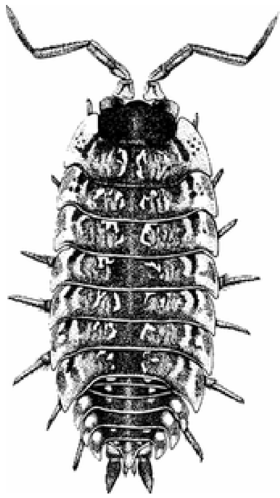
PALACKÝ UNIVERSITY OF OLOMOUC
Faculty of Science
Department of Ecology and Environmental Sciences

CHILOPODA, DIPLOPODA, AND ONISCIDEA IN THE CITY

by

Pavel RIEDEL



A Thesis submitted to the

Department of Ecology and Environmental Sciences,

Faculty of Science, Palacky University,

for the degree of Master of Science

Supervisor: Ivan H. Tuf, Ph. D.

Olomouc 2008

Drawing on the title page is *Porcellio spinicornis* (original in Oliver, P.G., Meechan, C.J. (1993): Woodlice. Synopses of the British Fauna No. 49. London, The Linnean Society of London and The Estuarine and Coastal Sciences Association.)

Thesis Committee

....

....

....

....

....

....

....

....

....

Riedel, P.: Stonožky, mnohonožky a suchozemští stejnonožci ve městě. Diplomová práce. Katedra ekologie a životního prostředí PřF UP v Olomouci, 53 stran, anglicky

Abstrakt

Předkládaná diplomová práce se skládá ze dvou samostatných manuskriptů, prezentujících část širšího výzkumu prováděného ve městech Olomouci, Jičíně a Hodoníně.

První manuskript se zabývá výskytem suchozemských stejnonožců a mnohonožek ve městě Olomouci. Studovaní živočichové byli získáváni od dubna do prosince 2006 pomocí zemních pastí rozmístěných na 30 lokalitách. Na každé lokalitě byly vyhodnoceny základní environmentální charakteristiky. Tepelná extrakce půdních vzorků a individuální sběr byly použity jako doplňkové metody. Celkem bylo zaznamenáno 17 druhů suchozemských stejnonožců (7 719 jedinců) a 19 druhů mnohonožek (3 488 jedinců). Nejdůležitějším faktorem pro obě skupiny byla umělost, jejíž vliv byl většinou negativní. Nejzajímavějšími faunistickými výsledky byly nález stejnonožce *Armadillidium nasatum* (mediteránní druh nalezený ve skleníku Botanické zahrady), *Androniscus roseus, Haplophtalmus danicus* (druhá známá lokalita na Moravě) a mnohonožka *Oxidus gracilis* (exotický druh pocházející pravděpodobně z Japonska, v Olomouci i mimo skleníky).

Druhý příspěvek je věnován fauně stonožek a mnohonožek Jičína a Hodonína. Živočichové byli získáváni metodou zemních pastí, tepelnou extrakcí z půdních vzorků a individuálním sběrem po dobu 12 měsíců (2006-07). Hodnocenými environmentálními faktory byly množství opadu, bylinný pokryv, stromový zápoj, půdní struktura, umělost, pH a množství humusu a vápníku v půdě. Celkem jsme získali 1 056 stonožek (20 druhů) a 1 890 mnohonožek (24 druhů). Mnohorozměrné techniky, provedené na datovém souboru z odchytů zemních pastí, potvrdily jako nejdůležitější faktory obsah humusu v půdě a množství opadu. Nejzajímavějšími faunistickými výsledky byl první nález stonožky *Henia vesuviana* v České republice a nové lokality druhů *Schendyla montana*, *Geophilus pygmaeus, Geophilus oligopus, Allajulus nitidus* a jedinců jeskynního rodu *Brachychaeteuma*.

Klíčová slova: Hodonín, Jičín, městský ekosystém, Olomouc, půdní makrofauna, zemní pasti

Riedel, P.: Chilopoda, Diplopoda, and Oniscidea in the city. Master Thesis, Department of Ecology and Environmental Sciences, Faculty of Science, Palacky University of Olomouc, 53 pp., in English

Abstract

The submitted thesis is composed of two individual manuscripts. They present a part of a wider research project, conducted in cities of Olomouc, Jičín and Hodonín.

The first manuscript deals with distribution of terrestrial isopods and millipedes in the city of Olomouc. Studied animals were obtained by pitfall trapping from April to December 2006 in 30 localities. In each locality basic environmental characteristics were evaluated. Heat extraction of soil samples and individual hand collection were used as additional methods. A total of 17 species of terrestrial isopods (7,719 ind.) and 19 species of millipedes (3,488 ind.) were recorded. The most important factor for both groups appears to be artificiality; the response is mostly negative. The most interesting faunistical records from Olomouc were isopods *Armadillidium nasatum* (Mediterranean species found in the greenhouses of the Botanical Garden), *Androniscus roseus, Haplophtalmus danicus* (only the second known locality from Moravia) and the millipede species *Oxidus gracilis* (exotic species probably originating from Japan, in Olomouc recorded also outside the greenhouse).

The second manuscript is devoted to centipede and millipede faunas of Jičín and Hodonín. Animals were collected using pitfall traps, heat extraction of soil samples and individual hand collecting during 12 months (2006-07). The evaluated environmental characteristics were amount of litter, herbal coverage, canopy coverage, soil structure, artificiality, pH, amount of humus and amount of calcium. In total 1,056 individuals of centipedes (20 species) and 1,890 individuals of millipedes (24 species) were caught. Multivariate techniques that were made on data set from pitfall traps revealed that amount of humus and leaf litter were the most important factors for distribution of myriapods. The most interesting faunistic results were the first record of centipede *Henia vesuviana* in the Czech Republic and new localities of species *Schendyla montana*, *Geophilus pygmaeus, Geophilus oligopus, Allajulus nitidus* and individuals of the cave genus *Brachychaeteuma*.

Key words: Hodonín, Jičín, Olomouc, pitfall traps, soil macrofauna, urban ecosytem

Declaration

I, Pavel Riedel, hereby proclaim that I made this study on my own, under the supervision of Dr. Ivan H. Tuf and using only cited literature.

Lázně Bělohrad, May 16, 2008

Contents

List of tables viii

List of figures ix

Acknowledgements x

1 Introduction 1

2 Terrestrial isopods (Isopoda: Oniscidea) and millipedes (Diplopoda) of the City of Olomouc (Czech Republic) 11

3 Centipedes and millipedes in urban environment 28

4 Summary 52

List of tables

Chapter 2

Tab. 1: Presence of terrestrial isopods in Olomouc town, their dominance of activity in groups of sites and sizes and indices of species diversity of those communities 21

Tab. 2: Significance of environmental variables for terrestrial isopod distribution 22

Tab. 3: Presence of millipedes in Olomouc town, their dominance of activity in groups of sites and sizes and indices of species diversity of those communities 23

Tab. 4: Significance of environmental variables for millipede distribution 24

Chapter 3

Tab. 1: List of centipede and millipede species in Jičín... 45

Tab. 2: List of centipede and millipede species recorded in Hodonín... 46

Tab. 3: Significance of environmental variables for centipede and millipede distribution 47

List of figures

Chapter 2

Fig. 1: Distribution of studied localities in city of Olomouc 25

Fig. 2: CCA plot of distribution of terrestrial isopods in relation to environmental variables 26

Fig. 3: CCA plot of distribution of millipedes in relation to environmental variables 27

Chapter 3

Fig. 1: CCA plot of distribution of centipedes and millipedes in relation to environmental variables 48

Fig. 2: Generalized additive model (GAM) for millipede species and the variable amount of humus 49

Fig. 3: Generalized additive model (GAM) for millipede species and the variable amount of litter 50

Fig. 4: Dendrogram of localities classified according to catches of centipede and millipede species trapped using pitfall traps. 51

Acknowledgements

I would like to thank my thesis supervisor Ivan H. Tuf for his encouragement and help throughout this study. Furthermore, I would like to thank Jana Tufová for identification of collected millipedes, Petr Hekera for his kind help with chemical analysis, Josef Hotový for lending a binocular loupe and Marek Navrátil for cooperation in field work and providing his data. I also thank John O'Donovan and Julia O'Donovan for helping with checking the English of the manuscripts. I would like to express my gratitude to Radim Kalfus, my mother and my sister for their help with the field work. Furthermore, I thank to my whole family for their support.

1 Introduction

The submitted thesis is composed of two individual manuscripts. The first manuscript deals with distribution of terrestrial isopods and millipedes in the city. The second manuscript is devoted to millipede and centipede faunas of two towns: Jičín and Hodonín. The aim of both studies was to contribute to the knowledge about how these animals respond to urbanisation and what conditions they prefer in urban area, and no least to investigate the species spectrum of three mentioned cities.

Centipedes (Chilopoda), millipedes (Diplopoda) and terrestrial isopods (Isopoda: Oniscidea) are small invertebrate groups. Altogether, 65 species of millipedes, 80 species of millipedes and 42 species of isopods are known from the Czech Republic (Tuf and Tufová in press). Centipedes and millipedes belong to the class Myriapoda. Centipedes are carnivores while millipedes feed on plant material and fragments of decaying vegetation. Terrestrial isopods are macrophytophagous (primary decomposers), consuming freshly fallen leaves. Moreover, as saprophytophages, they can feed on overwintered leaves already been degraded by microorganisms (Eisenbeis et Wichard 1987). Representatives all three groups are found in similar conditions, mostly in habitats with low insulation, higher humidity and stable temperatures, e.g. under stones, bark, fallen branches, in leaf litter or directly in soil (Lee, 2006, Oliver and Meechan, 1993).

Urban ecosystem

City is generally recognized as area profoundly and constantly affected by local human activity (McIntyre et al. 2001). Urban ecosystems are created by the process termed urbanization. This process entails conversion of indigenous natural habitat to various forms of anthropogenic habitats, fragmentation and isolation areas of indigenous habitat and increase in local human population density. The area dynamically changes and becomes a spatially heterogeneous mosaic of residential, industrial and commercial zones, along with more or less unaffected localities (Parlange 1998, McIntyre et al. 2001).

The areas under human activity differ from previous conditions in many respects. Urban ecosystems are affected by atmospheric and aquatic pollution, excess of light and noise (McIntyre et al. 2001). Further features of space under human activities are greater presence of impervious surfaces caused by soil compaction and paving, absence of a litter layer in the majority of areas and frequent mowing of the vegetation (Schaefer 1989).

The typical factor of all the towns and cities is the wide variety of environmental conditions. Mosaic of habitats includes open sites with high relative irradiance as well as very dark habitats such as collectors, sewerage, underground piping and tunnels are the contrary extreme. Man-made underground spaces are termed „artificial caves“. Sites vary also in water conditions. Habitats differ significantly from dry to wet, although dry sites are included more often in urban ecosystem (Rebele 1994). With respect to degree of human activities (past or recent), urban area consists of various habitats from heavily man-influenced to more or less unaffected. The most impacted ecosystems are connected with industrial zones, rail and road system (embankments) and partially with residential zones. The human activity in such areas changes available resources, substrate availability or the physical environment (Moss and Hassall 2004).

Urban soils may be basically divided in two types: relict soils and manmade soils (Kühnelt 1989). Soils can be very poor in nutrients, or highly enriched. Some substrates have been also introduced and are alien to original states. The introduced substrates can be both natural substrates from other regions, or artificial, or a mixture of artificial and natural substrates (Rebele 1994). Original soil profiles can be substantially altered due to excavation, mixing and compaction. Recently created urban soils often have restricted aeration and water infiltration and support limited plant growth (Smetak et al. 2007). A lot of places are also affected by toxicity, due to deposits of toxic substances or as a result of atmospheric and water solution (Rebele 1994).

Areas in towns and cities that support vegetation and have better permeable surfaces are generally termed „green spaces“. Remnants of indigenous vegetation are regarded to be the least impacted areas of the city. However, the major component of urban green spaces occur primarily as public parks, green road-verges, gardens, allotments, sport fields, churchy yards and cemeteries (Blume 1989, Smith et al. 2006). In such areas management practices are often implemented, including mulch-mowing, irrigation, and fertilization (Blume 1989, Smetak et al. 2007). Unsurprisingly, in cities an orderly city landscape is preferred and thus undecomposed leaf litter is often removed. The typical feature of urban green spaces are then well-groomed trees and trimmed hedges with bare earth beneath and park grass in between. The plants are mostly not planted or retained for ecological reasons to simulate the balance of nature but often just for optical effect (Weigman 1989).

Urbanization causes transformation of the local environment also through its impact upon climate. Urban areas are generally warmer than adjacent rural areas. The phenomenon is termed „effect of urban hot island" and is directly linked with cities (Smith et al. 2006). The reason is particularly replacing natural vegetation with a dry impervious surface such as buildings and roads and thus the high percentage of stone, concrete and asphalt surfaces. These materials have higher conductivity in comparison with vegetation or soil. Unlike vegetation cover, which cools the surrounding air by reflecting sunlight and evaporating water, artificial surfaces absorb and reradiate the sun's heat. This alters the exchange of energy and moisture between the surface and atmosphere and modifies the meteorology of the local climate (Jin et al. 2005, Hough 2004). The difference of the mean annual temperature can be 0.5 to 2°C and the result is also higher soil temperature (Blume 1989). The warming is also supported by energy consumption connected with almost all human activities and by high content of dust particles and other pollution substances in the atmosphere. Moreover, high aerodynamic roughness of urban surfaces decreases airing (Hough 2004).

City as an environment for organisms

As said above, fragmentation is a characteristic feature of urbanization. The division of continuous habitat into smaller isolated areas results in a loss of species through a reduction in remnant area, an increase in remnant isolation and decrease in habitat connectivity. The equilibrium theory of island biogeography was formerly used to explain this phenomenon. It predicts that the species diversity will be greater on the mainland than on the islands. However, it seems to be not enough satisfactory (Gibb and Hochuli 2002). The remnant habitats are different from oceanic islands as they are surrounded by an anthropogenic habitat which mostly does not create as fundamental barrier as water. The urban matrix comprises besides green spaces and various inhospitable anthropogenic areas also corridors that enable communication between patches. Such corridors can be formed by grassy road edge or other seemingly non-valuable sites (Smith 2006b). When the human-modified matrix is impermeable to dispersal it may result in relaxation, or even faunal collapse in the case of zero recolonization. (Bolger et al. 2000). According to the theory of island biogeography, islands should have a natural turnover of species. The main processes that adjust the equilibrium and determine number of species on oceanic islands are immigration and extinction. However, in urban islands the processes underlying the turnover of species are not determined solely by the ability of species to disperse and by interactions between them. The main factors are introduction, dispersal and local extermination by human activity. There is not a balance of species richness in cities. The number of species can either increase or decrease (Rebele 1994). A further difference from the oceanic islands is that there is generally no evident mainland to serve as a species source for the fragments (Yamaguchi 2005).

