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Assemblages of carabid beetles (Coleoptera: Carabidae) as zoo-indicator of water tourism impact on forest – lake ecotones

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We studied the impact of medium rate and high rate water tourism on epigeic carabid beetles inhabiting alder forest (A) located on lakesides and pine forest (P) located 50 meters away from the first ones. The main exploratory questions were, whether (1) an increase of water tourism pressure will result in an increase of carabid species numbers, changes of assemblages structure and a decrease of Mean Individual Biomass (MIB) of Carabidae and SPC index and (2) the intensity of these changes depends on intensity of tourism pressure and quality of the forest habitats. The modifications of carabid beetle assemblages were proven by both the SPC and the MIB indicator and demonstrated by a SPC/MIB model. The results showed that a higher level of regressive changes (increase of share of individuals of small zoophages and dimorphic species and decrease of percentage share of individuals belonging to autumn and hygrophilous species) was correlated with an increase of water tourism pressure. Under stronger tourism pressure the number of species standardized by rarefaction increased as well. The results suggest changes in the studied forest environments. However, the level of changes was lower in comparison to changes caused by clear cuts. Our results suggest modifications in carabid assemblages not only due to intensity of tourism impact but also to differences in quality of the environment. However, the latter factor seems to have less relevance.

Key words: outdoor recreation, water tourism, tourism pressure, Carabidae, structure of assemblages, Mean Individual Biomass, MIB index, SPC index

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INTRODUCTION

Tourism and recreation is an important source of income for numerous communities. On the other hand, however, it causes strong modifications of the natural environment. These modifications may be due to impact of tourism and recreation on physical, chemical and biological characteristics of the environment. An example of physical impact is trampling the ground by walking, horse or even llama riding tourists (the last example has not taken place in the Masurian

Landscape Park, so far) (Liddle 1975, Bratton 1985, Cole and Spildie 1998).

Examples of biological impact of tourism are the decreasing reindeer populations (Helle and Sarkela 1993), changes in species composition in the Sequoia National Park (Vankat and Major 1978), or the death-rate of invertebrates and rodents penetrating empty bottles and other packages dumped by tourists (Sklodowski and Podsciański 2004). Moreover, tourists can be active "vectors" for introduction and removal of chemicals in soils as well as for changing chemical composition of the soil (Andrés-Abellįm et al. (2005), Arocena *et al.* 2006).

In Poland, tourism is rapidly increasing especially in lakeside areas. Sailing on great lakes in connection with mooring in forest areas seems to be an exceptionally attractive way of spending holidays. Water tourists have a particular great impact on the forest environment of their camping places, where they collect wood to set fire, prepare food, sleep and depose organic material (food remnants, urine and excrements) and, above all, trample the ground. This impact causes numerous changes in the water – forest ecotones (Mądrzejowska and Borowski 2003, Skłodowski *et al.* 2006).

A monitoring of ecosystem transformation can be carried out using many different methods. One of them is tracking changes in assemblages of epigeic fauna, especially assemblages of epigeic carabid beetles (Szujecki *et al.* 1983, Szyszko 1983, Skłodowski 1995, Leśniak 1997, Schwerk at al. 2004, Skłodowski 2006, Szujecki 2006, Schwerk and Szyszko 2007). Since trampling by tourists may cause considerable changes in habitats, especially in microhabitats, as removal of above ground vegetation, removal of litter and compaction of the soil, we may expect an impact on the carabid fauna. Especially the decrease of litter and shelters in the soil may result in diminishing species – especially forest specialized species. On the other hand, they may be replaced by a wide number of non-specialized species known from earlier stages of forest succession.

Therefore, we expect that changes in carabid assemblages due to tourism pressure will take place in structure of assemblages (e.g., replacing of forest species by species not characteristic for forests) as well as an increase of species number and a decrease of Mean Individual Biomass (MIB). Mean Individual Biomass (MIB) of Carabidae has been described as a simple and effective indicator of the stage of succession of a habitat (Szyszko 1990, Szyszko *et al.* 2000). With ongoing succession species characterised by small size are replaced by large bodied species so that MIB increases as succession progresses. Szyszko (1983) suggested that a stronger anthropogenic impact on the environment will lead to more pronounced changes in the assemblages. The intensity of these changes depends also on the forest environment quality. Skłodowski (1995, 1997, 2002) made similar observations, correlated with age of stands, using the SPC index (for description of SPC index see chapter 3.2). Therefore, the main exploratory questions of our study are, whether (1) an increase of water tourism pressure will result in an increase of carabid species numbers, changes of assemblages structure and decrease of Mean Individual Biomass of Carabidae and SPC index and (2) the intensity of these changes depends on intensity of tourism pressure and quality of the forest habitats.

