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Ground beetle (*Coleoptera, Carabidae*) bioecology in forests of Aukštasis Tyras Mire reserve

Algimantas Žiogas,

Stasys Vaičikauskas

Lithuanian University of Agriculture,
Department of Plant Protection,
Studentų 11, Akademija,
LT-53361 Kaunas district, Lithuania
E-mail: aa@nora.lzua.lt

In eight forest types, 43 species of ground beetles (*Coleoptera, Carabidae*) from 15 genera were caught. Species variety in different forest types fluctuated from 0.47 in *Pinetum ledo-sphagnosum* pine stand to 2.66 in *Betuletum calamagrostidosum* birch forest. The highest number of species and species variety was ascertained in deciduous forests. According to the qualitative data on the similarity of ground beetle species composition, the forest types were divided into two groups: 1 – temporarily overmoistured, waterlogged and boggy forests – *Betuletum oxalido-nemorosum, Betuletum calamagrostidosum, Pinetum carico-sphagnosum, Alnetum caricosum*, and 2 – *Picetum myrtillosum* and *Picetum myrtillo-oxalidosum*. *Pinetum ledo-sphagnosum* and *Picetum oxalidosum* according to qualitative indices were hardly similar to other forest types.

According to humidity requirements, ground beetle species were distributed as follows: 57% were hygrophilous, 36% mesophilous and 7% eurihygrophilous species. According to the number of individuals, 73% of ground beetles belonged to mesophilous, hygrophilous and 3% to eurihygrophilous species.

According to zoogeographical characteristics, most (84%) of ground beetles belonged to boreal species. The greatest portion of boreal ground beetles was found in *Pinetum ledo-sphagnosum* pine (100%) and *Picetum myrtillo-oxalidosum* spruce stands (95%) and the greatest portion of paratetic species in the *Picetum oxalidosum* spruce stand (46%).

Key words: ground beetles, specific composition, variety, forest type

INTRODUCTION

The Aukštasis Tyras Mire Reserve was founded in 1992 to preserve the marshland complex of Žemaičiai Highlands. Its area covers 881 ha. The Reserve is abundant in forests which are managed in accordance with the requirements raised for second-category forests. Woods of the reserve belong to the Rietavas forest enterprise and are included in the Natura 2000 network.

Worldwide, there are more than 25000 species of ground beetles (*Carabidae*) which are among the largest by the number of species and the most abundant family of the order *Coleoptera*. In cultivated fields of Europe, one beetle of the genus *Carabus* is found on an average per 2.98 m^2 and one beetle of the genus *Pterostichus* per 0.98 m^2. In Lithuania, 287 ground beetle species (50–60 species have to be found) are known. Insufficiently studied are small ground beetles of the genera *Dyschirius, Bembidion, Dromius* (Pileckis, Monsevičius, 1995).

At the same time it is one of the best studied families from the taxonomic, faunistic and zoogeographic points of view. Most ground beetles are highly polyphagous, depending on the sum of abiotic and biotic factors of the territory. The peculiarities of the ground beetle family are the reason why of all beetles they are most widely used as indicators of environmental changes (Pileckis, 1960, 1976).

A large portion of forest and field ground beetles are mesophilous. Some of them may damage germinating seeds and seedlings of grassy and woody plants (some species of the genera *Bembidion, Amara, Harpalus*). Hygrophilous beetles are usually found near water basins. To them belong some species of the genera *Carabus, Agonum*, most *Pterostichus* and almost all *Elaphrini, Nebria, Loricera* species. Meanwhile, the genera *Blethisa* and *Bembidion* as characteristic coastline inhabitants are found in the coastline belt from several tens of centimetres to several metres. To phytophilous beetles are ascribed ground beetles whose imago and sometimes larvae live and feed on trees, bushes and large grassy vegetation (Крыжановский, 1983).

In the Dukstyna Entomological Reserve, on comparing the species composition of the fauna of its biotopes, the fauna of ground beetles was found to consist

of three main complexes – forest, river bank and meadow (Двилявичюс и др., 1988).

