EFFECT OF HABITAT FRAGMENTATION DUE TO TRAFFIC IMPACT OF DIFFERENT INTENSITY ON EPIGEIC BEETLE COMMUNITIES IN CULTURAL LANDSCAPE OF THE CZECH REPUBLIC

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Abstract

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Epigeic beetles were studied along two roads with different character and traffic intensity (a highway and a 1st class road) in different areas with similar physical-geographic location. Pitfall trapping in transects of forested and unforested landscape along the roads was used for sampling in both areas. There were not found any specific beetle species in habitats along the roads. Species diversity was higher along the 1st class road than along the highway. Stronger effects of the highway on beetle communities were found in a narrow adjacent strip. This effect was not found along the smaller 1st class road. The equitability is lower in forested landscape along the highway (the activity of dominant species is higher) whereas in agricultural landscape this effect was not found. The frequency of generalists increased near the narrow strip beside the roads. The number of migrating specimens on the opposite side of 1st class road was low both in forested and unforested landscape (a few specimens out of one hundered marked individuals) and only one specimen was found on the opposite side of the highway.

Key words: habitat fragmentation, transport effect, epigeic beetle communities, migration possibilities, Central Europe

Introduction

A lot of data are available about the barrier effect of roads on great mammals that have large ranges or migrate within long distances in mainly natural or seminatural areas. There is less known about the impact of roads on smaller organims in a more modified landscape with a long history and intensive land use and land management (Underhill, Angold, 2000).

The Czech Republic is an example of this type of cultural landscape under long-time influence of man. The road network is relatively dense, but the highways with intensive traffic are sparse and they are represented by two highways in operation: Praha-Brno and Praha-Plzeň. The position of the Czech Republic in the centre of Europe determines this area for the construction of roads connecting Europe both in West-East and North-South directions. Therefore the construction of new highways in various parts of the Czech Republic is planned.

Epigeic beetles, mainly ground beetles (Carabidae), are frequently used for landscape ecological studies connected with the role of landscape structure, habitat fragmentation, connectivity of corridors and metapopulation dynamics (e.g. Brouat et al., 2003; Burel, 1992; Gibb, Hochulli, 2002; Hunter, 2002; Šustek, 1994, etc.). They are suitable for ecological studies due to numerous species and individuals and various ecological requirements (e.g. trophic relationship, habitat preference, migration possibilities) in nearly any terrestrial habitat (Boháč, 2003). With the exception of carabids, other groups of epigeic beetles, often dominant in communities (e.g. staphylinids or carryon beetles), are less known concerning their ecology in cultural landscape.

Epigeic beetles are not often studied in the road-side habitats. We only have some data about carabids studied in the vicinity of roads concerning their habitat preference, habitat borders and velocity in a heathland area in the Netherlands (Vermeulen, 1993; 1994).

The aim of this study was:

- to describe the difference in the diversity and activity of beetle communities along transects in studied areas with different character of roads and traffic intensity
- to find if the verges along roads can be used as habitats for studied beetles
- to find if the roads of various width and with different intensity of traffic are barriers for studied beetles.

Research sites and methods

Stand and site characteristics

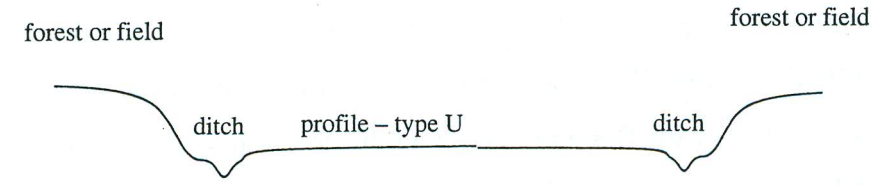
Two model areas were selected with similar physical-geographic locations but different character of traffic. Both territories are situated in hilly cultural landscape with mosaics of forest and agricultural landscape. There are some differences in the profile of roads in studied areas (Fig. 1). The highway was situated higher or lower in the profile of terrain while the position of the road was more flat.

Model area along the highway – the Větrný Jeníkov territory lies in the Bohemian-Moravian Highlands close to the highway Praha–Brno. The model area is situated approximately in the half of the distance between Humpolec and Jihlava.