RESEARCH AREA

The research area covered three lakes situated in the Forest Promotion Complex "Masurian Forests" on the Masurian Plain. The area was chosen in order to find three representative variants of hypothetic water - tourism pressure: control area (0) devoid of tourism pressure (Jegocin Lake), medium rate (1) of tourism pressure (Nidzkie Lake), and the highest rate of tourism pressure (2) - Beldany Lake. In each variant three study sites were established, each composed of two investigation transects. The first transects ran parallel to the lake edge, directly in the forest – lake ecotones made up of alder forest (damp deciduous forest) (forest type A). Therefore, each three transect of the following type were selected in the alder forests: control (A0), medium (A1) and high tourism pressure (A2). The second transects were also situated parallel to the lake edge, but ran about 50 meters away from the first ones, in pine forests (fresh mixed coniferous forest) situated higher above the water table (forest type P). Again, each three transects of the different variants of tourism pressure were established: control (P0), medium (P1) and high tourism pressure (P2).

Control area lake (0) - Jegocin Lake

The Jegocin Lake is situated 122 m above the see level. It is a ditch – type lake situated in a forest and excluded of tourists activity. Lakesides are high, steep and wooded. The lake covers about 120 ha, ditch depth reaches down to 36 m. The Jagocin Lake is situated northeast from Ruciane – Nida, it is possible to reach it by the road. There are no tourist centers, hostels, camping places, watering places or beeches and tourist equipment rentals all around the lake.

Medium rate of tourism pressure variant (1) - Nidzkie Lake

The whole lake is designated as nature reserve, characterised by a medium rate of tourist activities (lower rate of tourism pressure compared to Beldany Lake). It is ditch - type lake, with steep, sandy, wooded edges. The lake covers the area of 1831 ha and reaches a depth of 23.7 m. In the north it is connected with the Beldany Lake through the Great Guzianka and the Small Guzianka Lake. The Masurian Landscape Park is located close to the Nidzkie Lake Nature Reserve. Several tourism centres are located along the lakesides: The landing place "Pod Debem" in the north and a few bungalow summer resorts in Ruciane - Nida city. The nearest landing place besides the city is situated in Krzyze, the next one in Karwica. There are also summer cottages located along the lakesides as well as camping places in former timber depots – Fasty, Rybacza Buda, Łysa, Drapacz. On the south edge the Wiartel village is situated.

The highest rate of tourist pressure variant (2) - Beldany lake

The lake is 12.5 km long and it is situated in a 35 km long ditch extended from Ryn to Ruciane. The area of the lake makes up 1000 ha, the width ranges from 200 m to 2500 m, and the depth reaches down to 31 m. There are eight isles covering the area of 33 ha altogether. The water of the lake is of third class clarity. The lake edges are steep and wooded, up to 31 m high. The water fairways from Sorkwity, Pisz, Węgorzewo, Ruciane-Nida and Mikołajki are linked here. A few camping places are accessible from the water located on the east lake side – tarpan, Goly Rozek and others, there are also numerous summer resorts, and the Korektywa landing place. On the west lakeside the Pollena and PTTK Kamien tourist resorts are situated, a smaller landing place in Wygryny village, the large tourist center Galindia close to Iznota village, and a few camping places accessible from the lake and from the land. There is also a large landing place and landing stage with petrol station in Wierzba in north, close to the ferry line crossing the lake.

METHODS

Sampling of carabids

Standard STN traps (modified Barber traps – fig. 1) were used for sampling. A trap consists of a glass jar, with a plastic funnel situated on the top. The diameter of the funnel was 10 cm, but the outlet diameter was only 1.8 cm to protect small vertebrates (as rodents) from being trapped. Traps were installed in such a way that the upper funnel edge was flush with the mulch top. The traps were protected from the rain by a small roof suspended a few cm above the funnel (fig.1).

