

Spatial Distribution of Carabid and Staphylinid Beetles (Coleoptera: Carabidae, Staphylinidae) in a Forest Plantation Mosaic in Belarus

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ABSTRACT

The study was carried out in the Berezinsky Biosphere Reserve (northern part of Belarus, ca. 120 km to north-east of Minsk) in 1993-94. Pine plantations (*Pinetum pleuroziosum*) and adjacent deciduous plantations (*Betuletum pteridiosum*) were selected for the study. Beetles were collected using pitfall traps. The majority of dominant species were found along the entire transect. Distribution of only one carabid species, *Notiophilus biguttatus*, depended on the location of the plantations edge. This species was found in samples from the pine plantation only. It did not penetrate into the deciduous plantation completely. One staphylinid species, *Bolitochara pulchra*, was found in the deciduous plantation only. A zone adjacent to the edge of plantations limited distribution of two staphylinid species, *Tachinus corticinus* and *Olophrum assimile*. Edge zone influenced mainly the activity (a proxy for the abundance) of carabids and staphylinids. Carabid activity decreases at the plantations edge. That edge effect was expressed especially in activity changes of carabids *Pterostichus oblongopunctatus* and *Calathus micropterus* and staphylinid *Atheta europaea*. Staphylinid activity increased in the deciduous plantation. Activity of only one carabid species, *Cyberus caraboides*, and two staphylinids, *Tachinus corticinus* and *Olophrum assimile*, increased at the plantations edge. For effective support of species diversity the patch of deciduous plantations must have a width no less than 60-70 m. Then the populations of common in deciduous forests species can be maintained at the high level.

KEY WORDS

Carabids, staphylinids, forest plantation mosaic, spatial distribution, edge effect, Belarus.

INTRODUCTION

Conservation and sustainable exploitation of managed forests in the modern forestry need to solve a problem of better diagnostics of quantitative and qualitative diversity of animal and plant taxa inhabiting forests at any particular landscape point. Mosaic of forest types becomes an important factor affecting forest communities under conditions of modern intensive forest restoration (FAO UN, 2003).

The major tree species used in silviculture in Belarus is Scotch Pine (*Pinus silvestris* L.) oak (*Quercus robur* L.) and birch (*Betula pendula* Roth.). Occupy largest areas among young and middle-aged deciduous forest plantations, above 180 thousands ha and 1 million ha correspondingly. According to the program of forest restoration in Belarus for the period up to 2015, areas occupied by deciduous plantations will be increased. Areas occupied by oak will be extended twofold. Birch stands could be added to pine plantations to increase fire resistance and timber productivity of stands. Different transition zones or ecotones appear as a result of pine and deciduous plantation alternation.

Members of dynamic animal population actively use the space to choose habitats rich in resources and the most convenient environmental conditions. Animals may affect the shape of landscape borders as agents of matter and energy shifting or “vectors” (Wiens *et al.* 1985). Carabids and staphylinids are the most diverse and abundant families of epigeal beetles in temperate forests. Diversity of their assemblages depends substantially on the age and type of forest habitats as well as regional habitat mosaic (Szyszko 1983, Baguette and Gérard 1993, Butterfield 1997, Derunkov 2003). It was shown for northern Finland that different beetle assemblages are characteristic of different forest types, therefore preservation of different forest types may be the best general strategy to maintain the overall beetle species diversity in boreal forests (Similä *et al.* 2002). Carabids and staphylinids can be used as appropriate groups in investigation of responses of forest communities to modern cultivation practice (Skłodowski 2001, Smoleński 2001, Smoleński and Szujewski 2001). The aim of this study is to uncover ecological effects of plantation type mosaic on forest assemblages of epigeal beetles.

MATERIAL AND METHODS

The study was carried out in the Berezinsky Biosphere Reserve (northern part of Belarus, ca. 120 km north-east of Minsk) in 1993-94. Pine plantations (*Pinetum pleurozjosum* 28 years old, average height 12 m, average diameter 12 cm) and adjacent deciduous plantations (*Betuletum peridiosum*, the first layer – birch, 25 years old, height 16 m, diameter 12 cm; the second layer – oak, 30 years old, height 5 m, diameter 4 cm) were selected for the study (nomenclature for forest formations after Yurkevich *et al.* 1979). The edge between plantations was very clear without any transition zone, formed by trees or shrubs.

Beetles were collected using pitfall traps from the end of April to the beginning of October annually. During this period, beetles were extracted from the traps twice a month. Plastic cups with an opening diameter of 72 mm and a volume of 250 ml were used as pitfall traps. A 4% formalin water solution was used as a preservative. Twenty-one traps were placed at least 5 m apart along the line transect installed perpendicularly to the edge between plantations. Nine traps, designated as P1 – P9, were located in pine plantation, one trap, designated as 0 – on the edge and eleven traps, designated as D1 – D11 – in deciduous plantation (Fig. 1). Material from every trap for the year was considered as an independent sample.

Sampling effort (i.e. number of trap days) varied among years, and some traps were lost due to disturbance by wild mammals and people. Therefore, each sample was standardized to 100 trap days (number of traps/number of trap exposure days). Pitfall catches partly depend on beetle activity and reflect the “dynamic density” of the species (Ghilarov 1987). Therefore, the term “activity” was used for description of the species abundance. Totally ca. 10,000 carabids and ca. 4,300 staphylinids were collected. Relatively abundant species (more than 40 specimens captured

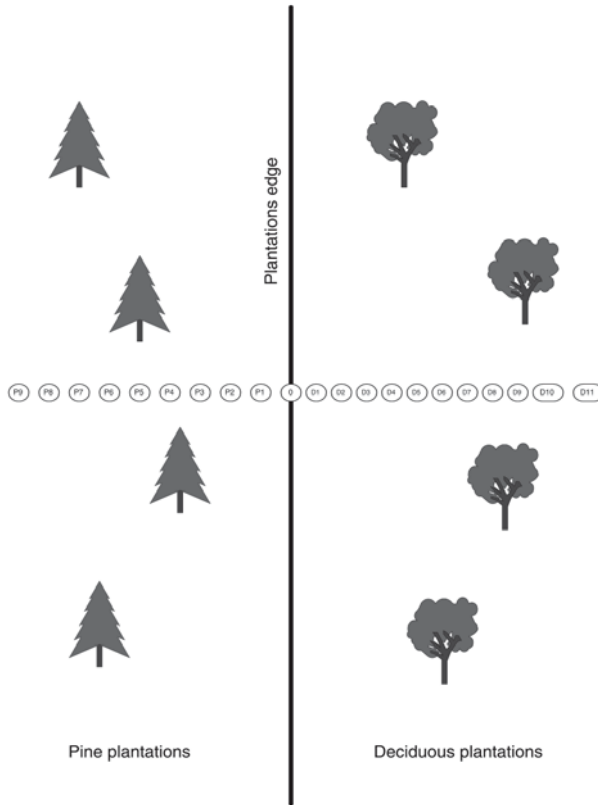


Fig. 1. Scheme of placing of soil traps along the transect at the plantations edge. Explanations in the text.

in one year, activity or dynamic density more than 6 beetles/100 trap days) were used to estimate the edge effect. Some less abundant species (15-30 specimens, activity 1-3 beetles/100 trap days) with characteristic distribution were also considered. I performed cluster analysis of Bray-Curtis percentage similarities with group averaging as weighting procedure using the software BioDiversity Professional (1997) to depict relationships of beetle samples along transect. The regression analysis was used to reveal the trends of species distribution.