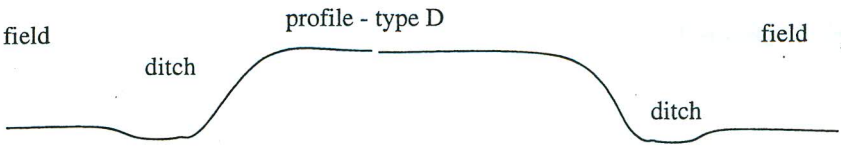
Unforested area is mainly covered by wheat fields on both sides of the highway. There were found 129 species of higher plants, more than in the forested area (119 species). Dense shrubs of trees (e.g. *Alnus incana* and its hybrids, *Ligustrum vulgare, Spiraea salicifolis, Rosa rugosa*) were characteristic for the slopes of the highway. The species composition of plants between the base of slope and the field was affected by various factors (water flush from the highway, salting effect during winter period, use of herbicides).

Forested area was covered by Norway spruce forest, or mixed pine – Norway spruce forest. There are differences in the number and species composition of higher plants along the transect with pitfall traps across the

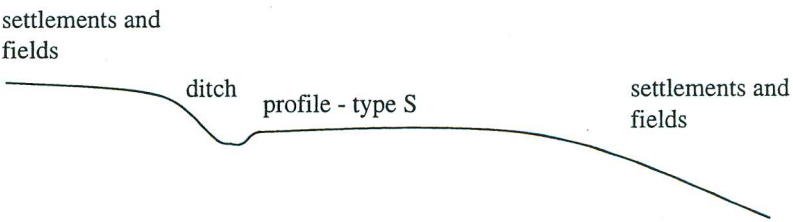
1. Highway



2. Highway



3. Road of 1st class



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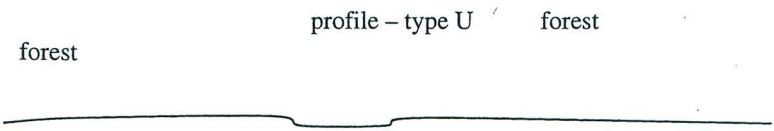

Fig. 1. Profile in the vicinity of studied roads.

highway on both sides. The highest number of plant species was found in the ecotone between the spruce forest and the ditch (19 species), or the ditch and the highway (24-41 species). The number of plant species was the same in spruce forest and the ecotone between the highway and ditch (5-25 species). The management along the highway (cutting of vegetation, use of herbicides and salting) has effect on specific species composition (e.g. occurrence of *Spergularia salina* and *Amorpha fruticosa*).

Model area along the 1st class road – Velešín model territory, in the Šumavské Podhůří hills, is 5 km east of the town of Český Krumlov. The construction of a new highway is planned instead of the existing road connecting Praha-České Budějovice-Linz (Austria).

The plant cover of forested area was very close to this along the highway. The great difference was found in the plant cover in unforested area of the 1st class road and the highway. The plant cover of the transect beside the road was more patchy with more diverse plant associations than by the highway. The influence of management was less dramatic and indicated in smaller row along the road.

Sampling and data analysis

Beetles were collected using pitfall traps filled with ethylenglykol. Each locality contained 10 traps arranged in two rows across the studied roads in forested and unforested landscape, which were usually controlled monthly during the snow-free period (May-November) in 2001-2002. More than a hundred beetle species and about four thousand beetle specimens were collected during the study period.

The numbers of species and specimens in selected studied sites and pitfall traps along the transects were compared. Mathematical diversity index (Shannon-Wiener) and index of equitability (Pielou index) were used for alpha diversity calculating.

Ordination analysis by the DCA method (Hill, 1979a; ter Braak, 1985) was made as well the classification of samples by the TWINSPAN method (Hill, 1979b) and hierarchical aglomerative classification by the Ward method (Legendre, Legendre, 1998). Ecological analysis of beetle communities was accomplished.

The degree of human impact will be studied by finding out about the frequency of species of different ecological groups (Boháč, 1999; Hůrka et al., 1996).