In entomological studies, most indices of diversity estimation are applied. At present, the most widespread are Shenon's, Simpson's and Berger-Parker's indices, although earlier they were criticized. There is no unanimous opinion on which the diversity index should be chosen, because it is highly dependent on the available data and certain natural conditions. The preciseness of any index under concrete conditions is easily checked by calculating several indices and comparing them among themselves (Magurran, 1988). For instance, with the aid of Shenon's index English scientists have ascertained that ground traps catch the highest number of species of the beetles (the highest diversity index), another method (collecting from the litter) better reflected the index of species distribution – the index of evenness was the highest (Dennison, Hodkinson, 1984). Applying Shenon's diversity index, Hungarian scientists have found that the diversity of ground beetles is reliably higher on the forest edge and in meadow than in the forest (Magura et al., 2001). In Mexico, Shenon's diveristy index in undamaged pine and oak stands showed a higher diversity of ant species than in damaged ones (Flores-Maldonado et al., 1999).

According to the data of S. Pileckis, V. Monsevičius (Pileckis, Monsevičius, 1995), the species composition of Lithuanian ground beetles is similar to that of the subzone of European mixed forests. However, also many representatives of the boreal fauna (*Nebria rufescens* Ström (*gyllenhali* Schön.), *Blethisa multipunctata* L. *Elaphrus riparius* L., *Miscodera arctica* Payk., *Patrobus septentrionis* Dej., *Amara erratica* Duft.), as well as species characteristic of the broadleaved forests of Central Europe (*C. inquisitor* L., *Stomis pumicatus* Panz., *Calathus fuscipes* Goeze, *Sphodrus leucopthalmus* L., *Olisthopus rotundatus* Payk., *Diachromus germanus* L.) and elements of pontic fauna (*Nothiophilus aesthuans* Motsch. *(pusillus* Water.), *Clivina collaris* Hbst., *Dyschirius obscurus* Gyll., *Bembidion punctulatum* Drap., *Chlaenius vestinus* Payk., *Masoreus wetterhallii* Gyll.) are found.

According to feeding, ground beetles are divided into three main groups: zoophagous, phylophagous and mixophagous. They are natural predators of most pests. This preconditions their significant value, while their voracity and activity determine their role in not only regulating the number of other invertebrates, but also taking part in natural exchange cycles of materials.

At present, ground beetles are often used to evaluate the extent of anthropogenic impact, because much attention is paid to assess protected areas and forest biocoenoses. The aim of the present work was to determine the species composition and distribution of ground beetles in different forest types of the Aukštasis Tyras Mire Reserve.

METHODS

Studies of ground beetls were carried out in 2004–2005 in forests of the Aukštasis Tyras Mire Reserve. For the purpose, in eight forest types (1 – *Picetum oxalidosum,* 2 – *Picetum myrtillosum,* 3 – *Picetum myrtillo-oxalidosum,* 4 – *Betuletum oxalido-nemorosum,* 5 – *Betuletum calamgrostidosum,* 6 – *Pinetum ledo-sphagnosum*, 7 – *Pinetum carico-sphagnosum,* 8 – *Alnetum caricosum)* observation plots were chosen, in which six Barber's traps (0.5 l capacity jars were dug into the ground, 1/3 of them filled with formaline solution) were placed at a distance of 10 m from each other. Beetles from the jars were collected once in two weeks.

The following indices were used to characterize the communities of ground beetles:

1. Relative abundance (prevalence) – the portion of species in a collection per cent:

$$p^i = n^i /N,$$

where n^i is the number of individuals of i species in the collection, N is the total number of individuals in the collection.

