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Changes in alpine meadow epigeal fauna in the Západné Tatry Mts induced by nitrogen and phosphorus additions to the soil and analysed on example of beetles (Coleoptera) assemblages

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Abstract

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Changes in structure of an epigaeon were studied in alpine meadows of the Tatry Mts influenced by nitrogen and phosphorus additions. Five sites were compared according to their epigeal beetle fauna. In total we recorded 65 species, including dominant *Carabus sylvestris*, *Otiorhynchus arcticus*, *Calathus metallicus* and *Aphodius abdominalis*. Communities in the study sites treated with the highest nitrogen amounts (site N15) and with phosphorus (P) reflected significant changes in species composition and abundance in comparison with the background (control) site (C).

Key words

Coleoptera, ecology, nitrogen input, phosphorus input, alpine meadows

Introduction

At present, impact of air-transported polluting substances, especially nitrogen deposition, on terrestrial as well as aquatic ecosystems is devoted an increasing attention (Bowmann et al., 1995, 1996; Theodose et al., 1996, and Thomas et al., 1998). The deposition of anthropogenic nitrogen from the atmosphere onto the land and onto the plant surface has considerable influences on processes running in terrestrial ecosystems. For insect herbivores, concentration of N in the host plants strongly controls such processes as growth, survivorship, population level and outbreak frequency (Throop and Lerdau, 2004). Epigeal beetles are of high significance for biocoenoses, not only due to high number of the species, but also due to huge number of the individuals. Complex and multiple relationships between different species of epigeal beetle communities and their environment are reflected in species composition of the communities. For this reason we were focussing on changes to beetle communities influenced by inputs of nitrogen and phosphorus. As a model locality was established an area of acidic alpine meadows in the Západné Tatry Mts.

Previously, in 1992, the epigeal beetles were studied in three localities (Sivý vrch, Brestová and Salatín) in the alpine zone of the Západné Tatry Mts (Majzlan, 2003). Apart from the beetles studied in frame of the project, our research also included epigeal spider assemblages (Gajdoš, 1993).

The aim of this study was to describe the beetle species composition, to characterise the beetle assemblages of the alpine meadows and to compare the changes in structure of epigeal assemblages influenced by nitrogen and phosphorus additions.

Study area

The study area is situated in the Western Tatras Mountains, and it is administered as a part of the High Tatras Mountains National Park. The permanent experimental area was established in May 2002 in the upper part of the Jalovecká dolina valley, near the Salatín Mt in the Západné Tatry Mts (N Slovakia). The area is situated at the top of the mountain at an altitude of 1,900 m asl on granitoid bedrock (Fig. 1). The study area represents the alpine meadow stands of Juncion trifidi with the dominant grasses *Oreochloa disticha*, *Festuca supina* and the lichen *Cetraria islandica*. Moreover, the stand also comprises less frequent *Juncus trifidus*, *Agrostis rupestris*, *Campanula alpina*, *Hieracium alpinum* or even the rare species *Carex bigelowii*, *Poa chaixii*, *Bistorta major*, *Deschampsia flexuosa*, *Homogyne alpina*, *Vaccinium vitis-idaea*. Bryophytes are represented by *Polytrichum alpinum* and *Polytrichum sexangulare* (Halada et al., 2007).

Material and methods

Sampling and study sites

The study area comprised five blocks with five study sites (totally 25 sites), (Fig. 2). Study of epigeal fauna was realised in one block (5th block). Its sites (2 × 2 m) were selected randomly in homogenous block with an radius of 20 m. Three sites (N2, N6 and N15) in the study block were supplied with nitrogen in three different amounts (2 g m^{-2}, 6 g m^{-2}, 15 g m^{-2}), in form of NH_4NO_3 solutions. One site was treated with phosphorus (8 g m^{-2}) in form of a KH_2PO_4 solution. Application of the chemicals was repeated three times a year, since 2002. The last, control site (C) was only supplied with water. Out of the study block, another site (C_o) was provided with two traps, and left without chemicals.