Six traps were installed in each study site: three in the transect in the alder woodland (A) and three in the pine forest transect (P). Therefore, altogether 54 traps were used (three variants of tourism pressure, each with two different forests environments, all of them replicated three times. In each of the six possible combinations

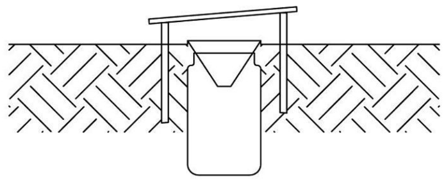

Fig. 1. Scheme of a STN trap (modified Barbers trap).

of tourism pressure and forest environment three transects with each three traps). Traps were set in 2004 and 2006. Traps were inspected every six weeks, from first of May to mid-September.

Data analysis

The length of each carabid beetle was measured with accuracy of 0.5 mm. These values were converted in biomass according to the formula by Szujecki *et al*. (1983). Mean Individual Biomass (MIB) was calculated by summing up the biomass of all carabids in a sample and dividing the result subsequently by the total number of individuals.

Using the rarefaction method of Simberloff (Krebs 1999) the number of species was standardised by the smallest number of species trapped in one variant.

To illustrate the differences between the assemblages with respect to species-abundance data, Whittaker diagrams were created. Whittaker diagrams show the abundances of the species in rank order on a logarithmic scale (Krebs 1999).

Development stages of the assemblages were described by the sum of progressive characteristics SPC indicator, the values of which are positively correlated with the age of the woodland. (Skłodowski 1995, 1997). The indicator is a sum of the percentage shares of groups of species characteristic for old, mature woodlands in the assemblage. These groups are defined on the base of four different classifications of Carabidae, which are share of forest species, large zoophages (predators over 100 mg weight), stenobiont species with range connected within Europe, and species of autumnal development type (regarding to the larger amount of energy transformed to biomass and slower rate of transmission of the energy to higher trophic levels, these species are regarded as energy-saving). In theory, the SPC indicator may reach a maximum value of 400 units (4 x 100%). However, in practice a maximum of 350 units was observed.

Statistics were done using the Statistica software package (StatSoft 1997). Compatibility of data with normal distribution was checked by Shapiro-Wilk test. In case of data compatible with normal distribution, three-way ANOVA was performed. The first group of elements described the grade of tourism pressure (3 levels), the second group described the type of investigated stands (2 levels), and the third group the year of study (2 levels). The data of the three traps arranged in a transect at a study site were pooled and chosen as a "unit" for the statistical analysis. Therefore, each possible combination of groups of elements was replicated three times. To examine post-hoc the differences between data, NIR tests were carried out. Data deviating from normal distribution were compared by non-parametric Mann-Whitney U test.

A cluster analysis of the assemblages was carried out by calculating euclidic distances and using Ward˙s method of clustering.

Nomenclature of carabid beetles follows Hurka (1996) and Turin (2000).

RESULTS

During the two years of study 4973 specimens of 53 carabid species were trapped. Average standardised number of species trapped in one study area was higher in the year 2004 (2.42 *vs.* 1.94; F = 7.9162; $p = 0.009$; NIR: $p = 0.009$). Generally, more specimens were trapped in the wet alder woodlands than in the less humid fresh mixed coniferous forest (2.44 *vs.* 1.92; F = 8.9751; $p = 0.006$; NIR: $p = 0.006$).

An increase of tourist pressure resulted in an increase of the average number of species (control area (0) – 1.87, medium pressure (1) – 2.29 and high pressure (2) – 2.37; F = 3.3205; $p = 0.053$; NIR: ”0” *vs.* “1” – $p = 0.054$ and “0” *vs.* “2” – $p = 0.025$).

The Whittaker diagram of species-abundances of the assemblages for alder woodlands points to a lower amount of rare (accessory) species (represented by lower numbers of specimens) in the control area compared to medium and high pressure variants (fig. 2). In the fresh mixed coniferous forest habitats an inverted trend was observed – with increase of tourism pressure the number of species represented by low numbers decrease.

Percentage share of autumn species was higher in assemblages inhabiting alder forests (61% *vs.* 51%; F = 5.0518; $p = 0.044$; NIR: $p = 0.044$). In the areas of medium and high tourism pressure the percentage share of autumn species was half the amount of the control areas (64.5% and 67.5% *vs.* 35.5%; F = 21.7841; $p < 0.001$; NIR: $p < 0.001$).