RESULTS

Carabid distribution. Carabid activity was the highest in deeper parts of plantations. Activity reduction was observed on the plantation edge (polynomial trend curve of activity change has two peaks and a drop on the edge, Fig. 2A). Five species groups were selected according to activity change characteristics. Species with activity depression on the plantations edge were included in the first group. Depression zone was shifted into deciduous plantations. They were common forest species like *Calathus micropterus* (Duft.), *Pterostichus oblongopunctatus* (F.), *Pt. strenuus* (Panz.), *Carabus hortensis* L., *C. convexus* F., *Leistus terminatus* Panz. and *Amara brunnea* (Gyll.) (Fig. 2B – 2H). Activity of these species was the lowest within ca. 25 m into deciduous plantation and

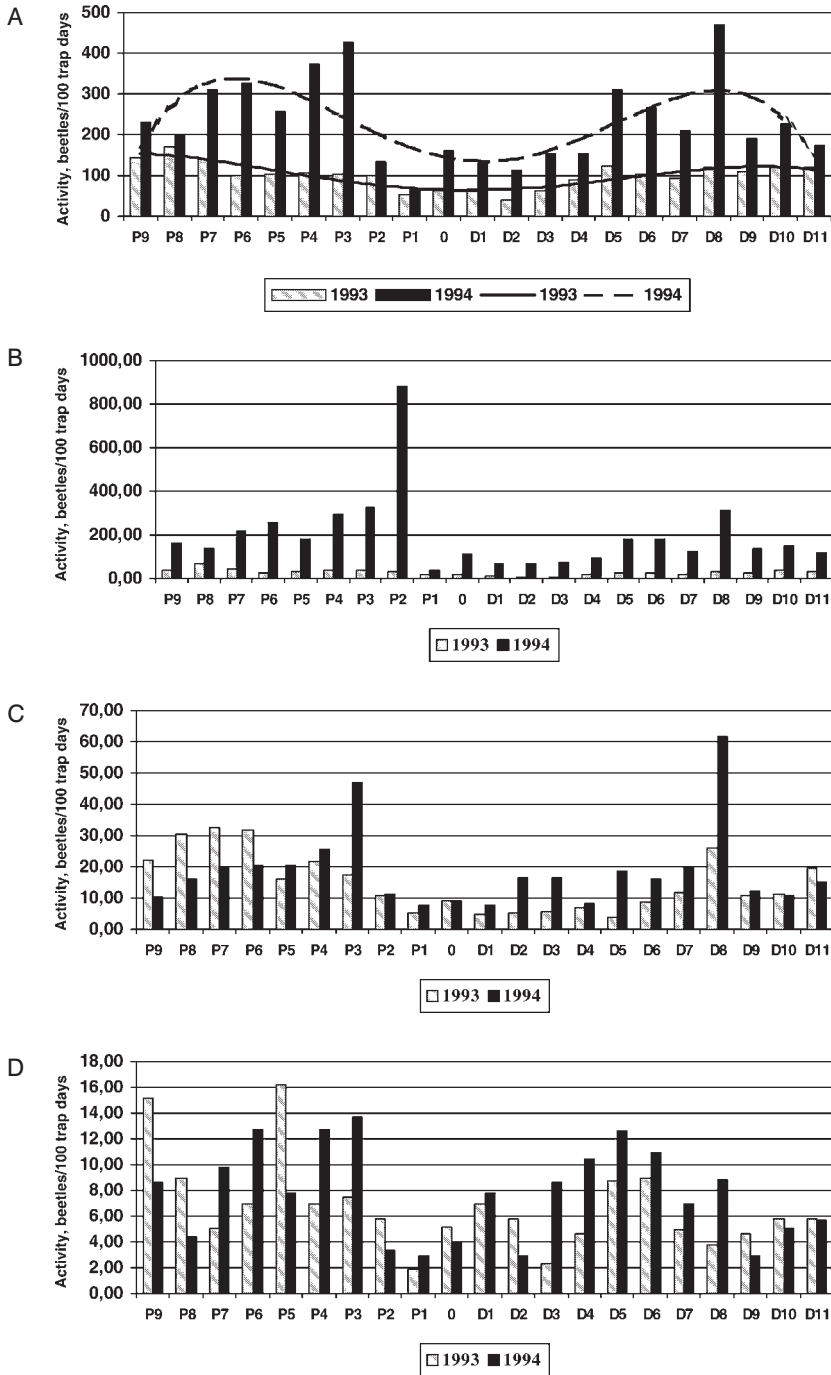


Fig. 2. Carabid activity at the edge of pine and deciduous plantations. A – all species; B – *Calathus micropterus*; C – *Pterostichus oblongopunctatus*; D – *Pterostichus strenuus*.

