Variation in epigeic carabid fauna (Coleoptera: Carabidae) on differently-treated post-agricultural land

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Schwerk A., Szyszko J. 2012. Variation in epigeic carabid fauna (Coleoptera: Carabidae) on differently-treated post-agricultural land . *Baltic J. Coleopterol., 12(1): 39 – 48.*

The treatment of post-agricultural areas may influence ecological processes such as succession, and thus influence species occurrence. We studied carabid coenoses on differently treated post-agricultural land. Carabids were collected using pitfall traps on five study sites during 2004-2010: a planted pine forest (26 years old in 2004), a naturally-regenerated pine stand (about 5 years old in 2004), two irregularly-mown sites without biomass removal, and a regularly-mown site with biomass removal. The number of species, number of individuals, total biomass and Mean Individual Biomass (MIB) were analysed to compare the successional processes among the five study sites. Unconstrained ordination (CA) was run to obtain information about the environmental basis in determining the structure of the carabid coenoses based on the variation pattern. Altogether 5539 individuals from 77 species were collected. Five species, *Harpalus rubripes*, *Calathus fuscipes*, *Calathus erratus*, *Pterostichus niger* and *Calathus melanocephalus*, made up > 50% of all specimens. Numbers of species and individuals were highest on the regularly-mown site and lowest in the forest. These parameters showed decreasing trends on all sites, but were significant only for the species number on the planted pine stand. Total biomass decreased in almost all cases, with particularly low values for the irregularly-mown sites. MIB was low for the managed sites, but high in the planted pine forest. MIB increased significantly on the naturally-regenerated pine forest during the study years. CA indicated that the stage of succession was the most important factor in determining the carabid coenoses. The method of treatment of post-agricultural land significantly influences the successional stage and species composition of carabids. Therefore, a well-thought-out management of post-agricultural areas within a landscape may be an important instrument to protect biological diversity.

Key words: Carabidae, fallow ground, forest, succession, MIB, landscape

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INTRODUCTION

Agricultural land constitutes a significant human-dominated ecosystem. Type of agriculture influences the biological components of the system, and agricultural intensification is regarded as a major target of research and development (Matson et al. 1997). With respect to carabids in agricultural landscapes, surprisingly similar species compositions across different European countries exist (Luff 2002), with a dominance of eurytopic species (Kotze et al. 2011). However,

the spatial arrangement of different landscape elements affects carabid assemblages (Holland & Luff 2000, Kotze et al. 2011).

Intensification of agriculture can have drastic side consequences, e.g. with respect to soil biota or natural resources, such as soil organic matter, water and nutrients, which may be reduced by ecologically-based management strategies (Matson et al. 1997). Moreover, often due to economic reasons, agricultural areas may get abundant from agriculture and turn into fallow land which offers possibilities with respect to nature conservation, as such patches may serve as habitat for rare species or as elements ecologically connecting patches of a given habitat type (Jedicke 1989). For example, Sieren & Fisher (2002) describe an example of abandoning agricultural areas for enlargement of a dry grassland biotope. However, the treatment of such post-agricultural areas may significantly influence ecological processes such as succession, and thus influence the species composition. Since successional processes may run differently in different habitat types (e.g. Szyszko 1990, Schwerk 2008), long-term studies are necessary to understand changes in species composition.

The aim of the present paper is to study the spatial and temporal variation in carabid coenoses (i.e. the carabids collected in the respective biotype) on differently-treated post-agricultural sites. Carabids are considered to have good potential for indication of environmental variation (Koivula 2011) and they react on management practices in grassland habitats (Rainio & Niemelä 2003) and on changes in the stage of succession (Szyszko 1990). An increasingly frequently-used measure of the state of succession is the Mean Individual Biomass of Carabidae (MIB) (e.g. Szyszko et al. 1996, Szyszko et al. 2000, Serrano & Gallego 2004, Schwerk et al. 2006, Cárdenas and Hidalgo 2007, Šerić Jelaska et al. 2011). The method assumes an ongoing process of succession with which the MIB of carabid coenoses increases. As Koivula (2011) states, "the 'behaviour' of MIB warrants further research before applying it in conservation and management, but it may already have potential in landscape-level assessments".