2. Index H' of species diversity according to Shennon's formula (Песенко, 1982):

$$H' = -\sum (n^i /N)\ ln(n^i /N).$$

3. Pielou's evenness index E:

$$E = H'/H_{max} = H'/ln(S).$$

4. Zoogeographical characteristics (ecological groups within the structure of communities, their interrelation).

5. Similarity I_{cs} of individual communities according to Czekanowski–Sorensen's formula for qualitative indices:

$$I_{cs} = 2a/(a+b)+ (a+c),$$

where $a+b$ is the number of species of one list, $a+c$ is the number of species of another list, and a is the number of common species of both lists.

Based on these data, applying the method of cluster analysis, the dendrogram of the similarity of individual biotopes was designed.

To establish the species and distribution of ground beetles, works of Lithuanian, Polish and Russian entomologists have been used (Pileckis, Monsevičius, 1995; Burakowski et al., 1973; Грюнталь, 1983; Шарова, 1971, 1981; Шарова, Грюнталь, 1983).

RESULTS AND DISCUSSION

In the Aukštasis Tyras Mire Reserve, 2166 ground beetles belonging to 42 species from 15 genera were caught. The most characteristic among them were forest, forest-bog and raised bog complexes According to moisture requirements, the species were divided into mesophilous, hygrophilous and eurihygrophilous. The largest portion of mesophilous species was detected in *Picetum*

oxalidosum spruce stand (80%), as well as in *Betuletum oxalido-nemorosum* (65%). Meanwhile, hygrophilous species were most frequent in *Betuletum calamagrostidosum* (48%) and *Alnetum caricosum* (50%) forest types.

By the number of species, the group of hygrophilous (57%) ground beetles dominated. However, a large portion of hygrophilous species were not abundant (one–two individuals). Therefore, by the number of individuals, hygrophilous comprised only 24%. Abundance of individuals was not characteristic of eurihygrophilous species (3% from the total number of individuals). The greatest portion (73%) of caught ground beetles belonged to mesophilous species, such as *Calathus micropterus* Duft. (299 individuals), *Carabus hortensis* L. (165 individuals), *Pterostichus oblongopunctatus* Fabr. (337 individuals), *P vulgaris* L. (*melanarius* Ill.) (251 individuals). Beetles of these species prevailed during the whole study. The ratio of their abundance in the forests of the reserve is shown in Fig. 1.

The relative abundance of *Carabus hortensis* was highest in *Picetum myrtillosum* spruce stand (12.9%). This species was also sufficiently abundant in *Picetum myrtillo-oxalidosum* spruce stand (10.5%). In other forest types the abundance of the species failed to exceed 10%.

Cychrus caraboides L. was most frequent in *Pinetum carico-sphagnosum* pine stand (8.5%), although commonly this species is more characteristic of drier growth sites. Such a high frequency of the species is related to the small total number of individuals in this forest type.

Pterostichus oblongopunctatus was frequent both in dry and moist forest types. For instance, in *Alnetum caricosum* forest type this species was abundant only in May–June when it was rather dry. Later, with increased amount of precipitation, only several specimens were caught in the forest.

In the literature, it is admitted also that *P. oblongopunctatus* in marshlands is found only during droughts (Шарова, Грюнталь, 1983). It is frequent also in *Picetum myrtillosum* (24.7%), and in *Picetum myrtillo-oxalidosum* (23.1%) spruce stands.

Pterostichus nigrita Fabr. was found only in boggy forests, most often in *Betuletum calamagrostidosum* birch stand (11.3%) and *Pinetum carico-sphagnosum* pine stand (9.5%). This species may be considered the indicator of forest types characterized by waterlogged and boggy soils.

Pterostichus vulgaris (*melanarius*) is common in moist fertile forest types. It was most abundantly caught in *Picetum myrtillo-oxalodosum* spruce stand (23.6%), less frequently in *Betuleum oxalido-nemorosum* birch stand (13.7%) and even less often in *Betuletum calamagrostidosum* type (12%). It was not found at all in *Pinetum carico-sphagnosum* and *Pinetum ledo-sphagnosum* pine stands. It shows that this species avoids infertile boggy forest types.