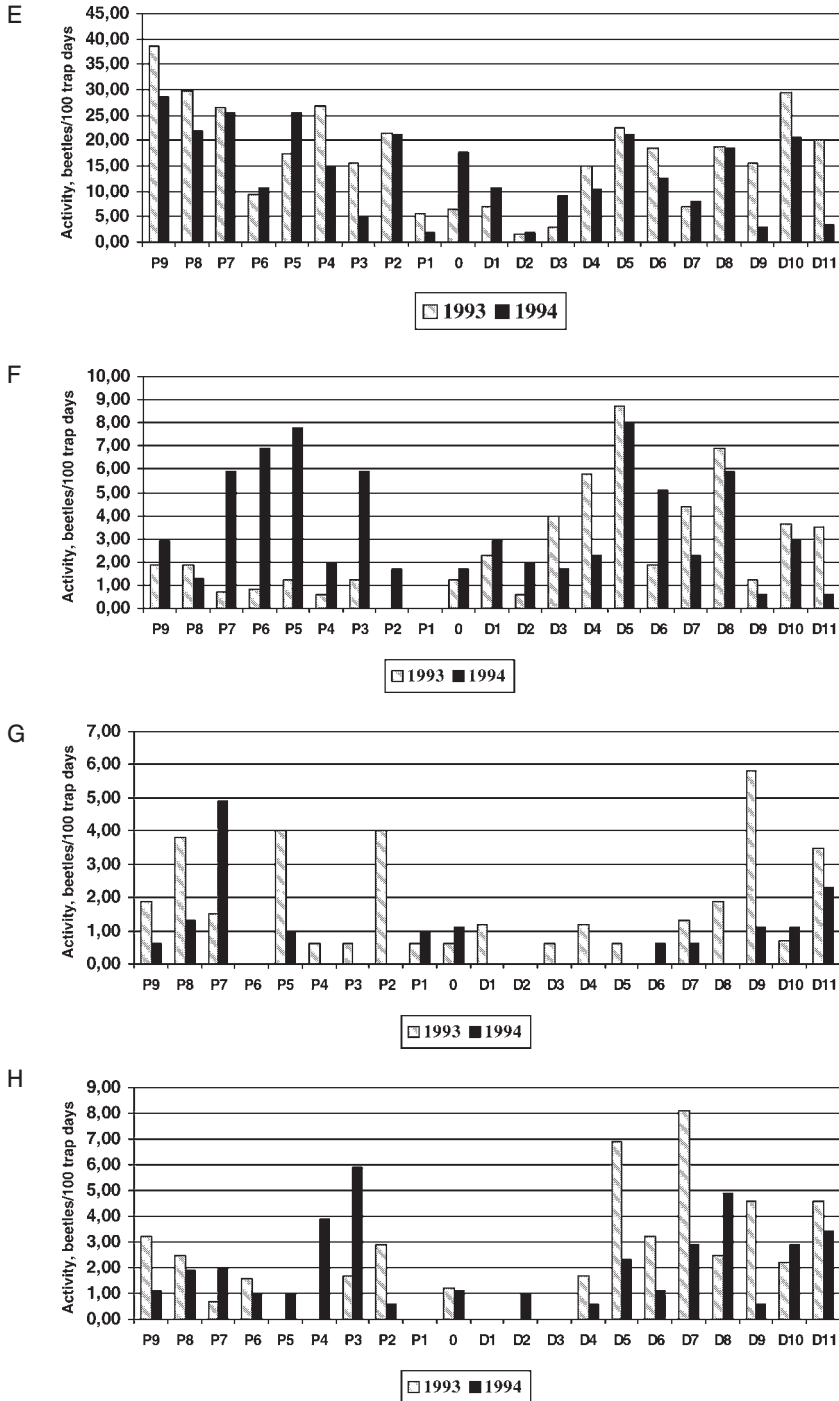


Fig. 2. E – *Carabus bortensis*; F – *Carabus convexus*; G – *Leistus terminatus*; H – *Amara brunnea*.

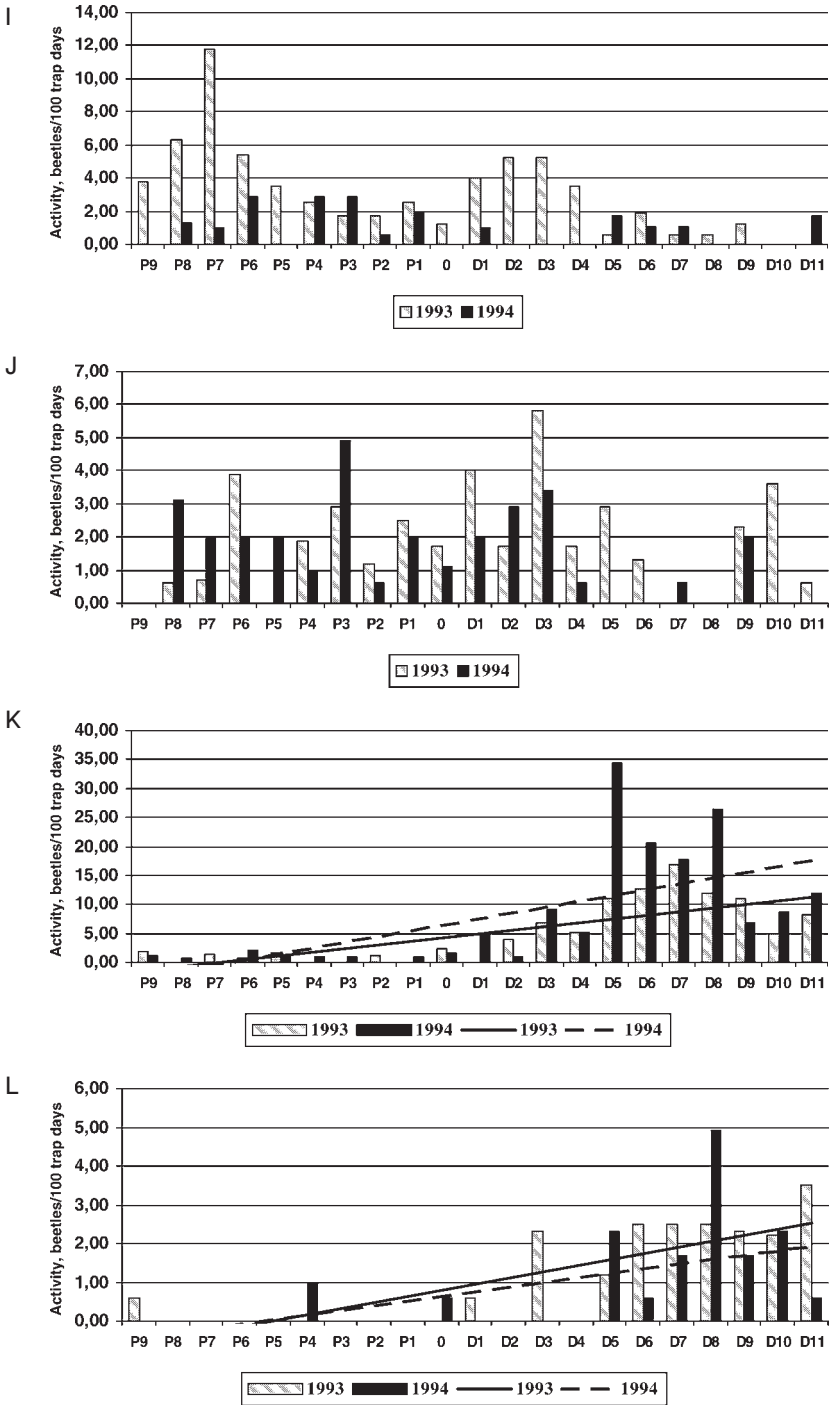


Fig. 2. I – *Pterostichus aethiops*; J – *Cyclus caraboides*; K – *Pterostichus melanarius*; L – *Poecilus versicolor*.