The method of ecological analysis of beetle communities (Boháč, 1999) was used particularly for evaluating forest community structure. For this, the species were divided into groups as follows:

- specialists encompass species of both natural and managed forests which are not able to colonize man managed areas
- generalists comprise eurytopic species that successfully occupy deforested sites and are also found in areas strongly affected by man.

The migration and exchange of studied animals will be studied by mark-recapture techniques. Selected beetles species (*Carabus nemoralis nemoralis* M ü l l., *Carabus granulatus* L., *Pterostichus melanarius* (I l l.), *Poecilus cupreus cupreus* L., *Drusilla canaliculata* (F.) were individually labelled with small dots on the elytra using a brush (diameter 0.5 mm) with white or silver colour. The marked adults were let out in the afternoon and pitfall traps were controlled two days later, in the morning. Two experiments were made with marked individuals in the mid of May and mid of June. The capture of marked adults was provided with forty parallel pitfall traps in two rows on the each side of the road and the highway. The first row of traps was situated by the ditch of roads, the second one in the distance of about 20-25 m in the forest or field, depending on the locality. *Carabus nemoralis* M ü l l. has completely stunted wings. *Carabus granulatus* L. exhibits wings polymorphism and macropterous individuals are capable of flight. *Poecilus cupreus* L. has fully developed wings and is good at flying. *Pterostichus melanarius* (I l l.) is normally brachypterous but macropterous adults also occur, and are capable of flight. Macropterous specimens are usually easily recognized externally by their longer, parallel-sided elytra. These specimens were not found in the studied areas. *Drusilla canaliculata* (F.) has rudiments of wings only .

Results and discussion

Number of species, their activity and habitat preference

The number of species found in the transects across the road of the 1st class was rather higher (125 species) than in the transects across the highway (111 species). Carabids and staphylinids prevailed in both transects (18% of the whole number of species in the transect across the road of the 1st class and 11% in the transect across the highway respectively). This result has been confirmed by some authors (Andersen, 1997) stating that more patched landscape has a higher number of beetle species. The number of carabid species was evidently higher in more patched landscape beside the smaller road (31 species) than beside the highway (25 species). This effect was not found in staphylinids (65 species near the smaller road and 67 along the highway). In our opinion it means the confirmation of the fact that predators such as carabids are more influenced by the fragmentation of landscape than species with higher number of trophic groups such as staphylinids (Gibb, Hochulli, 2002).

The generalists prevailed in open landscape in both studied areas (more than 80% of species). The specialists preferring the seminatural or forest areas were dominant in forested areas of both studied areas (more than 50% of species). No specific species living in the habitats along the road or the highway were found.

The frequency of both specialists and generalists was practically the same in forested landscape in both studied areas (16 and 17% of specialists and 84 and 83% of generalists along the smaller road and the highway respectively). Great differences were found in the frequency of ecological groups in unforested landscape (51 and 60% of specialists and 49 and 40% of generalists in studied areas). This is the confirmation of the fact that the proportion of specialists to generalists in arthropod predators is affected by habitat fragmentation (Kruess, Tscharntke, 1994). These data were obtained in agricultural landscape and were not available for sites in the vicinity of roads.

The activity of specimens along transects varied and the effect of the roads is not clearly distinct (Fig. 3). On the other hand, in some cases the highest number of species was found in the greatest distance from roads.

Seasonal dynamics of studied beetles

The typical seasonal distribution of activity is characteristic of some species along the roads (Fig. 2). Some of the species have the highest activity in spring (e.g. carabid *Poecilus cupreus*)(not included in Fig. 2 due to very high spring activity). Other carabid beetles, *Carabus granulatus,* have the spring maximum with gradual decrease of the activity of adults. Staphylinid species *Olophrum assimile* has spring and autumn activity of adults only, and the adults are absent during the summer period. The absence of beetles with autumn activity was characteristic in the vicinity of the road and the highway in open landscape.