The proportion of successfully established introduced species is in cities generally higher than in natural habitats. Various human activities enable to eliminate biographical barriers and the result is that species migrate widely even between continents and islands. Anthrpochorous dispersal causes meeting of species that could otherwise never encounter. Thus it is common in cities to find communities consisting of species without a common evolution that have not previously been found elsewhere in such combination. Not only geographical barriers but also ecological barriers can be overcome this way. In such case species that had been separated by ecological demands meet on the new site created by human. Besides introduced species, also native species can be very abundant and successful colonizers. A typical feature of such species is their ability to regenerate themselves after disturbances or to settle new gaps. For example species from naturally disturbed areas, e.g. river banks, settle open habitats. Open sites are very common in cities due to the creation of new habitats and the disturbances (Rebele 1994). The first colonizers are often generalist species that extend their ranges disproportionately. The species richness within fragments then often increase, however, in regional level it can decrease (Gibb and Hochuli 2002).

Research on urban soil fauna

Until recently, urban areas were perceived to be just replacements of natural habitats and were overlooked (McIntyre et al. 2001). First studies conducted in urban settings were focused on presence animals in houses (Backer 1920, Back 1942), that generally disrupt the contentment of any home, and on outbreaks of pests and their invasion into houses (Stojalowska 1949). Recently it has become apparent that urban areas should be considered as individual ecosystems with feedback loops among both natural and anthropogenic forms of the physical and biological setting. The assessment of effects of urbanization on biotic communities is now starting to be an objective of many studies (McIntyre et al. 2001). Knowledge about interaction between communities and urban environment can help in planning future urban development that will minimize the negative effects.

Arthropods comprise the most diverse taxa in most ecosystems and play mostly important roles in ecosystem processes (Bolger et al. 2000). Although they are ubiquitous, surprisingly little is known about how they respond to urbanization (McIntyre 2001). However, urbanization has been unequivocally identified as one of the leading causes of declines in arthropod diversity and abundance (Davis 1978). Arthropods are assumed to have following pre-adaptations to life in the cities: euryecy and minor body size (as pre-adaptation to various stress factors), high vagility, high dispersal capacity and preference of vegetation layer. It also seems to be probable that periods of reproduction, parameters of life cycle and population may be correlated with urban factors. Thermophilism seems to be advantageous feature too because thermophilous species are mostly favoured by urban environments (Schaefer 1989). Many species occur even more often in anthropogenic ecotopes than in natural ecotopes. They can be characterized as cultural followers or synantropic species (Weigman 1989).

There are many studies only from last decades that deal with arthropod communities, mostly from European and North American cities. Although distribution and ecology of some groups is relatively well known (e.g. Carabidae, Araneida), others have been almost completely neglected (Schaefer 1989, Keplin 1995). Species-lists on the centipede and millipede fauna were published for Copenhagen (Enghoff 1973), Sofia (Stoev 2004) and Vienna (Christian and Szeptycki 2004). Studies focused on the centipede fauna concerns Gothenburg (Anderson 1983), Warsaw (Wytwer 1995, 1996), Poznan (Lesniewska 1996), Rome (Zapparoli 1997), and Eskişehir (Misirlioğlu 2003). Isopod communities were studied e.g. in Sorø (Vilisics et al. 2007) and Debrecen (Hornung 2007). The studies from Budapest (Korsós et al. 2002), Košice (Palkovičová and Mock 2008) and

Bucharest (Giurginca 2006) deal with both millipede and isopod fauna. All three groups were examined in Kiel (Tischler 1980) and Vienna (Christian 1998).

The first records for three mentioned groups from urban setting in the Czech Republic were published already around the turn of 19th and 20th century (Uličný 1883, Vališ 1902, 1904). However, the majority of studies arose recently (Samšiňák 1981, Frouz 1991, Tajovský 1996, Tuf 2001, Dvořák 2002, Kocourek 2001, 2004, Riedel et al. in press).

References

Andersson, G. (1983): The Chilopoda fauna in the vicinity of Göteborg – a comparison between collecting results obtained in the 1920s and the 1970s years. Acta entomologica Fennica (Helsinki), 42: 9-14.

Back, E.A. (1942): Centipedes and millipedes in the house. U.S. Dept. Agence Washington, Leaflet 192 (1939): 1-6.

Baker, A.C. (1920): The house centipede in Canada. The Canadian Entomologist, 52: 93.

Blume, H.-P. (1989): Characteristics of urban soils. In: Report on MAB workshop "International scientific workshop on soils and soil zoology in urban ecosystems as a basis for management and use of green/open spaces, Berlin 1986". MAB-Mitteilungen 30: 23-46.

Bolger, D.T., Suarez, A.V., Crooks, K.R., Morrison, S.A., Case, T.J. (2000): Arthropods in urban habitat fragments in southern California: Area, age, and edge effects. Ecological Applications, 10: 1230-1248.

Christian, E. (1998): Die Fauna der Katakomben des Wiener Stephansdomes. Verhandlungen der Zoologisch-Botanischen Gesellschaft in Wien, 135: 41-60.

Christian, E., Szeptycki, A. (2004): Tausendfüßer und Bodeninsecten aus dem Botanischen Garten der Universität Wien. In: Pernstich, A., Krenn, H.W. (eds.): Die Tierwelt des Botanisches Gartens der Universität Wien. Eigenverlag Institut für Angewandte Biologie und Umweltbildung, Wien: 53-64.

Davis, B.N.K., Jones, P.E. (1978): The ground arthropods of some chalk and limestone quarries in England. Journal of Biogeography, 5: 159-171.

Dvořák, L. (2002): Někteří bezobratlí živočichové sklepů na území západních Čech a Šumavy. Erica, Plzeň, 10: 97–106.

Eisenbeis, G., Wichard, F. (1987): Atlas on the Biology of soil arthropods. Springer Verlag, Berlin, Heidelberg, New York, London, Paris, Tokyo.

Enghoff, H. (1973): Diplopoda and Chilopoda from suburban localities around Copenhagen. Videnskabelige Meddelelser fra Dansk Naturhistorisk Forening i København, 136: 43-48

Frouz, J. (1991): Bezobratlí táborských podzemních chodeb. Sborník Jihočeského muzea v Českých Budějovicích, 31: 47-50.

Gibb, H., Hochuli, D.F. (2002): Habitat fragmentation in an urban environment: large and small fragments support different arthropod assemblages. Biological Conservation, 106: 91–100.

Giurginca, A. (2006): On some Oniscidea and Diplopoda from Bucharest, Romania. Archive of Biological Sciences, Belgrade, 58: 31-35.

Hornung, E., Tóthmérész, B., Magura, T., Vilisics, F. (2007): Changes of isopod assemblages along an urban-suburban-rural gradient in Hungary. European Journal of Soil Biology, 43: 158-165.

Hough, M. (2004): Cities and Natural Process, A Basis for Sustainability. London, Second edition. New York: Routledge

Jin, M., R.E. Dickinson, Zhang, D., (2005). The footprint of urban areas on global climate as characterized by MODIS. Journal of Climate, 18: 1551-1565.

Keplin, B. (1995): Effects of extensive management practices on soil fauna of urban lawns. Acta Zoologica Fennica, 196: 239-242.

Kocourek, P. (2001): Pozoruhodné společenstvo mnohonožek Botanické zahrady UK. Živa, 49: 125-126.

Kocourek, P. (2004): Mnohonožky – skrytá fauna v Zoo Praha. Živa, 52: 169-171

Korsós, Z., Hornung, E., Szlávecz, K., Kontschán, J. (2002): Isopoda and Diplopoda of urban habitats: new data to the fauna of Budapest. Annales Historico–Naturales Musei Nationalis Hungarici., 94: 193-208.

Kühnelt, W. (1989): Characteristics and development of urban soil fauna. In: Report on MAB workshop "International scientific workshop on soils and soil zoology in urban ecosystems as a basis for management and use of green/open spaces, Berlin 1986". MAB-Mitteilungen 30: 57-70.

Lesniewska, M. (1996): Centipedes of Poznan Town (Poland). In: Geoffroy, J.-J., Mauriés, J.-P., Nguyen-Duy Jacquemin, M. (eds.): Acta Myriapodologica Mémoires du Muséum National ďHistoire Naturelle,, 169: 221-224.

McIntyre, N.E., Rango, J., Fagan, W.F., Faeth, S.H. (2001): Ground arthropod community structure in a heterogeneous urban environment. Landscape and Urban Planning, 52: 257-274.

Misirlioğlu, M. (2003): Some Chilopoda (Myriapoda) records from the city of Eskişehir. Turkish Journal of Zoology., 27: 39-41.

Moss, A., Hassall, M. (2006): Effects of disturbance on the biodiversity and abundance of isopods in temperate grasslands. European Journal of Soil Biology, 42: 254-268.

Palkovičová, S., Mock, A. (2008): Epigeická makrofauna (Oniscidea, Diplopoda) Botanickej záhrady Univerzity P. J. Šafárika v Košiciach. [Epigeic macrofauna (Oniscidea, Diplopoda) of Botanical Garden of P. J. Šafárik University in Košice]. Študentská vedecká konferencia, Univerzita Komenského v Bratislavě, Bratislava, Zborník príspevkov, 1. zväzok – biologická sekcia, 242 – 244.

Parlange, M. (1998): The city as ecosystem. Bioscience 48: 581–585.

Rebele, F. (1994): Urban ecology and special features of urban ecosystems. Global Ecology and Biogeography Letters, 4: 173-187.

Riedel, P., Navrátil, M., Tuf, I.H., Tufová, J. (in press): Terrestrial isopods (Isopoda: Oniscidea) and millipedes (Diplopoda) of the City of Olomouc. Contributions to Soil Zoology in Central Europe.

Samšiňák, K. (1981): Some species of troublesome arthropoda in buildings. Anzeiger für Schädlingskunde, Pflanzenschutz, Umweltschutz, 54 (8): 120-122.

Schaefer, M. (1989): Soil and litter arthropods of green urban spaces. In: Report on MAB workshop "International scientific workshop on soils and soil zoology in urban ecosystems as a basis for management and use of green/open spaces, Berlin 1986". MAB-Mitteilungen 30: 85-102.

Smetak, K. M., Johnonson-Maynard, J. L., Lloyd, J. E. (2007): Earthworm population density and diversity in different-aged urban systems. Applied Soil Ecology, 37: 161-168.

Smith, J., Chapman, A., Eggleton, P. (2006a): Baseline biodiversity surveys of the soil macrofauna of London's green spaces. Urban Ecosystem, 9: 337–349.

Smith, R.M., Gaston, K.J., Warren, P.H., Thompson, K. (2006b): Urban domestic gardens (VIII): environmental correlates of invertebrate abundance. Biodiversity and Conservation, 15: 2515–2545.

Stoev, P. (2004): Myriapoda (Chilopoda, Diplopoda) in urban environments in the city of Sofia. In: Penev, L., Niemelä, J., Kotze, D.J., Chipev, N. (eds.): Ecology of the City of Sofia. Species and Communities in an Urban Environment. Pensoft Publisher, Sofia-Moscow: 299-306.

Stojalowska, W. (1949): Masowe pojawy krocionogów w okolicy Lublina. The mass appearences of Diplopoda in the Lublin area. Annales Universitatis Mariae Curie-Sklodowska, 4 (12): 269-275.

Tajovský, K. (1996): Life-cycles of the millipede *Melogona voigti* (Verhoeff, 1899) from a suburban forest in South Bohemia. In: Geoffroy, J.-J., Mauries, J.-P., Nguyen Duy - Jacquemin, M., (Eds.), Acta Myriapodologica. Mémoires du Muséum National ďHistoire Naturelle, Paris 169, 509-514.

Tischler, W. (1980): Asseln (Isopoda) und Tausenfüßer (Myriopoda) eines Stadtparks im Vergleich mit der Umgebung der Stadt: zum Problem der Urbanbiologie. Drosera, 1: 41-52.

Tuf, I.H. (2001): Lithobiidae (Chilopoda) okolí Hodonína (jižní Morava) a Václavovic (severní Morava). Myriapodologica Czecho - Slovaca, 1: 77-79.

Tuf, I.H., Tufová, J. (in press): Proposal of ecological classification of centipede, millipede and terrestrial isopod faunas for evaluation of habitat quality in Czech Republic. Časopis Slezského Zemského Muzea Opava (A), 51: XX-XX, 2008.

Uličný, J. (1883): Bericht über bei Brünn gesammelte Myriopoden. Naturforschender Verein in Brünn, 22: 17-21.

Vališ, J. (1902): Příspěvky k poznání moravské myriopodofauny. Časopis vlasteneckého spolku musejního v Olomouci, 19: 20-27.

Vališ, J. (1904): Předběžný přehled dosud z Moravy známých Myriopodů. Věstník Královské České Společnosti Nauk, tř. 2, 28: 1-12.

Vilisics, F., Elek, Z., Lövei, G., Hornung, E. (2007): Seasonal dynamics of isopod species under different urbanisation stages in Denmark. In: Tajovský, K. (ed.): 9th Central European Workshop on Soil Zoology, Abstract book. Institute of Soil Biology, Biology Centre, ASCR, v.v.i., České Budějovice: 70.

Weigman, G. (1989): Soil zoology as an instrument of urban planning. In: Report on MAB workshop "International scientific workshop on soils and soil zoology in urban ecosystems as a basis for management and use of green/open spaces, Berlin 1986". MAB-Mitteilungen 30: 125-138.

Wytwer, J. (1995): Faunistical relationships between Chilopoda of forest and urban habitats in Mazowia. Fragmenta faunistica, 38: 87-133.

Wytwer, J. (1996): Chilopoda of urban greens in Warsaw. In: Geoffroy, J.-J., Mauries, J.-P., Nguyen Duy-Jacquemin, M., (eds.): Acta Myriapodologica. Mémoires du Muséum National ďHistoire Naturelle, 169: 213-220.

Yamaguchi, T. (2005): Influence of urbanization on ant distribution in parks of Tokyo and Chiba City, Japan II. Analysis of species. Entomological Science, 8: 17-25.

Zapparoli, M. (1997): Centipedes of a wasteland urban area in Rome, Italy (Chilopoda). Entomologica Scandinavica Supplemenet, 51: 121-124.

2 Terrestrial isopods (Isopoda: Oniscidea) and millipedes (Diplopoda) of the City of Olomouc (Czech Republic)

Pavel Riedel, Marek Navrátil, Ivan H. Tuf, Jana Tufová

Department of Ecology & Environmental Science, Faculty of Science, Palacky University, Svobody 26, 77126 Olomouc, Czech Republic, ivan.tuf@upol.cz

Abstract

This is the first ecological attempt at studying terrestrial isopods (Oniscidea) and millipedes (Diplopoda) in urban environments in the city of Olomouc. Studied animals were obtained by pitfall trapping from April to December 2006 in 30 localities, subsuming city parks, built up areas, yards and ruderal grounds. Additional methods included soil sampling and hand collecting. Basic environmental characteristics of localities were evaluated: amount of litter, coverage by herbal and canopy layer, structure of soil and rate of artificiality of locality. A total of 17 species of terrestrial isopods (7,719 ind.) and 19 species of millipedes (3,488 ind.) were sampled. The most abundant species were *Armadillidium versicolor* and *Brachydesmus superus*. Mediterranean isopod species *Armadillidium nasatum* and *Androniscus roseus* and millipede *Oxidus gracilis*, these belong to interesting faunistic records. After evaluation of distribution of animals, depending on characteristics of localities, the rate of artificiality of biotope was the most important factor for both groups; the response was mostly negative.