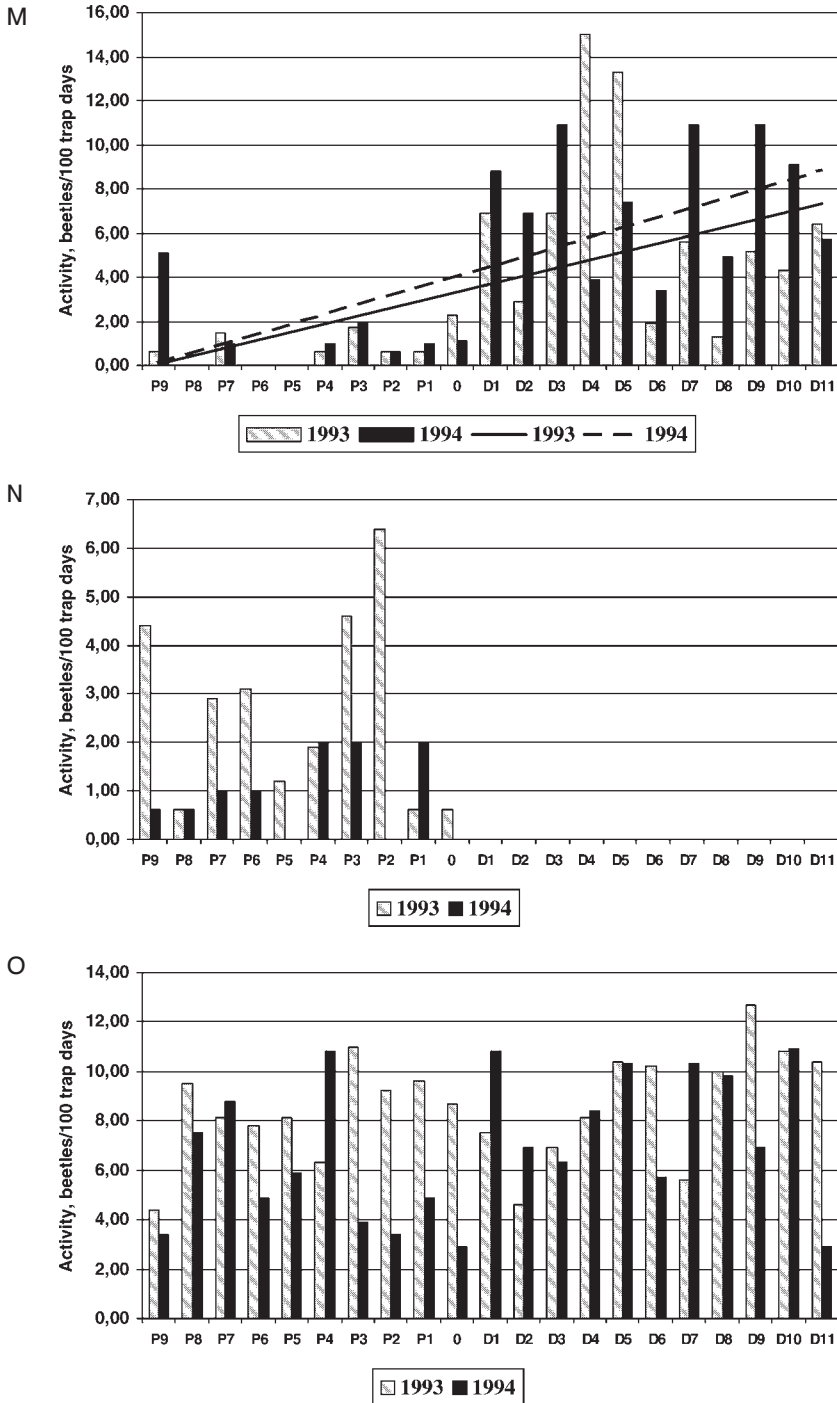


Fig. 2. M – *Epaphius secalis*; N – *Notiophilus biguttatus*; O – *Pterostichus niger*.

ca. 5 m into pine plantation, with the exception of *Leistus terminatus*. Activity of *L. terminatus* decreased within up to 20 m from the edge into pine plantation and up to 40 m into deciduous plantations (see Fig. 2G).

Pterostichus aethiops (Panz.) was attributed to the first group too, but his zone of activity depression differed considerably between study years. In 1993, zone of *Pt. aethiops* activity depression was in the pine plantation and reached up to 20 m from the edge (Fig. 2I). In 1994, it shifted to the deciduous plantation, up to 25 m deep from the edge.

Only one species, *Cybrus caraboides* (L.), was attributed to the second group. Activity of this species was highest at the plantations edge (Fig. 2J). It was called an “ecotone dominant”.

Pterostichus melanarius (Ill.), *Poecilus versicolor* (Sturm) and *Epaphius secalis* (Payk.) were included in the third group. Their activity in the pine plantation was very low. They were absent in the many samples. Activity of these species linearly increased from the edge into the deciduous plantation (see linear trend, Fig. 2K – 2M).

The fourth species group included only one species, *Notiophilus biguttatus* (F.). This species was common in the pine plantations (its activity exceed 6 beetles/100 trap days) to the plantations edge (Fig. 2N). But this species did not penetrate completely into deciduous plantations.

The fifth group of species included *Pterostichus niger* (Schall.). No defined trends in its activity changes were determined (fig. 2O). Activity of *Pt. niger* was high along the entire transect. This species in Belarus is common in forests of different types and is characterized by the wide amplitude of environmental preferences (Alexandrovich 1991, Khotko 1993). Therefore, it is possible that environmental changes at the plantations edge did not affect the *Pt. niger* activity.

Thus, the analysis of the carabid activity changes suggests that the most of dominant species avoid the plantations edge. Their activity in the contact zone was sometimes also low. Only *Cybrus caraboides* activity was higher in the contact zone than deeper into plantations away from the ecotone.

Staphylinids distribution. Activity of staphylinids increased linearly along the transect from the pine plantation into the deciduous plantation (see linear trend, Fig. 3A). As for carabids, five species groups were selected by activity change characteristics of staphylinids. *Staphylinus erythropterus* L., *Tachyporus abdominalis* F., *Oxyptoda abdominalis* (Mannh.), *Oxyptoda lividipennis* Mannh., *Atheta fungi* (Grav.) were included to the first group. Activity of these species evenly increased along transect (Fig. 3B – 3F). They were absent in many samples in the pine plantation. In the deciduous plantation, activities of the most of these species increased 2 – 4 times. *Atheta crassicornis* (F.), *A. gagatina* (Baudi), *Xantholinus tricolor* (F.) and *Othius punctulatus* (Goeze) can be attributed to the first group too. There was increasing trend in their activity in the deciduous plantation (see linear trend, Fig. 3G – 3J). However, the activities of these species were high in some samples in the pine plantation.

Bolitochara pulchra (Grav.) was not found neither in the pine plantation nor on the edge. This species was registered in the deciduous plantation only, 30 – 40 m from the edge. Activity of *Bolitochara pulchra* increased linearly along transect into the deciduous plantation (see linear trend, Fig. 3K).

The second group of species included *Anthobium atrocephalum* (Gyll.) and *Philonthus decorus* (Grav.), which represented opposite trends of activity changes. Activity of *Anthobium atrocephalum* was high in the pine plantation and was about two times lower in the deciduous plantation, especially in 1993 (see linear trend, Fig. 3L). Activity of *Philonthus decorus* also was 2 – 3 times lower in the deciduous plantation (Fig. 3M), but the peak of its activity was observed on the plantations edge.