Calathus micropterus is distinguished among other predominants. It is a species typical of dry forests, thus it was most frequent in *Picetum oxalidosum* spruce stand (59.7%). In *Picetum myrtillosum* spruce stand this species was also quite frequent (10.1%). Many individuals of the species were caught also in *Picetum myrtillo-oxalidosum* spruce stand (8.9%). *C. micropterus* may serve as an indicator of dry forest types. This species is characterized by a high abundance of individuals (299 beetles of the species were caught).

Qualitative similarity analysis of the communities revealed two groups covering two and four forest types, as well as two separate forest types which differed from the others (Fig. 2).

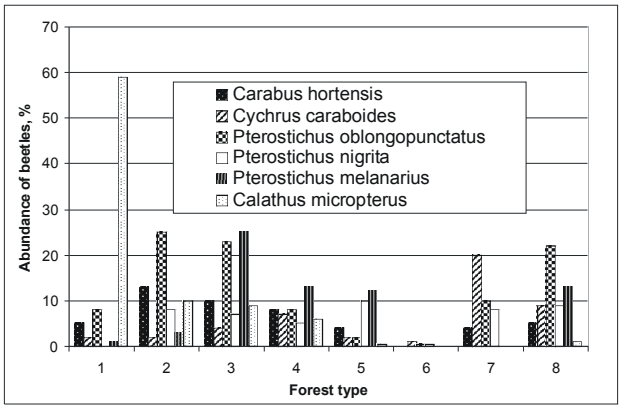

Fig. 1. Relative abundance of prevailing ground beetle species by forest types (1 – *Picetum oxalidosum,* 2 – *Picetum myrtillosum,* 3 – *Picetum myrtillo-oxalidosum,* 4 – *Betuletum oxalido-nemorosum,* 5 – *Betuletum calamgrostidosum,* 6 – *Pinetum ledo-sphagnosum*, 7 – *Pinetum carico-sphagnosum,* 8 – *Alnetum caricosum*)

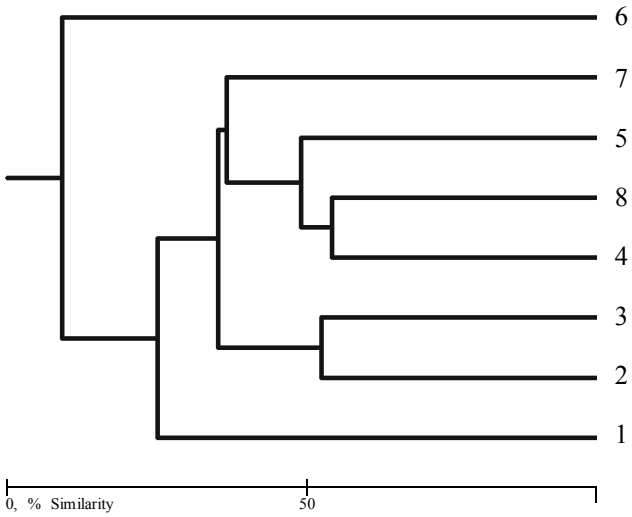

Fig. 2. Qualitative similarity (I_{cs}) of species composition of ground beetles in Aukštasis Tyras Mire Reserve by forest types (1 – *Picetum oxalidosum,* 2 – *Picetum myrtillosum,* 3 – *Picetum myrtillo-oxalidosum,* 4 – *Betuletum oxalido-nemorosum,* 5 – *Betuletum calamgrostidosum,* 6 – *Pinetum ledosphagnosum*, 7 – *Pinetum carico-sphagnosum,* 8 – *Alnetum caricosum*)

The first group consisted of overmoistured, waterlogged and boggy forests. The following forest types belong to this group: *Betuletum oxalido-nemorosum, Betuletum calamagrostidosum, Alnetum caricosum, Pinetum carico-sphagnosum*. Two subgroups can be distinguished in this group, to the first belonging *Pinetum carico-sphagnosum* and to the second *Betuletum oxalido-nemorosum*, *Betuletum calamagrostidosum, Alnetum caricosum*. The second group consists of *Picetum myrtillosum* and *Picetum myrtillo-oxalidosum*. Two types were distinguished among them: *Pinetum ledo-sphagnosum*, *Picetum oxalidosum*.