Keywords: urban ecosystem, soil macrofauna, pitfall traps, distribution pattern

Introduction

Terrestrial isopods (Isopoda: Oniscidea) and millipedes (Diplopoda) are important primary decomposers, feeding on plant residues. They are found in similar habitats: under stones, bark, fallen branches, layers of leaf litter or directly in soil – i.e. in habitats with low insulation, higher humidity and stable temperatures (Lee, 2006, Oliver and Meechan, 1993). Microhabitat diversity potential of the city is extended with stacks of building materials, dilapidated houses, various walls, compost piles and garbage piles etc.

The town ecosystem is under constant pressure from human activities. This changes natural habitats into various artificial areas, therethrough the relics of the original habitats are fragmented and isolated. As a result, the area becomes a mosaic of residental, industrial and commercial zones, along with more or less unaffected localities. It forms spatially and time heterogeneous environment (Schaefer, 1989, McIntyre et al., 2001).

It is widely known that the proportion of introduced species is higher in urban areas than in the surrounding landscape. Non-native species come, for example, from planting exotic, non-native species of plants in city and suburban parks; unique synantropic invertebrate communities are created. It could never occur elsewhere (Rebele, 1994, Smith et al., 2006) and it is dirrectly tied to human activity. It doesn´t have an unilaterally negative effect on soil fauna; quite the contrary, in many cases it could have a positive impact as creation of suitanable biotopes for uncommon species.

We have had two aims: a) to recognize species diversity and community structure of Oniscidea and Diplopoda occupying middle-size Central European city and b) to explain pattern of their distribution in urban environment.

Material and methods

The city of Olomouc, Central Moravia (49°45´N, 17°15´E, 219 m a.s.l.) is the fifth biggest Czech city with about 103,000 inhabitants. Its climate is characterized by 8.7 °C mean temperature and 570 mm of mean year precipitation. Olomouc is a historic city, this location has been settled for the past 6,000 years. Therefore the present status and composition of its intravilan localities represents a mosaic of historicalbuilds wth old gardens, well developed parks, modern urban settlements, fabrics and brownfields.

Animals were obtained by pitfall trapping from April to December 2006. Simple pitfall traps (diameter 6 cm, with natural cover as wood pieces or stones) were filled with a 4% water solution of formaldehyde. They were emptied every fourteen days. Totally 90 pitfall traps were installed at 30 localities (Fig. 1) in the residential area, including parks, built up areas, yards, railway and road embankments etc. Localities were classified into three categories: parks (= managed sites, PARK), ruderals (= abandoned sites, RUDE) and nature (= rests of natural sites, NATU). Basic environmental characteristics of localities were evaluated; these parameters were ranked at scale from 1 to 4 according to quantity or quality of selected parameter and were observed within 1 m diameter round the trap. **Amount of litter** – 1 indicates a site without leaf litter, 4 indicates a site with litter covering in a thick layer over the entire surface around the trap; coverage by **herbal layer** and by **canopy layer** – 1 indicates a coverage from 0 to 25 %, 2 means 25 – 50 % etc.; **soil structure** – 1 indicates a clay soil, 2 indicates a loamy soil, 3 indicates a sandy soil and 4 indicates a soil with stones; **artificiality** – 1 indicates a site with a natural soil profile, 4 indicates completely artificial soil substrates (e.g. railway embankment) and 2 and 3 indicates a different level of man-made soils (displaced soils at residential areas etc.). Distribution patterns and evaluation of importance of individual environmental factors were evaluated by Canonical Correspondence Analysis in CANOCO for Windows 4.5© (Ter Braak and Šmilauer, 1998), logarithms of numbers of caught animals were used. Significance of relationships between species and environmental data was calculated using Monte-Carlo permutation test (499 repetitions).

Except of traps two additional collecting methods were used. Soil samples were taken from the 30 main localities (1/30 m^2, depth 10 cm, November 2006 and February 2007). They were heat extracted for 10 days using a Tullgren funnel. Animals were collected individually by hand also in areas where pitfall trapping was not viable.

Results

Terrestrial isopods

A total of 7,719 terrestrial isopods representing 17 different species were obtained, 5,987 individuals of 15 different species of them were captured by pitfall trapping (Tab. 1). The species missing in pitfall traps were: *Armadillidium nasatum* (Budde-Lund, 1885) hand collected in the greenhouses of Botanical Garden, and *Androniscus roseus* (C.L. Koch, 1838) collected at locality PARK22 (moist biotope) and heat extracted from soil at NATU23 (near part of Botanical Garden).

The most abundant species were *Armadillidium versicolor* (33 % of the trapped isopods), *Porcellio scaber* (21 %), and *Porcellium collicola* (17 %). The highest mean number of trapped isopods was in ruderals (324 ± 89.7 ind./3 traps/8 months), the lowest mean number was in natural sites (125 ± 27.6 ind./3 traps/8 months). More than half of individuals of *A. versicolor* were captured in just one locality (PARK26).

The highest average value of the Shannon-Weaver index was reached in natural sites (1.8) followed by parks (1.7) and ruderals (1.5). There were differences in species spectrum according to categories of habitats too. The most abundant species of parks as well as of ruderals were *A. versicolor* and *P. scaber*. In natural localities there were diverse community compositions, where the most abundant species was *P. collicola* followed by *A. versicolor*, whereas *P. scaber* represented on average only 3% of communities. Mainly endogenous species *Haplophthalmus danicus*, *Haplophthalmus mengii* and *Platyarthrus hoffmannseggii* were caught only in parks, whereas *Ligidium hypnorum* inhabited exclusively natural sites. Other species were present in all three categories of sites.

The CCA plot (Fig. 2) was used to evaluate the pattern of isopod distribution at these localities. The model was significant ($F = 12.872$, $p = 0.002$), the sum of all canonical eigenvalues was 0.488 %, all four canonical axes explain 7.6 % of variability in species variability. The most important factor for their distribution was **artificiality** (Tab. 2). *A. versicolor* and *Porcellionides pruinosus* seem to be the species that prefer the man-made localities. Most of the other species preferred sites with a higher amount of litter and dense **herbal layer.**

Millipedes

During our research, 3,488 specimens of 19 millipede species were collected, 2,005 individuals of 13 species of them were obtained by pitfall traps (Tab. 3). Five species were collected individually: *Enantiulus nanus* (Latzel, 1884) was collected at one natural site (NATU23) and *Cylindroiulus latestriatus* (Curtis, 1845) was found in greenhouse of Botanical Garden. At these two localities, *Oxidus gracilis* (C.L.Koch, 1847) was found too. *Choneiulus palmatus* (Němec, 1895) was collected at grass plot (PARK14). Millipede *Melogona broelemanni* (Verhoeff, 1897) was collected at three park sites (PARK19, PARK20 and near Faculty of Law PU Olomouc). The sixth species, *Geoglomeris subterranea* Verhoeff, 1908, was heat-extracted from soil substrate at railway embankment (RUDE10).

The most frequently trapped species were *Brachydesmus superus* (66 %) and *Cylindroiulus caeruleocinctus* (19 %). The highest mean number of millipedes were obtained in natural sites (122 ± 65.8 ind./3 traps/8 months), especially due to *B. superus*, detected in 71 % of individuals at only 3 natural localities. The lowest number was detected in ruderal sites (29 ± 10.3 ind./3 traps/8 months). At 6 localities, representing all 3 categories, no millipedes (or only one species) were obtained, so there is zero diversity. The highest values of Shannon-Weaver diversity index were reached in ruderal site RUDE28 (2.4), the low indexes were generally at natural sites. The most abundant species recorded in parks were *B. superus* followed by *C. caeruleocinctus*. These two species were the most dominant in ruderals, in reverse order. In natural sites *B. superus* was also dominant. *C. caeruleocinctus* also participated here, but much less frequently (5 %).

The CCA plot (Fig. 3) was used for evaluation of millipede pattern distribution at various localities. The model was significant ($F = 6.382$, $p = 0.002$), the sum of all canonical eigenvalues was 0.542, all four canonical axes explain 6.8 % of variability in species variability. As well as for isopods, the most important factor for millipede distribution was **artificiality** (Tab. 4), *Brachyiulus bagnalli, Kryphyoiulus occultus, Proteroiulus fuscus, C. caeruleocinctus* and both species of *Polydesmus* appeared to be the species that favour artificial localities. Most of other species preferred sites with a higher **amount of litter** and the presence of trees and shrubs (i.e. **canopy layer**).

Discussion

Evaluations of species after their relation to naturalness of habitats (Tuf and Tufová, in press) show that in both groups the major part of species spectrum was represented by adaptable species (56% and 58% respectively), whereas eurytopic species represented 44% and 37% respectively. Only one relic species, *G. subterranea*, was found in the City of Olomouc.

Terrestrial isopods

In total 17 species captured represent 40 % of Czech terrestrial isopod fauna (Flasarová, 2000). The relatively high number of species is comparable with 18 species known from the Budapest City (Korsós et al., 2002), 14 species known from Bucharest (Giurginca, 2006), or 11 species known from Kiel (Tischler, 1980). The typical mean number of species found in Central European woods is approximately 5-9 (Tajovský, 1998, Farkas et al., 1999, Tuf, 2003) only.

In the Czech Republic, for example in Prague, Teplice, Ústí nad Labem, Brno, or in the city of Olomouc, the Mediterranean species *A. nasatum* was found almost exclusively in the greenhouses of the Botanical Garden (Mišurcová, 2007). Its presence is likely related to the exotic plants. The first report about its presence in Olomouc greenhouse was done already by Frankenberger (1959). Another rare species, *A. roseus*, is an inhabitant of deeper soil layers. Only two specimens were found, although the species was recorded in the nearby forests in the Litovelské Pomoraví Protected Landscape Area (Tuf, 2003). To date, the presence of a well developed population of small soil species *H. danicus* (extracted from soil samples in high numbers at several sites in Olomouc) represents the second known locality of this species from Moravia (Tajovský, 1998).

The size of populations of isopods in parks, ruderal and natural sites differed markedly, however, the species spectrum was very similar. It appears that human activity impacts the community structure, but doesn't affect species spectrum. A similar species spectrum, from localities differing in urbanisation, was also found in Sorø, Denmark (Vilisics et al., 2007) and Debrecen, Hungary (Hornung et al., 2007). The likely reason is that most of them are synanthropic or eurytopic. The similar species composition was also detected in other European cities, for example in Budapest (Korsós et al., 2002).

Nevertheless, it appears that higher species richness is reached at less cultivated localities. The most important factor for isopods appears to be artificiality, the response is mostly negative. Both species that reacted positively, *P. pruinosus* and *A. versicolor*, are thermophile isopods from Mediterranean or Eastern Europe (Schmalfuss, 2003). They were present at several localities, but the highest densities were reached in artificial localities (railway and road embankments), with similar conditions as at a limestone hillside in the Pálava Protected Landscape Area (Tajovský, 1998).

Millipedes

In total we obtained 19 species of millipedes that comprises 24 % of Czech millipede fauna (Tuf and Tufová, in press). This is a relatively high number compared to the up today mentioned 14 species in Sofia (Stoev, 2004) or 15 species known from Kiel (Tischler, 1980), but low compared to the 23 species detected in Copenhagen (Enghoff, 1973), the 26 species known in Budapest (Korsós et al., 2002) or the 50 species found in Prague (Kocourek, 2004).

From common species, *C. caeruleocinctus* is the most interesting one. This Atlantic species is frequently collected at anthropogenic habitats in whole Europe (Kime, 1999), where it invades a human residences also (Samšiňák, 1981; Mock, 2006). This species was alone at 4 from 6 sites with zero Shannon-Weaver index of diversity. Only two specimens of *O. gracilis* were found in Olomouc, one at an outdoor locality near Rosarium and one in a greenhouse. It originally comes from Japan probably (Lewis, 2003) but it was diffused by humans throughout the world. Its distribution is connected with greenhouses and gardens with compost heaps in higher latitudes, although the northernmost outdoor occurrence is known from the Northern Norway at 69°16´N (Bergersen et al., 2006).

The abundance of millipede species in parks, ruderal and natural sites differ markedly. Most of the species were detected in parks, only some of them in natural sites. This was probably caused by higher presence of synantropic species in parks, for example *Blaniulus guttulatus* prefers cultivated land (Lee, 2006). The lowest average diversity value in natural sites was evidently influenced by high dominance of *B. superus* at these localities. This species has short lifespan and tends to be very abundant in suitable habitats (Blower, 1985).

The most important factor for millipede distribution was **artificiality**. Significant influence of human arrangements of habitats on the millipede species spectrum was also observed in Budapest (Korsós et al., 2002). *C. caeruleocinctus* and *K. occultus* were the species with the highest preferences of artificial environment. Both they are closely associated with cultivated land. In Britain and Poland it was found that they more prefer urban environments than natural sites (Lee, 2006, Stojałowska, 1961).

Acknowledgements

We are grateful to Adam Véle, M.Sc., (Palacky University) for his help with statistical evaluation of material. We also thank John O'Donovan, PE (Environmental Engineer), and Julia O'Donovan, MA, for helping with checking the English of the manuscript.

References

Bergersen, R., Olsen, K.M., Djursvoll, P., Nilssen, A.C., 2006. Centipedes (Chilopoda) and millipedes (Diplopoda) in North Norway. Norwegian Journal of Entomology, 53: 23-38

Blower, J.G., 1985. Millipedes. Synopses of the British Fauna, 35. Brill/Blackhuys, Leiden/London, 242 pp.

Enghoff, H., 1973. Diplopoda and Chilopoda from suburban localities around Copenhagen. Videnskabelige Meddelelser fra Dansk Naturhistorisk Forening i København, 136: 43-48

Farkas, S., Hornung, E., Morschhause, T., 1999. Composition of isopod assemblages in different habitat types. In: Tajovský K., Pižl, V. (eds.), Soil Zoology in Central Europe. ISB ASCR, České Budějovice, p. 37-44

Flasarová, M., 2000. Übersicht über die faunistische Erforschung der Landasseln (Isopoda, Oniscidea) in der Tschechischen Republik. Crustaceana, 73: 585-608

Frankenberger, Z., 1959. Stejnonožci suchozemští – Oniscoidea. [Terrestrial isopods – Oniscoidea.] Fauna ČSR, 14. NČSAV, Praha. 218 pp. (in Czech)

Giurginca, A., 2006. On some Oniscidea and Diplopoda from Bucharest, Romania. Arch. Biol. Sci., Belgrade, 58: 31-35

Hornung, E., Tóthmérész, B., Magura, T., Vilisics, F., 2007. Changes of isopod assemblages along an urban-suburban-rural gradient in Hungary. European Journal of Soil Biology, 43: 158-165

Kime, R.D., 1999. The continental distribution of British and Irish millipedes. Bulletin of the British Myriapod Group, 15: 33-76

Kocourek, P., 2004. Mnohonožky – skrytá fauna v Zoo Praha. [Millipedes – hidden animals in Zoological Garden of Prague.] Živa, 52: 169-171 (in Czech)

Korsós, Z., Hornung, E., Szlávecz, K., Kontschán, J., 2002. Isopoda and Diplopoda of urban habitats: new data to the fauna of Budapest. Annls hist.-nat. Mus. natn. Hung., 94: 193-208

Lee, P., 2006. Atlas of the Millipedes (Diplopoda) of Britain and Ireland. Pensoft Publisher, Sofia-Moscow. 216 pp.

