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Original Article

Communities of Carabid Beetles and Small Mammals in the Fragmented Cryoarid Forest-Steppe of Vitim Upland (Northern Transbaikalia)

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Abstract

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Communities of carabid beetles and small mammals in the cryoarid forest-steppes of Vitim upland (Northern Transbaikalia) are considered in this article. Analysis of communities of carabid beetles and small mammals in the forest steppes of Vitim upland revealed differences in species composition and community structure among the different biotopes, namely open habitats, fragmented and continuous forests. Carabid beetle and small mammal communities in this region can be identified both as "stable" (open habitats and continuous forests), with high species diversity and evenness, and "unstable" (birch and larch fragmented forests), with lower diversity indices and evenness, and high indices of dominance. Despite having the appearance of a forest habitat, communities inhabiting fragmented forests of Vitim upland more closely resembled those found in forest-steppe and steppes.

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Introduction

In Transbaikalia, the continuous permafrost alternates with the seasonal freezing and is treated as a single transition area. Under these conditions, the cryoarid forest-steppe, located on the south of Vitim upland (Northern Transbaikalia), has been formed. Ecosystems in the permafrost zone are most vulnerable, so the study of these communities as indicators of natural and disturbed habitats is highly relevant.

Carabid beetles and small mammals are useful model organisms for environmental research (for example, Halme & Niemela, 1993; Lovei & Sunderland, 1996; Davies & Margules, 1998; Litvinov, 2001; Vinogradov *et al*., 2011). Both groups can be characterized by high abundances and reproductive rates, settled lifestyles and small habitat ranges, high sensitivity to external agents, and the fact that they are easily captured.

The main objectives of this study were to investigate the abundance and distribution of carabid beetles and small mammals in the fragmented forest-steppes of Northern Transbaikalia, as well as to compare the diversity of their communities in fragmented forests with communities of open habitats (steppes and meadows) and continuous forests.

Materials and Methods

Study area. I studied communities of carabid beetles and small mammals in the south of Vitim

upland, which located in Eastern Siberia, 300 km east of Lake Baikal and 350 km north of Mongolia (Fig. 1). The upland is mostly covered with larch taiga forests, apart from its southern area (Eravninskaya hollow), where a larch-birch cryoarid forest-steppe extends. This forest-steppe is characterized by seasonally frozen and cryogenic soils (Badmaev *et al.*, 2006). Based on climatic conditions, as well as soil characteristics, and the composition of flora and fauna, Eravninskaya hollow is a transitional region: its northern part is dominated by ecosystems which are common in the Siberian taiga, and the southern part of the hollow is characterized by open habitats of Southern Transbaikalia and Northern Mongolia (Mukhina, 1965; Khobrakova, 2008; Moroldoev, 2009; Moroldoev & Litvinov, 2014). Field studies were conducted during May-September, 2005-2007 (carabid beetle communities) and July-September, 2009-2010 (small mammal communities).

Carabid beetle and small mammal samplings. For carabid beetles, I used 10 pitfall traps, which were placed approximately 10 m apart, in a transect line, within each of the studied sites. Plastic cups (250 ml) with an upper diameter of 75 mm served as traps. Each pitfall trap was placed in the ground with its mouth level with the soil surface. The pitfall traps were half-filled with formalin. Overall, about 12000 specimens of carabid beetles were sampled in 29200 trap days (Table 1).

Small mammals were caught by 50 m trap lines. Each site received one trap line with 5 trap cones, 10 m apart from each other. The traps were built from iron cones 50 cm deep and 20 cm in upper diameter. In all, 457 specimens of small mammals were caught in 1800 trap days.

Study of community structure. The following parameters were used to analyze the community structure: species abundance, Shannon diversity index, Pielou evenness index, and Simpson dominance index.

Shannon diversity index was measured as

$$H' = -\sum p_i \ln p_i$$

where p_i is the proportion of individuals belonging to the *i* th species ($\frac{n_i}{N}$).

Table 1. Studied biotopes in the forest steppe of Vitim Upland.