One can see that according to the species composition of ground beetles, most similar are broadleaved forest types. They are characterized by a very high degree of species diversity – 2.49 on an average. This index for the second group was only 2.14. Such a high species diversity of waterlogged and boggy forests is determined by a high number of species and a low level of their predominance. All the data show a great influence of moisture on the development of insects. Thus, in the forest types studied, the high soil moisture content and abundance of food are the most important conditions limiting the number of species and individuals of ground beetles.

The second group is characterized by obvious dominants (*Calathus micropterus, Pterostichus vulgaris* (*melanarius*)*, P. oblongopunctatus*)*,* due to which the level of species diversity decreased.

Separately may be mentioned *Picetum oxalidosum* and *Pinetum ledo-sphagnosum* pine stands. The soil of *Picetum oxalidosum* spruce stand belonged to the normal humidity type. The species composition of ground beetles in it was specific and dissimilar to other forest types. In this forest type, mesophilous species of ground beetles were caught, which are not characteristic of other forest types and are often found in meadows. The highest number of ground beetles was caught in this forest type (746 species).

Among boggy forest types, *Pinetum ledo-sphagnosum* pine stand is distinguished, characterized by poor living conditions for insects and the least number of caught ground beetles (7). Here is found, adapted to the conditions of this biotope, the *Agonum ericeti* Panz. species which is listed in the Red Data Book of Lithuania. Many representatives of the species were caught (199 species). The species diversity of ground beetles in this forest type was the lowest, because the frequency of *Agonum ericeti* comprised 92%.

The number of species and the indices of species diversity were determined individually for broadleaves and conifers. Most of ground beetles (on an average 19) were caught and the highest species diversity (2.47) was found in broadleaved forests. In pure coniferous forests, on an average 15 species of ground beetles were found. Species composition was lower in them as well (1.68). Thus, it may be concluded that living conditions for ground beetles are the best in broadleaved forests, while in inconiferous forests live species adapted to specific conditions, and for other species of ground beetles it is difficult to compete with them. Meanwhile, in deciduous forests available food is abundant, therefore many species of ground beetles find their niche there.

Studying seasonal dynamics of the number of ground beetles, two increments of seasonal abundance were distinguished – the first in May–June and the second in August (Fig. 3).

In different forest types the dynamics of the number of ground beetles differed in the course of the year. For example, in *Pinetum ledo-sphagnosum* pine stand most ground beetles were caught in May–June when *Agonum ericeti* appeared, which is the dominant species of this forest type and is active only in spring. Meanwhile, in *Picetum myrtillo-oxalidosum* spruce stand most ground beetles were caught in August when the dominant species *Carabus hortensis* and *Pterostichus vulgaris* (*melanarius*) were active.

The species evenness index E ranged from 0 to 1. When all the species are evenly abundant, the index equals 1. Figure 4 shows that the abundance of ground beetle species, judging by the distribution evenness index E, was the highest in *Betuletum oxalido-nemorosum* birch stand and the lowest in *Pinetum ledo-sphagnosum* pine stand. In deciduous stands, the species evenness index E of ground beetles was much higher (0.85) than in coniferous stands (0.62). Among the forest types, *Pinetum carico-sphagnosum* pine stand may be distinguished. In it, the abundance of species was even higher than in some forest types with prevailing deciduous trees because of the absence of distinct dominants in this forest type (Fig. 4).

The highest species diversity of ground beetles was characteristic of the *Betuletum calamagrostidosum* forest type (Fig. 4) and the least of *Pinetum ledo-sphagnosum* pine stand. A statistically reliable difference was obtained comparing species composition in the *Picetum oxalidosum* spruce stand and *Pinetum ledo-sphagnosum* pine stand with the species diversity of ground beetles in all the rest of the forest types. It means that in these two forest types the conditions for ground beetles greatly differed and the species diversity of ground beetle communities in them was rather low. This was especially obvious in the *Pinetum ledo-sphagnosum* forest type.