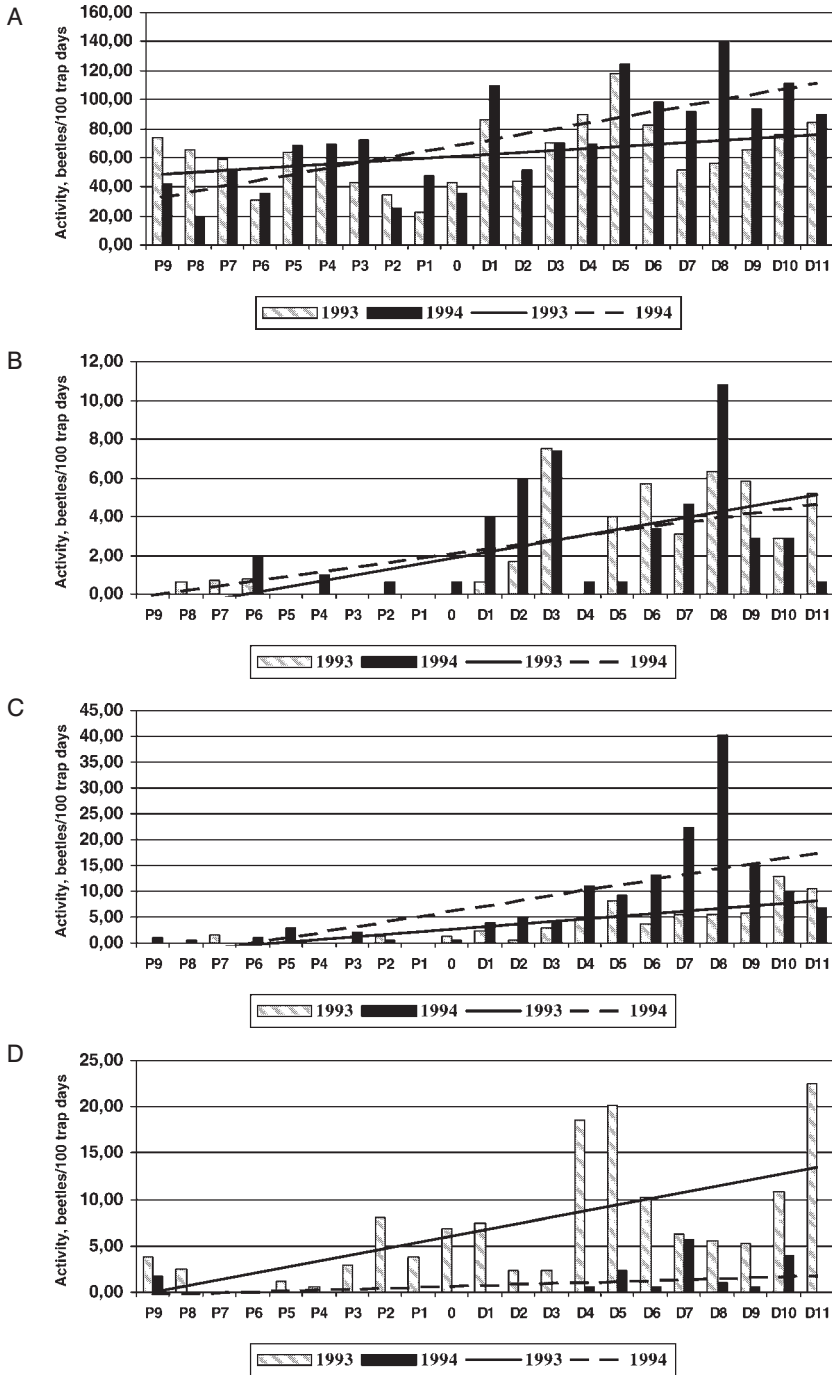


Fig. 3. Staphylinid activity at the edge of pine and deciduous plantations. A – all species; B – *Staphylinus erythropterus*; C – *Tachyporus abdominalis*; D – *Oxyptoda abdominalis*.

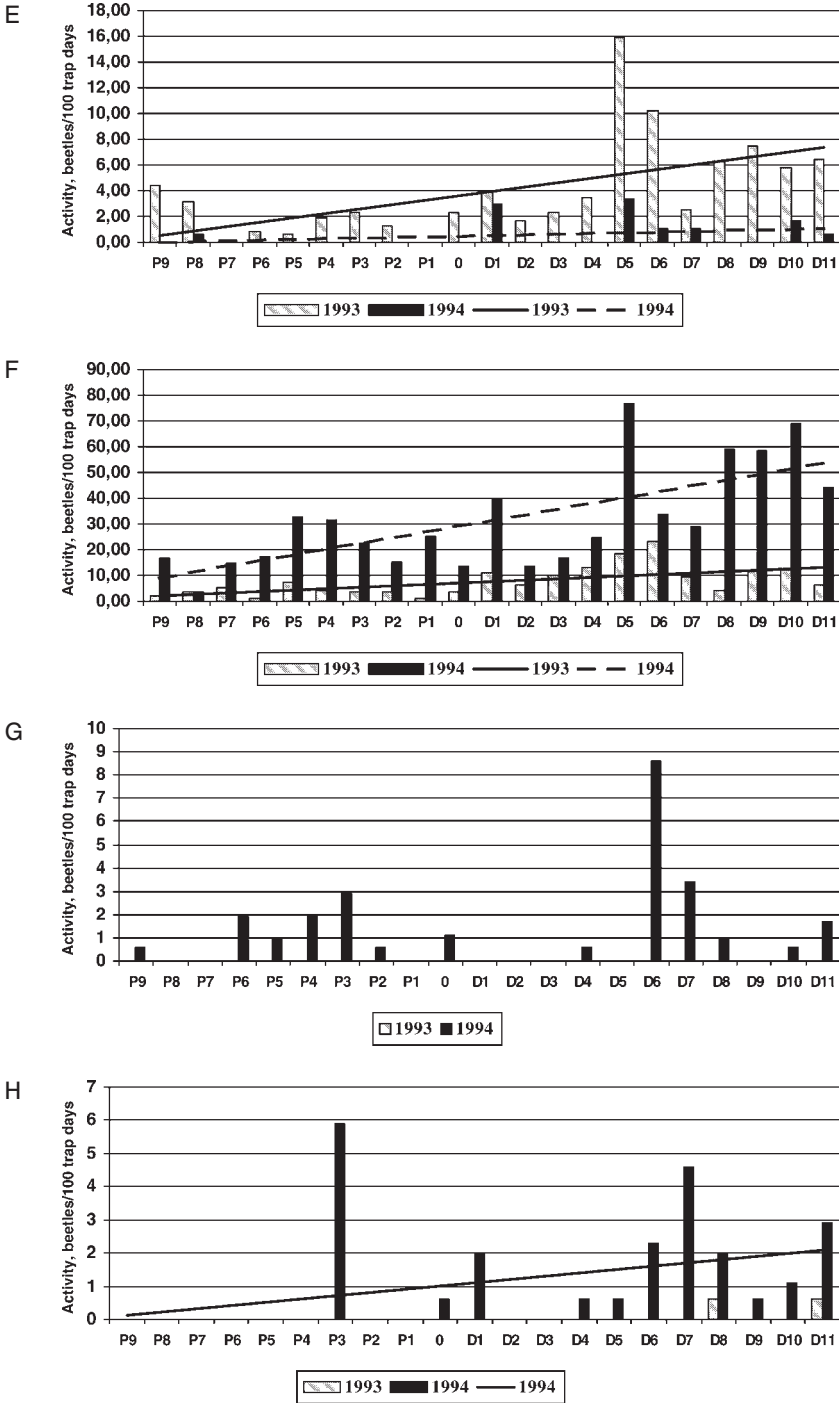


Fig. 3. E – *Oxytoda lividipennis*; F – *Atheta fungi*; G – *Atheta crassicornis*; H – *Atheta gagatina*.