Percentage share of small zoophages increased with increase of tourist pressure (control 17.9% vs. medium pressure 22.2% and high pressure 34.5%; F = 4.7932; $p = 0.030$; NIR: $p = 0.047$ and $p = 0.011$). Although the percentage share of large

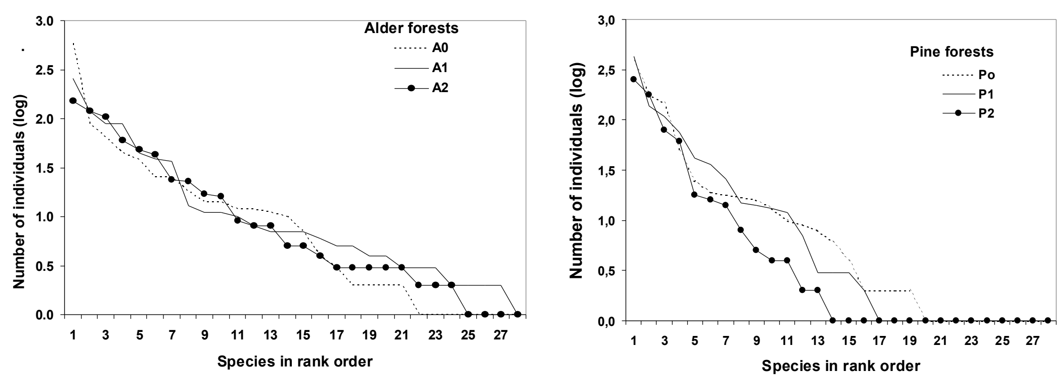

Fig.2. Whittaker diagrams of species-abundance of carabid species in alder woodland (left side) and pine woodlands (right side).

zoophages was reduced with increasing pressure, 74.5% (control) to 68.1% and 58.5% (medium and high pressure), this result was only close to statistical significance (F = 3.4457; $p = 0.066$).

Concerning environmental and geographical groups no trends related to an increase of tourism pressure were discovered. However, the synthetic value of SPC indicator was reduced in relation to the control area (309 *vs*. 288 and 245 in medium and high pressure variants respectively; F = 4.8143; $p = 0.029$; NIR: $p = 0.073$ and 0.009).

The results of MIB of the carabid beetle assemblages were only partially in agreement with the expectations, since in the high pressure variant the value of this indicator increased instead of decrease. In the control area MIB reached 229 mg, in the area of medium pressure MIB reached 203 mg, but in the area of high pressure the MIB value was 242 mg (F = 28.0154; $p < 0.001$; NIR: $p < 0.001$ and $p = 0.013$). The higher value of MIB in the area of high tourism pressure was observed in both years. In general, MIB values were higher in the fresh mixed coniferous forest when compared to the alder woodlands (242 *vs*. 208; F = 66.4259; $p < 0.001$; NIR, $p < 0.001$).

The SPC/MIB model illustrates the stage of successional development of the carabid beetle assemblages (fig. 3) The less disturbed assemblages of the mature woodlands are located at the top of the right side of the diagram, while assemblages observed in young or disturbed forests are situated at the bottom of the left side of the diagram. The assemblages of the alder forests are classified as it was predicted in the theoretical model, while the assemblages observed in the fresh mixed coniferous forest do not agree with the predictions of the model, mainly due to high MIB values.

Percentage share of hygrophilous specimens was highest in control areas (55.5%), while in the areas of medium and high pressure it decreased (47.3% and 24.6%; F = 6.4556; $p = 0.012$; NIR: $p = 0.025$ and $p = 0.004$). As expected, the percentage share of hygrophilous species was higher in the alder forests than in the fresh mixed coniferous