Five study sites on post-agricultural soil were chosen, which are a planted pine forest, a regularly-mown ground with biomass removal, two irregularly-mown grounds without biomass removal, and a naturally-regenerated pine forest. The different treatments of the study sites were predicted to impact on successional characteristics of the study sites as vegetation development and carbon enrichment and in turn influence the structure of carabid conenoses. According to Szyszko (1990) and Schwerk (2008), a successional process should be characterized by (a) a decrease in species numbers, (b) a decrease in numbers of individuals, (c) no clear trend with respect to total biomass, and (d) an increase in MIB. The stage of succession was predicted to be most advanced in the pine forest, be significantly inhibited on sites without biomass removal, and completely inhibited on the site with biomass removal.

MATERIAL AND METHODS

Field methods

The study was carried out on the research object "Krzywda" from 2004 to 2010 at Tuczno (west Poland, Wałecki district; Fig. 1). The area is composed of different forests and post-agricultural areas of different stages of succession, as well as about 68 ha of swamps highly eutrophicated due to wastewater inlet, supplied by three water courses. All these elements are subject to research on succession (Rylke & Szyszko 2002). The five study sites each represent different habitat types (see Introduction) and hence differ in many respects. On each study site three pitfall traps made of glass were installed from mid-May to mid-September, with pure ethylene glycol as trapping liquid. A funnel with a diameter of ca. 10 cm was installed over each trap flush with the soil surface to minimise by-catch, and a roof was installed a few cm above the funnel to protect the trap from rainfall.

Statistical methods

For each of the five study sites the numbers of species and individuals, total biomass, and MIB were calculated for each study year. MIB is calculated by dividing the biomass of all sampled individuals by the number of specimens. Biomass values were fixed for the recorded species using values from Szyszko (1990) or using the formula from Szyszko (1983) that describes the relationship between body length of a carabid individual (x) and its biomass (y):

$$\ln y = -8.92804283 + 2.55549621 \times \ln x$$

<div align="right">(eq. 1)</div>

Numbers of species and individuals, total biomass, and MIB were checked for correlations with an increasing age of the study site, using Spearman rank correlation (Sachs 1984). Differences between the study sites with respect to these parameters were tested using non-parametric Kruskal-Wallis test, followed by pair-wise Mann-Whitney U tests with sequential Bonferroni adjustment for multiple probabilities (Holm 1979). All tests were carried out using SPSS Statistics Version 19.

The Canoco for Windows version 4.53 (ter Braak 1987, ter Braak & Šmilauer 2002) was used to perform an indirect gradient analysis to obtain information about the environmental basis in determining the structure of the carabid coenoses based on the variation pattern (Ter Braak & Prentice 1988). Detrended Correspondence Analysis (DCA) was carried out first to select the appropriate statistical model, based on the gradient length of the first DCA axis (Ter Braak & Prentice 1988). Based on DCA, a Correspondence Analysis (CA) was applied using scaling on inter-sample distances and Hill's scaling, as recommended for long gradients (ter Braak & Šmilauer 2002). Because the dominance values were used, the data were not transformed.

RESULTS

Altogether 5539 individuals from 77 species were collected. Five species, namely *Harpalus rubripes* (790 individuals), *Calathus fuscipes* (657 individuals), *Calathus erratus* (520 individuals), *Pterostichus niger* (513 individuals) and *Calathus melanocephalus* (512 individuals), altogether made up > 50% of all specimens.

Among the five habitat types, only the pine forest showed a statistically significant decrease in the number of species across the seven years of study (r = -0.955, p < 0001). The site with natural regeneration of pine showed a marginally significant decreasing trend in species numbers (r = -0.679, p < 0.1) (Fig. 2a). However, the species numbers peaked on the regularly-mown site, followed by the irregularly-mown sites. The site subject to natural regeneration of pine and the pine forest showed the lowest species numbers (Fig. 2b).

None of the study sites showed a significant change in numbers of individuals (Fig. 3a), but there was a clear trend of decreasing numbers in the pine forest (r = -0.739, p < 0.1). The number of individuals peaked on the regularly-mown site but was almost equally low on the other sites (Fig. 3b).

No significant changes in total biomass over the seven years could be observed on the study sites (Fig 4a). The total biomass was high on the regularly-mown site, the site subject to natural regeneration and the pine forest, but was low on the irregularly-mown sites (Fig. 4b).

