*Cymindis vaporariorum* (Linnaeus, 1758	PAL	1.2.4	23
85	*Paradromius ruficollis* (Motschulsky, 1844)	PAL	1.2.5	3
Total:				**6409**

[1]HOL – Holarctic; PAL – Palearctic; E-SI – Eurosiberian; EUR – European; [2]1 – Zoophagous: 1.1. – Epigeobios (1.1.1 – walking, 1.1.2 – running); 1.2. – Stratobios (1.2.1 – surface and litter-dwelling, 1.2.2 – litter-dwelling, 1.2.3 – litter and soil-dwelling, 1.2.4 – crevice-dwelling, 1.2.5 – litter and bark-dwelling); 1.3 – Geobios (1.3.1 – digging, 1.3.2 – running and digging); 2 – Mixophytophagous: 2.1 –Stratohortobionts; 2.2 – crevice-dwelling Stratobionts; 2.3 – Geohortobionts; * – first record in the forest-tundra belt of the Polar Urals.

Table 4. Carabidae beetle life forms of the Polar Urals local fauna

Life form	Number of species, *s*	Percentage of species, %
Zoophagous:	**67**	**78.8**
walking epigeobionts	8	9.4
running epigeobionts	4	4.7
surface and litter-dwelling stratobionts	26	30.6
litter-dwelling stratobionts	15	17.6
litter and soil-dwelling stratobionts	6	7.05
crevice-dwelling stratobionts	1	1.2
litter and bark-dwelling stratobionts	1	1.2
digging geobionts	5	5.9
running and digging geobionts	1	1.2
Mixophytophagous:	**18**	**21.2**
stratohortobionts	1	1.2
crevice-dwelling stratobionts	6	7.05
geohortobionts	11	12.9

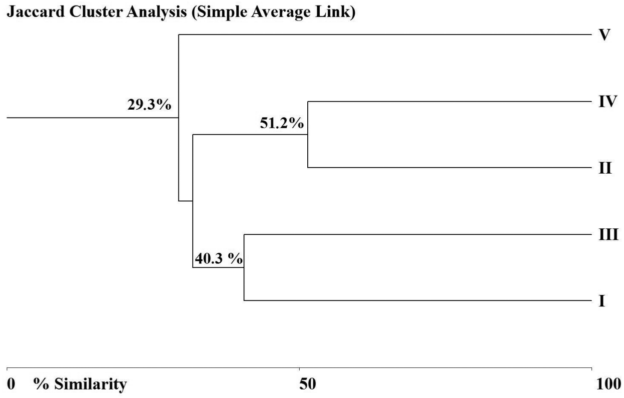


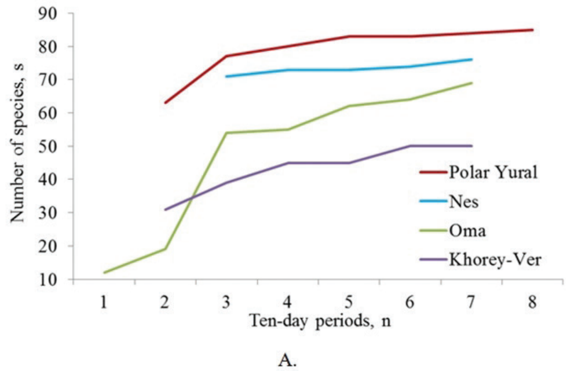
Fig. 2. Dendrogram of species similarity Carabidae local faunas in the Nenets Autonomous Okrug: I – Naryan-Mar, II – Oma (Markov, 2011), III – Khorey-Ver, IV – Nes (Filippov, 2008), V – Polar Urals

Nenets Autonomous Okrug ground beetles are 40–50% similar in terms of species composition.

Carabid sampling periods in four local faunas of the forest-tundra zone of the Polar Urals and North Europe were conducted at different times of the vegetation seasons from June to September (see Table 2). During those periods, more than 90% of the ground beetle species were collected during the first two to four ten-day periods of the field studies (see Fig. 3A). The appearance of new species in samples collected over the study periods is specific for each local fauna, due to phenological variance and the number of sites for each territory.