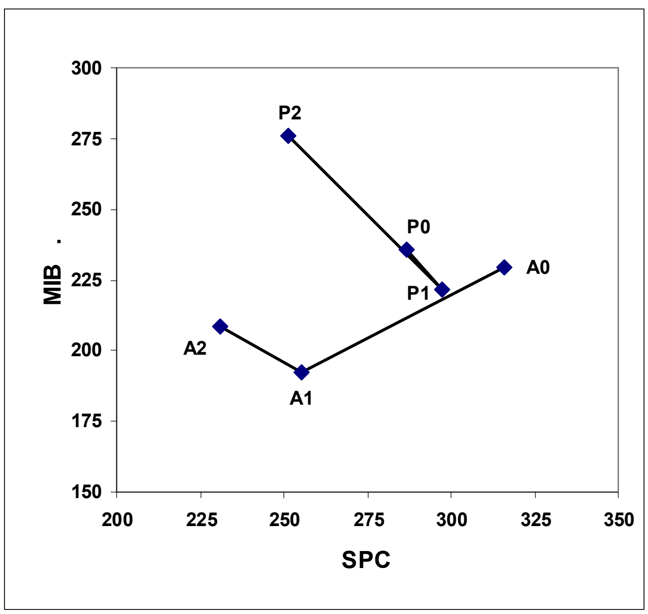

Fig. 3. Model of state of carabid beetle assemblages in pine woodlands (B) and alder woodlands (A) in control area (0), medium pressure (1) and high pressure (2).

forest (50.4% *vs*. 34.6%; F = 4.6750; $p = 0.052$; NIR: $p = 0.052$). The percentage share of mesophilous species in the assemblages compared to the control increased with tourist pressure – 35.2% *vs*. 48.2% and 72.8% (F = 9.798; $p = 0.003$; NIR: $p = 0.014$ and $p < 0.001$). The share of dimorphic species in assemblages in comparison to the control and medium pressure was strongly reduced in the high pressure variant: 54.9% and 54.9% *vs.* 18.0% (F = 34.85; $p < 0.001$; NIR: $p < 0.001$). The percentage share of individuals of brachypterous species in the high pressure variant occurred to be doubled in comparison with control or medium pressure (55.3% vs. 25.6% and 22.5%; Z = 2.8823; $p = 0.004$).

The cluster analysis (fig. 4) clearly separates the assemblages of control and medium pressure areas (A0, A1, P0 and P1) from the high pressure variants (A2 and P2). This separation occurred independently from the habitat type. Regarding control or medium pressure areas it seems than the quality of environment has a stronger impact on the similarity of the assemblages, since the assemblages of the fresh mixed coniferous forest (control and medium pressure variants (P0 and P1) are linked first and the control and medium pressure variants of the alder forest (A0 and A1) afterwards.

DISCUSSION

Since an attempt was made to verify two investigation aims in the present paper, the results will be discussed in two parts.

5.1. Intensity of changes in species numbers, carabid beetle assemblage structure and average biomass as a result of the water tourism

Water tourists exploring lakesides trample the undergrowth plants and soil, make a bonfire, collect wood to be burned, and exceptionally cut down the trees (Mądrzejowska and Borowski 2003, Skłodowski *et al*. 2006). However, these activities seem to be not sufficient for a significant clearance of the woodland canopy. *Ipso facto*

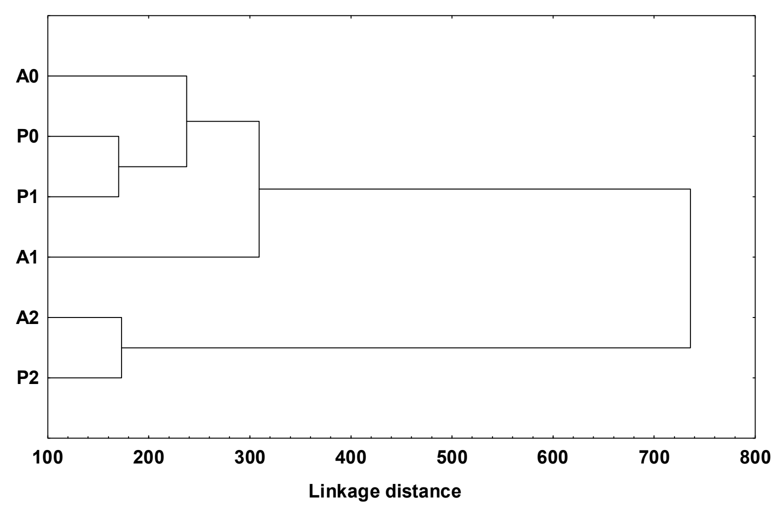

Fig. 4. Cluster analysis of the study sites (euclidic distances, Ward's method) based on carabid beetle assemblages

Table 1. List of Carabidae species (in alphabetical order) with dominance values for the carabid assemblages of alder forests "A" (forest – water ecotone) and pine forests "P" (fresh mixed coniferous forest in farther distance from the lakeside) in three variants of tourism pressure (0-2).