During the seven study years, MIB decreased significantly on one of the irregularly-mown sites (study site 17; r = -0,821, p < 0.05) and increased significantly on the site subject to natural regeneration (r = 0.964, p < 0.001) (Fig 5a). MIB peaked in the pine forest, followed by the site subject to natural regeneration. The regularly-mown and the irregularly-mown sites had low MIB (Fig. 5b).

The first axis of the CA explained 26.2% and the second axis explained an additional 10.3% of the total variance (Fig. 6). A clear separation of the study sites was detected along the first axis, which apparently reflects the stage of succession. Study sites of young stages of succession (sites 17, 18 and 19) were located on the left-hand side and

the pine forest was located on the right-hand side of the ordination. The site with natural regeneration of pine was located close to the sites representing young stages of succession in 2004 but shifted towards the advanced stage of succession during the years of study.

DISCUSSION

The successional stages and processes on the study sites followed the expectations: succession was inhibited on the regularly- and irregularly-mown sites. Contrary to this, the results point to a succession on the study site subject to natural regeneration of pine. Even if the numbers of species and individuals did not significantly decrease on this site, MIB and CA reflected the successional process. Skłodowski & Sławski (2003) demonstrated similar successional changes of naturally-regenerated pine forests on former agricultural land in the forest range Niedźwiady, western Poland. The pine forest, studied in the present study, showed the most advanced stage of succession. However, the time of seven years may generally be too short to
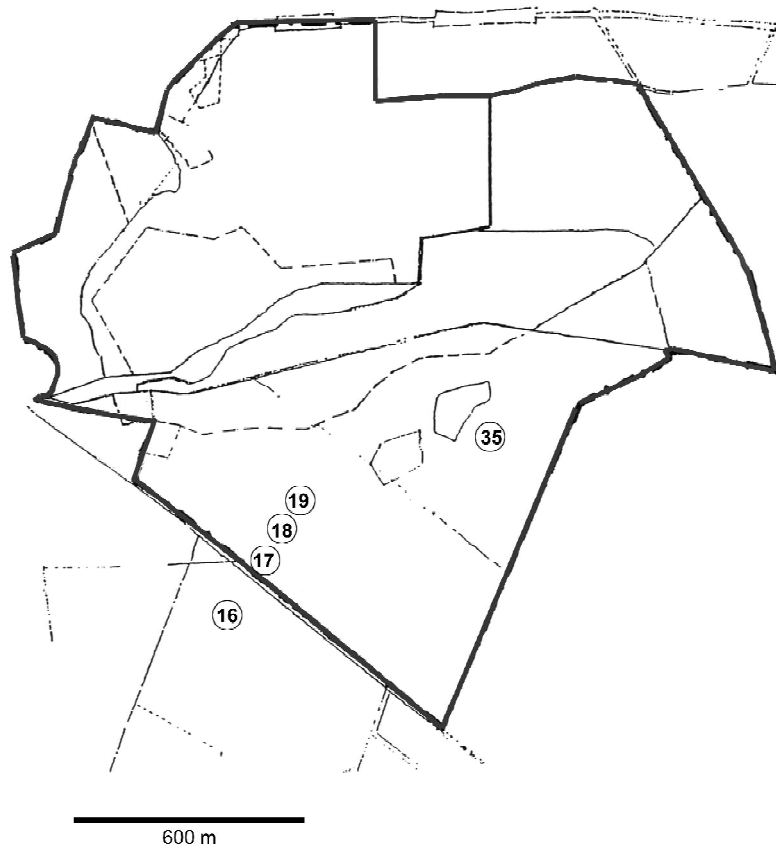

600 m

Fig 1. Location of the study sites of the research area "Krzywda". Bold line shows the perimeter of the research area "Krzywda"; study sites (after Rylke & Szyszko 2002): 16, Planted pine forest - 26 years old in 2004; 17 and 19, Irregularly mown without biomass removal; 18, Regularly mown with biomass removal; 35, Natural regenerated pine forest - about 5 years old in 2004

demonstrate remarkable successional changes. On planted pine stands on post-agricultural soil MIB may reach a 'plateau' already after about 20 years and only moderately increase afterwards (Schwerk 2008). Yet, a significant decrease in

species numbers during the seven years of study was visible on this study site.