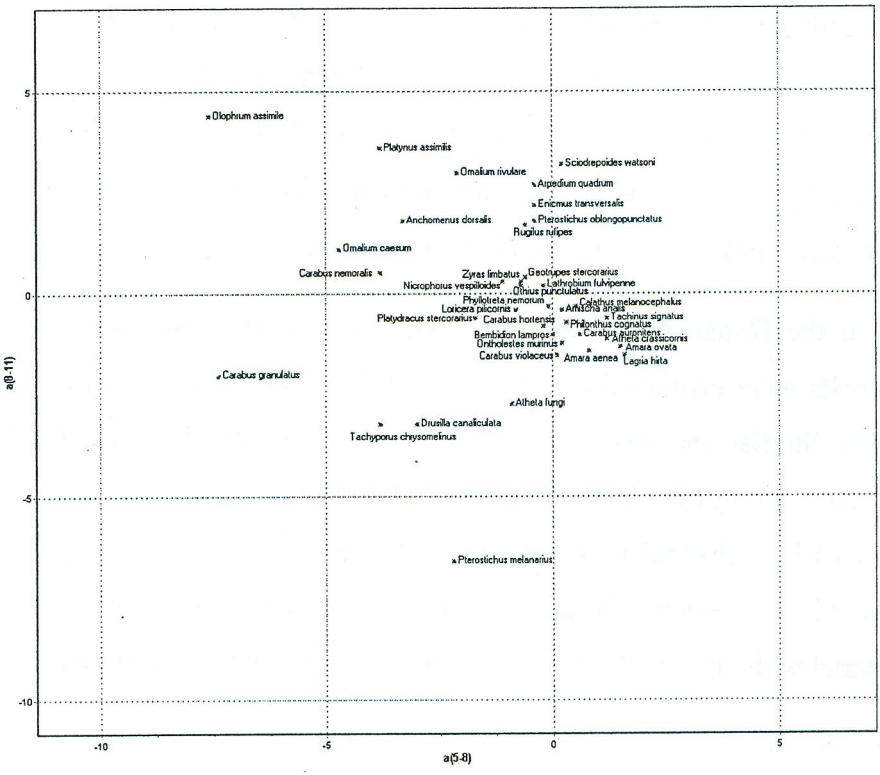

Fig. 2. Annual dynamics of dominant beetle species evaluated by linear regression of the number of caught individuals in period May-August (a5-8, the horizontal axis) and in August-November (a8-11, the vertical axis).

The dynamics of samples in particular months in studied areas shows a bigger difference between the transects of pitfall traps in agricultural than in forested landscape. The greater variability of communities is characteristic for communities in agricultural landscape (Fig. 4).

The dependence of activity upon the season of the year is known for beetles living in agricultural landscape (Varchola, Dunn, 2001). It seems that woody edges appear to be important for the overwintering of beetle populations. We assume that in some cases the woody edges of roads in open landscape can play an important role for the overwintering of predaceous beetles from agricultural landscape along the roads.

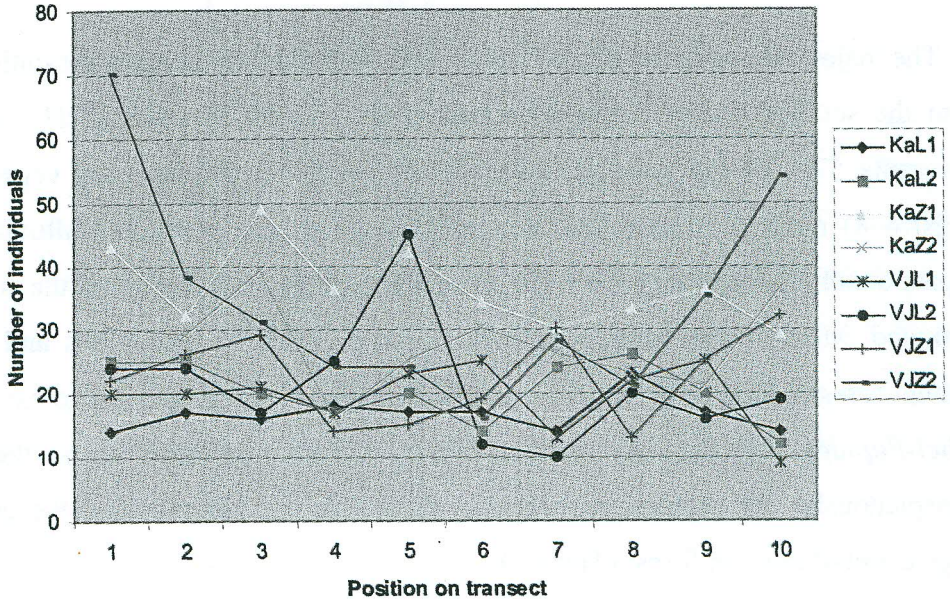

Fig. 3. The number of individuals collected along studied transects (1-10 number of pitfall trap).