In 2004 we launched monitoring epigeal fauna. For this purpose we installed two pitfall traps in each site of study block (N2, N6, N15, P and C, in total 10,

Fig. 1. A view on the study site situated in an alpine meadow 1900 m asl

on June 17, 2004). The material was collected on the following dates: July 22, August 16 and October 13, 2004. In 2005 the traps were installed on June 3 and they were emptied on June 24, July 18, August 18, October 10, 2005 and June 6, 2006. Each pitfall trap consisted of a one-litre jar (diameter 10 cm) with an antifreeze substance Fridex as a conservation medium. Other two pitfall traps were installed at the background site (C_o) outside the study block, in 2005. In such a way, the material comes from 12 traps. During the research period, these additional traps were several times destroyed by chamois. The data from these traps are listed in Table 2, but they were not used in analysis of changes in the studied assemblages.

The collected species were determined by competent experts: Staphylinidae (T. Jászay), Carabidae (I. Rychlík), Hydrophilidae (R. Cséfalvay), Elateridae (O. Šauša).

The more detailed methods as well as soil and vegetation analyses were published by Sedláková (2005a, b).

Data analysis

As tools for comparison of the epigeal spider communities we used Detrended Corespondence Analysis (DCA – length of gradient = 0.68), Principal Component Analysis (PCA) and Redudancy Analysis (RDA) provided in the CANOCO programme (Ter Braak and Šmilauer, 1998). We compared the total catches consisting of more than one specimen for each site and