Thus, the greatest differences in ground beetle species diversity were found among the forest types differing in soil humidity and fertility. It is possible to state that the species diversity of ground beetles was predetermined by forest type, soil humidity and fertility.

Carrying out zoogeographical analysis of a certain group of beetles, usually many different habitat types are differentiated. However, as I. Lopatin (Лопатин, 1979, 1986) points out, there are only two main fauna types: boreal (Siberian) and paratetic (Meditteranean). The fauna types of Aukštasis Tyras ground beetles are shown in Fig. 5.

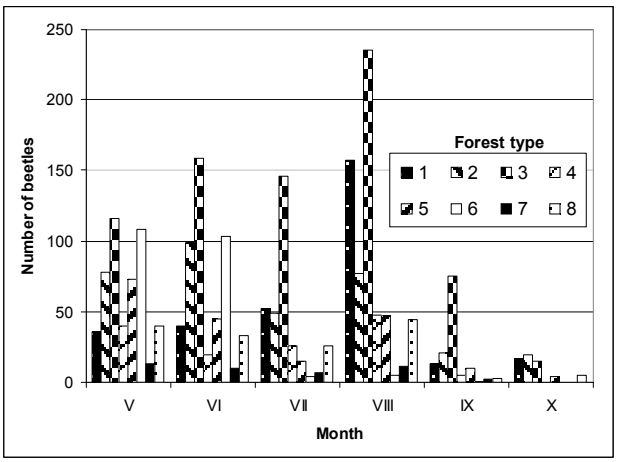

Fig. 3. Abundance of ground beetles in different forest types (*1 – Picetum oxalidosum,* 2 – *Picetum myrtillosum,* 3 – *Picetum myrtillo-oxalidosum,* 4 – *Betuletum oxalido-nemorosum,* 5 – *Betuletum calamgrostidosum,* 6 – *Pinetum ledo-sphagnosum*, 7 – *Pinetum carico-sphagnosum,* 8 – *Alnetum caricosum*)

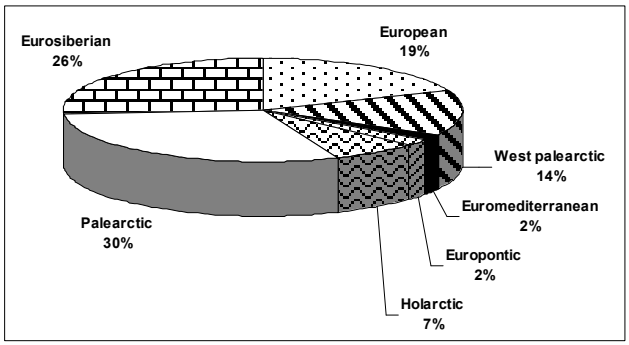

Fig. 5. Percentage ratio of habitat types of Aukštasis Tyras Mire Reserve ground beetles

Even 84% of the caught ground beetles belonged to the boreal type. It is related to the fact that the studies were carried out with a complex of forest ground beetles, which comprised only individual ground beetle species of meadows, dry pine woods and broadleaved forests, which in the Boreal and Atlantic periods migrated from the Mediterranean and Caspian centers.

Boreal species (species which migrated in the Postglacial, Subarctic and Preboreal periods from the East) are ecologically related to forests and marshlands. These species of ground beetles comprise the largest portion of ground beetles in the study.

The bulk of the ground beetle fauna comprised the boreal type to which 35 species (82%) belonged.

Boreal species are characterized by Holarctic (3 species), Palearctic (13 species), Eurosiberian (11 species) and European (8 species) habitats.