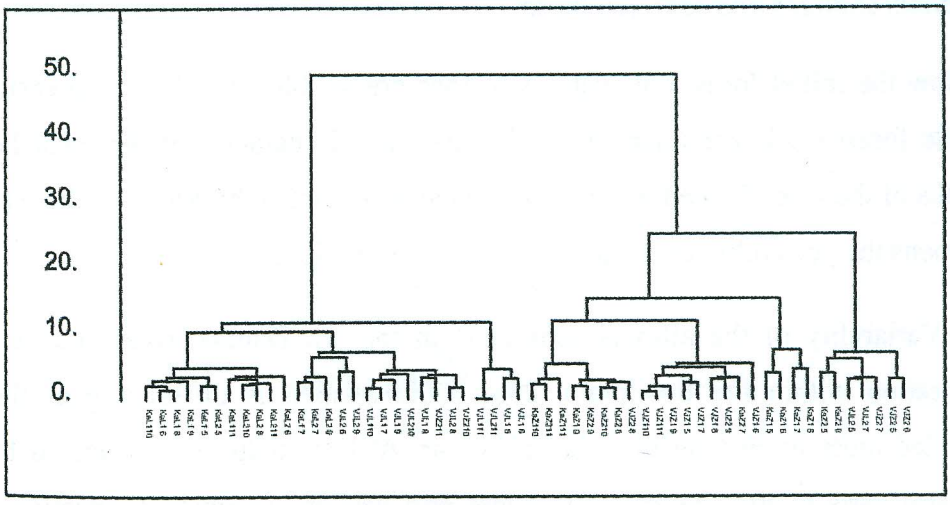

Fig. 4. Classification of samples in particular months in studied areas (Ward´s method with logaritmic transformation of data, vertical axis – similarity of samples). Ka – 1st class road, VJ – highway, L – forest, Z – agricultural landscape, 1 – 2001, 2 – 2002, number of months.

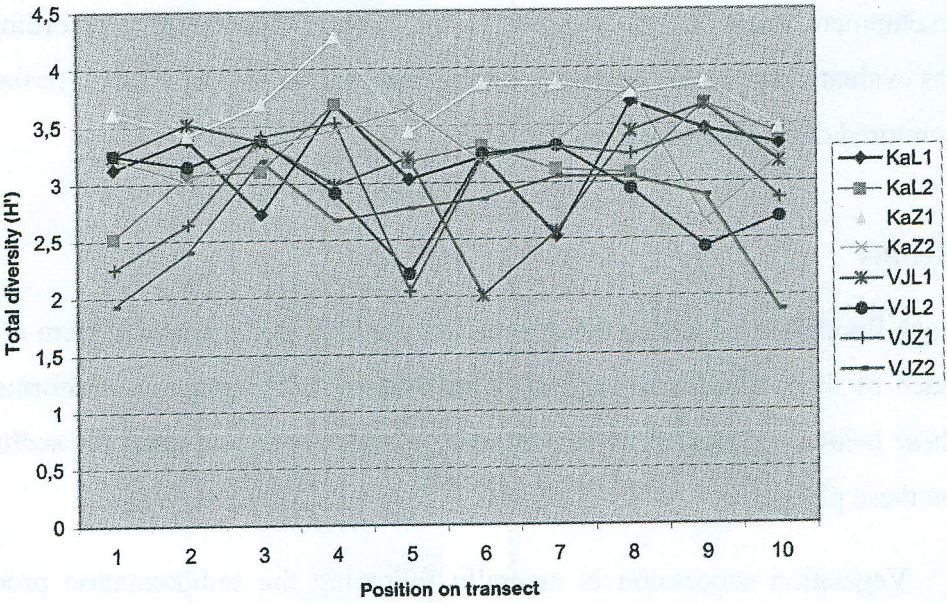

Fig. 5. Species diversity (index H´) along studied transects (1-10 number of pitfall trap).