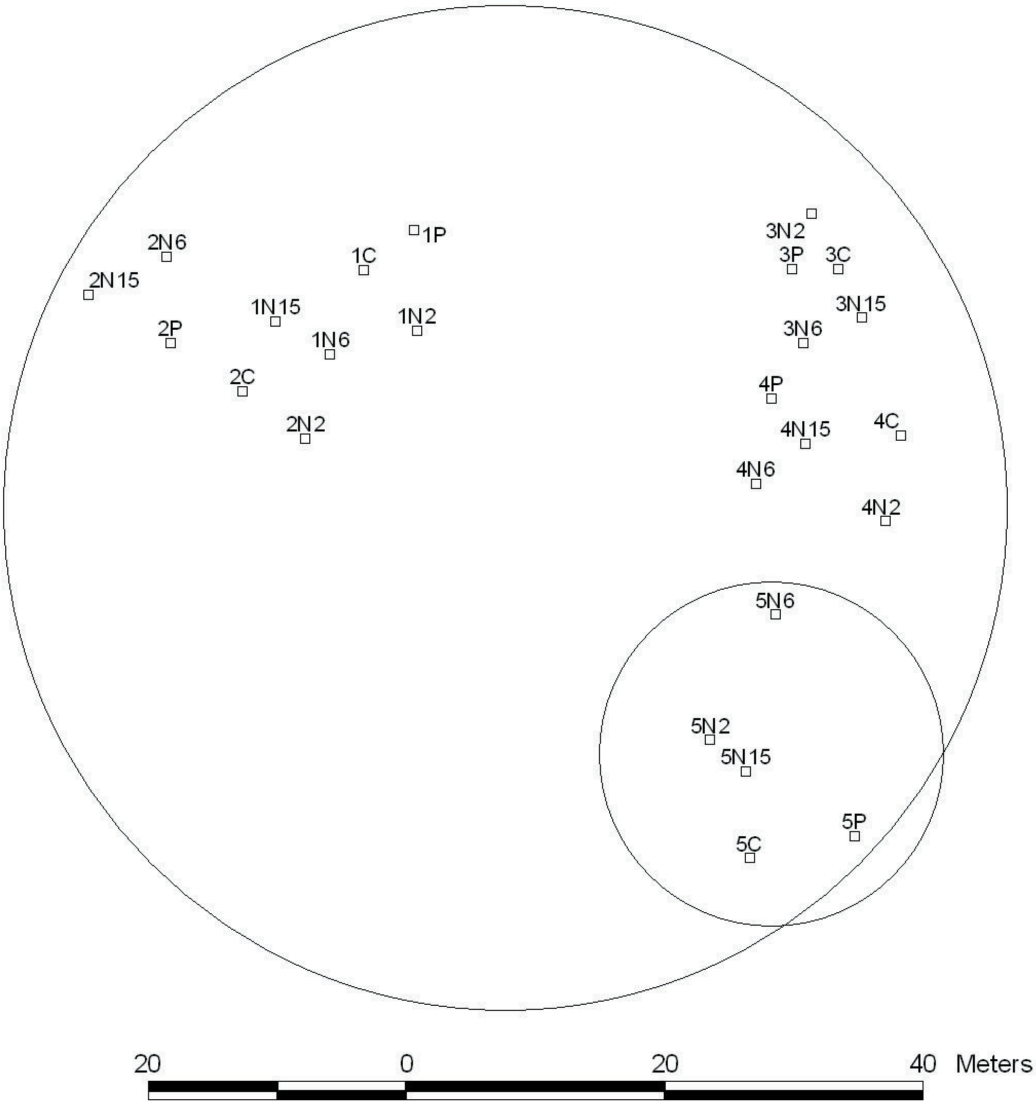

Fig. 2. Location of study sites

analysed the log-transformed abundances. Species with abundance more than one specimen were subjected to the site × species analyses.

Results and discussion

Dominance and abundance

In 2004 we recorded in the study material the following eudominant species: *Carabus sylvestris* 44.25%, *Calathus metallicus* 13.9% and *Otiorhynchus arcticus* 11.3%, forming altogether 69.5% of all the specimens (within 43 species) (Table 1.)

In 2005/2006 the material included these eudominant species: *Carabus sylvestris* 12.3%, *Leptusa flavicornis* 29.3%, *Otiorhynchus arcticus* 17% and *Aphodius abdominalis* 15.3%. They formed 73.9% of all the specimens recorded within 49 species (Table 2). The category of subdominant species contained *Calathus metallicus* (3.3%). High dominance of *Leptusa flavicornis* may refer to its accidental presence in just 6 samples. The highest dominance thus belongs to the four species, which determine the socion (coleopterocoenosis). The project was aimed at evaluation of changes to beetle assemblages at the five compared sites. For 2004 we observed just a gentle decrease in quality at the sites chemically impacted (from 18 to 23 species) in comparison with the background site (28 species). On the study site supplied with the highest concentration of nitrogen (N15), the abundance was evidently the lowest.

A similar situation in quality appeared also in 2005. The richness at the background site (C) was the highest. Also abundance on study site (N15) was three times lower (288 specimens) in comparison with the background site and sites with lower input of nitrogen (N2 and N6) what may suggest about certain influence of higher concentrations of chemical substances on epigeal beetle species, particularly on their larval stages permanently living in soil.