Stage of succession seems to be a very important factor in determining the carabid coenoses
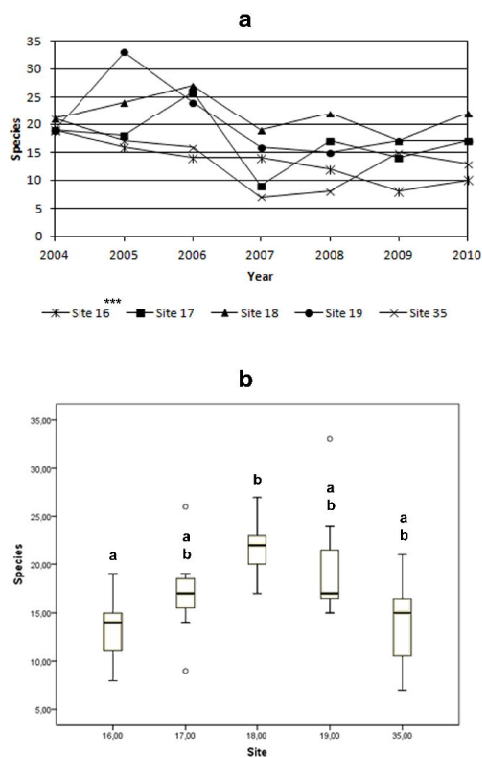

Fig 2. (a) Relationship between numbers of carabid species and age of the study sites. Spearman rank correlation coefficient: *, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$. (b) Numbers of carabid species on the study sites shown as box-whisker plots. Median values are drawn in, and the boxes show inter-quartile distances. Whiskers indicate range of data without outliers (distance from the edge of the box between 1.5 and 3 times of box length, shown as circles), and extreme values (distance from the edge of the box more than 3 times of the box length, shown as squares). Kruskal-Wallis test, $p < 0.01$; lower-case letters indicate statistically significant differences (Mann-Whitney U tests with Bonferroni correction)
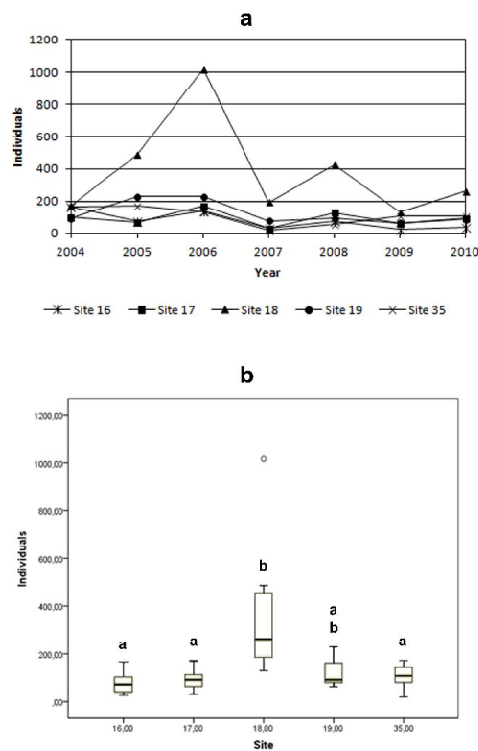