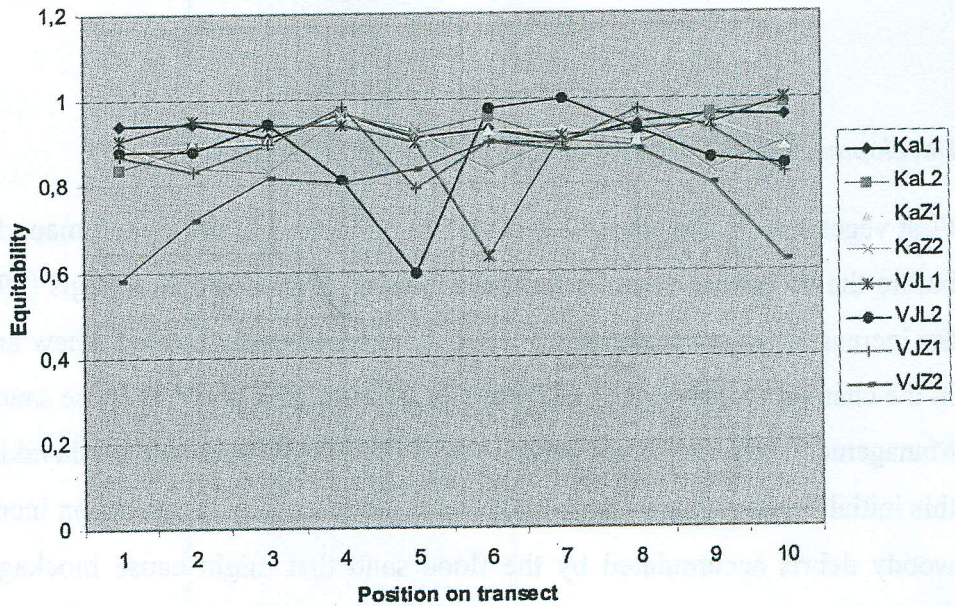

Fig. 6. Species equitability along studied transects (1-10 number of pitfall trap).

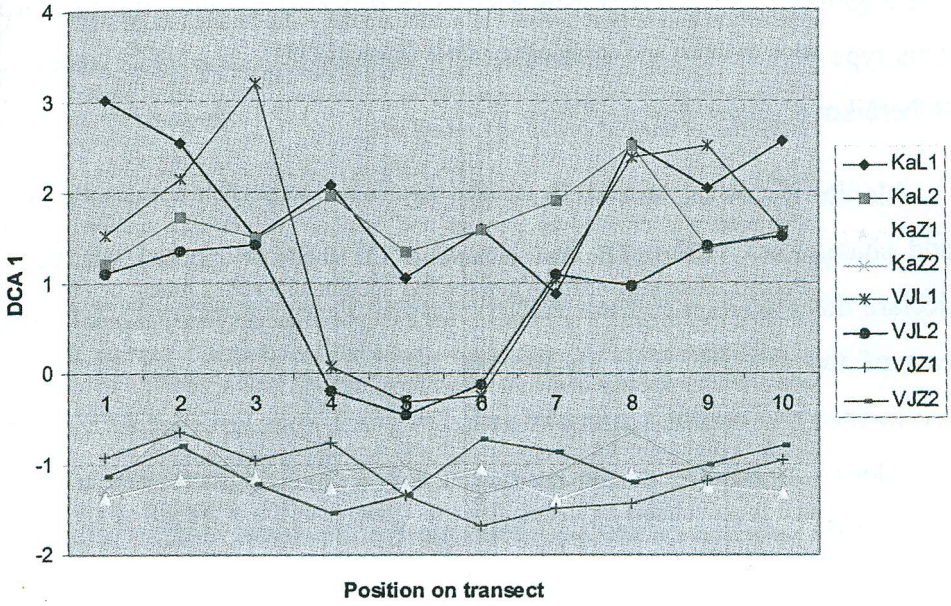

Fig. 7. Ordination of beetle samples along studied transect (1-10 number of pitfall trap).