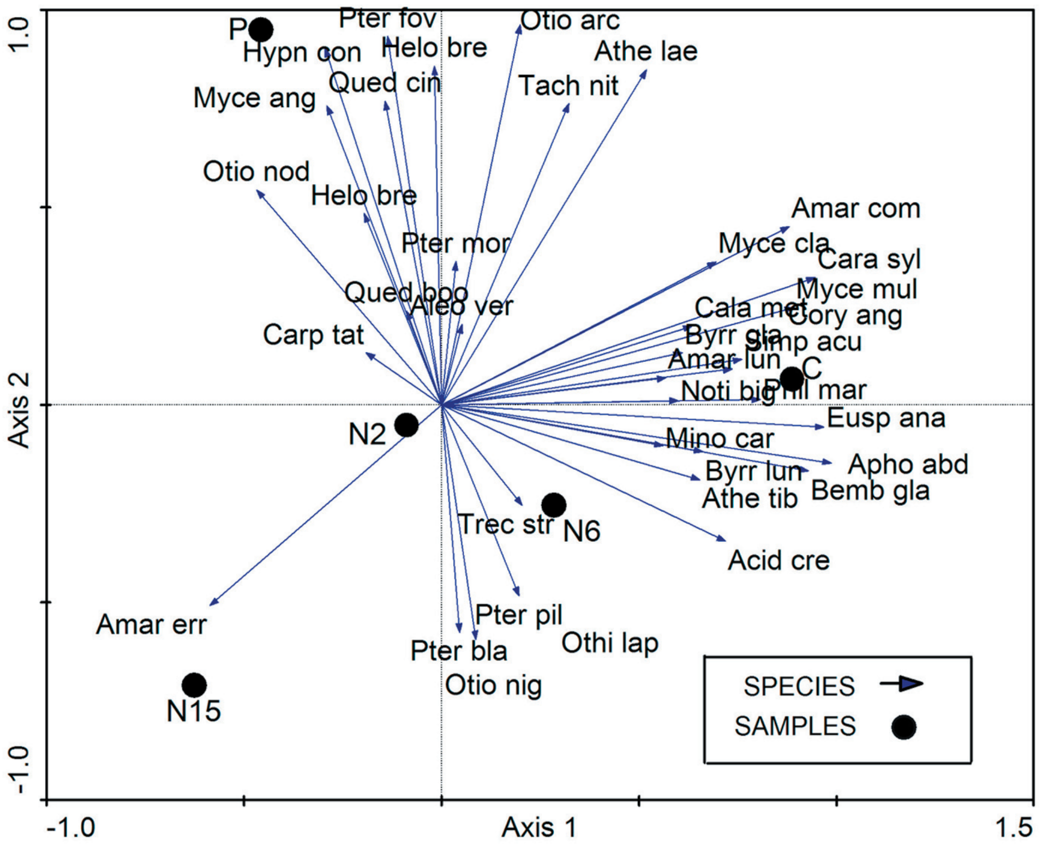

Fig. 3. Principal Component Analysis (PCA) – sites × species plot
Sites: C – background (control) site, N2, N6, N15 and P – sites influenced by nitrogen and phosphorus additions.
Abbreviations of the species name: 4 first letters are abbreviation of the genus and 3 other letters are abbreviation of the species name. Full species name: see Table 1 and 2

Table 1. A systematic survey of beetles recorded in 2004, including number of specimens per site and dominance for control, for sites affected by selected elements and for the total study material

Species, **Family**	Control		Input of element						Total
	C	D(%)	N2	N6	N15	P	Σ	D(%)	D(%)
Carabidae									
Carabus sylvestris Panzer, 1796	214	50.2	160	196	140	167	663	42.6	44.25
Cychrus caraboides (Linnaeus, 1758)		0		1			1	0.06	0.05
Bembidion glaciale Heer, 1837	1	0.23		3			3	0.19	0.20
Bembidion inoptatum Schaum, 1857	1	0.23						0	0.05
Bembidion quadrimaculatum (Linnaeus, 1761)	1	0.23						0	0.05
Bembidion lampros (Herbst, 1784)	1	0.23						0	0.05
Deltomerus tatricus (Miller, 1859)	1	0.23						0	0.05
Calathus metallicus Dejean, 1828	78	18.3	36	39	64	59	198	12.7	13.93
Pterostichus blandulus Kult, 1947	7	1.64	14	7	16		37	2.38	2.22
Pterostichus morio carpathicus Kult, 1944	9	2.11	19	19	5	5	48	3.08	2.88
Pterostichus pilosus (Host, 1789)	1	0.23						0	0.05
Pterostichus foveolatus (Duftschmid, 1812)	6	1.41	17	9	9	47	82	5.27	4.44
Amara communis (Panzer, 1797)	2	0.47	1	1		1	3	0.19	0.25
Amara erratica (Duftschmid, 1812)		0			1		1	0.06	0.05
Hydrophilidae									
Helophorus brevipalpis Bedel, 1881		0	1	1		1	3	0.19	0.15
Helophorus brevitarsis Kuwert, 1886	1	0.23		1	1	1	3	0.19	0.20
Staphylinidae									
Eusphalerum anale (Erichson, 1840)	3	0.7	2	2			4	0.26	0.35
Acidota crenata (Fabricius, 1793)	3	0.7		4	1		5	0.32	0.40
Coryphium angusticolle Stephens, 1834		0			2	2	4	0.26	0.20
Othius lapidicola Märkel et Kiesenwetter, 1848		0			1		1	0.06	0.05
Philonthus mareki Coiffait, 1967	10	2.35	10	7	6		23	1.48	1.67
Gabrius subnigritulus Joy, 1913		0	1				1	0.06	0.05
Quedius cincticollis Kraatz, 1857	1	0.23	2			1	3	0.19	0.20
Quedius boops (Gravenhorst, 1802)	2	0.47		2	2		4	0.26	0.30
Mycetoporus mulsanti Ganglbauer, 1895	3	0.7		1		1	2	0.13	0.252
Mycetoporus clavicornis (Stephens, 1832)	3	0.7				1	1	0.06	0.20
Tachyporus nitidulus (Fabricius, 1781)	1	0.23						0	0.05
Atheta tibialis (Heer, 1839)		0			1		1	0.06	0.05
Atheta brunneipennis (Thomson, 1852)		0			1		1	0.06	0.05
Pselaphidae									
Euplectus bescidicus Reitter, 1881		0				1	1	0.06	0.05
Scarabaeidae									
Aphodius abdominalis Bonelli, 1812	7	1.64	43	43	19	13	118	7.58	6.31
Byrrhidae									
Simplocaria acuminata Erichson, 1847		0	1				1	0.06	0.05
Carpathobyrrhulus tatricus Mroczkowski, 1957	6	1.41	10	18	6	12	46	2.96	2.62
Elateridae									
Hypnoidus consobrinus (Mulsant et Guillebeau, 1855)	3	0.7	1	2		14	17	1.09	1.01