#	Biotopes	Latitude and longitude	Altitude, m a.s.l.	Carabid beetles communities			Small mammal communities		
				Study period	Trap-days	Amount of individuals	Study period	Trap-days	Amount of individuals
1	Lakesides of Eravna Lakes	N52°29’ E111°29’	949	2007, V-VIII	2000	172	-	-	-
2	Larch forest at the river terraces	N52°30’ E111°26’	951		2600	1534		225	21
3	Larch-birch forest at the river terraces	N52°29’ E111°26’	952		2600	1058		225	158
4	Birch forest at the river terraces	N52°29’ E111°26’	952	2005, V-IX	2600	944	2009, VII-VIII;	225	57
5	Dwarf-birch thicket	N52°38’ E111°26’	970		2600	1491	2010, VIII-IX	175	31
6	Meadow steppe	N52°35’ E111°25’	956		2600	1166		175	42
7	Larch fragmented forests	N52°38’ E111°18’	996	2006, VI-VIII	2000	572	2009, VII- VIII	120	23
8	Birch fragmented forests	N52°28’ E111°32’	958	2006, V-IX	5000	2474	2010, VIII-IX	120	13
9	Wet meadow	N52°30’ E111°27’	952		2600	703	2009, VII- VIII	225	18
10	Floodplain willow forest	N52°31’ E111°27’	951	2005, V-IX	2600	211	2010, VIII-IX	225	23
11	Coniferous forest at the slopes of the hollow	N52°40’ E111°26’	1010	2007, V-VIII	2000	1566	2010, VIII-IX	100	71
	Total				29200	11891		1815	457

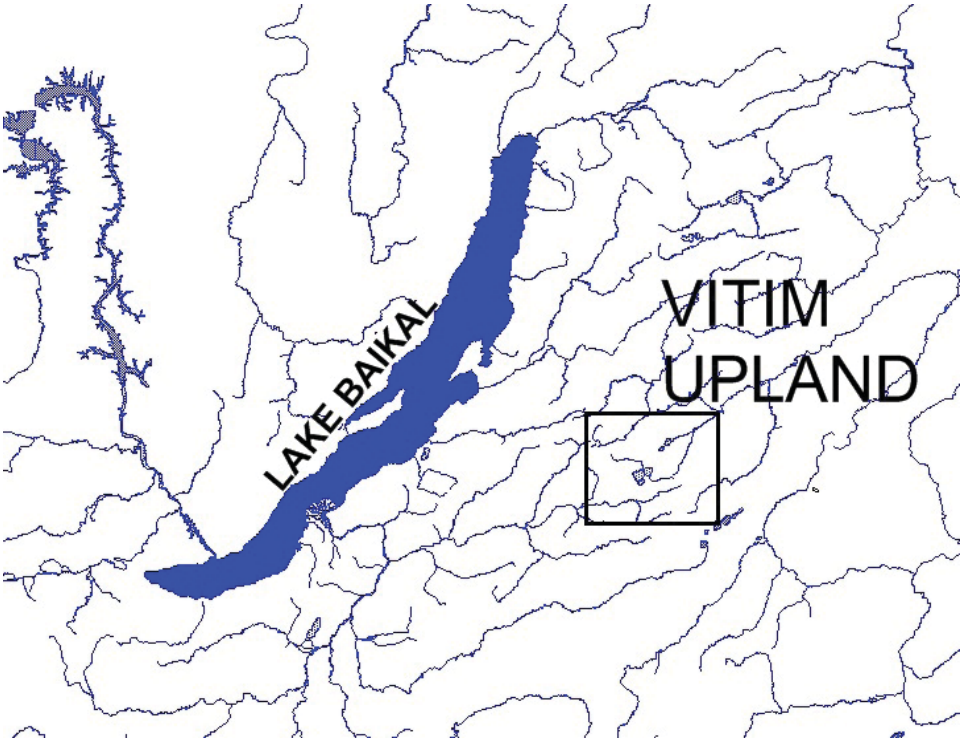

Figure 1. Study area in Transbaikalia.

Pielou evenness index is

$$J = \frac{H_i}{H_{\max}} = \frac{H_i}{\ln S}$$

where S is total number of species in the community.

Simpson dominance index was calculated as

$$C = \sum (\frac{n_i}{N})^2 = \sum (p_i)^2$$

The communities were compared with regard to the importance of species according to Sorensen's qualitative similarity index. All calculations and graphs were made with software in Statistica10 (StatSoft, 2010).

Results and Discussion

The ecological structure of carabid beetle and small mammal communities in the larch-birch forest-steppe of the Vitim upland was studied in the area from the lakeside biotopes through the meadow steppes, bushes, forest outliers, and river terrace forests to the larch taiga on slopes along the sides of the Eravninskaya hollow.