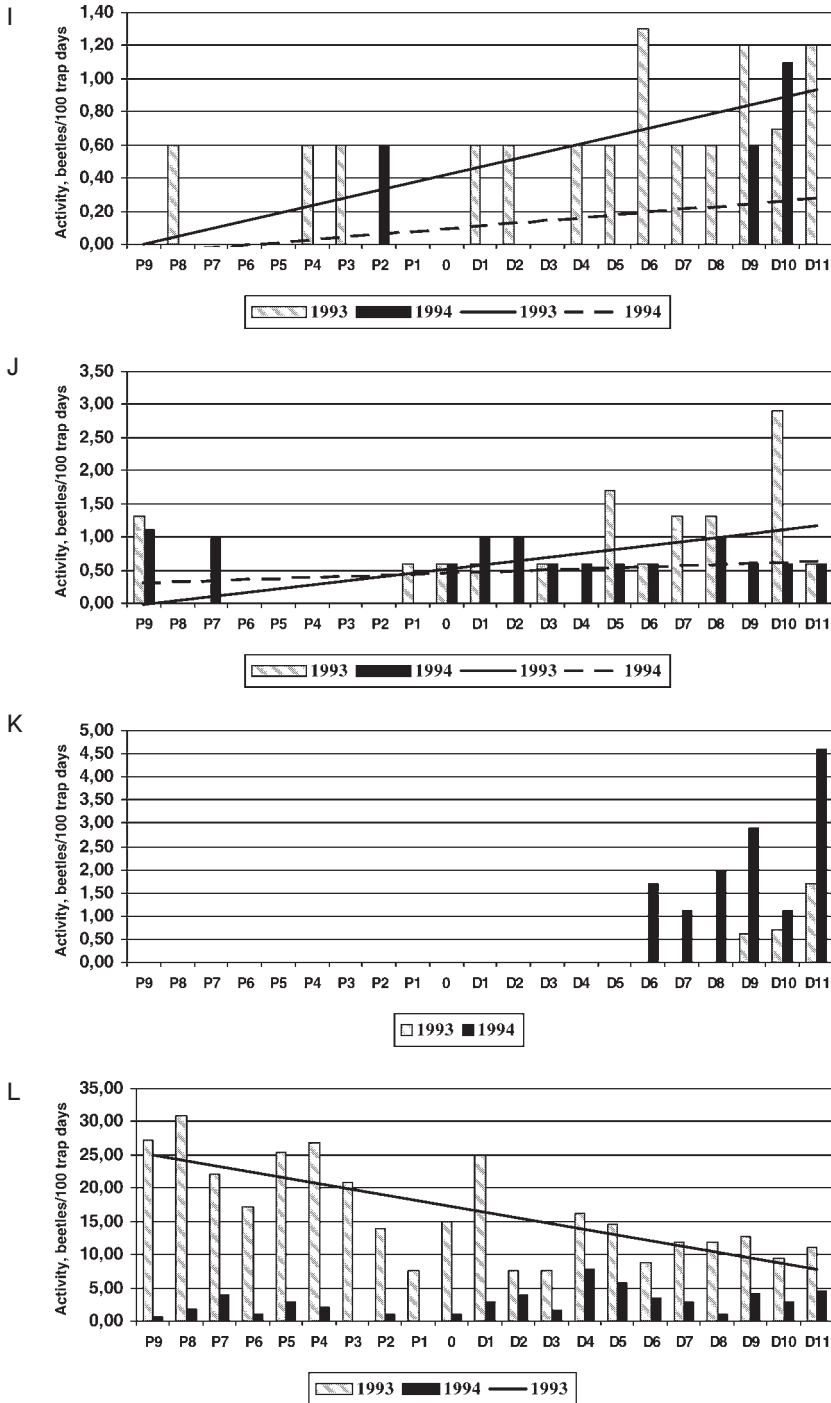


Fig. 3. I – *Xantholinus tricolor*; J – *Othius punctulatus*; K – *Bolitochara pulchra*; L – *Antibobium atrocephalum*.

Both above-mentioned species (especially *Anthobium atrocephalum*) are sensitive to moisture and light changes. They prefer habitats with lesser annual amplitude of soil moisture and soil temperature (Thiele and Kolbe 1962). Probably, the less pronounced seasonal moisture and temperature fluctuations in the pine plantation caused higher activities of these species here.

The third group of species included *Tachinus corticinus* Grav. and *Olophrum assimile* (Payk.) (Fig. 3N, 3O). These species were absent in the samples deep in pine and deciduous plantations (with the exception of some *Tachinus corticinus* specimens in two samples in deciduous plantation and some *Olophrum assimile* specimens in two samples in pine plantation). Activity of these species was highest in the sample on the edge of plantations and in adjacent samples in the deciduous

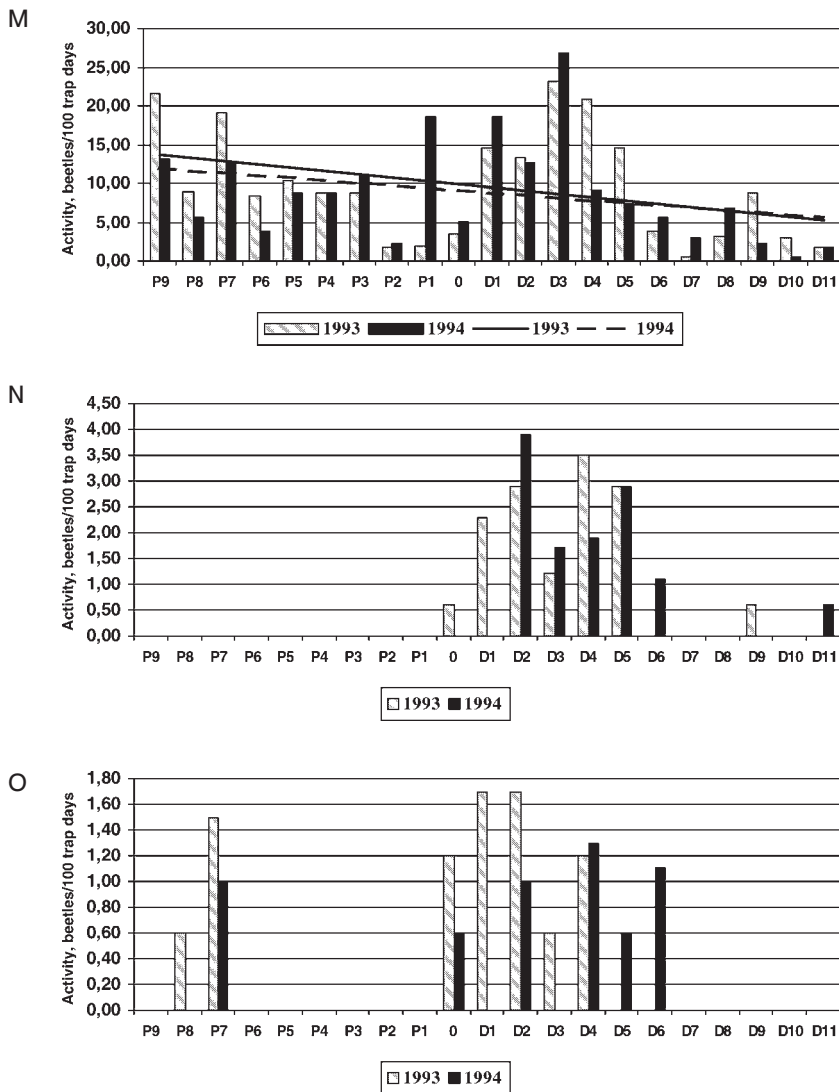


Fig. 3. M – *Philonthus decorus*; N – *Tachinus corticinus*; O – *Olophrum assimile*.

plantations (up to 30 m from the edge). Both species visit blooming plants in meadows and forest gaps. Because of light changes at the plantations edge some herbaceous plants grow there and their blooming attract *Tachinus corticinus* and *Olophrum assimile*. Spatial distribution of these species illustrates the ecotone effect. They may be characterized as “ecotonal”.

The fourth group of species included one species only, *Atheta europaea* Lik. Its activity changes were very close to the revealed for the entire staphylinid assemblage (Fig. 3P). Activity of *A. europaea* was high both in pine and deciduous plantations. At the plantations edge, up to 15 m deep into plantations, activity decreased 2-5. *A. europaea* was even absent in some samples at the edge.