Table 1. Continued

Species, **Family**	Control		Input of element						Total
	C	D(%)	N2	N6	N15	P	Σ	D(%)	D(%)
Cantharidae									
Rhagonycha maculicollis Märkel, 1851		0				1	1	0.06	0.05
Coccinellidae									
Adonia variegata (Goeze, 1777)		0			1		1	0.06	0.05
Chrysomelidae									
Chaetocnema hortensis (Geoffroy, 1785)		0		1			1	0.06	0.05
Minota carpathica Heikertinger, 1911	7	1.64	2	8	4	2	16	1.03	1.16
Curculionidae									
Otiorhynchus arcticus (Fabricius, 1780)	48	11.3	77	50	36	71	234	15	14.23
Otiorhynchus niger (Fabricius, 1775)		0	1		1		2	0.13	0.10
Otiorhynchus nodosus (Müller, 1764)		0	1	2	1		4	0.26	0.20
Plinthus sturmi (Germar, 1824)	1	0.23						0	0.05
Total	426	100	402	435	319	400	1,556	100	100
Number of species	28		20	23	22	18			

Table 2. A systematic survey of beetles recorded in 2005–2006, including number of specimens per site and dominance or control, for sites affected by selected elements and for the total study material

Species, **Family**	Control			Input of element						Total
	C_o	C	D(%)	N2	N6	N15	P	Σ	D(%)	D(%)
Carabidae										
Carabus sylvestris Panzer, 1796	30	121	16.8	97	81	59	87	324	18.2	12.3
Calathus metallicus Dejean, 1828	7	42	5.82	37	19	8	18	82	4.62	3.39
Notiophilus biguttatus (Fabricius, 1779)		1	0.14	1				1	0.06	0.05
Trechus striatulus Putzeys, 1847	4	2	0.28	12	13	7	8	40	2.25	1.19
Bembidion glaciale Heer, 1837	1	4	0.55	3	2	2	2	9	0.51	0.36
Pterostichus blandulus Kult, 1947	2	10	1.39	29	13	7	2	51	2.87	1.63
Pterostichus morio carpathicus Kult, 1944	13	17	2.35	22	21	16	26	85	4.79	2.98
Pterostichus pilosus (Host, 1789)			0			1		1	0.06	0.03
Pterostichus foveolatus (Duftschmid, 1812)	8	25	3.46	6	24	8	20	58	3.27	2.36
Amara erratica (Duftschmid, 1812)		1	0.14	1		3	1	5	0.28	0.16
Amara lunicollis Schiødte, 1837		2	0.28		1	1	1	3	0.17	0.13
Microlestes minutulus (Goeze, 1777)			0	1				1	0.06	0.03
Hydrophilidae										
Helophorus brevitarsis Kuwert, 1886		5	0.69	7	7	3	9	26	1.46	0.8
Staphylinidae										
Eusphalerum anale (Erichson, 1840)		2	0.28						0	0.05
Coryphium angusticolle Stephens, 1834		17	2.35						0	0.44
Stenus clavicornis (Scopoli, 1763)		1	0.14						0	0.03
Stenus parcior limonensis Fagel, 1958		1	0.14						0	0.03
Othius brevipennis Kraatz, 1857			0	1				1	0.06	0.03