Species	A0	P0	A1	P1	A2	P2
Agonum assimilie (Paykul, 1790)	-	0.11	1.38	-	1.34	-
A.fuliginosus (Duftschmid, 1812)	1.82	-	5.63	-	3.42	-
A.livens (Gyllenhal, 1810)	-	-	0.88	-	-	-
A.lugens (Duftshmid, 1812)	-	-	1.00	-	-	-
A.obscurum (Herbst, 1784)	0.40	0.22	-	-	0.45	0.31
Amara aenea (De Geer, 1774)	-	-	-	-	0.30	-
A.bifrons (Gyllenyhal, 1810)	1.41	0.97	0.38	0.32	0.74	0.61
A.brunnea (Gyllenhal, 1810)	0.71	-	0.25	0.21	0.45	-
A.lunicollis Schiodte, 1837)	0.10	0.11	0.50	3.86	-	-
A.ovata Fabricius, 1792)	-	-	0.13	0.75	-	-
A.plebeja (Gyllenhal, 1810)	-	-	0.88	-	0.15	-
A.tibialis (Paykull, 1798)	-	0.22	-	-	-	-
Badister lacertosus Sturm, 1815	-	-	0.13	-	0.15	-
Bembidion semipunctatum (Donovan, 1806)	-	-	-	-	0.15	-
Calathus micropterus (Duftschmid, 1812)	0.20	-	0.63	0.32	0.15	-
Carabus arcensis Herbst, 1784	1.41	5.29	-	2.79	-	-
C. convexus Fabricius, 1775	0.20	1.08	0.75	1.50	0.45	2.76
C.glabratus Paykull, 1790	0.20	0.11	0.13	-	1.19	0.15
C.granulatus Linnaeus, 1758	2.53	-	4.63	-	3.57	-
C.hortensis Linnaeus, 1758	4.55	1.94	11.00	4.50	8.92	9.37
C.nemoralis O.F.Muller, 1764	6.57	15.87	1.63	8.04	22.59	39.02
C.violaceus Linnaeus, 1758	1.01	1.73	0.13	1.39	-	-
Cychrus caraboides (Linnaeus, 1758)	3.84	2.70	0.50	1.61	0.74	2.46
Dromius linearis (Olivier, 1795)	-	0.11	-	-	-	-
Elaphrus cupreus Duftschmid, 1812	0.10	-	0.13	-	-	-
Harpalus affinis (Schrank, 1781)	-	0.11	-	-	-	-
H. froelichi Sturm, 1818	-	-	0.13	-	-	-
H.fuliginosus (Panzer, 1809)	-	-	0.25	-	0.15	0.77
H.latus (Linnaeus, 1758)	1.11	1.84	1.25	1.29	0.30	2.15
H.quadripunctatus Dejean, 1829	0.20	1.40	0.13	0.32	-	1.23
H.picipennis (Duft.)	-	0.11	-	-	-	-
H.rufipes (De Geer, 1774)	0.30	0.86	0.38	0.11	1.19	0.15
H.tardus (Panzer, 1797)	-	-	0.63	0.11	-	-
Loricera pilicornis (Fabricius, 1775)	-	-	0.13	-	0.59	-
Miscodera arctica (Paykull, 1798)	-	0.11	-	-	-	-
Notiophilus germinyi Fauvel in Grenier, 1863	0.10	-	-	0.11	-	0.15
Nebria brevicollis (Fabricius, 1792)	0.10	-	0.38	0.11	-	-
Oodes helopioides (Fabricius, 1792)	-	-	0.25	0.11	-	-
Patrobus atrorufus (Stroem, 1768)	1.21	0.22	4.88	-	15.60	-
Pterostichus aethiops (Panzer, 1797)	0.10	0.65	0.13	0.11	-	-
P.anthracinus (Illiger, 1798)	1.21	0.11	1.38	-	2.53	-