Fig 3. (a) Relationship between numbers of carabid individuals and age of the study sites. Spearman rank correlation coefficient: *, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$. (b) Numbers of carabid individuals on the study sites shown as box-whisker plots. Median values are drawn in, and the boxes show inter-quartile distances. Whiskers indicate range of data without outliers (distance from the edge of the box between 1.5 and 3 times of box length, shown as rhombs), and extreme values (distance from the edge of the box more than 3 times of the box length, shown as squares). Kruskal-Wallis test, $p < 0.01$; lower-case letters indicate statistically significant differences (Mann-Whitney U tests with Bonferroni correction).
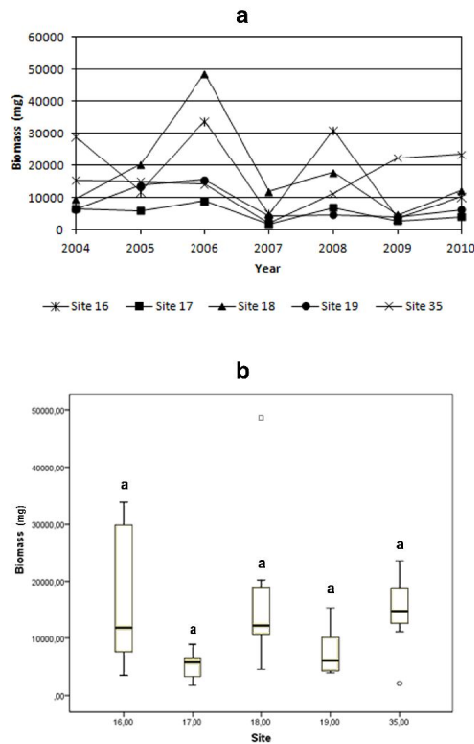
Fig 4. (a) Relationship between carabid biomass (mg) and age of the study sites. Spearman rank correlation coefficient: *, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$. (b) Carabid biomass (mg) on the study sites shown as box-whisker plots. Median values are drawn in, and the boxes show inter-quartile distances. Whiskers indicate range of data without outliers (distance from the edge of the box between 1.5 and 3 times of box length, shown as rhombs), and extreme values (distance from the edge of the box more than 3 times of the box length, shown as squares). Kruskal-Wallis test, $p < 0.05$; lower-case letters indicate statistically significant differences (Mann-Whitney U tests with Bonferroni correction)
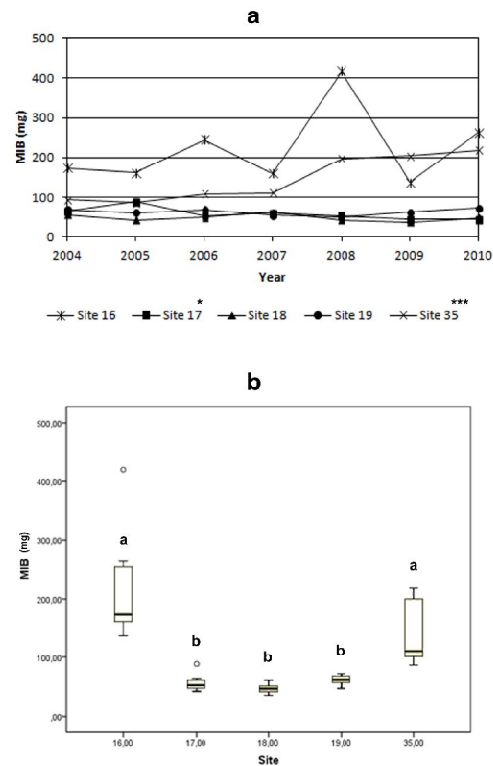
Fig 5. (a) Relationship between MIB values (mg) and age of the study sites. Spearman rank correlation coefficient: *, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$. (b) MIB values (mg) on the study sites shown as box-whisker plots. Median values are drawn in, and the boxes show inter-quartile distances. Whiskers indicate range of data without outliers (distance from the edge of the box between 1.5 and 3 times of box length, shown as rhombs), and extreme values (distance from the edge of the box more than 3 times of the box length, shown as squares). Kruskal-Wallis test, $p < 0.001$; lower-case letters indicate statistically significant differences (Mann-Whitney U tests with Bonferroni correction)

on the studied sites. Individual carabid species may react sensitively even to subtle differences in habitat characteristics (Schwerk & Szyszko 2009). Similarly, comparisons of agricultural fields subject to organic farming with those subject to conventional farming demonstrated sensitive re-