Lewis, J.J., 2003. *Pseudotremia reynoldsae*, a new species of troglobitic milliped (Diplopoda: Chordeumatida: Cleidogonidae), with a synopsis of the cavernicolous millipeds of the Hoosier National Forest in Indiana. Proceedings of the Indiana Academy of Science, 112: 36-42

McIntyre, N.E., Rango, J., Fagan, W.F., Faeth, S.H., 2001. Ground arthropod community structure in a heterogenous urban environment. Landscape and Urban Planning, 52: 257-274

Mišurcová, J., 2007. Atlas rozšíření suchozemských stejnonožců (Isopoda: Oniscidea) v České republice s příspěvkem k poznání společenstev fragmentované krajiny. [Distribution atlas of terrestrial isopods (Isopoda: Oniscidea) of the Czech Republic, with contribution to knowledge of their communities at fragmented landscape.] Master thesis, Palacky University Olomouc, Faculty of Science, Department of Botany. 237 pp., 4 appendices at CD-ROM, Ms. (in Czech)

Mock, A., 2006. First record of *Cylindroiulus caeruleocinctus* (Diplopoda, Julidae) in Slovakia. Biologia, Bratislava, 61: 144

Oliver, P.G., Meechan, C.J., 1993. Woodlice. Synopses of the British Fauna No. 49. The Linnean Society of London and The Estuarine and Coastal Sciences Association, London, 136 pp.

Rebele, F., 1994. Urban ecology and special features of urban ecosystems. Global Ecology and Biogeography Letters, 4: 173-187

Samšiňák, K., 1981. Some species of troublesome arthropoda in buildings. Anzeiger für Schädlingskunde, Pflanzenschutz, Umweltschutz, 54: 120-122.

Schaefer, M., 1989. Soil and litter arthropods of green urban spaces. In: Report on MAB workshop "International scientific workshop on soils and soil zoology in urban ecosystems as a basis for management and use of green/open spaces, Berlin 1986". MAB-Mitteilungen, 30: 85-102

Schmalfuss, H., 2003. World catalog of terrestrial isopods (Isopoda: Oniscidea). Stuttgarter Beiträge zur Naturkunde, Serie A, 654: 1-341

Smith, J., Chapman, A., Eggleton, P., 2006. Baseline biodiversity surveys of the soil macrofauna of London's green spaces. Urban Ecosyst., 9: 337–349

Stoev, P., 2004. Myriapoda (Chilopoda, Diplopoda) in urban environments in the city of Sofia. In: Penev, L., Niemelä, J., Kotze, D.J., Chipev, N. (eds.), Ecology of the City of Sofia. Species and Communities in an Urban Environment. Pensoft Publisher, Sofia and Moscow, p. 299-306

Stojałowska, W. 1961. Krocionogi (Diplopoda) Polski. [Millipedes (Diplopoda) of Poland.] Państwowe Wydawnictwo Naukowe, Warszawa, 216 pp. (in Polish)

Tajovský, K., 1998. Diversity of terrestrial isopods (Oniscidea) in flooded and nonflooded ecosystems of southern Moravia, Czech Republic. Israel Journal of Zoology, 44: 311-322

Ter Braak, C.J.F., Šmilauer, P., 1998. CANOCO Reference Manual and User´s Guide to Canoco for Windows: Software for Canonical Community Ordination (version 4). Microcomputer Power, Ithaca, 352 pp.

Tischler, W., 1980. Asseln (Isopoda) und Tausenfüßer (Myriopoda) eines Stadtparks im Vergleich mit der Umgebung der Stadt: zum Problem der Urbanbiologie. Drosera, 1: 41-52

Tuf, I.H., 2003. Development of the community structure of terrestrial isopods (Crustacea, Isopoda, Oniscidea) after a summer flood. In: Sfenthourakis, S., de Araujo, P.B., Hornung, E., Schmalfuss, H., Taiti, S., Szlávecz, K. (eds), The biology of terrestrial isopods V. (Crustaceana Monographs, 2). Brill Academic Publisher, Leiden, p. 231-242

Tuf, I.H., Tufová, J., in press. Proposal of ecological classification of centipede, millipede and terrestrial isopod faunas for evaluation of habitat quality in Czech Republic. Časopis Slezského Muzea Opava (A), 57 (1)

Vilisics, F., Elek, Z., Lövei, G.L., Hornung, E., 2007. Composition of terrestrial isopod assemblages along an urbanisation gradient in Denmark. Pedobiologia, 51: 45-53

Tab. 1: Presence of terrestrial isopods in Olomouc town (material from pitfall traps only), their dominance of activity in groups of sites (D, %) and sizes and indices of species diversity of those communities

locality	*Ligidium hypnorum* (Cuvier, 1792)	*Hyloniscus riparius* (C.L. Koch, 1838)	*Trichoniscus pusillus* Brandt, 1833	*Haplophthalmus danicus* Budde-Lund, 1880	*Haplophthalmus mengii* (Zaddach, 1844)	*Platyarthrus hoffmannseggii* Brandt, 1833	*Oniscus asellus* Linnaeus, 1758	*Cylisticus convexus* (De Geer, 1778)	*Trachelipus rathkii* (Brandt, 1833)	*Porcellium collicola* (Verhoeff, 19907)	*Porcellionides pruinosus* (Brandt, 1833)	*Porcellio scaber* Latreille, 1804	*Porcellio spinicornis* Say, 1818	*Armadillidium versicolor* Stein, 1859	*Armadillidium vulgare* (Latreille, 1804)	number of cought animals	number of species	Shanon-Weaver index
PARKS (195 ± 72.3 ind.)																		
PARK01	-	+	-	+	-	-	+	+	+	+	-	+	-	-	+	52	8	2.3
PARK02	-	-	-	-	-	+	+	-	+	+	+	+	-	-	+	78	7	2.2
PARK03	-	+	-	-	-	-	+	+	+	+	-	+	-	-	-	205	6	1.6
PARK05	-	+	-	-	-	-	-	-	+	+	-	+	-	-	+	82	5	1.9
PARK06	-	+	-	-	-	-	-	-	+	+	-	+	-	+	+	49	6	1.9
PARK07	-	+	-	-	-	-	-	-	+	+	-	+	-	+	+	504	6	1.1
PARK09	-	+	-	+	-	+	-	+	+	+	+	+	-	-	+	88	9	2.1
PARK14	-	-	-	-	-	-	-	-	+	+	-	-	+	-	+	59	4	1.5
PARK17	-	-	-	-	-	-	-	+	+	+	-	+	-	+	+	47	6	1.8
PARK18	-	+	-	-	-	-	-	-	+	+	-	+	+	-	+	89	6	2.0
PARK19	-	+	+	-	-	-	-	-	+	+	-	+	+	-	+	157	7	2.1
PARK20	-	+	-	-	-	+	-	-	+	+	-	+	-	+	+	276	7	1.7
PARK22	-	+	+	-	-	-	+	-	+	+	-	+	-	-	-	65	6	2.0
PARK26	-	-	-	-	-	-	-	+	-	+	+	+	-	+	+	1106	6	0.2
PARK30	-	-	-	-	+	-	-	-	+	+	-	+	-	-	-	65	4	0.4
D	0.0	5.3	0.5	0.1	0.0	0.3	1.0	5.1	8.0	7.6	0.3	23.2	0.1	37.2	11.3			
RUDERAL SITES (324 ± 89.7 ind.)																		
RUDE04	-	+	+	-	-	-	-	-	+	+	-	+	-	-	+	318	6	1.0
RUDE10	-	+	-	-	-	-	-	-	+	+	-	+	-	+	+	174	6	1.7
RUDE12	-	+	-	-	-	-	+	+	+	+	+	+	-	+	+	624	9	1.9
RUDE15	-	+	-	-	-	-	+	-	+	+	+	+	+	+	+	541	9	1.3
RUDE27	-	+	-	-	-	-	-	-	+	+	-	+	-	-	-	53	4	1.0
RUDE28	-	+	+	-	-	-	+	+	+	+	-	+	+	+	+	234	10	2.0
D	0.0	3.2	0.2	0.0	0.0	0.0	1.1	0.3	4.2	19.5	0.8	29.1	0.6	32.7	8.5			
NATURAL SITES (125 ± 27.6 ind.)																		
NATU08	-	-	-	-	-	-	-	-	+	+	-	+	-	-	+	85	4	1.5
NATU11	-	+	-	-	-	-	-	-	+	+	-	+	-	+	-	298	5	1.7
NATU13	-	+	-	-	-	-	-	-	+	+	-	+	-	+	+	114	6	1.8
NATU16	-	+	-	-	-	-	-	+	+	+	-	-	-	+	+	183	6	1.8
NATU21	+	+	-	-	-	-	+	-	+	+	-	+	+	+	-	57	8	2.0
NATU23	-	+	+	-	-	-	+	-	+	+	-	+	+	+	+	177	9	1.6
NATU24	-	+	-	-	-	-	-	-	+	+	+	+	-	-	+	26	6	2.1
NATU25	-	+	+	-	-	-	+	-	+	+	+	+	-	+	+	80	9	2.3
NATU29	-	+	-	-	-	-	+	-	+	+	-	-	+	-	+	101	6	1.6
D	0.2	13.5	0.3	0.0	0.0	0.0	2.2	0.1	8.0	38.3	0.3	3.0	0.4	22.5	11.2			

Tab. 2: Significance of environmental variables for terrestrial isopod distribution (F-test and p-value by CCA in CANOCO)

Variable	F	P
artificiality	26.92	0.002
amount of litter	12.7	0.002
canopy layer	9.6	0.002
soil structure	8.59	0.002
herbal layer	4.92	0.002

Tab. 3: Presence of millipedes in Olomouc town (material from pitfall traps only), their dominance of activity in groups of sites (D, %) and sizes and indices of species diversity of those communities

locality	*Polyxenus lagurus* (Linnaeus, 1758)	*Melogona voigti* (Verhoeff, 1899)	*Blaniulus guttulatus* (Fabricius, 1798)	*Proteroiulus fuscus* (Am Stein, 1857)	*Brachyiululs bagnalli* (Curtis, 1845)	*Cylindroiulus caeruleocinctus* (Wood, 1864)	*Cylindroiulus nitidus* Verhoeff, 1891	*Kryphioiulus occultus* (C.L.Koch, 1847)	*Ophyiulus pilosus* (Newport, 1842)	*Unciger foetidus* (C.L.Koch, 1838)	*Brachydesmus superus* Latzel, 1884	*Polydesmus complanatus* (Linnaeus, 1761)	*Polydesmus inconstans* Latzel, 1884	number of cought animals	number of species	Shanon-Weaver index
PARKS (49 ± 10.6 ind.)																
PARK01	-	-	-	+	-	+	-	-	-	-	+	-	-	38	3	1.1
PARK02	-	+	+	-	-	+	-	+	+	-	+	-	-	57	6	1.9
PARK03	-	+	+	-	-	+	-	-	-	-	+	-	-	80	4	1.3
PARK05	-	-	-	-	-	+	-	-	-	-	-	-	-	72	1	0.0
PARK06	-	-	-	-	-	+	-	-	-	-	-	-	-	13	1	0.0
PARK07	-	-	-	-	-	+	-	-	-	-	-	-	-	5	1	0.0
PARK09	-	-	-	-	-	+	-	-	-	-	+	-	-	44	2	1.0
PARK14	-	+	+	+	+	+	-	+	-	+	+	-	+	75	9	2.1
PARK17	-	-	-	-	-	+	-	-	-	-	+	-	-	7	2	0.9
PARK18	-	-	+	-	+	-	-	-	-	+	+	-	-	170	4	0.3
PARK19	+	+	-	-	+	+	+	-	+	-	+	-	-	46	7	2.2
PARK20	-	-	+	+	+	+	-	-	-	-	+	-	+	41	6	2.2
PARK22	-	+	-	-	-	-	-	-	-	+	+	-	+	11	4	1.5
PARK26	-	-	-	+	+	+	-	-	-	-	+	-	-	31	4	1.4
PARK30	-	-	-	-	-	+	-	-	-	+	-	-	-	39	2	0.2
D	0.1	3.3	1.0	3.0	4.1	36.9	0.1	0.4	4.1	1.0	43.6	0.0	2.3			
RUDERAL SITES (29 ± 10.3 ind.)																
RUDE04	-	+	-	-	-	-	-	-	-	-	-	-	-	3	1	0.0
RUDE10	-	-	+	+	+	+	-	-	-	-	+	-	-	52	5	1.8
RUDE12	-	-	-	-	-	+	-	-	-	-	-	-	+	18	2	0.3
RUDE15	-	-	-	-	+	+	-	+	-	-	+	+	+	47	6	1.9
RUDE27	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.0
RUDE28	-	+	-	+	+	+	-	-	+	+	+	-	-	56	7	2.4
D	0.0	2.3	1.7	1.7	22.7	32.4	0.0	4.0	5.1	2.8	25.0	0.6	1.7			
NATURAL SITES (122 ± 65.8 ind.)																
NATU08	-	-	-	+	+	+	-	+	-	-	-	-	-	25	4	0.9
NATU11	-	-	-	-	-	+	-	-	-	-	-	-	-	2	1	0.0
NATU13	-	-	-	-	+	+	-	-	-	-	-	-	-	21	2	0.8
NATU16	-	+	-	-	-	+	-	-	-	+	+	-	+	231	5	0.3
NATU21	-	+	-	-	-	+	-	-	-	+	+	-	-	608	4	0.3
NATU23	-	+	-	-	-	+	+	-	+	+	+	-	-	57	6	1.2
NATU24	-	+	-	-	+	+	-	-	-	-	+	-	+	137	5	0.5
NATU25	-	-	-	-	-	+	-	-	-	-	+	-	-	16	2	0.3
NATU29	-	-	-	+	-	-	-	-	+	-	-	-	-	3	2	0.9
D	0.0	1.5	0.0	0.3	0.8	4.8	0.2	0.2	4.1	1.0	86.8	0.0	0.4			

Tab. 4: Significance of environmental variables for millipede distribution (F-test and p-value by CCA in CANOCO)

Variable	F	P
artificiality	15.96	0.002
amount of litter	6.42	0.002
canopy layer	5.77	0.002
herbal layer	1.93	0.024
soil structure	1.31	0.198

Fig. 1: Distribution of studied localities in city of Olomouc. Numbers are codes of localities, circles are parks, squares are ruderal sites and triangles are natural sites.