P.caerulescens (Linnaeus, 1758)	-	0.22	-	0.11	0.45	-
P.diligens (Sturm, 1824)	-	-	-	-	0.45	0.15
P.melanarius (Illiger, 1798)	2.53	2.05	15.00	14.79	6.39	0.61
P.minor (Gyllenhal, 1827)	-	-	-	-	0.30	-
P.niger (Schaller, 1783)	58.99	41.90	32.00	45.98	7.13	12.14
P.nigrita (Paykul, 1790)	0.10	0.43	0.88	-	2.38	-
P.oblongopunctatus (Fabricius, 1787)	8.89	19.44	11.13	11.58	17.68	27.50
P.strenuus (Panzer, 1797)	-	-	0.13	-	-	0.31
P.cupreus (Linnaeus, 1758)	-	-	0.13	-	-	-
P.vernalis (Panzer, 1796)	-	0.11	-	-	-	-
Stomis pumicatus (Panzer, 1796)	-	-	0.25	-	-	-
Synuchus vivalis (Illiger, 1798)	0.10	-	-	-	0.15	0.15

the bottom of the forest remains shaded. Therefore, the visitors impact on carabids seems to be not very strong in comparison to the forester˙s typical managing like clear-cuts (Szyszko 1983, 2002, Niemelä *et al.* 1993, Szujecki *et al.* 1983, Skłodowski 1995, 2006, Atlegrim *et al.* 1997, Koivula 2001, 2002, du Bus de Warnaffe and Lebrun 2004).

Particularly strong trampling causes extinction of all undergrowth plant species, with grasses as the last to disappear (Hall and Kuss 1989, Gibson *et al.* 2000). Trampling leads to compaction and degradation of litter (Dufey 1975) and soil (Liddle and Greig-Smith 1975). High tourism pressure causes mechanical scrubbing and removing of top litter layer (Leney 1974). These changes cause the loss of hiding places for carabids, especially of species requiring wet refugees to survive during daytime. Areas trampled by tourists can be compared to reinforced roads and tracks. Several carabid beetle species avoid entering reinforced roads and tracks and move alongside only (Mader *et al.* 1990).

The assumption is justified that in the areas of tourism pressure a part of the species requiring hiding places (in the forest litter layer) will be less numerous and occurrence of these species will depend on specimens immigrating from outer, not trampled areas. The reactions of carabid fauna observed in our study are moderate in comparison to modifications as result of clear-cutting of forests (Szyszko 1983, 2002, Niemelä *et al.* 1993, Szujecki *et al.* 1983, Skłodowski 1995, 2006, Atlegrim et al.1997, Koivula 2001, 2002, du Bus de Warnaffe and Lebrun 2004).

In areas under tourism pressure the percentage share of individuals of autumn species and hygrophilous species was reduced to the half in comparison to the control area. The percentage shares of small zoophages and dimorphic species, however, increased to the double amount. Modifications in number of species, values of synthetic SPC indicator and MIB turned out to be small, but statistically significant.

The magnitude of modifications of species numbers ranged 20 – 35 %, while the amplitude of SPC indicator modifications hardly reached values of 60 units. Also modifications of MIB were slight and within a stable interval of 20 - 35 mg. These slight modifications of both indicators are perfectly illustrated by the SPC/MIB model. This small level of modification in Carabidae assemblages is similar to the modification level observed in the context of forest clear cuts (Skłodowski and Zdzioch 2003).

5.2. Dependence of the degree of modification in carabid beetle assemblage structure on intensity of tourism impact and quality of the forests habitats

With increasing disturbance the intensity of the reaction of Carabidae assemblages increases (Szujecki *et al.* 1983, Szyszko 1993, 2002, Skłodowski 1995, 1997, 2006, Schwerk and Szyszko 2007). In our study the reaction on water tourism pressure proved to be not very strong. Anyhow, clear reactions in areas of medium and high tourism pressure were noticed. The reduction of percentage share of autumn species compared to the control variant might serve as an example, but this reduction took place only in the area of high tourism pressure (from 64.5 % to 35.5 %). According to Grüm (1976) autumn species characterise higher amounts of assimilated energy sequestrated in biomass and slower transition of produced biomass to higher trophy levels compared to spring species. Therefore, autumn species are more energy saving than spring species. According to Odum˙s model of ecological succession, energy saving species are more frequent in advanced stages of succession (Odum 1959). Therefore, a reduction of the share of autumn species (more energy saving) in an assemblage caused by high tourism pressure is relevant as indicator of regressive succession in the forest environment.