According to the accumulative curve which is beginning to reach an asymptote, sampling was successfully conducted for only one local fauna – the forest-tundra zone of the Polar Urals (Fig. 3B). Species richness was incomplete for the sampled ground beetle local faunas of Nes, Oma and Khorey-Ver settlements, and the accumulative curves show no signs of leveling off (Fig. 3B).

Structures of forest-tundra ground beetle community assemblages depend on local fauna. For instance, in the forest-tundra Polar Urals 12 species of ground beetles were established for all types of habitat and 56



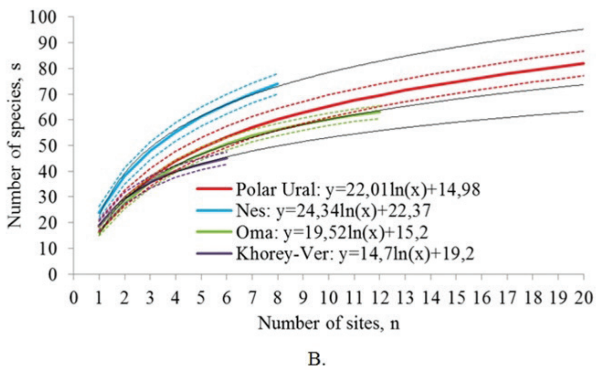


Fig. 3. Species accumulation curves of Carabidae: A – by period of research works; B – by number of sites. Dotted lines – 95% confidence intervals, solid lines – trend lines

species were collected from two or three habitat types. Rare species, which were sampled in only one habitat type, belong to 17 species of carabids. More than half of the rare species (9 species) were collected from meadows; 5 species in tundra and 3 species in forest habitats. Thus, under the sampling design used in the present study approximately one third of the sites should have selected specimens from meadow communities. Carabid species richness in meadow has significant differences with respect to tundra, forest and bog habitats according to rarefaction analysis whereby the confidence intervals are overlapping (see Fig. 4A).

In the forest-tundra zone of the Nes, Oma and Khorey-Ver settlements in the Polar Urals the tendency was to provide the smallest contribution of zonal community types (bogs, tundra) in the ground beetle species richness that was determinated (see Fig. 4). For local faunas of the Nenets Autonomous Okrug no significant differences were estimated in the collected number of carabid species between forest and meadow communities (see Fig. 4). Only for Nes was the maximum number of carabids species collected in forest habitats (see Fig. 4B).

Discussion

The aforementioned "local fauna method" was used, and to our knowledge this was the first time, in the forest-tundra of the Polar Urals and within one vegetation season this allowed the collecting of 77% of the regional carabid fauna. Ground beetle species richness in the fauna of the present study is comparable with local fauna (81 species) of the Kanin and Timan highlands in the forest-tundra zone of the European part of the Russian Arctic (Markov, 2011).