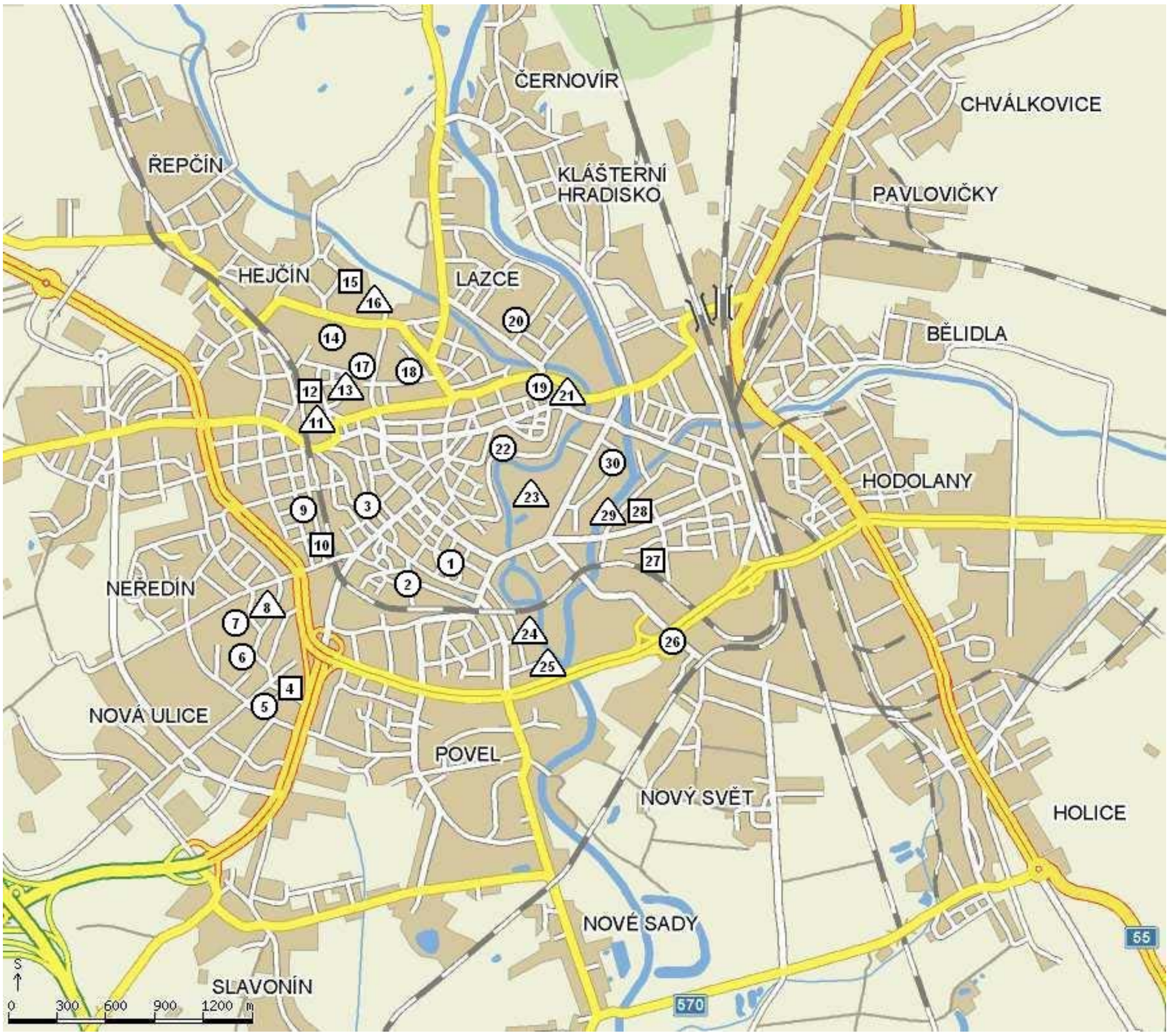


Fig. 2: CCA plot of distribution of terrestrial isopods in relation to environmental variables

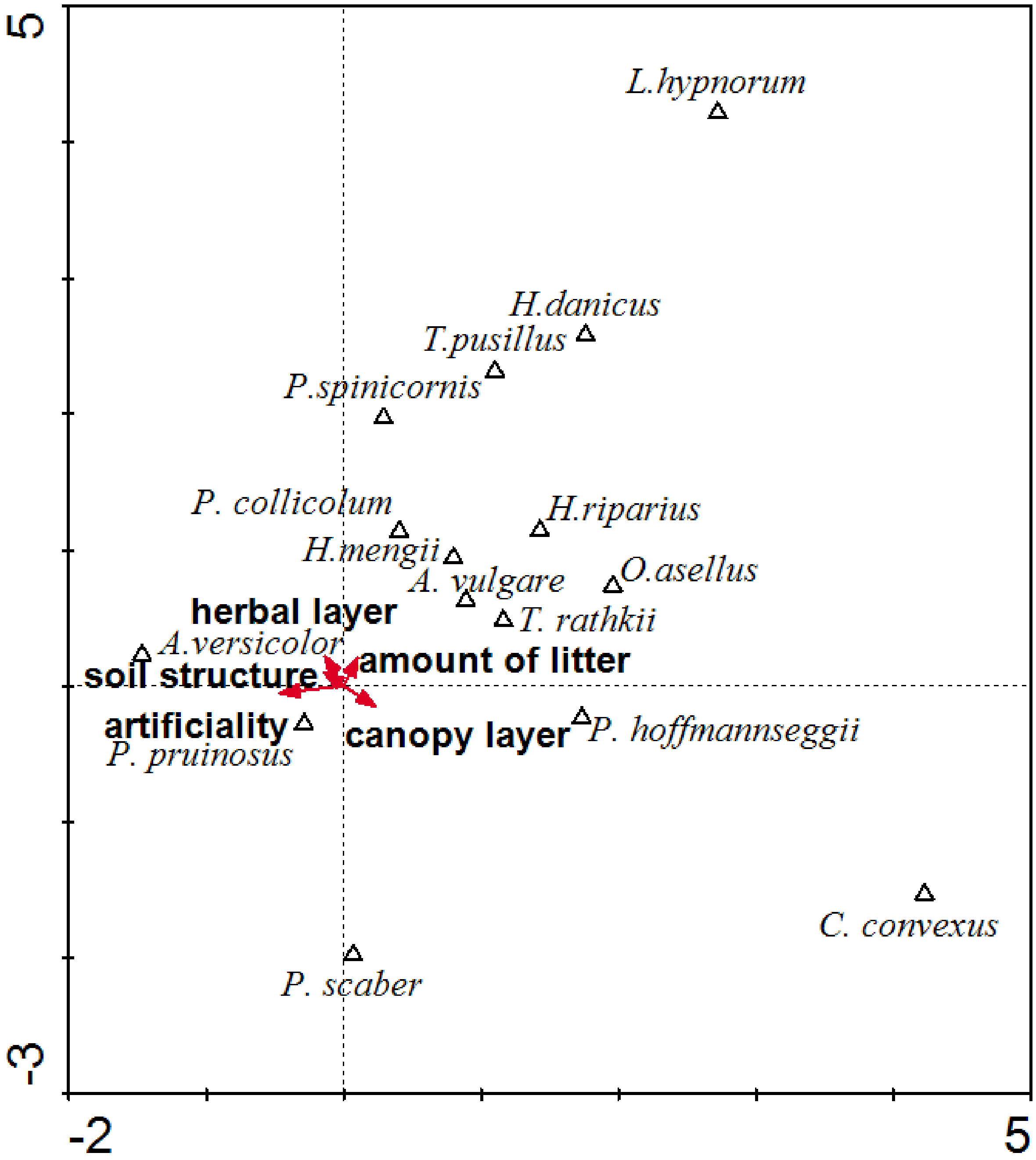
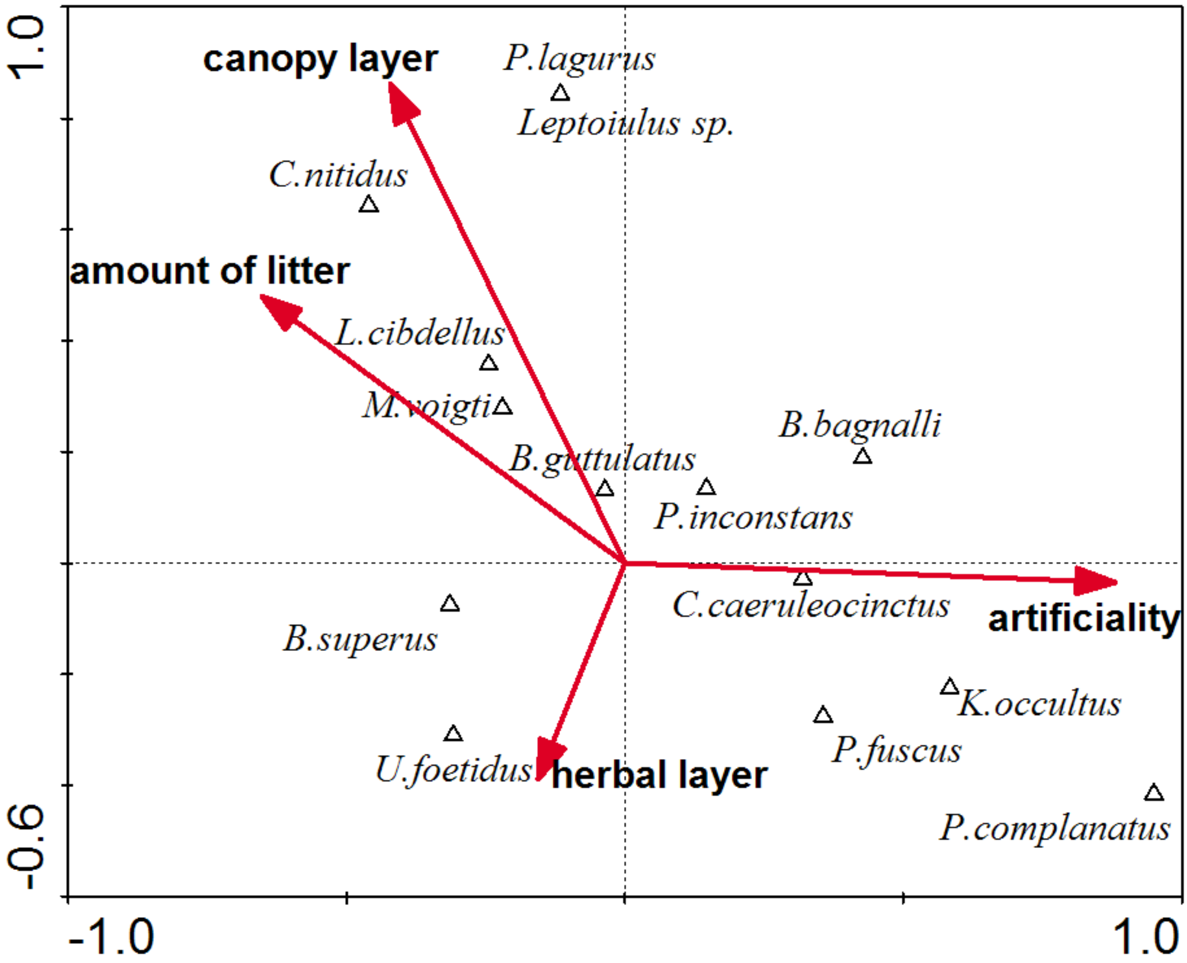


Fig. 3: CCA plot of distribution of millipedes in relation to environmental variables



3 Centipedes and millipedes in urban environment

Pavel Riedel, Marek Navrátil, Ivan H. Tuf, Jana Tufová

Department of Ecology & Environmental Science, Faculty of Science, Palacky University, Svobody 26, 77126 Olomouc, Czech Republic, ivan.tuf@upol.cz

Abstract

The communities of millipedes and centipedes were studied in two towns of similar size located in different parts of the Czech Republic: Jičín (East Bohemia) and Hodonín (South Moravia). Studied animals were obtained using pitfall traps, heat extraction of soil samples and hand collecting. In total 45 pitfall traps were installed in each town in 15 localities including parks, built up areas and abandoned ruderal sites. Localities were classified into three categories: parks, ruderals and nature. Basic environmental characteristics of each locality were evaluated: artificiality, coverage by leaf litter, by herbal and canopy layer, structure and pH of the soil and amount of humus and calcium in soil. The hand collecting was used to get more complete knowledge of the species spectrum since the animals were collected in areas where pitfall trapping was not viable too.

. In total 20 species of centipedes (1,056 ind.) and 24 species of millipedes (1,890 ind.) were recorded which is 30 % of known Czech centipede and millipede fauna. It confirms a high diversity of these communities in urban ecosystem. In both groups the major part of species spectrum was represented by adaptable or eurytopic species whereas only one species fell into category relic. Multivarite technics that were used for data set from pitfall traps revealed that the amount of humus and leaf litter are the most important factors for distribution of myriapods.

The most interesting faunistic result was the first recorded finding of the centipede *Henia vesuviana* in the Czech Republic and new localities of rare species *Schendyla montana* and *Geophilus pygmaeus* (listed in Hodonín). Further interesting results are the occurrence of *Geophilus oligopus*, *Allajulus nitidus* and individuals of the cave genus *Brachychaeteuma* in Jičín.

Key words: Chilopoda, Diplopoda, Jičín, Olomouc, pitfall traps, soil macrofauna, urban ecosystem

Introduction

Although urban ecosystems have many characteristic features, they have been neglected in ecological research for a long time. The process of urbanization entails conversion of indigenous natural habitat to various forms of anthropogenic habitats, fragmentation and isolation areas of indigenous habitat. Cities then represent diversified areas with the mosaic of remaining natural sites, various artificial sites, abandoned ruderal areas and nature-like sites as parks, lawns and graveyards (Parlange 1998, McIntyre et al. 2001). Additionally, mesoclimatic conditions in cities are distinct from environs by higher temperature and faster precipitation runoff. The city fauna is often enriched with introduced species; their proportion is generally higher than in other areas. Non-native species come from horticultural planting and many other human activities (Rebele 1994, Smith et al. 2006) and together with indigenous fauna create unique synantropic communities.

Centipedes and millipedes belong to the class Myriapoda. Centipedes are carnivores while millipedes feed on plant material and fragments of decaying vegetation. Representatives of both groups are found in similar conditions, mostly in habitats with low insulation, higher humidity and stable temperatures, e.g. under stones, bark, fallen branches, in leaf litter or directly in soil (Eisenbeis et Wichard 1987). Urban areas extend common microhabitat potential with stacks of building materials, dilapidated houses, various walls, compost piles and garbage piles etc.