Also the increase of percentage share of small zoophages from 17.9 % to 22.2 % (medium pressure) and 34.5% (high pressure), even if not as high as in the case of clear cuts (Szujecki *et al.* 1983, Szyszko 1993, 2002, Skłodowski 1995), points to an increase of negative influence due to increasing tourism pressure. It seems to be analogously with respect to the disappearance of hygrophilous species, whose percentage share decreased with increase of tourism pressure: 55.5 % (control), 47.3 % (medium pressure) and 24.6 % (high pressure). The opposite tendency, but also depending on the tourism pressure rate, was observed concerning mesophilous species, whose percentage share increases along the tourism pressure gradient as follows: 35.3 % (control), 48.2 % (medium pressure) and 72.8 % (high pressure). The replacement of hygrophilous by mesophilous species suggests drying out of trampled habitats. According to Marion and Olive (2006) strong trampling of soil causes compaction, reduces water permeation and, in consequence, increasing surface flooding and leads to drying up of soil.

Standardised by the lowest number of specimen, the number of carabid species increased with increase of tourism pressure rate (1.87 – 2.29 – 2.32), what is in accordance with effects observed in strong modified forests (Szujecki et al.1983, Szyszko 1993, 2002, Skłodowski 1995, 2006). The Whittaker diagrams (fig. 2) revealed higher carabid species abundance under tourism pressure in comparison to control areas in alder forests (fertile habitat) and lower species abundance under tourism pressure in comparison to control areas in pine forests (poorer habitat). This observation suggests modifications in carabid assemblages not only due to tourism impact but also to differences in quality of the environment.

Changes of species composition in the carabid assemblages caused by increase of tourism pressure are confirmed by the cluster analysis (fig. 4), clearly separating assemblages of areas of high tourism pressure from assemblages of control and medium pressure areas. The cluster analysis shows also that the quality of the environment has a less significant impact on the changes of the carabid assemblages than the tourism impact in the case of high pressure.

Since our study refers to waterside environments (alder forest) and areas in a distance of 50 m from the lake edge, it may be concluded that water tourists not only penetrate a narrow strip along the lake-edge, but also significantly enter deeper parts of forests collecting berries and firewood.

On this background very interesting seem to be the observed modifications with respect to percentage share of dimorphic and brachypterous species. According to Kotze and O˙Hara (2003) dimorphic species can better survive ecosystem disturbances. Therefore, the percentage share of these species should be higher in areas of high tourism pressure. Our observation points to the opposite – the number of individuals of dimorphic species in high pressure areas was 2.5 times lower than in control and medium pressure area (18.0 % vs. 54.9 %). Percentage share of brachypterous species in the high pressure variant was double in comparison to the control. Brachypterous species more often recede or vanish from disturbed habitats (Szyszko 1983, Ribera *et al.* 2001, Skłodowski 2006, Schwerk and Szyszko 2007).

The results of our study suggest that even high tourism pressure does not act as strong as disturbances like clear cuts or wind throws. Due to the constantly small amplitude of modifications as result of tourism pressure in the studied environments, the conclusion can be drawn that this factor seems to operate rather as a stress factor than as a disturbance.

The SPC/MIB model suggests similar conclusions. The SPC indicator rate decreases with increase of tourism pressure (309 – 288 – 245) but the reduction is rather small, which points to moderate impact of tourism on the environment. Moderate impact is also indicated by MIB values, since MIB occurred to be the highest in areas of high tourism pressure. This effect is contradictory to our expectations, since an increase of tourism pressure was assumed to result in a stronger degradation of the habitat. With increasing degradation a decrease of MIB values is to be expected (Szujecki et al. 1983, Szyszko 1993, 2002, Skłodowski 1995, 2006, Schwerk and Szyszko 2007).

The high MIB values in areas of high tourism pressure were caused by replacement of *P. niger* (weight 215 mg), which dominated in control and medium pressure areas, by the significantly bigger *C. nemoralis* (weight 548 mg). *C. nemoralis* is the less hygrophilous of these two species, so the dominance of this species in areas of high tourism pressure supports the assumption of drying-up of the habitats as an result of tourism impact. Despite the achieved results suggest only small changes in the studied forest environments, they are of importance with respect to forest protection, since they illustrate a degradation of the studied forest ecosystems.

CONCLUSIONS

- An increasing regression of carabid beetle assemblages connected with an increase of water tourism pressure was observed.

- This modification was of lower degree compared to assemblages inhabiting strongly disturbed ecosystems.

- The type of the environment (damp and fertile alder forest vs. poorer fresh pine forest) had a minor impact on the modifications of the carabid beetle assemblages than the tourist pressure.

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