To paratetic were ascribed 7 species (18%). They are characterized at present by West Palearctic (5 species), Euromediterranen (1 species) and Europontic (1 species) habitats. Ecologically, paratetic species are related to dry, well heated by the sun meadows, light pine woods and deciduous forests. Also, one pontic species (*Nebria brevicollis*) was detected.

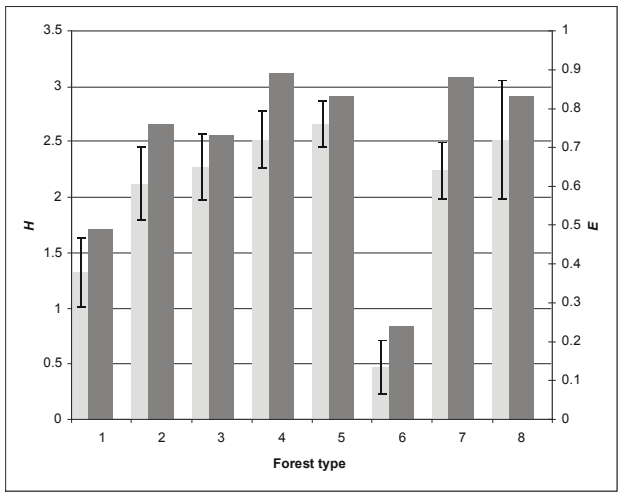

Fig. 4. Species diversity indices of ground beetle communities (*H*) and indices of species evenness (*E*) in different forest types (1 – *Picetum oxalidosum,* 2 – *Picetum myrtillosum,* 3 – *Picetum myrtillo-oxalidosum,* 4 – *Betuletum oxalido-nemorosum,* 5 – *Betuletum calamgrostidosum,* 6 – *Pinetum ledo-sphagnosum*, 7 – *Pinetum carico-sphagnosum,* 8 – *Alnetum caricosum*)

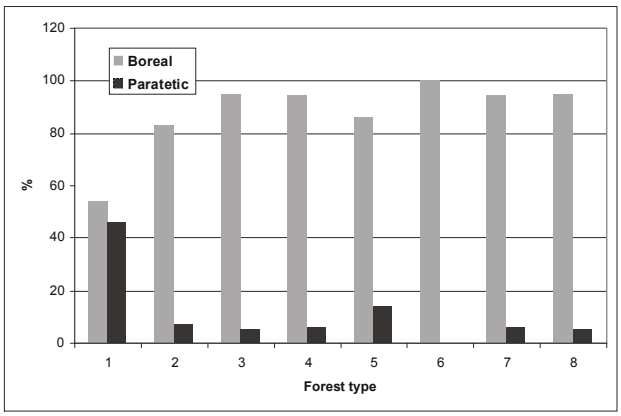

Fig. 6. The ratio of boreal and paratetic fauna types of ground beetles (%) in forest types (1 – *Picetum oxalidosum,* 2 – *Picetum myrtillosum,* 3 – *Picetum myrtillo-oxalidosum,* 4 – *Betuletum oxalido-nemorosum,* 5 – *Betuletum calamgrostidosum,* 6 – *Pinetum ledo-sphagnosum*, 7 – *Pinetum carico-sphagnosum,* 8 – *Alnetum caricosum*)

The ratio of the boreal and the paratetic fauna types of ground beetles in the study forests is shown in Fig. 6.

One can see that paratetic species in the Reserve are relatively inabundant and their portion in all forest types is far lower than on the whole in Lithuania.

The portion of boreal fauna was greatest in boggy forest types*: Pinetum ledo-sphagnosum* (100%*), Pinetum carico-sphagnosum* (93%), *Alnetum caricosum* (95%), *Picetum myrtillo-oxalidosum* (95%), *Betuletum oxalido-nemorosum* (94%). The highest portion of paratetic fauna type was found in dry forests: *Picetum oxalidosum* (46%), *Betuletum calamagrostidosum* (12%).

Our study has confirmed that ecologically the boreal species of ground beetles are related to forests and

marshlands, while the paratetic ones prefer dry, well heated meadows, light pine woods and broadleaved forests.