This study deals with distribution of centipedes and millipedes in two towns of similar size located in different parts of the Czech Republic: Jičín and Hodonín. It has two aspects – ecological and faunistical. The first goal of the study is to find which of tested variables influence distribution and abundance of these animals, and, generally speaking, to contribute to the knowledge about how Myriapoda respond to urbanisation. The faunistical aspect of the study is investigates the millipede and centipede species spectrum of both cities.

Methods

Study sites

Hodonín is located in the southern Moravia, in the southern part of Dolnomoravský úval Graben (48°50′56.17″N 17°7′56″E). It is situated on Morava river in a flatland plain at an altitude of about 200 m, covering 63.78 km^2. Geological setting is composed of Quaternary sandy and gravely sandy sediments overlaid by loamy sandy flood soil formation. The average annual temperature is 9.5 °C and annual rainfall reaches 585 mm. Hodonín has population of 22,200.

Jičín is located in North-East Bohemia in the undulating country on Cidlina river (50°26′12″N 15°21′6″E). It is situated at the altitude of 287 m, covering 24.93 km^2. Geological setting is composed partially of cretaceous formation and partially of Quaternary eolian sediments; the soils include brown earths and loess soil. Average annual temperatures range around 7–8 °C, the annual rainfall is 650-700 mm. The town has 16,400 inhabitants.

Sampling methods

Three standard sampling methods were used for collecting both millipedes and centipedes. Pitfall traps were used particularly to trap ground dwelling species. 45 simple pitfall traps were placed in 15 localities in each city. The sampling sites were selected with regard to various habitat types, subsuming urban greens like parks, built up areas, yards and ruderal grounds. Pitfall traps were half-filled with a 4 % water solution of formaldehyde and emptied once every two weeks from April 2006 to March 2007. Soil samples were taken using sample rings (1/30 m^2, depth 10 cm) at the same localities where the pitfall traps were used. Two samples were taken from each of 30 localities (November 2006 and March 2007) and were heat extracted for 10 days using a Tullgren funnel. Individual hand collecting was used with the purpose to describe the species spectrum as exhaustively as possible. It was conducted also in areas where pitfall trapping was not viable, continuously from April 2006 to March 2007. A combination of these three methods is generally used to describe both occurrence and biology of various groups of soil fauna (Czechowski and Mikoljaczyk 1981).

Localities were classified into three categories: parks (= managed sites), ruderals (= abandoned sites) and nature (= rests of natural sites). In each locality environmental conditions were evaluated. The following parameters were evaluated on a scale from 1 to 4 according to quantity or quality and were sampled within 1 m of the trap: *amount of litter* – 1 indicates no leaf litter, 4 indicates leaf litter covering the whole area in a thick layer; coverage by *herbal layer* and by *canopy layer* – 1 indicates a coverage from 0 to 25 %, 2 means 25 – 50 % etc.; *soil structure* – 1 indicates a clayey soil, 2 indicates a loamy soil, 3 indicates a sandy soil and 4 indicates a stony soil; *artificiality* – 1 indicates a site with a natural soil profile, 4 indicates completely artificial soils. Furthermore content of calcium, humus and pH were evaluated. These factors were measured by laboratory analysis and actual values were used. Distribution patterns and impact of environmental factors were evaluated by Canonical Correspondence Analysis in CANOCO for Windows 4.5© (Ter Braak and Šmilauer, 1998), logarithms of numbers of caught animals were used. Significance of relationships between species and environmental data were calculated using Monte-Carlo permutation test (499 repetitions). Additionally, localities were classified using Ward's clustering method.

Results

Centipedes

In total we captured 1,056 centipedes of 20 species in both cities, including 9 species belonging to Lithobiomorpha and 11 to Geophilomorpha. In Jičín we recorded 414 centipedes of 15 species (Tab. 1), 642 centipedes of 13 species were captured in Hodonín (Tab. 2). In total 8 species were found in both towns. The most abundant species obtained by pitfall traps were *L. forficatus* (Jičín: 50 %, Hodonín: 67 %) and *L. microps* (Jičín: 32 %, Hodonín: 19 %). The most dominant species in soil were *L. microps* (Jičín: 50 %, Hodonín: 58 %) and *S. nemorensis* (Jičín: 29 %, Hodonín: 37 %). Sequence of the most dominant species did not change among parks, ruderals and natural sites analogous to numbers of species per locality (parks: 4.5 ± 0.5; ruderals: 4.3 ± 0.4; natural sites: 4.0 ± 0.3).

Millipedes

In total 1,890 millipedes of 24 species were captured in Jičín and Hodonín. Four of them belong to order Chordeumatida, 14 to Julida and 5 to Polydesmida. 750 specimens collected in Jičín represented 14 species, 1137 specimens of 18 species we recorded in Hodonín. Only 9 species were common for both cities. The most abundant species obtained by pitfall trapping in Jičín were *P. inconstans* (35 %), *O. pilosus* (15 %) and *B. superus* (15 %) whereas *P. complanatus* (29 %), *C. caeruleocinctus* (24 %) and *B. bagnalli* (21 %) were the most abundant millipedes recorded using pitfall traps in Hodonín. The most dominant species in soil samples in Jičín were *O. pilosus* (26 %), *A. nitidus* (22 %) and *B. gutullatus* (21 %). The most abundant soil-dwelling millipedes of Hodonín were: *K. occultus* (44 %), *B. bagnalli* (24 %) and *C. caeruleocinctus* (16 %). There were some differences in millipede species spectrum between parks, ruderals and natural sites. For example *P. inconstans*, which was the most dominant species in parks and ruderal sites of Jičín (30 % and 50 % respectively), reached only 1.4 % in natural sites. *J. scandinavius* was the second most abundant species in natural sites of Jičín (21 %) but reached only 7 % in parks and 1 % in ruderal sites. The clearly dominant species of natural sites of Jičín *O. pilosus* (39 %) reached only 11 % in ruderals and 7 % in parks. In Hodonín we found the obvious difference in occurrence of *B. bagnalli* between parks, ruderals and natural sites. Although it was dominant in parks and ruderals (23 and 21 %), it has not been found in natural sites at all. The average numbers of species per locality were 5.4 ± 0.7 in ruderals, 5.2 ± 0.7 in parks, and 4.6 ± 0.7 at natural sites only.

Environmental conditions and characteristic of habitats

The highest mean catch (ind. / 3 traps / 12 months) of centipede specimens in pitfall traps was reached in parks (21.4 ± 6.3), followed by ruderals (21.0 ± 5.0), whereas mean catch at natural sites was relatively low (12.4 ± 4.2). For millipedes the largest value was reached in ruderals (68.7 ± 14.5), followed by parks (30.6 ± 12.5) and natural sites (17.8 ± 3.7). The myriapod communities were the most diverse at natural sites (S-W index of biodiversity = 2.25), followed by parks (2.24) and ruderals (2.05).

The CCA plot (Fig. 1) was used to evaluate the pattern of myriapod distribution at investigated localities. The model was significant ($F = 6.957$, $p = 0.002$), the sum of all canonical eigenvalues was 1.737; all four canonical axes explained 72.5 % of variability in species variability. The largest proportion of the variability was explained by factor amount of humus ($F = 12.77$, $p = 0.02$), the second most important factor was artificiality ($F = 10.23$, $p = 0.02$). Canopy layer seemed to be the least important factor ($F = 3.36$, $p = 0.02$). However, all the tested factors were significant (Tab. 3).

In total 28 of 34 species showed significant relation to amount of humus (Fig. 2) and 26 species to amount of litter (Fig. 3). The strong positive relationship to amount of humus and litter was found for millipedes *A. nitidus*, *M. stigmatosum*, *O. pilosus*, *J. scandinavius* and *M. voigti*. Two polydesmids *P. inconstans* and *B.*

superus tend to settle artificial habitats with high amount of humus and low amount of litter. *C. caeruleocinctus*, *B. bagnalli* and *C. palmatus* preferred artificial localities with low amount both humus and litter. From centipedes *L. melanops* and *L. macilentus* seem to be the species most preferring artificial habitats and low amount of litter. To the contrary, *G. flavus* and *C. flavidus* tend to settle natural sites.

A classification using Ward distance was carried out for pitfall traps in all 30 localities (Fig. 4). The dendrogram shows that there are some localities obviously separated from the rest and on the other hand also similar localities forming clusters. Within majority of clusters localities of Jičín and Hodonín are represented about equally, thus the city factor doesn't seem to be the most important.

Discussion

Centipedes

Finding of 20 species in both cities represent roughly 30 % of Czech centipede fauna (Tuf and Tufová in press). We recorded 15 species of centipedes in Jičín and 13 species in Hodonín. These numbers are similar to that ones recorded in other European cities. In total12 species were found in Warsaw (Wytwer 1996), 15 species in Copenhagen (Enghoff 1973), 16 species in Sofia (Stoev 2004) and 18 species representing 33 % of Polish centipede fauna were recorded in Poznan (Lesniewska 1996). Only 4 species were found during research in the Eskhir, Turkey (Misirlioğlu 2003); 34 species detected in Roma (Zapparoli 1992) is the divergent extreme. Pitfall trapping was the most successful method; however, additional methods broadened the species spectrum with 5 species in Jičín (33 % of all recorded species) and 4 species in Hodonín (38 %).

The average numbers of species 4.0 to 4.5 per locality is lower value than 5-10 species generally recorded in Central European forest communities (Albert 1979, Becker 1982, Wytwer 1990, 1992). Wytwer (1996) found on average 5.8 species in wooded areas, 5.0 in park lawns and 4.5 species in street lawns during the research of urban greens in Warsaw.

In total 9 species were found in both cities; except *Lithobius melanops* and *Henia illyrica* all of them were found in great numbers and can be considered as common. *Geophilus electricus* was relatively abundant species too. It was found only in Jičín but then it was recorded from almost all the investigated localities. After

Lesniewska (1996), it is a eurytopic species that tends to be numerous in urban localities. Other species were found in less than 10 specimens and may be thus considered as rare. According to Tuf and Tufová (in press) the species may be divided in three categories after their habitat requirements. 55 % of species recorded in Jičín and Hodonín then come under category 'adaptable' (able to colonize both undisturbed and moderately disturbed habitats), 35 % belong to 'eurytopic' (colonizing different biotopes include heavily anthropically disturbed sites) and only 2 species *L. burzenlandicus* and *G. oligopus* (10 %) come under the category 'relic' (restricted to natural, undisturbed habitats). This ratio is evidently different from total Czech centipede fauna where 40 % of species are classified as relic, 45 % as adaptable and 15 % as eurytopic. It shows on high proportion of synantropical and intruduced species in both cities. This feature was also found in other European cities. The most abundant species of both Jičín and Hodonín as well as other researched cities were *Lithobius forficatus* and *Lithobius microps* (Enghoff 1973, Lesniewska 1996, Wytwer 1996).

Henia vesuviana is the most interesting faunistical result in Jičín. It is the first recorded finding in the Czech Republic. However, it was also found in Olomouc during the simultaneous sampling as a part of the same extensive research of urban areas. *H. vesuviana* is a Mediterranean species; however, it occurs naturally in France and Germany. In east Germany it is found only in cities (Munich, Jena, Leipzig) and its possible synantropic occurrence in Czech cities was predicted (Lindner 2007). Findings in Jičín and Olomouc confirm a tendency of this species to spread. It is an animal of disturbed soils often found in urban settings (Barber and Keay 1988) with a high tendency to colonize new biotopes (Spelda 2005). *G. oligopus* is another interesting representative of centipede fauna of Jičín. This species has an Alpin-Dinarian distribution area; recently it was recorded also from Carpathians (Romania) (Dányi 2007). The finding in Jičín is thus very surprising; probably it was spread by human. *G. pygmaeus* is the most interesting faunistical record from Hodonín. It is only the second record for the Czech Republic, after 100 years. For the first time it was recorded from Boskovice, southern Moravia; Vališ (1902), collected one female. *S. montana* is another interesting representative of Geophilomorpha; Hodonín is the third known location of its occurrence in the Czech Republic, until today it was known only from Podyjí National Park and Labské Pískovce Protected Landscape Area (Tajovský 1998a, 1998b). *Lithobius* *burzenlandicus* is the most interesting representative of Lithobiomorpha. The natural range of this Balkan species (Matic 1966) reaches south Moravia. All the specimens found in Hodonín were captured in the sites lying alongside the railway corridor connecting the town with South European destinations. The corridor may be considered likely route into the town.

Millipedes

In total we recorded 24 species of millipedes which amount to roughly 30 % of species known in the Czech Republic (Tuf and Tufová in press). Numbers from investigated cities (Jičín: 14, Hodonín: 18) are not fundamentally different from 14 species identified in Sofia (Stoev 2004) and 15 species from Kiel (Tischler 1980). Much higher millipede richness was found in Copenhagen (23 species, Enghoff 1973), Budapest (26 species, Korsós et al. 2002) and in Prague, where 50 species were recorded (Kocourek 2004). However, biotope settled with more than 10 millipedes can be termed rich (Kocourek 2004).

The millipede faunas of Jičín and Hodonín are not as similar as faunas of centipedes. The lists of most abundant species of Jičín and Hodonín differ completely not only between each other but also from other European cities. The most dominant species of pitfall traps in Jičín were absent or very rare in Hodonín, and vice-versa. Data from soil samples indicate a similar divergence. *K. occultus* and *B. superus* were the only species found in relatively large numbers in both cities. *Allajulus nitidus* recorded in Jičín may be considered as interesting record; it is generally assumed to be rare (Kocourek 2001) and it is only the 3rd record for the Czech Republic. However, the population recorded in the area of the Botanical Garden of Charles University in Prague was also very abundant (Kocourek 2001), and high abundances in the areas of its occurrence are realized in England (Blower 1985).

As in the case of centipedes, also millipede fauna of Jičín and Hodonín consists of adaptable and eurytopic species. Specifically 50 % of species are included in category adaptable, 42 % in eurytopic and only two species (*C. transsilvanicum* and *Brachychaeteuma* sp.) represent the category relic. Within the millipedes known from the Czech Republic, 31 % are categorized as relic, 49 % as adaptable and 20 % as eurytopic. The obvious difference, as well as in foregoing case of centipedes, thus confirms a general dissimilarity in species spectrum between urban and natural habitats.

Detection of specimens of the genus *Brachychaeteuma* is the most interesting faunistical result of sampling in Jičín. We have found only one female; for identification to species level male specimens will have to be obtained. Up today in Czech Republic species *Brachychaeteuma bradeae* was recorded only from caves (Tajovský and Mlejnek 2007). However, in UK its non-cave occurrence is common (Lee 2006). *Cylindroiulus britanicus* is one of the few species recorded during previous studies in Jičín (Kocourek 2006). Its occurrence is not surprising, this synantropic species is known e.g. from Prague (Kocourek 2004). However, the current inventory failed to trace it within the city boundaries. *M. bosniensis*, *C. transsilvanicum*, *C. boleti* and *U. transsilvanicus* are representatives of Southeast European fauna. They were found only in Hodonín; only *U. transsilvanicus* was found in Jičín as well, even in higher numbers than in Hodonín. However, the species was recorded also from the Arba Nature Reserve in Bohemian Switzerland National Park which represents the north-westernmost occurrence of this species in Europe (Tajovský 2002).