The evaluation of beetle communities characteristics along studied transects

Differently from the highway (Fig. 5), higher and more stable species diversity was found along the smaller road.This fact is in conformity with the number of species in studied areas (see part *Number of species, their activity and habitat preference*). The strongest impact of the highway was found in the narrow strip along the way. This effect was not found along the smaller road.

The highway negatively affects species equitability in adjacent forest parts. The equitability is lower in these areas, it means that the activity of dominant species is higher than that of the others (Fig. 6). This effect was not found in agricultural landscape in both open and forested landscape near the smaller road.

The ordination of beetle communities along transects (Fig. 7) showed significant influence of the highway on beetles in forested landscape. This effect was not found in forested area beside the smaller road. It seems that the highway is an important border for epigeic beetles in forested landscape. We think that specialists prevailing in forested landscape have stronger reaction to the highway as a border than prevailing generalists in open landscape of both studied areas. The highway is not a strong border for these ubiquitous species with higher tolerance to temperature changes of soil surface (Boháč, 1999). This is in confirmation with the studies of Vermeulen (1994) who found similarly stronger reaction of stenotopic carabids to habitat borders in grasslands. In forested areas it was found that

the width, composition and height of the winbreaks are the main characteristics influencing the migration of forest and eurytopic carabids (Šustek, 1994).

Migration possibilities of various groups of organisms

The succcess in crossing the roads by labelled carabid and staphylinid species was very low. The smaller road was crossed by 3 males and 1 female of *Carabus nemoralis* (46 labelled specimens), 5 males of *Carabus granulatus* (123 labelled specimens), 3 males and 5 females of *Pterostochus melanarius* (87 labelled specimens) and 2 males of *Poecilus cupreus* (187 labelled specimens). The migration of staphylinid beetles *Drusilla canaliculata* was successful only in one case (54 specimens labelled). The attempt to capture labelled specimens of the previous species in the vicinity of the highway was successful in one case of female *Carabus nemoralis* in forested study area only. It means that the highway means a serious border for epigeic beetles, even for winged species.

The mark-recapture method is convenient for the study of particular species for no more than a few days, and it is not suitable for longer distances (more than 100 or 200 m) owing to low recapture rates or limited number of traps (Riecken, Raths, 1996). The distance of opposite strips along the highway (about 200 m) is the limit for this method. It may be the reason for the low succcess of recapturing in our study. The average direct distance covered within 12 h activity varies between 6 – 387 m for big *Carabus* species (Riecken, Raths, 1996) and it is sufficient to cross the smaller road, even the highway. Carabids are active mainly during the night when the density of transport is not so high and the chance to cross the road is higher. On the other hand, carabids mainly move along ecotone habitats like forest edges and other biotopes along the roads. We think that the highway is not an important barrier between the populations of carabids on both sides. According to some data, the distance of 14 km is sufficient for genetic differentiation of carabids from various isolated plots (Brouat et al., 2003).

Conclusions

Roads have significant effect on the communities of beetles (species diversity and equitability, seasonal dynamics, frequency of ecological groups). The influence on beetle communities characteristics along the highway is stronger than that along smaller roads. There were not found any specific species living along the roads in comparison with surrounding landscape. The ability to cross the highway is low but it is not impossible. The ability to cross the 1st class road is relatively high. Woody edges of roads in open landscape can play an important role for the overwintering of predaceous beetles from agricultural landscape along the roads.

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References

Andersen, A., 1997: Densities of overwintering carabids and staphylinids. Journal of Applied Entomology, *121*, p. 77-80.

Boháč, J., 1999: Staphylinid beetles as bioindicators. Agriculture Ecosys. and Envir., *74*, p. 357-372.

Boháč, J., 2003: The effect of environmental factors on communities of carabid and staphylinid beetles (Coleoptera: Carabidae, Staphylinidae). In Frouz, J., Šourková, M., Fruzová, J. (eds): Soil physical properties and their interactions with soil organisms and roots of plants. Institute of Soil Biology AS CR, České Budějovice, p. 113-118.

Brouat, C., Sennedot, F., Audiot, P., Lebois, R., Rasplus, J.Y., 2003: Fine-scale genetic structure of two carabid species with contrasted levels of habitat specialization. Molecular Ecology, *7*, p. 1731-1736.