Carabid beetles communities of forest steppe of Vitim upland. A total of 92 species of carabid beetles from 22 genera were found in the forest steppe of Vitim upland. The highest species richness was observed for such genera as *Harpalus*, *Pterostichus* (15 species each), *Amara* (13 spp.), *Bembidion* (11 spp.) and *Carabus* (10 spp.). Species within the genera *Carabus, Poecilus, Pterostichus,* and *Curtonotus* accounted for 91.2% of the total number of individuals in the carabid beetle communities studied.

Using Sorensen's qualitative similarity index, I divided the carabid beetle communities into three groups (Fig. 2).

Firstly, the coastal communities of carabid beetles (1) occupy a separate position in the dendrogram. The community of carabid beetle of the Eravna Lakes consists of 20 species; of which *Carabus maeander, C. arcensis, Bembidion scopulinum, B. obliquum, B. obscurellum, B. varium, Elaphrus sibiricus* are the dominant species. The Simpson index for this community is the lowest among all studied communities, indicating a large number of species, but low numbers of individuals.

The second group with two subgroup units consists of the meadow-forest carabid beetle communities. The first subgroup due to significant numerical abundances of *Carabus granulatus* includes communities of wet meadow (4) and floodplain willow forest (2). Communities of meadows and scrub, combined due to the

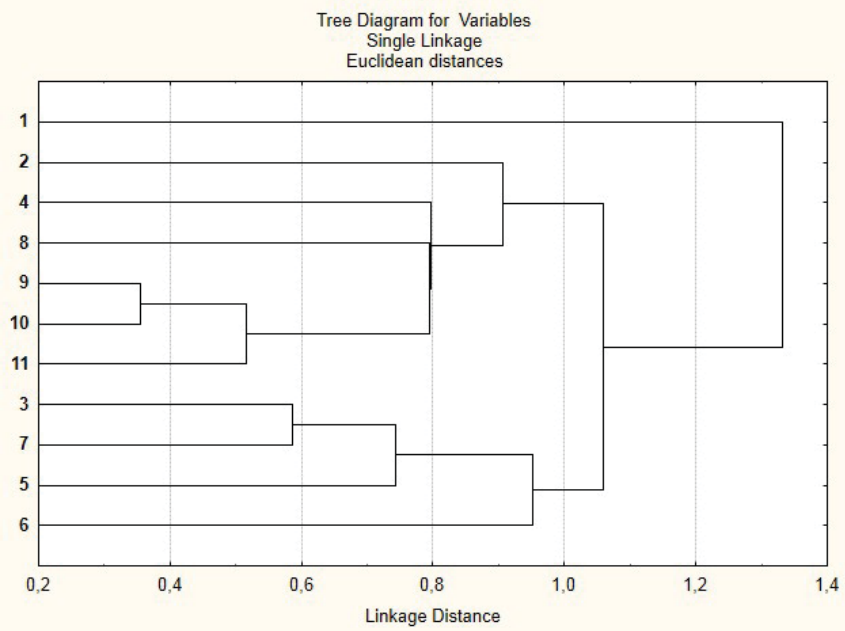

Figure 2. Dendrogram showing the similarity between the communities of carabid beetles in the forest steppe of the Vitim upland.

Notes: 1 – lakesides of Eravna Lakes, 2 – floodplain willow forest, 3 – dwarf-birch thicket , 4 – wet meadow, 5 – meadow steppe, 6 – larch fragmented forests, 7 – birch fragmented forests, 8 – larch forest at the river terraces, 9 – larch-birch forest at the river terraces, 10 – birch forest at the river terraces, 11 – coniferous forest at the slopes of the hollow.

dominance of *C. granulatus*, are characterized by significant species abundances and diversity. In the next subgroup, carabid beetle communities from continuous larch, birch and mixed larch-birch forests (8-11) fall together. All of them are characterized by average values for species abundance, diversity, and catchability. Forest species dominated in all communities within this subgroup, and *Carabus canaliculatus, C. billbergi, Pterostichus interruptus, P. eximius, Curtonotus hyperboreus* were the dominant species in all continuous forests.