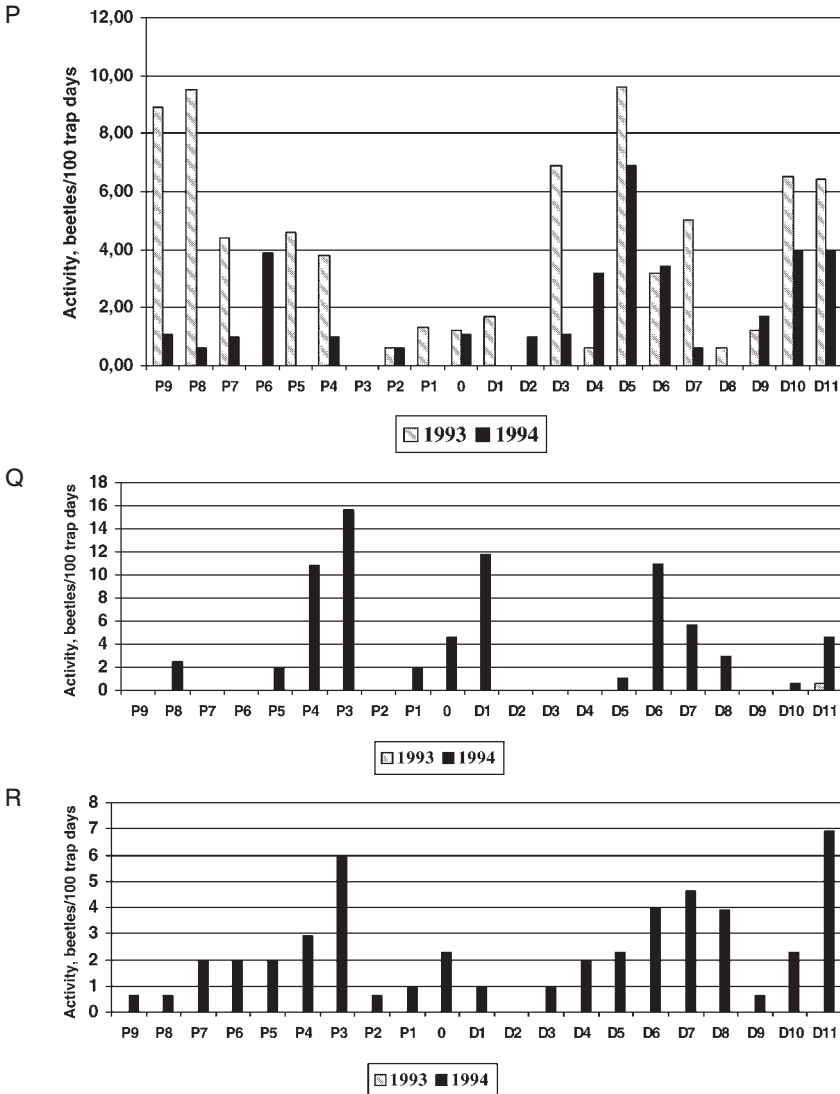


Fig. 3. P – *Atheta europaea*; Q – *Lordithon lunulatus*; R – *Atheta paracrassicornis*.

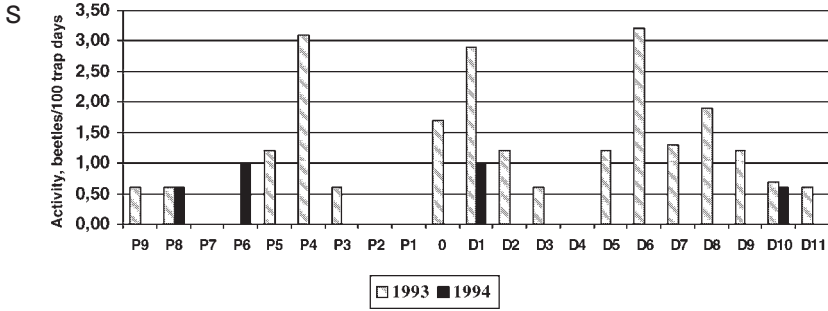


Fig. 3. S – *Mycetoporus rufescens*.

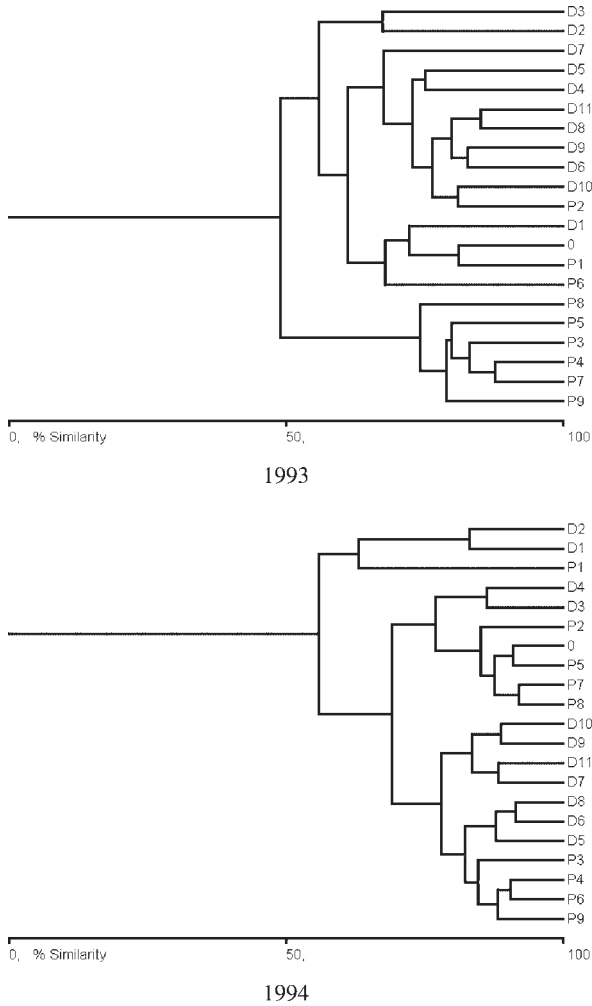


Fig. 4. Cluster analyses of Bray-Curtis measures of percent similarity for the carabid samples at the plantations edge

Finally, no clear trends were determined in activity changes of fifth species group. This group included *Lordithon lunulatus* (L.), *Atheta paracrassicornis* Brundin and *Mycetoporus rufescens* (Steph.) (Fig. 3Q – 3S).

Cluster analysis revealed a difference in similarity between beetle assemblages in pine plantations, deciduous plantations and their edge (Fig. 4-5). Two carabid sample groups from pine and deciduous plantations clustered at ca. 50% similarity in 1993 (see Fig. 4). Edge samples (samples 0, P1, D1 with P6) formed distinct group at ca. 70% similarity. This group is more similar to carabid assemblage of the deciduous plantation. Another sample group, formed by samples adjacent to plantations edges (D2, D3), clustered with groups of samples from deciduous plantation and from edge at ca. 60% similarity. In 1994, the edge samples P1, D1 and D2 clustered with other sample groups at ca. 55% similarity only. Differences between carabid assemblages in