CONCLUSIONS

1. In forests of the Aukštasis Tyras Mire Reserve, the highest species diversity of ground beetles was found in *Betuletum calamagrostidosum* (25 species) and the least in *Pinetum ledo-sphagnosum* stands (7 species). Species diversity was directly dependent on soil fertility and moisture content. The conditions for ground beetles were optimal in fertile and humid broadleaved forests.

2. According to the qualitative data of the similarity of ground beetle species composition, the forest types were divided into two groups: 1 – temporarily overmoistured, waterlogged and boggy forests – *Betuletum oxalido-nemorosum, Betuletum calamagrostidosum*, *Pinetum carico-sphagnosum, Alnetum caricosum*, and 2 – *Picetum myrtillosum*, *Picetum myrtillo-oxalidosum*. *Pinetum ledo-sphagnosum* and *Picetum oxalidosum* according to qualitative indices were hardly similar to other forest types.

3. According to humidity requirements, the ground beetle species were distributed as follows: 57% were hygrophilous, 36% mesophilous and 7% eurihygrophilous. According to the number of individuals, 73% of ground beetles belonged to mesophilous, 24% to hygrophilous and 3% to eurihygrophilous species.

4. The bulk of the ground beetle fauna in the Aukštasis Tyras Mire Reserve forests – (82%) comprised 35 species of boreal type. They were characterized by Holarctic (3 species), Palearctic (13 species), Eurosiberian (11 species) and European (8 species) habitats. To the paratetic type belonged 7 species (18%). They are characterized by Western Palearctic (6 species), Euromediterranean (1 species) and Europontic (1 species) habitats.

The greatest portion of boreal ground beetles was found in the *Pinetum ledo-sphagnosum* pine stand (100%) and *Picetum myrtillo-oxalidosum* spruce stand (95%), while the greatest portion of paratetic species lived in the *Picetum oxalidosum* spruce stand (46%).

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Algimantas Žiogas, Stasys Vaičikauskas

ŽYGIŲ (*COLEOPTERA, CARABIDAE*) BIOEKOLOGIJA AUKŠTOJO TYRO PELKIŲ REZERVATE

Santrauka

2004–2005 m. tyrimų aštuoniuose Aukštojo Tyro telmologinio draustinio miško tipuose metu buvo surinkti 43 rūšių (15 genčių) žygiai. Rūšių įvairovės indeksas S kito nuo 0,47 – *Pinetum ledo-sphagnosum* pušyne iki 2,66 – *Betuletum calamagrostidosum* beržyne. Pagal žygių rūšinės sudėties panašumo kokybinius duomenis miško tipai suskirstyti į dvi grupes: 1 – laikino perteklinio drėgnumo, užmirkę ir pelkiniai

miškai – *Betuletum oxalid-nemorosum*, *Betuletum calamagrostidosum*, *Pinetum carico-sphagnosum*, *Alnetum caricosum*, 2 – *Picetum myrtillosum*, *Picetum myrtillo-oxalidosum*. *Pinetum ledo-sphagnosum* ir *Picetum oxalidosum* pagal kokybinius rodiklius buvo mažai panašūs į kitus miško tipus. Pagal poreikį drėgmei žygių rūšys pasiskirstė taip: 57% – higrofilinių, 36% – mezofilinių ir 7% – eurihigrofilinių. Pagal individų skaičių žygiai priklausė: 73% – mezofilams, 24% – higrofilams ir 3% – eurihigrofilams. Žygių faunos pagrindą sudarė borealinio tipo rūšys. Daugiausia borealinių žygių rūšių buvo *Pinetum ledo-sphagnosum* pušyne (100%) ir *Picetum myrtillo-oxalidosum* eglyne (95%), o paratetinių rūšių – *Picetum oxalidosum* eglyne.

Raktažodžiai: žygiai, rūšinė sudėtis, įvairovė, miško tipas