The third group consisted of carabid beetle communities from open habitats and fragmented forests of the Vitim upland. Communities of birch fragmented forests (7) and dwarf-birch thicket (3) were characterized by low diversity and high values of Simpson's dominance index. This is due to the fact that more than half of the abundance of carabids in these communities is attributed to *Poecilus fortipes*. Steppe communities of carabid beetles (5) consisted of 46 species, and the community was quite diverse. The dominant species is *Poecilus fortipes*, which occupies 31% of the total numerical abundance of carabids. *Poecilus major, Harpalus aequicollis, Carabus kruberi* and *C. latreillei* are also numerous. In order of dominance, the species that comprised the carabid communities occupying larch fragmented forests were *Cymindis collaris, Carabus latreillei, C. canaliculatus, Poecilus fortipes,* and *Pterostichus dauricus*. In general, steppe elements predominated over the forest elements in terms of species and numerical abundance in this community. It is known that fragmentation of landscapes directly affects abundance and diversity of communities of carabid beetles (Niemela *et al.*, 1998; Niemela, 2001).

Small mammal communities of the forest steppe of Vitim upland. The most abundant small mammals species found was the northern red-backed vole (*Myodes rutilus*), with high numbers in larch and larch–birch forests. Maximowicz's vole (*Microtus maximowiczii*) ranked second based on its abundance, especially when including the small mammals of mixed and birch forests. Among shrews, the Tundra shrew (*Sorex tundrensis*) inhabited almost all studied biotopes and had highest abundances in birch continuous and fragmented forests. All small mammal communities were numerically divided into three groups (Fig. 3).

The first group included small mammal communities of the continuous forests: larch (1), birch–larch (2), and birch (3) forests growing at

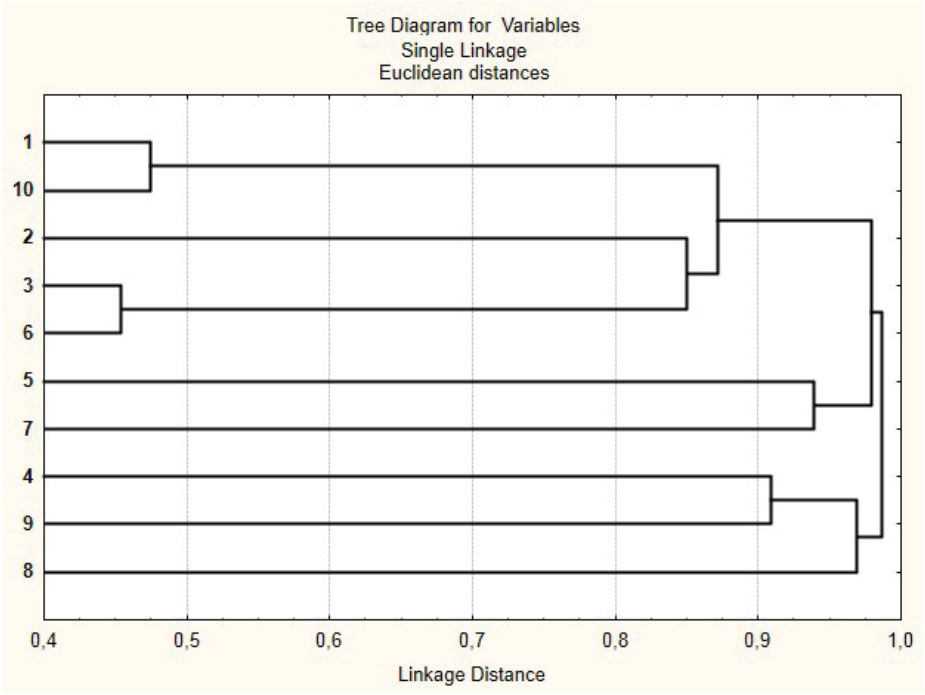

Figure 3. Dendrogram showing the similarity between the communities of small mammals in the forest steppe of the Vitim upland.

Notes: 1 – larch forest at the river terraces, 2 – larch-birch forest at the river terraces, 3 – birch forest at the river terraces, 4 – dwarf-birch thicket, 5 – meadow steppe, 6 – birch-forest outliers mixed with larch, 7 – larch fragmented forests, 8 – wet meadow, 9 – floodplain willow forest, 10 – coniferous forest at the slopes of the hollow.

the river terraces, coniferous forests at the slopes of Eravninskaya hollow (10), and birch-forest outliers mixed with larch (6). Almost all these communities were characterized by high species diversity and evenness. They were merged into a single cluster in a dendrogram because they were dominated by forest-dwelling species (different species of *Sorex*, *M. rutilus*, and *Apodemus peninsulae*). The larch forest was the least diverse (*H'*=1.12; this value is the lowest among all communities under consideration). It also had the highest value of Simpson's dominance index (*C*=0.63), because the species structure is significantly dominated by *M. rutilus*.