Table 2. Continued

Species, **Family**	Control			Input of element						Total
	C_o	C	D(%)	N2	N6	N15	P	Σ	D(%)	D(%)
Othius lapidicola Märkel et Kiesenwetter, 1848		1	0.14						0	0.03
Philonthus mareki Coiffait, 1967		40	5.54	36	25	14	23	98	5.52	3.57
Quedius boops (Gravenhorst, 1802)		1	0.14	4	9	2	8	23	1.3	0.62
Quedius cincticollis Kraatz, 1857			0	1	1		2	4	0.23	0.1
Tachyporus nitidulus (Fabricius, 1781)			0				1	1	0.06	0.03
Tachyporus ruficollis Gravenhorst, 1802		1	0.14						0	0.03
Mycetoporus angularis Mulsant et Rey, 1853			0		1		2	3	0.17	0.08
Mycetoporus mulsanti Ganglbauer, 1895		1	0.14	1				1	0.06	0.05
Mycetoporus bimaculatus Lacordaire, 1853			0				1	1	0.06	0.03
Leptusa flavicornis Brancsik, 1874		165	18.6	474	468		26	968		29.3
Atheta tibialis (Heer, 1839)		3	0.42	1				1	0.06	0.1
Atheta laevicauda Sahlberg, 1876		2	0.28	1	1		2	4	0.23	0.16
Aleochara verna Say, 1839			0		2		1	3	0.17	0.08
Scarabaeidae										
Aphodius abdominalis Bonelli, 1812	65	236	32.7	73	138	41	39	291	16.4	15.3
Byrrhidae										
Simplocaria acuminata Erichson, 1847		5	0.69	4	3	1	2	10	0.56	0.39
Carpathobyrrhulus tatricus Mroczkowski, 1957	4	16	2.22	10	19	21	20	70	3.94	2.33
Byrrhus glabratus Heer, 1841	3	9	1.25	4	2	4	4	14	0.79	0.67
Byrrhus luniger Germar, 1817	2	4	0.55	5	3	1	1	10	0.56	0.41
Elateridae										
Hypnoidus consobrinus (Mulsant et Guillebeau, 1855)	2	5	0.69	1	5	2	32	40	2.25	1.22
Athous vittatus (Fabricius, 1792)	1									0.03
Rhizophagidae										
Rhizophagus dispar (Paykull, 1800)	1									0.03
Coccinellidae										
Ceratomegilla redtenbacheri alpina (Capra, 1928)			0	1				1	0.06	0.03
Coccinella septempunctata Linnaeus, 1758			0				1	1	0.06	0.03
Lathridiidae										
Stephostethus angusticollis (Gyllenhlal, 1775)			0				1	1	0.06	0.03
Chrysomelidae										
Minota carpathica Heikertinger, 1911	1	7	0.97	4	12	5	8	29	1.63	0.96
Curculionidae										
Otiorhynchus arcticus (Fabricius, 1780)	83	134	18.6	102	110	75	152	439	24.7	17
Otiorhynchus niger (Fabricius, 1775)	4	4	0.55	10	13	6	2	31	1.75	1.01

Table 2. Continued

Species, **Family**	Control			Input of element						Total
	C_o	C	D(%)	N2	N6	N15	P	Σ	D(%)	D(%)
Otiorhynchus nodosus (Müller, 1764)	1	1	0.14	3	2	1	5	11	0.62	0.34
Sitona inops Gyllenhal, 1832			0	1				1	0.06	0.03
Scolytidae										
Ips cembrae (Heer, 1836)		1	0.14						0	0.03
Pityogenes chalcographus (Linnaeus, 1761)			0				1	1	0.06	0.03
Total	232	887	100	953	995	288	508	2,744	100	100
Number of species		34		31	26	23	32			

Frequency

Frequency has been evaluated as a regularity of occurrence in the samples. The category of euconstant species in both years included the following beetles: *Pterostichus blandulus*, *Pterostichus morio carpathicus, Calathus metallicus, Pterostichus foveolatus, Philonthus mareki, Carpathobyrrhulus tatricus and Hypnoidus consobrimus.*

Seasonal dynamics

In the seasonal dynamics, remarkable peaks appeared in August in both years. The similar results were obtained in 1992 at the same site (Majzlan, 2003).

Trophical groups of beetles

In the beetle assemblages 3 basic trophical groups may be established: zoophagous, phytophagous and pantophagous species. The category of zoophagous beetles includes representatives of the following families: Carabidae, Staphylinidae, Pselaphidae, Cantharidae, Coccinellidae and Rhizophagidae. They form 46% of the community.

