Structural transformations of ground beetle meadow communities in the Northeastern Baikal region because of post-anthropogenic successions

To cite this article: T L Ananina and A A Ananin 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **908** 012014

IOP Conf. Series: Earth and Environmental Science **908** (2021) 012014 doi:10.1088/1755-1315/908/1/012014

Structural transformations of ground beetle meadow communities in the Northeastern Baikal region because of post-anthropogenic successions

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Abstract. Ground beetles are sensitive to environmental changes. We analysed the consequences of haymaking and cattle grazing on communities of meadow ground beetles in Barguzin State Reserve. We assessed community structures during 12 years of the anthropogenic disturbance and after its cessation. The number of categories, types, and variants increased. A decrease in species diversity, a rearrangement of the composition of dominant species, an increase in the relative abundance and share of participation of dominants in the carabid community observed. Of nine dominant species of ground beetles six showed increase of the population number, while others were stable.

1. Introduction

A human disturbance in the environment leads to a decline in plant and animal populations [1, 2]. Insects are sensitive to environmental disturbances and always choose suitable habitats. Regular destruction of the grass cover during haymaking and cattle grazing leads to increased illumination and xerophytization of meadow vegetation [3, 4]. The Carabidae family is widespread throughout the world. Monitoring the species composition and the number of ground beetles is a very efficient way to assess the anthropogenic impact [2, 8, 9] because ground beetles actively respond to climatic and anthropogenic influences, demonstrating high selectivity to habitat conditions [5, 6, 7]. The study of the meadow ground beetles community was carried out in 2004-2020 in Barguzin State Nature Biosphere Reserve [10, 11], the Baikal-Dzhugdzhur mountain-taiga region of North Asia [12]. The meadows occupy only 0.03% of the reserve area. However, they are hotspots of floristic and entomological diversity: e.g., out of 152 species of ground beetles recorded in the Reserve, 41 species (26.9%) live in these meadows. These intrazonal biotopes are confined to estuaries, valleys, and low-lying river surfaces [13].

The tasks of the research were: to reveal the habitat peculiarities of the model ground beetles communities; to carry out a comparative assessment of the structure of meadow ground beetles communities during the period of anthropogenic impact and after its termination; to analyse the long-term dynamics of the dominant ground beetles number.

2. Materials and methods

Quantitative surveys of ground beetles were carried out on three types of meadow plots. The meadows were influenced by anthropogenic activity during the creation of stationary sites in 1988 and 2004. This impact ceased in 2008 after the departure of most of the inhabitants of the village of Davsha. These meadows differed in hydrothermal and soil-vegetation characteristics (table 1).

Table 1. Characteristics of the meadow sites (2020).

Site #	1	2	3
Meadow type	Herbal-shrub dry	Low-grass thermal lowland	Tall-grass floodplain
Coordinates	54°21' N; 109°30' E	54°21' N; 109°32' E	54°21' N; 109°30' E
Establishment year	2004	2004	1988
Location	elevated part of the second Baikal terrace	lower part of the second Baikal terrace	valley of the Davsha river, 12.5 km from Lake Baikal
Vegetation layer	tree, shrub, herbaceous	herbaceous	herbaceous
Dominant plants	*Betula baicalensis* Sukacz., *Pinus sylvestris* L., *Larix czekanowskii* Szaf., *Empetrum nigrum* L., *Vaccinium vitis-idaea* L., *Festuca ovina* L., *Poa attenuata* Trin., *Geranium bifolium* Patrin, *Vicia cracca* L., *Viola altaica* Ker-Gawl., *Ranunculus propinquus* C A Mey.	*Trifolium lupinaster* L., *Carex globularis* L., *Sanguisorba officinalis* L., *Campanula rotundifolia* L., *Melica nutans* L.	*Lilium pilosiusculum* (Freyn) Miscz., *Polygala sibirica* L., *Heracleum dissectum* Ledeb., *Ranunculus monophyllus* Ovcz., *Thalictrum minus* L., *Lathyrus pilosus* Cham.
Soil type	Humus-podzolic sandy loam	Meadow loamy-sandy	Floodplain sod-humus
Mean air t, °C	+13.4	+13.4	+14.1
Min. soil t, °C	+6.6	+7.0	+6.9