The forest communities were very different from those in wetlands: floodplain willow forests (9), dwarf birch thickets (4), and wet meadow (8). The latter was dominated by *S. tundrensis*, *M. maximowiczii,* and *M. rutilus*. These communities have high mean values of diversity indices.

The forest-steppe communities, meadow steppe (5) and fragmented forests (7) occupy a transitional position between the first two clusters in the dendrogram. Although some forest species can be found in these habitats, they are still dominated by the narrow-headed vole (*Lasiopodomys gregalis*) and the Chinese striped hamster (*Cricetulus barabensis*), both confined to the steppe biotopes.

Diversity of studied communities. The highest species diversity (*S*) was observed in the communities of carabid beetles of meadow steppes and communities of small mammals in different types of continuous forests. The lowest diversity was found in fragmented larch and birch forests both for carabid beetle and small mammal communities (Table 2).

The Shannon diversity index (*H'*) of carabid beetle communities was minimal in dwarf-birch thickets and birch outliers. Small mammal communities of larch fragmented forests were characterized by the lowest Shannon index. Communities of continuous forests at the river terraces were the most diverse communities. Also, carabid beetle communities of open habitats (lakesides of Eravna Lakes, wet meadows and meadow steppes) were quite diverse (*H'*> 2.20).

Open habitats (meadows and steppes) were characterized by less variation between the species in communities of carabids and small mammals, as indicated by the relatively high Pielou evenness index (*J'*). The index showed how even the community was numerically.

Table 2. Diversity indices of carabid beetle and small mammal communities.

#	Biotopes	Carabid beetle communities				Small mammal communities			
		S	*H'*	*J*	*C*	*S*	*H'*	*J*	*C*
1	Lakesides of Eravna Lakes	20	2.46	0.82	0.11	-	-	-	-
2	Larch forest at the river terraces	15	1.90	0.70	0.20	3	0.64	0.58	0.44
3	Larch-birch forest at the river terraces	18	2.07	0.72	0.18	7	1.43	0.74	0.34
4	Birch forest at the river terraces	19	2.23	0.76	0.15	7	1.68	0.87	0.21
5	Dwarf-birch thicket	25	1.50	0.47	0.45	6	1.33	0.74	0.37
6	Meadow steppe	46	2.43	0.63	0.15	4	1.31	0.94	0.29
7	Larch fragmented forests	14	1.90	0.72	0.19	2	0.57	0.83	0.61
8	Birch fragmented forests	20	1.49	0.50	0.35	3	0.95	0.86	0.44
9	Wet meadow	22	2.48	0.80	0.11	3	0.64	0.92	0.56
10	Floodplain willow forest	22	2.12	0.69	0.24	4	1.21	0.88	0.33
11	Coniferous forest at the slopes of the hollow	19	1.84	0.62	0.22	6	1.35	0.75	0.38

Notes. *S* – species abundance, *H'* – Shannon diversity index, *J* – Pielou evenness index, *C* – Simpson dominance index.

Simpson's dominance index (*C*) increased with a significant dominance of one or more species. In carabid communities occupying dwarf-birch thickets and birch fragmented forests, there were 20-25 fewer species and over 60% of the individuals belonged to one species, *Poecilus fortipes*. For this reason, the dominance index in these communities increased dramatically. The lowest value of the dominance index, which indicates a large number of species, but low numbers, was found on the shores of lakes and wet meadows. In small mammal communities, Simpson's index was high in larch fragmented forests because of low species diversity (*S*=2) and high numerical advantage of *M. rutilus.*

Conclusion

Analysis of communities of carabid beetles and small mammals in the forest steppes of Vitim upland revealed differences in species composition and community structure among the different biotopes, namely open habitats, fragmented and continuous forests.

Carabid beetle and small mammal communities in this region can be identified both as "stable" and "unstable". *"Stable"* communities were found in open habitats (meadows, steppes and lakesides) and continuous forests. Species composition in these communities consisted of stenotopic species, with high species abundances, diversity and evenness. *"Unstable"* communities included communities found in birch and larch fragmented forests, where species composition consisted of eurytopic species from surrounding steppe and forest habitats. I found lower diversity indices and evenness, and high indices of dominance in these communities. Despite having the appearance of a forest habitat, communities inhabiting fragmented forests of Vitim upland more closely resembled those found in forest-steppe and steppes.

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