actions of several carabid species to these farming practices, and some of these species might even qualify as indicators for organical farming (e.g. Kromp 1990, Döring & Kromp 2003, Falba & Janus 2009). Soil-preparation techniques may have an influence on the formation of the carabid
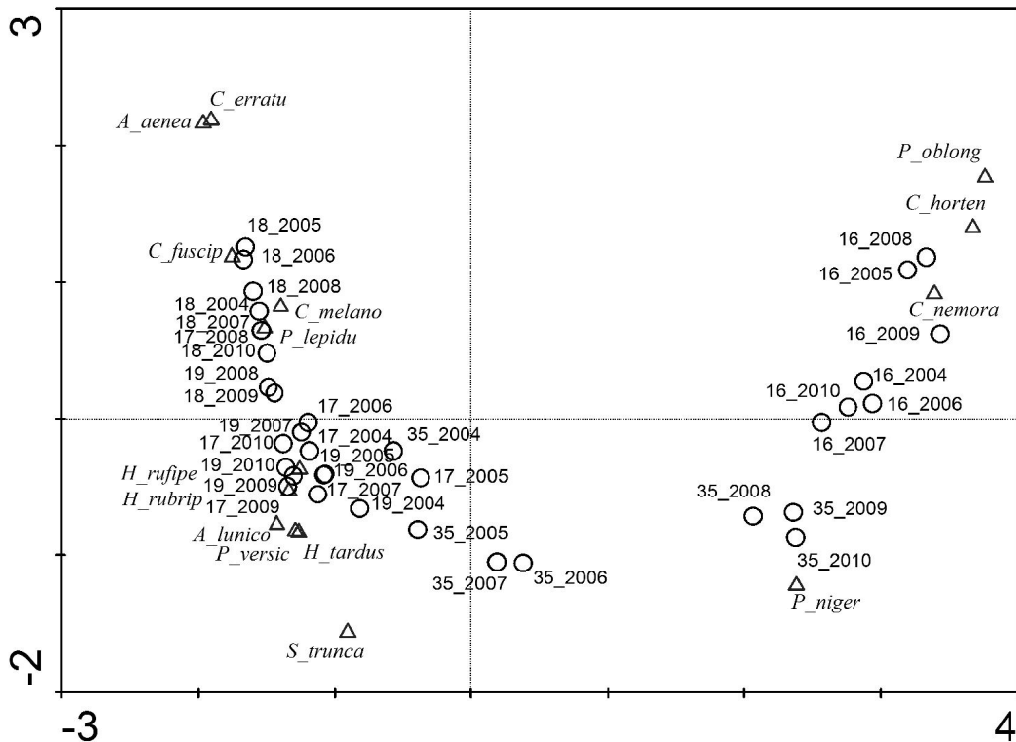
Fig 6. Ordination plot based on correspondence analysis (CA) of carabid species (triangles) and study sites (circles). Numbers of study sites as in Fig. 1 with the year of study attached. Abbreviations of the species: A_aenea, *Amara aenea*; A_lunico, *Amara lunicollis*; C_erratu, *Calathus erratus*; C_fuscip, *Calathus fuscipes*; C_melano, *Calathus melanocephalus*; C_horten, *Carabus hortensis*; C_nemora, *Carabus nemoralis*; H_rubrip, *Harpalus rubripes*; H_rufipe, *Harpalus rufipes*; H_tardus, *Harpalus tardus*; P_lepidu, *Poecilus lepidus*; P_versic, *Poecilus versicolor*, P_niger, P*terostichus niger*; P_oblong, *Pterostichus oblongopunctatus*; S_trunca, *Syntomus truncatellus*.

conenoses, too (Skłodowski 2005). Such results can be applied in improving management strategies of agricultural and post-agricultural areas, e.g. through the use of grazing as a measure for biotope conservation and species protection. Because each herbivore mammal has its specific grazing strategy (Kampf 2000), and also the animal density may be important (e.g. Röser 1990, Hill et al. 2004), different grazing regimes may lead to different successional pathways (Bokdam et al. 2002). They may also influence the composition of weed assemblages, which has an impact on carabid distribution on the micro-habitat scale (Saska 2008).

To conclude, management strategies have to take into account the overall structure of the landscape in question. For example, hedgerows and field boundaries influence the species distribution in agricultural landscapes (Holland et al. 2001, Holland et al. 2003). Therefore, successional changes in such landscape elements may have an impact on the species distribution at the site and landscape levels. A well-thought-out management of post-agricultural areas at the landscape level is an important instrument to protect native biological diversity (cf. Hartley et al. 2007).

REFERENCES

Bokdam J., van Braeckel A., Werpachowski C., Znaniecka M. (eds.) 2002. Grazing as a conservation management tool in peatland. Report of a Workshop held 22-26 April 2002 in Goniadz (PL). Nature Conservation and Plant Ecology Group, Department of Environmental Sciences, Wageningen University, Wageningen. pp. 104.

Cárdenas A.M., Hidalgo J.M. 2007. Application of the mean individual biomass (MIB) of ground beetles (Coleoptera, Carabidae) to assess the recovery process of the Guadiamar Green Corridor (southern Iberian Peninsula). Biodiversity and Conservation 16: 4131-4146.