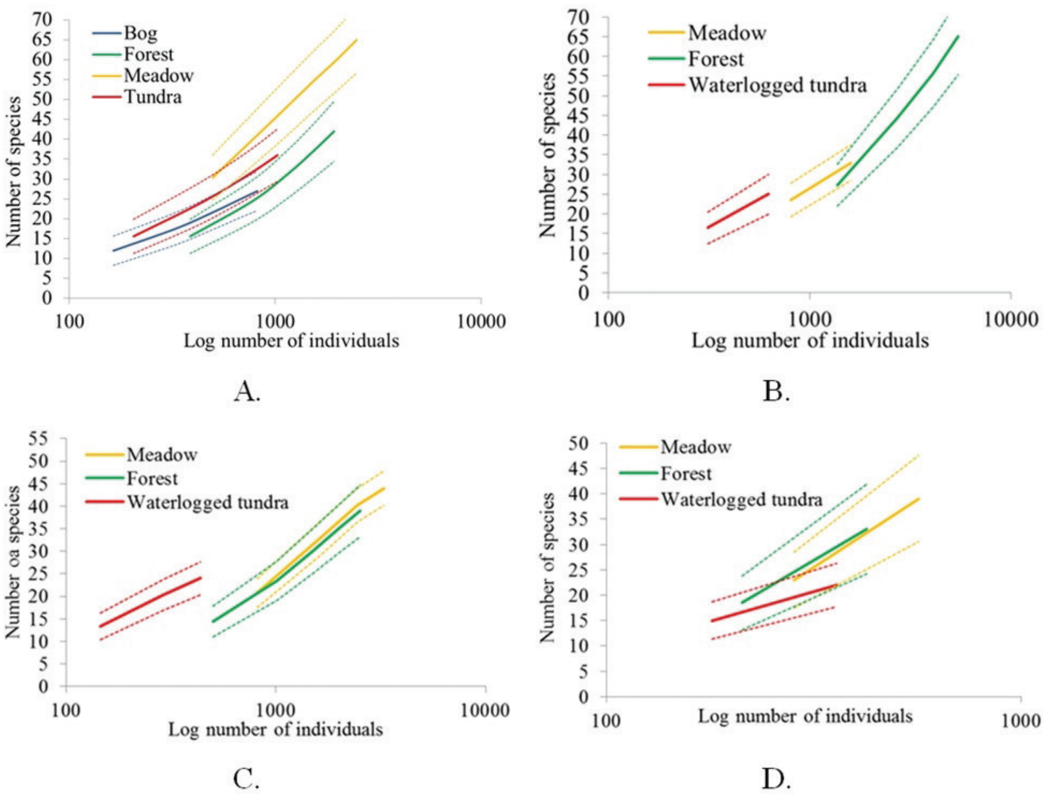


Fig. 4. Species abundance of Carabidae communities: A – Polar Urals, B – Nes, C – Oma, D – Khorey-Ver. Dotted lines – 95% confidence intervals

Seventeen (17) sampling sites were studied with respect to the collecting of 90% (77 species) carabid species richness in one local fauna of the forest-tundra of the Polar Urals. According to the estimated trend (logarithmic function) for the forest-tundra of Nenets Autonomous Okrug 90% carabid species richness was determined for the local faunas of Oma settlement (66 species) – with 13 sites, Nes (86 species) – with 14 sites and Khorey-Ver (57 species) – with 13 sites. Thus, for identifying the complete species richness of the local fauna in the forest-tundra zone, at least 15 sampling sites were used.

The zoogeographical group compositions for the local fauna of the Polar Urals with the Kanin-Timan tundra, Nes and Oma settlements is similar to the local faunas of the European forest-tundra (Filippov 2008, Markov 2011). A high proportion of Holarctic species in the carabid local fauna of the Polar Urals at 31.8% differs to that of Kanin (19.8%) and Oma (22.9%) in the forest-tundra zone of the European North (Filippov 2008, Markov 2011).

Life form groups of imago ground beetles life forms are typical for the subarctic forest-tundra zone on the border area of Europe and Asia. For instance, in the forest-tundra zone of Nenets Autonomous Okrug (Nes settlement) the subclass Stratobios is dominates, as it does in the Polar Urals: surface and litter-dwelling stratobionts (31.0%) and litter-dwelling stratobionts (14.7%), but the proportion of haploid geohortobionts is slightly higher in Nes with 18.9% (Filippov 2008).

In total, 85 species were collected during one vegetation period. According to the published data (Kozyrev et al. 2018), 84 species of ground beetles were recorded for the Salekhard and Labytnangi regions and 110 species for the forest-tundra zone of the Polar Urals within a study period of the last 60 years. In addition, in this study the species *Trachypachus zetterstedtii* was collected for the first time in the forest-tundra of the Polar Urals. We obtained data from the forest-tundra zone under study and the results of the "local fauna method" in sampling material during the one vegetation season is no less effective than using data collected in a multi-year research project using irregular sampling methods (Makarov and Matalin 2009).

We propose that when planning to study carabid local fauna of the forest-tundra zone, at least 15 model sites should be used for at least a 40-day period. Further, two-thirds of the studied sites should be of the intrazonal community type (forest and meadow), and the rest should be of the interfluve type (tundra and bog).

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