Burel, F., 1992: Effect of landscape structure and dynamics on species diversity in hedgerow networks. Landscape Ecology, *6*, p. 161-174.

Gibb, H., Hochulli, D.F., 2002: Habitat fragmentation in an urban environment: large and small fragments support different arthropod assamblages. Biological Conservation, *106*, p. 91–100.

Hill, M.O., 1979a: DECORANA – A FORTRAN program for detrended correspondence analysis an reciprocal averaging. Cornell University, Ithaca, New York.

Hill, M.O., 1979b: TWINSPAN – A FORTRAN programme for arranging multivariate data in an ordered two-way table by classification of individuals and attributes. Cornell University, Ithaca, New York.

Hunter, M.D., 2002: Landscape structure, habitat fragmentation, and the ecology of insects. Agricultural and Forest Entomology, *4*, p. 159-166.

Hůrka, K., Veselý, J., Farkač, J., 1996: Using of carabid beetles for bioindication of the environmental quality (in Czech). Klapalekiana, *32*, p. 15-26.

Kruess, A., Tscharntke, T., 1994: Habitat fragmentation, species loss, and biological control. Science, *264*, p. 1581-1584.

Legendre, P., Legendre, L., 1998: Numerical Ecology, 2nd English Edition. Elsevier, Amsterdam.

Pielou, E.C., 1966: The measurement of diversity in different types of biological collections. J. Theor. Biol., London, *13*, p. 131-144.

Riecken, U., Raths, U., 1996: Use of telemetry for studying dispersal and habitat use of *Carabus coriaceus* L. Ann. Zool. Fennici, *33*, p. 109-116.

Šustek, Z., 1994: Windbreaks as migration corridors for carabids in an agricultural landscape. Desender, K., Dufrene, M., Loreau, M., Luff, M.L., Maelfait J.P. (ed.): Carabid beetles: Ecology and Evolution. Kluwer Academic Publishers, Dordrecht, p. 377-382.

ter Braak, C.J.F., 1985: CANOCO – A FORTRAN program for canonical correspondence analysis and detrended correspondence analysis. IWIS-TNO, Wageningen, The Netherlands.

Underhill, J.E., Angold, P.C., 2000: Effects of roads on wildlife in an intensively modified landscape. Environ. Rev., *8*, p. 21-39.

Varchola, J.M., Dunn, J.P., 2001: Influence of hedgerow and grassy field borders on ground beetle (Coleoptera, Carabidae) activity in fields of corn. Agriculture, Ecosystems and Environment, *83*, p. 153-163.

Vermeulen, H.J.W., 1993: The composition of carabid fauna on poor sandy road-side verges in relation with comparable open areas. Biodiversity and Conservation, *2*, p. 331-350.

Vermeulen, R., 1994: The effects of different vegetation structures on dispersal of carabid beetles from poor sandy heaths and grasslands. Desender, K., Dufrene, M., Loreau, M., Luff, M.L., Maelfait, J.P. (ed.): Carabid beetles: Ecology and Evolution. Kluwer Academic Publishers, Dordrecht, p. 387-392.

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Boháč J., Hanousková I., Matějka K.: **Vliv fragmentace biotopů silniční dopravou s různou intenzitou na epigeické brouky v kulturní krajině.**

Epigeičtí brouci byli sbíráni metodou zemních pastí v lesních a nelesních transektech přes silnici první třídy a dálnici na Kaplicku a Jihlavsku. Nebyly zjištěny druhy vyskytující se jen v úzkém pruhu podél dálnice. Naopak zde převažovaly ubikvistní druhy. Druhová diverzita byla vyšší v biotopech podél silnice první třídy než u dálnice. Vliv dálnice se projevil snížením druhové diverzity v jejím bezprostředním okolí, což nebylo zjištěno u silnice první třídy. Ekvitabilita byla v blízkosti dálnice nízká v lesních biotopech, což nebylo zjištěno v otevřené krajině. Počet jedinců vybraných druhů schopných překonat silnici byl velmi malý (několik jedinců ze stovek označených) v lesních i nelesních biotopech. Dálnici překonal jen jeden jedinec ze stovek označených epigeických brouků.