The phytophagous species come from the families Hydrophilidae, Byrrhidae, Elateridae, Chrysomelidae, Curculionidae and Scolytidae and form 35.4% of the assemblage.

Finally the group of pantophagous (mycetophagous, coprophagous) beetles refers to the families of Scarabaeidae, Lathridiidae, and has a share of 18.6%.

Leptusa flavicornis was an eudominant species in 2005. Smetana (1958) mentioned this beetle in his paper on its occurrence frequency on micromammals in the Tatry Mts. He suggested a hypothesis about ecological interaction between the tiny specimens and fur of micromammals (Sorex, Neomys, Apodemus) in connection with low temperature. In our material several shrews were captured, what explains such a massive occurrence of the species in some samples.

Beetle assemblages

In our 2-year-long research we generally recorded 65 species at the study sites. From this number, 43 were observed in 2004, 49 in 2005. There are 27 species being present in both years. They particularly include dominant beetles, or beetles with the highest frequency.

There are stabilised assemblages (socions) of beetles at the study sites. They have been being formed since the end of the last glacier period, which marginally (by the southern boundary) influenced this area. Socions are determined by the dominant phytophagous species as well as the most frequent and dominant species generally. Thus such a type of alpine meadows may be hosting the socion of *Otiorhynchus arcticus*, resp. alternatively *Carabus sylvestris* and *Aphodius abdominalis*. This assemblage is characterised by the most stable interactions among its dominant, differential and accessory species. Any change in biotope conditions is supposed to reflect in its qualitative structure (Majzlan, 2003).

Principal Component Analysis

Analysis of the beetle assemblages' composition in the five study sites during the two trapping periods is visualised by means of the sites × species plot in Fig. 3. The positions of sites in the plot are very different: the background site (C) is situated central-right close to axis 1 (PC1), the sites supplied with nitrogen are grouped in the lower part (N2 near the centre, N6 downwards right from and close to the centre, N15 bottom left) and the site influenced by phosphorus is situated top left. The spacing of sites on the plot reflects the changes in communities that are connected with different addition of chemical substances to the ecosystem (phosphorus and different concentrations of nitrogen). Short distances between circles representing the sites with lower nitrogen input (N2 and N6) express similar species composition of communities in these sites, and also their considerable similarity to the background site (C). On the other hand, position of the sites N15 and P on the plot reflects remarkable changes in the species composition of their communities, also in comparison with the background (control) site (C). The site influenced by phosphorus input (site P) showed an increased primary production what corresponds to dominance of phytophagous species as *Otiorhynchus arcticus*, *O. nodosus*, *Carpathobyrrhulus tataricus*, *Hypnoidus consobrinus* and *Helophorus brevitarsis* in assemblage in this site (Fig. 3). On the other hand, increasing concentration of nitrogen input resulted in a decrease in lichens and mosses and in a decrease in herbs abundance in site N15 only (Gajdoš et al., 2006). These results correspond to the changes in the investigated beetle assemblages.

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Zmeny v epigeickej faune alpínskych lúk ovplyvnenej dodávaním dusíka a fosforu do pôdy a analyzované na príklade chrobačích spoločenstiev (Coleoptera)

Súhrn

Zmeny v zložení epigeónu boli skúmané na alpínskych lúkach Západných Tatier ovplyvnených dodávaním dusíka a fosforu. Skúmané plochy (3 plochy ovplyvňované dodávaním rôzneho množstva dusíka, 1 plocha ovplyvnená dodávaním fosforu a 1 kontrolná plocha bez zásahu) boli porovnávané na základe ich fauny chrobákov. Celkove bolo zistených 65 druhov s dominantne zastúpenými druhmi *Carabus sylvestris*, *Otiorhynchus arcticus*, *Calathus metallicus* a *Aphodius abdominalis*. Spoločenstvo na skúmanej ploche ošetrovanej najvyššou dávkou dusíka (plocha N15) a spoločenstvo na ploche ošetrovanej fosforom (plocha P) vykazovali preukazné zmeny v zložení a v abundancii v porovnaní so spoločenstvom na skúmanej ploche bez aplikácie dusíka a fosforu (kontrolná plocha C).

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