Döring T.F., Kromp B. 2003. Which carabid species benefit from organic agriculture?—a review of comparative studies in winter cereals from Germany and Switzerland. Agriculture, Ecosystems and Environment 98: 153-161.

Falba T., Janus K. 2009. Cultivation of agricultural land considering biodiversity of carabid fauna (coleopteran: Carabidae) and economical aspects. In: Szyszko J., Dymitryszyn I., Gałek M. (eds.): VIIIth International Workshop on Landscape Architecture and Regional Planning "Bees in the Landscape" and International Conference "Landscape conservation and bees or why the bees disappear from rural areas". WULS-SGGW Press, Warsaw. pp. 133-137.

Hartley D.J., Koivula M.J., Spence J.R., Pelletier R., Ball G.E. 2007. Effects of urbanization on ground beetle assemblages (Coleoptera, Carabidae) of grassland habitats in western Canada. Ecography 30: 673-684.

Hill B.T., Beinlich B., Köstermeyer H. Dieterich M., Neugebauer K. 2004. The pig grazing project: prospects of a novel management tool. In: Dieterich M., Van der Straaten J. (eds.): Cultural landscapes and land use. Kluwer Academiv Publishers, The Netherlands. pp. 193-208.

Holland J.M., Begbie M., Birkett T., Reynolds C.J.M., Thomas C.F.G. 2001. The influence of hedgerows on coleopteran distributions: results from a multi-field sampling study. Hedgerows of the world, Proceedings of IALE(UK): 177-186.

Holland J., Birkett T., Begbie M., Southway S., Thomas C.F.G. 2003. The spatial dynamics of predatory arthropods and the importance of crop and adjacent margin habitats. Landscape Management for Functional Biodiversity, IOBC wprs Bulletin 26: 65-70.

Holland J.M., Luff M.L. 2000. The effects of agricultural practices on Carabidae in temperate agroecosystems. Integrated Pest Management Reviews 5: 109-129.

Holm S. 1979. A simple sequentially rejective multiple test procedure. Scandinavian Journal of Statistics 6: 65-70.

Jedicke E. 1989. Brachland als Lebensraum. Maier, Ravensburg, 127 p.

Kampf H. 2000. Großflächige Beweidung in den Niederlanden. ABUinfo 24(2/00): 1-19.

Koivula M.J. 2011. Useful model organisms, indicators, or both? Ground beetles (Coleoptera, Carabidae) reflecting environmental conditions. In: Kotze D.J., Assmann T., Noordijk J., Turin H., Vermeulen R. (eds.): Carabid beetles as bioindicators: biogeographical, ecological and environmental studies. ZooKeys 100. pp. 287-317.

Kotze D.J., Brandmayr P., Casale A., Dauffey-Richard E., Dekoninck W., Koivula M., Lövei G., Mossakowski D., Noordijk J., Paarmann W., Pizzolotto R., Saska P., Schwerk A., Serrano J., Szyszko J., Taboada A., Turin H., Venn S., Vermeulen R., Zetto-Brandmayr T. 2011. Forty years of carabid beetle research in Europe – from taxonomy, biology, ecology and population studies to bioindication, habitat assessment and conservation. In: Kotze D.J., Assmann T., Noordijk J., Turin H., Vermeulen R. (eds.): Carabid beetles as bioindicators: biogeographical, ecological and environmental studies. ZooKeys 100. pp. 55-148.

Kromp B. 1990. Carabid beetles (Coleoptera, Carabidae) as bioindicators in biological and conventional farming in Austrian potato fields. Biol Fertil Soils 9: 182-187.

Luff M.L. 2002. Carabid assemblage organization and species composition. In: Holland J.M. (ed.): The agroecology of carabid beetles. Intercept Limited, Hampshire, pp. 41-79.

Matson P.A., Parton W.J., Power A.G., Swift M.J. 1997. Agricultural intensification and ecosystem properties. Science 277: 504-509.

Rainio J., Niemelä J. 2003. Ground beetles (Coleoptera: Carabidae) as bioindicators. Biodiversity and Conservation 12: 487-506.

Röser B. 1990. Grundlagen des Biotop- und Artenschutzes – Arten- und Biotopgefährdung, Gefährdungsursachen, Schutzstrategien, Rechtsinstrumente. ecomed, Landsberg/Lech, 176 p.