Environmental conditions and characteristic of habitats

Although in natural sites we recorded the lowest both numbers of individuals and species richness, the diversity there was the highest. This was caused by generally low abundances of synantropic and eurytopic species in natural localities. That species reached high abundances in ruderal and park sites and decreased their diversity. Although the impacts of all the tested environmental factors were significant, some of them were not essential, such as canopy layer, all the site type categories and surprisingly also artificiality which was the most important in Olomouc (Riedel et al. in press). A low significance of the amount of calcium in soil is another unexpected result. Millipedes require large amounts of calcium to produce calcified exoskeletons (Hopkin and Read 1992). There is a positive relation between increasing calcium in soil and millipede abundance (Kalisz and Powell 2003). Generally the most important factor seems to be the amount of humus followed by the amount of litter. A strong dependence on both these factors was identified especially in distribution of millipede species. It is in accordance with ecological requirements of millipedes as organisms feeding primarily on decaying plant material (Eason 1964). Dunxiao et al. (1999) found a positive correlation with soil organic matter content in urban areas..

Distribution of *C. caeruleocinctus* has its peak in sites with a low amount of humus in soil and a low amount of litter. The sites were also distinguished with the absence of a canopy layer, with recent soil disturbances and a high degree of artificiality. Owing to these characteristics and its considerable dominance at ruderal sites in Hodonín, *C. caeruleocinctus* seems to be a typical representative of species settling man-made sites. This Atlantic species was not recorded until 1954 in the Czech Republic (Kocourek 2004) and until recently in Slovakia (Mock 2006). Its occurrence at synantropic sites is common (Kocourek 2004). It is also known as a human residence's invader (Samšiňák 1981).

Although *P. inconstans* and *B. superus* significantly prefered humic soil, sites of its occurrence were distinguished by a low amount of litter on the ground. It is hard to pinpoint the cause of this pattern. More than 50 % of specimens were captured in just one locality that meets these conditions. Impact of values of environmental factors collected in this one locality is likely excessive and the established pattern may apparent, because of other ecological factors or even by coincidence. Tischler (1980) found a causeless absence of *P. inconstans* in some habitats and considered it as a consequence of the island character of urban habitats. *A. nitidus* seems to be a species strongly preferring high amounts of both humus and litter which is in accord with requirements published for this species. Its positive relationship to deciduous forests and generally to natural habitats (Kocourek 2001, Blower 1985) was not found because more than 77 % of individuals were captured in one locality categorized as park locality with relatively high degree of artificiality.

Cluster analysis showed a high dissimilarity among localities. One of the most substantial reasons is probably the distinct geographical location of Jičín and Hodonín. As mentioned above, fauna of Hodonín is enriched with Southeast European species (in particular millipedes) and Jičín has a lot of specific species as well. However, localities are not strictly separated in this respect.

Ruderal localities H02 and H14 differ from the others due to high abundance of *L. mutabilis* and millipedes *O. sabulosus*, *K. occultus* and chiefly due to presence of *M. bosniensis*. Both these localities are characterized by high amount of litter, low artificiality, and sandy soil which is typical surroundings for *O. sabulosus* (hence the trivial name) (Blower 1985). Ecology of this xerophilic species has been objective of many studies (conducted also in urban areas); its mass occurrences and migrations have been frequently observed throughout Europe and other regions of the world. It is known for its tendency to invade cities and even houses, and thus considered a pest and exterminated (Kania and Tracz 2005). Localities J02 and J13 seem to be the reverse of the two previously mentioned. They represent highly artificial localities, with low amounts of litter and loamy soil. An interesting factor of both these localities is the presence of *L. melanops* and *L. macilentus*. Surprisingly, the latter mentioned species is generally considered as a woodland species (Eason 1964). Park locality H12 differs from the others due to uncommon centipede species composition: very high abundance of *L. forficatus* (61 ind.) and a really low abundance of *L. microps* (1 ind.). To the contrary, the generally higher abundance of *L. microps* in comparison with *L. forficatus* is characteristic for localities J15, H10, J04, H08, H11, H13, J10 and J12 combined in one large cluster. These localities are predominately various grassy sites with some non-native or self-seeding trees and shrubs or without woody plants. A decrease of *L. forficatus* and its replacement by *L. microps* in such sites is in accord with Wytwer (1996). Ruderal localities H4, H15, H06 and H09 represent sites where soil was recently disturbed in various ways. Thus, it is not surprising that *C. caeruleocinctus*, which generally prefers cultivated land (Blower 1985), was very abundant at these places. The relationship between localities J06 and J07 is due to similar conditions (high amount o litter, clayey soil, and a well developed canopy layer) and possibly also due to their proximity. Both localities are settled by millipedes *O. pilosus*, *A. nitidus* and *J. scandinavius*. These are considered woody species (Kocourek 2001, Blower 1985) and were not abundant in other localities in Jičín.

Soil fauna and urban planning

In both cities we found high species richness which is similar to results published for other cities. For example, Enghoff (1973) investigated millipede fauna of heavily man-influenced localities in Copenhagen and he stated that fauna in Denmark reaches its peak of species diversity in the type of biotopes covered by that investigation. Thus the changing of environment connected with urbanization is not always detrimental to diversity of the fauna. Similarly for abundances, the highest densities of soil invertebrates can be found at the most un-naturalized biotopes (Vilisics et al. 2007). However, urbanization has been unequivocally identified as one of the leading causes of declines in arthropod diversity and abundance (Davis and Jones 1978). According to other studies, millipede and centipede faunas obviously reflect various degrees of human disturbance. Urban influences and urbanization seem to be stressors (Zapparoli 1992, Korsós et al. 2002). An explanation of the high species richness is the extreme heterogeneity of the urban landscape. A majority of the urban sites is formed by eurytopic species that are at least neutral to synantropic habitats; however, fragmented semi-natural habitats may still support populations of native species. Moreover, the species spectrum is often enriched with exotic species.

Thus the most important rule for urban ecosystem management seems to be to maintain habitats in conditions of high spatial diversity. The most important habitat factors for the distribution of centipedes and millipedes in Jičín and Hodonín were the amount of humus and leaf litter. Unsurprisingly, in cities, an orderly city landscape is often preferred and thus undecomposed leaf litter is often removed. For a large majority of myriapods this has a negative effect (Poser 1990). Urban green spaces should be created and managed using ecologically sensitive methods in order to simulate the balance of nature, not just for aesthetics (Weigman 1989). Another self-evident basic rule for urban management is to reduce, to the extent feasible, the chemical and mechanical stresses (Schaeffer 1989).

Acknowledgements

We thank John O'Donovan, PE (Environmental Engineer), and Julia O'Donovan, MA, for helping with checking the English of the manuscript.

References

Albert, A.M. (1979): Chilopoda as part of the predatory macroarthropod fauna in forests: abundance, life-cycle, biomass, and metabolism. In: Camatini, M. (ed.): Myriapod Biology, Academic Press: 215-231.

Barber, A.D., Keay, A.N. (1988): Provisional Atlas of the Centipedes of the British Isles. Grangeover-Sands, Institute of Terrestrial Ecology Merlewood Research station.

Becker, J. (1982): Hundertfüssler (Chilopoda) des Bausenbergs und der Östlichen Eifel. Decheniana – Beihefte (Bonn), 27: 76-86.

Blower, J.G. (1985): Millipedes. Synopses of the British Fauna, 35. Leiden/London, Brill/Blackhuys.

Blower, J.G. (1985): Millipedes. Synopses of the British Fauna, 35. Leiden/London, Brill/Blackhuys.

Czechowski, W., Mikolajczyk, W. (1981): Methods for the study of urban fauna. Memorabilia zool., 34: 49-58.

Dányi, L. (2007): *Geophilus oligopus* (Attems, 1895) a species new to the fauna of Romania and to the whole of the Carpathian Mountains. Schubartiana, 2: 39-48

Davis, B.N.K., Jones, P.E. (1978): The ground arthropods of some chalk and limestone quarries in England. Journal of Biogeography, 5: 159-171.

Dunxiao H., Chunru H., Yaling X., Banwang H., Liyuan, H., Paoletti, M.G.(1999): Relationship between soil arthropods and soil properties in a suburb of Qianjiang City, Hubei, China. Critical Review in Plant Sciences, 18: 467-473.

Eason, E.H. (1964): Centipedes of the British Isles. London, Frederick Warne & Co Ltd.

Eisenbeis, G., Wichard, F. (1987): Atlas on the Biology of soil arthropods. Springer Verlag, Berlin, Heidelberg, New York, London, Paris, Tokyo.

Enghoff, H. (1973): Diplopoda and Chilopoda from suburban localities around Copenhagen. Videnskabelige Meddelelser fra Dansk Naturhistorisk Forening i København, 136: 43-48

Hopkin, S.P., Read, H.J. (1992): The Biology of Millipedes. Oxfor University Press, Oxford.

Kalisz, P.J., Powell, J.E. (2003): Effect of calcareous road dust on land snails (Gastropoda: Pulmonata) and millipedes (Diplopoda) in acid forest soils of the Daniel Boone National Forest of Kentucky, USA. Forest Ecology and Management, 186: 177–183.

Kania, G., Tracz, H. (2005): Mass occurence and migration of *Ommatoiulus sabulosus* (Linnaeus, 1758) (Diplopoda: Julida: Julidae) in Poland. Peckiana, 4: 57-66.

Kocourek, P. (2001): Pozoruhodné společenstvo mnohonožek Botanické zahrady UK. [A remarkable community of millipedes.] Živa, 49: 125-126

Kocourek, P. (2004): Mnohonožky – skrytá fauna v Zoo Praha. [Millipedes - hidden fauna at the Prague Zoo.] Živa, 52: 169-171.

Kocourek, P. (2006): Diplopoda – mhohonožky. [Diplopoda – millipedes.] In: Mlíkovský, J., Stýblo, P. (eds.): Nepůvodní druhy fauny a flóry České republiky. Praha, ČSOP: 243-246.

Korsós, Z., Hornung, E., Szlávecz, K., Kontschán, J. (2002): Isopoda and Diplopoda of urban habitats: new data to the fauna of Budapest. Annales Historico–Naturales Musei Nationalis Hungarici, 94: 193-208.

Lesniewska, M. (1996): Centipedes of Poznan Town (Poland). In: Geoffroy, J.-J., Mauriés, J.-P., Nguyen-Duy Jacquemin, M. (eds.): Acta Myriapodologica. Mémoires du Muséum National ďHistoire Naturelle., 169: 221-224.

Lindner, E.N. (2007): Einige Anmerkungen zum Vorkommen von *Stigmatogaster subterraneus* (Shaw, 1789) und *Henia vesuviana* (Newport, 1845) (Chilopoda: Geophilida) in Deutschland sowie Überblick über deren Verbreitung in Europa. Schubartiana, 2: 49-56.

Matic, Z. (1966): Classe Chilopoda, Subclasse Anamorpha. Fauna RSR, Vol. 6, fasc. 1, Bucuresti, ARSR.

McIntyre, N.E., Rango, J., Fagan, W.F., Faeth, S.H. (2001): Ground arthropod community structure in a heterogeneous urban environment. Landscape and Urban Planning, 52: 257-274.

Misirlioğlu, M. (2003): Some Chilopoda (Myriapoda) records from the city of Eskişehir. Turkish Journal of Zoology, 27: 39-41.

Mock, A. (2006): First record of *Cylindroiulus caeruleocinctus* (Diplopoda, Julidae) in Slovakia. Biologia, Bratislava, 61: 144.

Parlange, M. (1998): The city as ecosystem. Bioscience 48: 581–585.

Poser, T. (1990): The influence of litter manipulation on the centipedes of a beech wood. In: Minelli, A. (ed.): Proceedings of the 7th International Congress of Myriapodology. E.J. Brill, Leiden: 235-245.

Rebele, F. (1994): Urban ecology and special features of urban ecosystems. Global Ecology and Biogeography Letters, 4: 173-187.

Riedel, P., Navrátil, M., Tuf, I.H., Tufová, J. (in press): Terrestrial isopods (Isopoda: Oniscidea) and millipedes (Diplopoda) of the City of Olomouc. Contributions to Soil Zoology in Central Europe.

Samšiňák, K. (1981): Some species of troublesome arthropoda in buildings. Anzeiger für Schädlingskunde, Pflanzenschutz, Umweltschutz, 54 (8): 120-122.

Smith, J., Chapman, A., Eggleton, P. (2006a): Baseline biodiversity surveys of the soil macrofauna of London's green spaces. Urban Ecosystem, 9: 337–349.

Spelda, J. (2005): Imrpovements in the knowledge of the myriapod fauna of southern Germany between 1988 and 2005 (Myriapoda: Chilopoda, Diplopoda, Pauropoda, Symphyla). Peckiana, 4: 101-129.

Stoev, P. (2004): Myriapoda (Chilopoda, Diplopoda) in urban environments in the city of Sofia. In: Penev, L., Niemelä, J., Kotze, D.J., Chipev, N. (eds.): Ecology of the City of Sofia. Species and Communities in an Urban Environment. Pensoft Publisher, Sofia-Moscow: 299-306.

Tajovský, K. (1998a): Mnohonožky (Diplopoda), stonožky (Chilopoda) a suchozemští stejnonožci (Oniscidea) NP Podyjí. [Millipedes (Diplopoda), centiupedes (Chilopoda) and terrestrial isopods (Oniscidea) of Podyjí National Park.] In: Zoologické dny Brno 1998. Abstrakta referátů z konference 5. a 6. listopadu 1998, 1 p.

Tajovský, K. (1998b): Terrestrial arthropods (Oniscidea, Diplopoda, Chilopoda) of Labské pískovce Protected Landscape Area (North Bohemia, Czech Republic). In: Pižl, V. Tajovský, K. (eds.): Soil Zoological Problems in Central Europe. Proc. 4th CEWSZ, České Budějovice: 235-242.

Tajovský, K. (2002): Terrestrial arthropods (Oniscidea, Diplopoda, Chilopoda) of the sandstone and adjancent habitats in Bohemian Switzerland National Park. In: Kopřivová, L. (ed.): Sandstone Landscapes: Diversity, Ecology and Conservation. 14-20 September, 2002, Doubice in Saxonian-Bohemian Switzerland, Czech Republic. Abstract book: 33

Tajovský, K., Mlejnek, R. (2007): Nálezy nových druhů troglofilních mnohonožek. [New troglophilous millipede species records.] Ochrana přírody, 62: 19-20.

Ter Braak, C.J.F., Šmilauer, P., (1998): CANOCO Reference Manual and User´s Guide to Canoco for Windows: Software for Canonical Community Ordination (version 4). Microcomputer Power, Ithaca, 352 pp.