The grass and shrub meadows had an artificial origin – they were formed after cedar-pine forest cutting for the airfield in 1947. An intensive overgrowth with meadow plants began after the airfield closure in 1960. Cattle periodically grazed on the meadow. The low-grass thermal meadow is natural. It is located near a thermal spring (46 °C). Cattle sometimes grazed here in 1947-2008. The tall-grass floodplain meadow is more humid than the meadows on the Baikal coast. Ice forms on the meadow in winter and melts at the end of May. The hay-making took place in 1947-2008.

The mean air temperature and the minimum temperature of the soil surface were measured with temperature data loggers Thermochron iButton DS1921G-F5 and the automatic meteorological complex AMK-3 (June – August) in 2012-2016 [14].

Ground beetles were sampled by half-litre glass jars, 9 cm mouth diameter, 1/4 filled with 4% formalin solution, serving as pitfall traps [15]. Five traps were placed in each site in one line at 5 m from each other. The traps were checked every ten days from May to September during the activity season of the beetles. The catch counts were standardized as relative abundance: individuals per 100 traps/day.

We used the hierarchical structure "category-type-variant" to characterize the communities of ground beetles. The structure is based on the criteria of dominant biotope groups [16]. Biotope groups consisted of dominant carabid species (5% or more of the total population). For this, we used data on the identified dominant species, their abundance, and biotope affiliation. [17].

First, we identified the category of the community based on the most dominant biotope groups; then, we determined the type by the number of dominant biotope groups; last, we determined the variant based on the composition of biotope groups and dominant species.

The long-term dynamics of the dominant ground beetles' number was analysed with Linear Regression Analysis [18] using Statistica 6.0. software.

3. Results and Discussion

A total of 65 species of seven genera were identified on three meadow sites. We caught in grass-shrub meadow 2,614, low-grass thermal – 1,247, tall-grass – 36,796 ground beetle individuals over 2004-2020.

Table 2. Structure of meadow ground beetle communities during the anthropogenic impact (2004).

Site #	1	2	3
Number of species	36	28	31
Catchability, ind. per 100 trap / day	13.9	6.8	49.1
Dominant species	*Pterostichus montanus* (22.9%, mt-f); *Poecilus fortipes* Chaud. (18.7%, m-s); *Pterostichus dilutipes* Motsch. (16.5%, f-g); *Calathus micropterus* Duft. (11.1%, f-g)	*Calathus micropterus* Duft. (18.5%, f-g); *Pterostichus eximius* A. Mor (18.8%, f-g); *Pterostichus montanus* (9.9%, mt-f); *Poecilus fortipes* Chaud. (8.1%, m-s)	*Calathus micropterus* Duft. (16.2%, f-g); *Carabus henningi* F. -W. (13.9%, f-g); *Amara similata* Gyll. (11,6%, m-fl); *Pterostichus montanus* (9.9%, mt-f); *Harpalus latus* L. (8.9%, f-g)
% Dominant species	68.4	55.3	60.5
Category	forest gumikol	forest gumikol	forest gumikol
Type	polydominant	polydominant	polydominant
Variant	f-g, mt-f, m-s	f-g, mt-f, m-s	f-g, m-fl, mt-f

Designations: **site** 1 – herbal-shrub, **site** 2 – low-grass thermal, **site** 3 – tall-grass floodplain;
biotopic group: mt-f – mountain forest; f-g – forest gumikol; m-s – meadow-steppe;
m-fl – meadow-field; m – meadow; sw – swamp.