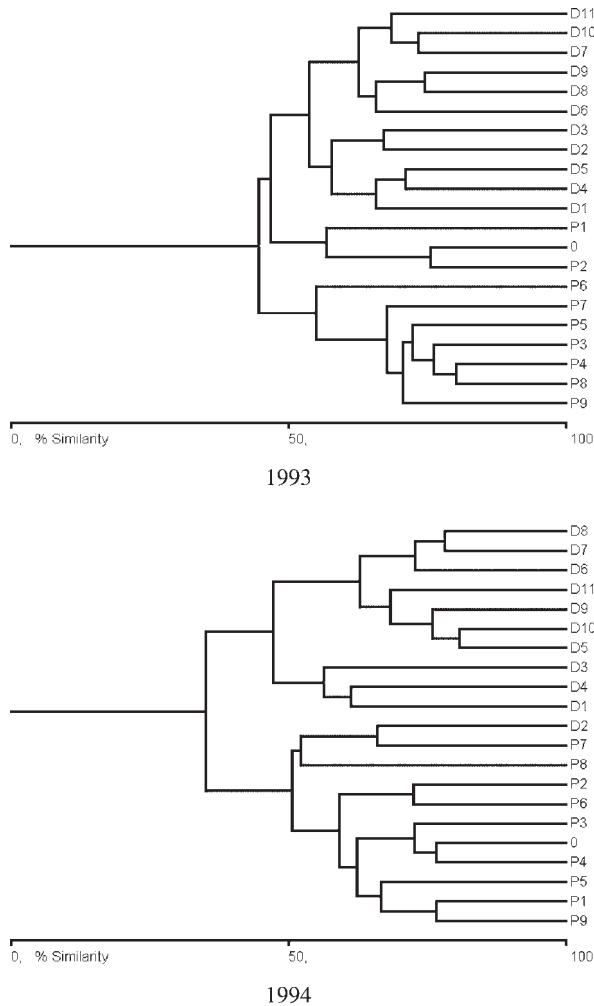


Fig. 5. Cluster analyses of Bray-Curtis measures of percent similarity for the staphylinid samples at the plantations edge

two types of forest plantations were less pronounced in 1994. Nevertheless, it is possible to distinguish two groups of samples from pine and deciduous plantations on the 1994 dendrogram (Fig. 4). Those groups clustered at a higher similarity level, than in 1993.

For staphylinid assemblages clustering was more clear, than for carabids (see Fig. 5). Narrower microhabitat association of staphylinids in comparison with carabids may cause this pattern. In 1993, all staphylinid samples were associated in three clearly distinct clusters at ca. 50% similarities: samples of pine plantation, samples of deciduous plantation and samples from the edge (0, P1, P2). In 1994, staphylinid samples from pine and deciduous plantations clustered at ca. 35% only. Edge samples (D1, D3, D4) formed distinct group at ca. 50% similarity, more similar with the group of samples from deciduous plantation. In 1994, activity of “ecotonal” species *Olophrum assimile* and *Tachinus corticinus* was the highest specifically in these samples.

DISCUSSION

It is difficult to characterize explicitly carabid and staphylinid distribution at the edge of plantations. The most of dominant species were found along the entire transect. Distribution of only one carabid species, *Notiophilus biguttatus*, depended on the location of the plantations edge. This species was found in samples from the pine plantation only. It did not penetrate into the deciduous plantation completely. One staphylinid species, *Bolitochara pulebra*, was found in the deciduous plantation only. A zone adjacent to the edge of plantations limited distribution of two staphylinid species, *Tachinus corticinus* and *Olophrum assimile*. Two more *Tachinus* Grav. species were collected at the plantations edge. However, their activity was so low that it is impossible to say for certain whether their distribution depends on the plantations edge location or not.

Difficulties in the edge effect interpretation for carabid communities were mentioned in other studies. For example, for fragmented pine and mixed West Canadian forests it was shown that edges of forest fragments are more suitable for open habitat species and habitat generalists (Spence *et al.* 1996). These authors found out that forest carabid populations were less abundant near the edge of forest fragments and clear-cuts, up to 5-10 m from the edge. In Bulgaria, on the Vitosha Mountain carabid communities could not be subdivided into any distinct groups along altitudinal gradient (Krusteva *et al.* 1993).

In our case, both adjacent habitats were forests. Therefore, general habitat conditions were similar in both types of plantations. Differences in conditions between two types of plantations are mainly due to differences in litter composition. Deciduous litter seems to influence distribution of soil invertebrates (including epigeal carabids and staphylinids) through the effect of some biotic and abiotic factors (features of niche structure, nutrient availability, moisture, temperature) (Koivula 1998). For example, large aspen (*Populus tremula*) trees within conifer stands are important source of deciduous litter and promote higher local invertebrate diversity in Finnish coniferous forests (Niemelä 1997). In Hungary, abundance of deciduous forest carabid species decreased significantly in non-native Norway spruce (*Picea abies*) plantations, and appeared in high densities only in native beech forests (Elek *et al.* 2001). Niemelä *et al.* (1992) have shown that the most numerous forest carabid species are distributed non-randomly and form aggregations within a ca.1.3 ha patch in Finland. Sites with abundant deciduous litter in coniferous forests are good-quality “resource spots” for many forest carabid species (Haila *et al.* 1994). Such “spots” may serve as source patches from which individuals move into nearby lower-quality patches.

Transition zone between studied pine and deciduous plantations may be considered as a version of “narrow” ecotone of van der Maarel (1990). In this case, the edge is sharp and is created by external factor, forests planted by humans. Ecotone in this sense does not possess distinct specific features in contrast to “wide” ecotone characterized by definite peculiarities of structure and functioning. The complex of environmental conditions seriously affecting such active epigeal beetles as carabids and staphylinids is absent in the ecotone of “narrow” type. Therefore, the edge effect on carabid and staphylinid assemblages is represented only in activity changes in the most numerous species.

Epigeal carabids and staphylinids may be considered as agents of ecological penetration, i. e. introduction of elements from one ecosystem to another (Turček 1975). Interaction of both studied forest ecosystems and development of transition zone will depend mainly on the mobility of assemblage members. We can see that the species not characteristic of pine forests, e.g. *Pt. melanarius*, *Poecilus versicolor*, *Epaphius secalis*, *Tachyporus abdominalis*, *Oxyptoda abdominalis*, *Oxyptoda lividipennis*, penetrate into this forest type from deciduous plantations. Pine plantations are the source from which eurytopic forest species *Philonthus decorus*, *Anthobium atrocephalum*, *Ischnosoma splendidum* and *Quedius limbatus* penetrate to deciduous plantations.

Results of our study agree with the Leśniak's (1981) conclusions about a carabid reaction on the habitat alterations in Polish pine forests. He found that abundance of all carabid assemblages and carabid species as well as their occurrence and functional community structure in some habitats are the most sensible indices for habitat changes. Leśniak (1984) had shown that carabid community stability in forest ecosystems depends on and is proportional to the species abundance and not to species richness. In my study site, edge zone influenced mainly the activity (a proxy for the abundance) of carabids and staphylinids. Carabid activity decreases at the plantations edge. That edge effect was expressed especially in activity changes of carabids *Pterostichus oblongopunctatus* and *Calathbus micropterus* and staphylinid *Atheta europaea*. Staphylinid activity increased in the deciduous plantation. Activity of only one carabid species, *Cychnus caraboides*, and two staphylinids, *Tachinus corticinus* and *Olophrum assimile*, increased at the plantations edge. For effective support of species diversity the patch of deciduous plantations must have a width no less than 60-70 m. Then the populations of common in deciduous forests species can be maintained at the high level.

Increase in habitat heterogeneity at different levels (from local to regional) is clearly linked to the increasing in diversity of many insect groups, including carabids and other epigeal beetles (Ma Shijun 1990, Rolstad 1991, Haila *et al.* 1994). But “quality” of such diversity is often considered to be low, because increase of proportion of habitat generalist species in forest invertebrate communities (Ball *et al.* 1994). In this case, it seems that the mosaic of different forest plantations affects positively assemblages of epigeal beetles. Staphylinid activity is higher in deciduous plantations than in pine plantations. Activity of *Cychnus caraboides*, forest specialist, increased at the plantations edge. “Ecotone” species complex of staphylinids (*Tachinus* species and *Olophrum assimile*) is formed here. Thus, mosaic of forest plantations promotes increase of epigeal beetles diversity.

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