Rylke J., Szyszko J. (eds.), 2002. Didactics trails for field classes on evaluation and assessment of natural resources. Warsaw Agricultural University Press, Warsaw, 167 p.

Sachs L. 1984. Angewandte Statistik: Anwendung statistischer Methoden, 6th ed. Springer, Berlin, Heidelberg, New York, Tokyo, 552 p.

Saska P. 2008. Composition of weed community determines carabid assemblage. In: Penev L., Erwin T., Assmann T. (eds.): Back to the roots and back to the future. Towards a new synthesis between taxonomic, ecological and biogeographical approaches in Carabidology. Pensoft Publishers, Sofia, Moscow. pp. 339-351.

Schwerk A. 2008. Model of the rate of succession of epigeic carabid beetles (Coleoptera: Carabidae) on degraded areas. Instytut Badawczy Leśnictwa, Sękocin Stary, 71 p.

Schwerk A., Sałek P., Duszczyk M., Abs M., Szyszko J. 2006. Variability of Carabidae in time and space in open areas. Entomologica Fennica 17: 258-268.

Schwerk A., Szyszko J. 2009. Distribution and spatial preferences of carabid species (Coleoptera: Carabidae) in a forest-field landscape in Poland. Baltic J. Coleopterol. 9: 5-15.

Šerić Jelaska L., Dumbović V., Kučinić M., 2011. Carabid beetle diversity and mean individual biomass in beech forests of various ages. In: Kotze D.J., Assmann T., Noordijk J., Turin H., Vermeulen R. (eds.): Carabid beetles as bioindicators: biogeographical, ecological and environmental studies. ZooKeys 100. pp. 393-405.

Serrano J., Gallego D. 2004. Evaluación de la regeneración y el estado de salud de las masas forestales de Sierra Espuńa (Murcia) mediante el análisis de la biomasa media in-

dividual en coleópteros carábidos. Anales de Biología 26: 191-211.

Sieren E., Fisher F.P. 2002. Evaluation of measures for enlargement, renaturation and development of a dry grassland biotope by analysing differences in the carabid fauna (Coleoptera). Acta Oecologia 23: 1-12.

Skłodowski J. 2005: Zooindykacyjna ocena różnych sposobów przygotowania gleby przy zalesieniach gruntów porolnych. Sylwan 149: 3-12.

Skłodowski J., Sławski M. 2003: Sukcesja biegaczowatych w procesie spontanicznej restytucji lasu na gruntach porolnych. Sylwan 147: 47-57.

Szyszko J., 1983. Methods of macrofauna investigations. In: Szujecki A., Szyszko J., Mazur S., Perliński S. (eds.): The process of forest soil macrofauna formation after afforestation of farmland. Warsaw Agricultural University Press, Warsaw. pp. 10-16.

Szyszko J., 1990. Planning of prophylaxis in threatened pine forest biocoenoses based on an analysis of the fauna of epigeic Carabidae. Warsaw Agricultural University Press, Warsaw, 96 p.

Szyszko J., Vermeulen H.J.W., den Boer P.J. 1996. Survival and reproduction in relation to habitat quality and food availability for Pterostichus oblongopunctatus F. (Carabidae, Col.). Acta Jutlandica 71: 25-40.

Szyszko J., Vermeulen H.J.W., Klimaszewski K., Abs M., Schwerk A. 2000. Mean individual biomass (MIB) of ground beetles (Carabidae) as an indicator of the state of the environment. In: Brandmayr P., Lövei G., Zetto Brandmayr T., Casale A., Vigna Taglianti A. (eds.) Natural history and applied ecology of carabid beetles. Pensoft Publishers, Sofia-Moscow. pp. 289-294.

ter Braak C.J.F. 1987. CANOCO – A FORTRAN program for canonical community ordination by [partial][detrended][canonical] correspondence analysis, principal components analysis and redundancy analysis (version 2.1). DLO-Agricultural Mathematics Group, Wageningen, 95 p.

ter Braak C.J.F., Prentice I.C. 1988. A theory of gradient analysis. Advances in ecological research 18: 271-317.

ter Braak C.J.F., Šmilauer P. 2002. CANOCO reference manual and CanoDraw for Windows User's guide: Software for Canonical Community Ordination (version 4.5). Microcomputer Power, Ithaca, 499 p.