The composition of vegetation and soil in the studied meadow areas was different. The mean air temperatures were 0.7 °C higher in remote from Lake Baikal site 3. The minimum soil temperatures were 0.1-0.4 °C higher in the coastal areas near the thermal spring (table 1). The decrease in vegetation density resulting from haymaking and cattle grazing led to changes in the hydrothermal regime. The xerophytization process caused a change in the microclimatic conditions. As a result, the structure of the community of meadow ground beetles changed, as given below (table 2). We have identified one category of forest gumikol, one polydominant type, and four variants of forest and meadow biotope groups. The forest category is possibly associated with the proximity of the cedar-pine forest. *Cal. micropterus* and *Pt. montanus* were dominants at all sites (table 2).

In the absence of anthropogenic influence, the vegetation changed at all sites. The grass-shrub meadow began overgrown with shrubs, coniferous and deciduous trees, low-grass thermal and tall-grass floodplain meadows – denser and taller vegetation [19]. As a result, the microclimatic conditions of the meadows were changing. The transformation of the ground beetle community structure occurred (table 3).

The following changes in the structure of the ground beetle community were revealed:

1. The total number of identified species decreased in all meadow areas significantly: in site 1 – by 17 (47.2%) species, in site 2 – by 10 (35.7%) species, in site 3 – by 3 (9.7%) species.
2. The catchability of beetles increased: in site 1 – 4.0 (28.7%), in site 2 – 0.5 (7.4%), in site 3 – 75.7 (60.6%) ind. per 100 trap / day.

3. There was a restructuring and replacement of the previous dominant composition: *Pt. montanus* replaced *Pt. eximius* in site 1. The number of dominant preserved and increased in site 2, where *H. rufipes, Pt. nigrita, Amara anxia, Cal. errathus* replaced *Pt. montanus* species. *Amara similata* replaced *Curtonotus aulicus* and *Car. henningi* became the leading dominant species in site 3.
4. The part of dominant species increased significantly: 21.9% in site 1; 36.9% in site 2; 31.2% in site 3.
5. The category of forest humicol replaced by meadow-field in site 2.
6. Polydominant type replaced by the oligodominant in site 1 and in site 2.
7. Two groups added (meadow, swamp) to the previous composition of biotope group variants (forest gumikol, mountain forest, meadow-steppe, meadow-field).

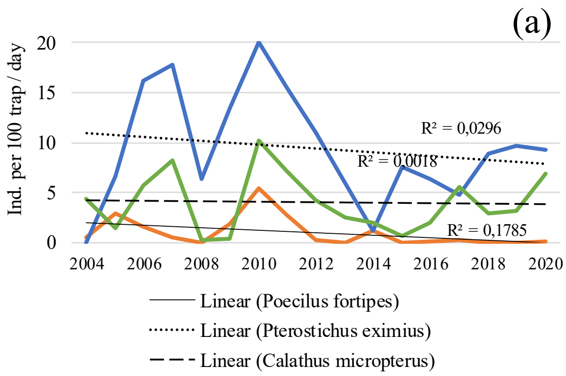
Table 3. Structure of meadow ground beetle communities after the anthropogenic influence cessation (2020).

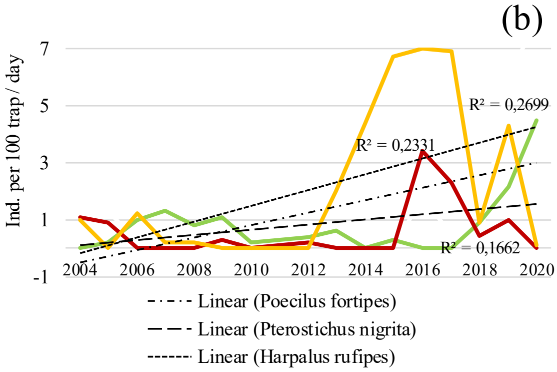
Site #	1	2	3
Number of species	19	18	28
Catchability, ind. per 100 trap / day	17.2	7.3	124.8
Dominant species	*Pterostichus eximius* A. Mor (46.6%, f-g); *Pterostichus dilutipes* Motsch. (17.4%, f-g); *Calathus micropterus* Duft. (17.0%, f-g); *Poecilus fortipes* Chaud. (5.9%, m-s)	*Harpalus rufipes* De Geer. (41.9%, m-fl); *Poecilus fortipes* Chaud. (17.1%, m-s); *Pterostichus nigrita* Payk. (11.0%, sw); *Amara anxia* Tschit (9.8%, m-s); *Calathus errathus* C. R. Sahlb. (7.8%, m); *Calathus micropterus* Duft. (6.3%, f-g)	*Carabus henningi* F. -W. (56.3%, f-g); *Curtonotus aulicus* Panz. (16.1%, m-fl); *Calathus micropterus* Duft. (11.8%, f-g); *Harpalus latus* (7.5%, f-g).
Dominant species, %	90.3	92.2	91.7
Category	forest gumikol	meadow- field	forest gumikol
Type	Oligodominant	Polydominant	Oligodominant
Variant	f-g, m-s	m-fl, m-s, m, sw	f-g, m-fl,

Designations: as in Table 2.

Our findings can be summarized as follows: in the absence of anthropogenic influence over 2008-2020, the species diversity of the meadow carabid community decreased, while the abundance and proportion of dominant species increased. Similar results of high diversity macropterous ground beetle's species in anthropogenic biotopes obtained by ourselves [20] and other authors [21]. The structure of communities of ground beetles has changed significantly with post-anthropogenic influences – the number of categories, types, and variants of dominant biotope groups have increased (table 3).

Long-term changes in the abundance of dominant ground beetle species in three sites were found (figure 1). In site 1, certain species were dropped from the total composition; meadow species *P. fortipes* demonstrated a tendency to decrease in abundance (figure 1, a). On the contrary, at site 2, a significant increase in the abundance of meadow and swamp species *H. rufipes*, *P. fortipes* and *Pt. nigrita* were observed (figure 1, b). After the end of haymaking in 2008, the number of macropterous *C. henningi* increased fourfold at site 3 [21, 22], while numbers of other dominant species did not (figure 1, c). The abundance of the small ground beetle *Cal. micropterus*, the invariable dominant of both natural and disturbed habitats, was consistent in three sites. Now, site 1 and site 3 became more favourable for forest carabids habitation (figure 1, a, c).





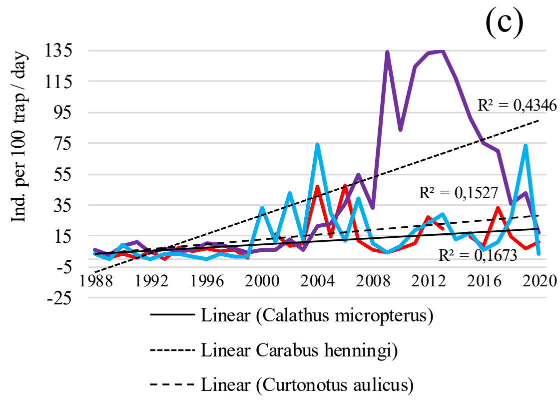


Figure 1. Trends of changes in the long-term abundance of dominant ground beetles in meadows: a) herbal-shrub; b) low-grass thermal; c) tall-grass floodplain.

4. Conclusion

The cessation of long-term haymaking and cattle grazing led to successional changes in meadow vegetation. An increase in the density and height of the vegetation cover and overgrowth with shrubs and trees transformed microclimatic conditions. As a result, the structure of the ground beetle community transformed in all meadow sites: ground beetle diversity decreased, relative abundance increased, the number of dominants and the composition of biotope dominant groups changed.

Acknowledgments

The study was partially performed within the framework of the state assignment of the Institute of General and Experimental Biology SB RAS No. 121030900138-8, and funded in part by FBI “Zapovednoe Podlemorye”, supported by the Federal Budget of the Russian Federation.

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