Tischler, W. (1980): Asseln (Isopoda) und Tausenfüßer (Myriopoda) eines Stadtparks im Vergleich mit der Umgebung der Stadt: zum Problem der Urbanbiologie. Drosera, 1: 41-52.

Tuf, I.H., Tufová, J. (in press): Proposal of ecological classification of centipede, millipede and terrestrial isopod faunas for evaluation of habitat quality in Czech Republic. Časopis Slezského Zemského Muzea Opava (A), 51: XX-XX, 2008.

Vališ, J. (1902): Příspěvky k poznání moravské myriopodofauny. [Contribution to knowledge of Moravian Myriapoda]. Časopis vlasteneckého spolku musejního v Olomouci, 19: 20-27.

Vilisics, F., Elek, Z., Lövei, G.L., Hornung, E. (2007): Composition of terrestrial isopod assemblages along an urbanisation gradient in Denmark. Pedobiologia, 51: 45-53.

Weigman, G. (1989): Soil zoology as an instrument of urban planning. In: Report on MAB workshop "International scientific workshop on soils and soil zoology in urban ecosystems as a basis for management and use of green/open spaces, Berlin 1986". MAB-Mitteilungen 30: 125-138.

Wytwer, J. (1990): Chilopoda of linden-oak-hornbeam (*Tilio-Carpinetum*) and thermophilous oak forests (*Potentillo albae-Quercetum*) of the Mazovian Lowland. Fragmenta faunistica, 34: 73-94.

Wytwer, J. (1992): Chilopoda communities of the fresh pine forests of Poland. Bericht des Naturwissenschaftlich-medizinischen Vereins in Innsbruck, 10: 205-211.

Wytwer, J. (1995): Faunistical relationships between Chilopoda of forest and urban habitats in Mazowia. Fragmenta faunistica, 38: 87-133.

Wytwer, J. (1996): Chilopoda of urban greens in Warsaw. In: Geoffroy, J.-J., Mauries, J.-P., Nguyen Duy-Jacquemin, M., (eds.): Acta Myriapodologica. Mémoires du Muséum National d'Histoire Naturelle, 169: 213-220.

Zapparoli, M. (1992): Centipedes in urban environments: records from the city of Rome (Italy). Bericht des Naturwissenschaftlich-medizinischen Vereins in Innsbruck, 10: 231-236.

Tab. 1: List of centipede and millipede species in Jičín. Presence of species (localities 01-15, data from pitfall traps and soil samples). Number of individuals (pitfall traps / soil samples / individual collecting). D – dominance (%; pitfall traps / soil samples)

	localities J															Number	
CENTIPEDES	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	of ind.	D
Lithobius agilis L.Koch, 1847	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 0	0.0 / 0.0
Lithobius burzenlandicus Verhoeff, 1934	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 0	0.0 / 0.0
Lithobius crassipes L.Koch, 1862	-	-	-	-	-	-	-	-	-	-	-	-	-	-		0 / 0 / 1	0.0 / 0.0
Lithobius erythrocephalus C.L.Koch, 1847	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 0	0.0 / 0.0
Lithobius forficatus Linnaeus, 1758	+	+	+	-	+	+	+	-	+	+	+	+	+	+	+	67 / 0 / 49	50.0 / 0.0
Lithobius macilentus L.Koch, 1862	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	2 / 0 / 0	1.5 / 0.0
Lithobius melanops Newport, 1845	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	2 / 0 / 1	1.5 / 0.0
Lithobius microps Meinert, 1868	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	43 / 77 / 19	32.1 / 50.0
Lithobius mutabilis L.Koch, 1862	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	1 / 0 / 0	0.7 / 0.0
Schendyla montana (Attems, 1895)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 0	0.0 / 0.0
Schendyla nemorensis (C.L.Koch, 1836)	-	+	+	+	+	+	-	+	+	+	+	+	+	+	+	6 / 45 / 2	4.5 / 29.2
Clinopodes flavidus C.L.Koch, 1847	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	2 / 0 / 23	1.5 / 0.0
Geophilus electricus (Linnaeus, 1758)	+	-	+	-	+	-	-	+	+	-	+	+	+	-	+	4 / 15 / 10	3.0 / 9.7
Geophilus flavus (DeGeer, 1778)	-	-	+	+	+	-	-	+	+	-	-	+	+	-	-	6 / 12 / 19	4.5 / 7.8
Geophilus insculptus Attems 1895	-	-	+	-	-	+	+	-	-	-	+	-	-	-	-	0 / 4 / 0	0.0 / 2.6
Geophilus oligopus (Attems, 1895)	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	0 / 1 / 0	0.0 / 0.6
Geophilus pygmaeus Latzel, 1880	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 0	0.0 / 0.0
Henia illyrica (Meinert, 1870)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 1	0.0 / 0.0
Henia vesuviana (Newport, 1845)	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	1 / 0 / 0	0.7 / 0.0
Strigamia transsilvanica (Verhoeff, 1928)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 1	0.0 / 0.0
Sum of individuals	3	15	19	12	28	19	5	17	18	25	45	27	16	29	10		
Number of species	2	5	8	4	5	5	3	4	5	3	5	5	7	4	4		
MILLIPEDES																	
Mastigona bosniensis (Verhoeff, 1897)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 0	0.0 / 0.0
Craspedosoma transsilvanicum (Verhoeff, 1897)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 0	0.0 / 0.0
Melogona voigti (Verhoeff, 1899)	-	-	+	+	+	+	+	-	+	+	-	+	-	-	-	10 / 5 / 3	2.6 / 4.2
Blaniulus guttulatus (Fabricius, 1798)	+	+	+	+	+	-	-	+	-	+	-	+	-	+	+	10 / 25 / 43	2.1 / 20.8
Choneiulus palmatus (Němec, 1895)	+	+	-	-	+	+	-	-	-	-	-	-	+	-	-	10 / 3 / 28	2.6 / 2.5
Proteroiulus fuscus (Am Stein, 1857)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 0	0.0 / 0.0
Brachyiululs bagnalli (Curtis, 1845)	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	2 / 0 / 3	0.5 / 0.0
Cylindroiulus boleti (C.L.Koch, 1847)	-	-	-	-	-	-	-	-	-	-	-	-	-	-		0 / 0 / 0	0.0 / 0.0
Cylindroiulus caeruleocinctus (Wood, 1864)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 0	0.0 / 0.0
Cylindroiulus latestriatus (Curtis, 1845)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 0	0.0 / 0.0
Allajulus nitidus (Verhoeff, 1891)	+	-	-	+	-	+	+	+	-	-	+	-	-	-	-	35 / 26 / 15	9.0 / 21.7
Julus scandinavius Latzel, 1884	-	-	+	+	-	+	+	-	-	-	+	-	-	+	-	24 / 0 / 1	6.2 / 0.0
Kryphioiulus occultus (C.L.Koch, 1847)	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	15 / 8 / 17	3.8 / 6.7
Megaphyllum unilineatum (C.L.Koch, 1838)	-	-	-	-	-	-	-	-	-	-	-	-	-	-		0 / 0 / 0	0.0 / 0.0
Ommatoiulus sabulosus (Linnaeus, 1758)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 0	0.0 / 0.0
Ophyiulus pilosus (Newport, 1842)	+	-	+	+	-	+	+	+	-	+	+	-	-	+	-	57 / 31 / 42	14.6 / 25.8
Unciger foetidus (C.L.Koch, 1838)	-	-	-	-	+	-	-	-	+	+	-	-	-	+	-	13 / 0 / 3	3.3 / 0.0
Unciger transsilvanicus (Verhoeff, 1899)	+	-	+	-	-	-	-	+	+	-	-	+	+	+	-	18 / 0 / 0	4.6 / 0.0
Strongylosoma stigmatosum (Eichwald, 1830)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 0	0.0 / 0.0
Brachydesmus superus Latzel, 1884	-	-	+	+	+	+	+	-	+	+	+	+	+	+	-	57 / 18 / 37	14.6 / 15.0
Polydesmus complanatus (Linnaeus, 1761)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 0	0.0 / 0.0
Polydesmus denticulatus C.L.Koch, 1847	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	3 / 0 / 1	0.8 / 0.0
Polydesmus inconstans Latzel, 1884	-	+	+	+	+	-	-	-	+	+	+	+	+	-	+	138 / 4 / 47	35.4 / 3.3
Sum of individuals	5	17	33	36	38	41	51	52	26	28	21	20	11	29	2		
Number of species	5	3	8	8	9	6	6	4	5	6	5	5	4	6	2		
Shannon-Weaver index of species diversity	2.5	2.5	3.2	2.6	3.0	2.1	2.1	1.3	2.0	2.5	2.5	2.2	1.5	2.7	1.8		

Tab. 2: List of centipede and millipede species recorded in Hodonín. Presence of species (localities 01-15, data from pitfall traps and soil samples). Number of individuals (pitfall traps / soil samples / individual collecting). D – dominance (%; pitfall traps / soil samples)

	localities H															Number	
CENTIPEDES	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	of ind.	D
Lithobius agilis L.Koch, 1847	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 1	0.0 / 0.0
Lithobius burzenlandicus Verhoeff, 1934	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	0 / 3 / 0	0.0 / 3.0
Lithobius crassipes L.Koch, 1862	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 0	0.0 / 0.0
Lithobius erythrocephalus C.L.Koch, 1847	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	3 / 0 / 0	0.7 / 0.0
Lithobius forficatus Linnaeus, 1758	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	306 / 0 / 45	66.7 / 0.0
Lithobius macilentus L.Koch, 1862	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 0	0.0 / 0.0
Lithobius melanops Newport, 1845	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 1	0.0 / 0.0
Lithobius microps Meinert, 1868	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	89 / 57 / 8	19.4 / 57.6
Lithobius mutabilis L.Koch, 1862	-	+	+	+	+	-	-	-	-	-	-	+	+	+	+	35 / 0 / 0	7.6 / 0.0
Schendyla montana (Attems, 1895)	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	1 / 0 / 0	0.2 / 0.0
Schendyla nemorensis (C.L.Koch, 1836)	+	-	+	+	+	+	+	+	+	+	+	+	-	-	-	15 / 37 / 1	3.3 / 37.4
Clinopodes flavidus C.L.Koch, 1847	+	+	-	-	+	-	-	+	+	+	-	-	-	+	-	8.2.2019	1.7 / 2.0
Geophilus electricus (Linnaeus, 1758)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 0	0.0 / 0.0
Geophilus flavus (DeGeer, 1778)	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	1 / 0 / 0	0.2 / 0.0
Geophilus insculptus Attems 1895	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 0	0.0 / 0.0
Geophilus oligopus (Attems, 1895)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 0	0.0 / 0.0
Geophilus pygmaeus Latzel, 1880	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	1 / 0 / 0	0.2 / 0.0
Henia illyrica (Meinert, 1870)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 9	0.0 / 0.0
Henia vesuviana (Newport, 1845)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 0	0.0 / 0.0
Strigamia transsilvanica (Verhoeff, 1928)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 0	0.0 / 0.0
Sum of individuals	68	42	37	72	63	15	13	18	52	9	30	79	15	34	11		
Number of species	6	6	4	6	8	3	3	4	4	5	2	5	3	5	3		
MILLIPEDES																	
Mastigona bosniensis (Verhoeff, 1897)	+	+	-	+	+	-	-	-	-	-	-	-	-	+	-	44 / 0 / 0	4.6 / 0.0
Craspedosoma transsilvanicum (Verhoeff, 1897)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2 / 0 / 0	0.2 / 0.0
Melogona voigti (Verhoeff, 1899)	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	3 / 2 / 0	0.3 / 4.0
Blaniulus guttulatus (Fabricius, 1798)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1 / 0 / 0	0.1 / 0.0
Choneiulus palmatus (Němec, 1895)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 0	0.0 / 0.0
Proteroiulus fuscus (Am Stein, 1857)	+	-	-	+	-	-	-	-	+	-	-	-	+	+	+	24 / 2 / 0	2.5 / 4.0
Brachyiululs bagnalli (Curtis, 1845)	+	-	-	-	-	+	-	-	+	+	+	-	+	+	+	200 / 12 / 0	20.9 / 24.0
Cylindroiulus boleti (C.L.Koch, 1847)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 2	0.0 / 0.0
Cylindroiulus caeruleocinctus (Wood, 1864)	+	+	-	+	+	+	+	+	+	+	-	+	-	+	+	226 / 8 / 110	23.6 / 16.0
Cylindroiulus latestriatus (Curtis, 1845)	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	6 / 0 / 0	0.6 / 0.0
Allajulus nitidus (Verhoeff, 1891)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 0	0.0 / 0.0
Julus scandinavius Latzel, 1884	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	2 / 0 / 0	0.2 / 0.0
Kryphioiulus occultus (C.L.Koch, 1847)	+	+	+	+	-	-	-	-	+	-	+	-	-	+	-	57 / 22 / 11	5.9 / 44.0
Megaphyllum unilineatum (C.L.Koch, 1838)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 1	0.0 / 0.0
Ommatoiulus sabulosus (Linnaeus, 1758)	-	+	+	+	-	-	-	-	-	-	-	-	-	+	-	97 / 0 / 0	10.1 / 0.0
Ophyiulus pilosus (Newport, 1842)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 0	0.0 / 0.0
Unciger foetidus (C.L.Koch, 1838)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 0	0.0 / 0.0
Unciger transsilvanicus (Verhoeff, 1899)	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	2 / 0 / 0	0.2 / 0.0
Strongylosoma stigmatosum (Eichwald, 1830)	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	1 / 0 / 0	0.1 / 0.0
Brachydesmus superus Latzel, 1884	+	-	-	+	-	-	-	-	+	+	-	+	-	+	+	17 / 4 / 2	1.8 / 8.0
Polydesmus complanatus (Linnaeus, 1761)	+	+	+	+	-	+	-	+	+	+	+	+	+	+	+	276 / 0 / 2	28.8 / 0.0
Polydesmus denticulatus C.L.Koch, 1847	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0 / 0 / 0	0.0 / 0.0
Polydesmus inconstans Latzel, 1884	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1 / 0 / 0	0.1 / 0.0
Sum of individuals	179	138	20	96	10	109	2	6	80	25	5	35	20	167	117		
Number of species	9	7	4	6	1	3	1	2	6	4	3	4	3	9	5		
Shannon-Weaver index of species diversity	2.3	2.8	2	2.2	2.3	0.8	2	2	2.6	2.5	1.3	1.7	2.1	2.8	1.2		

Tab. 3: Significance of environmental variables for centipede and millipede distribution (F-test and p-value by CCA in CANOCO)

Variable	F	P
amount of humus	12.77	0.002
amount of litter	10.23	0.002
pH	7.51	0.002
Ca	7.61	0.002
herbal layer	6.35	0.002
ruderal site	6.24	0.002
soil structure	5.13	0.002
artificiality	4.56	0.002
park	3.55	0.002
canopy layer	3.36	0.002

Fig. 1: CCA plot of distribution of centipedes and millipedes in relation to environmental variables (data from pitfall traps)

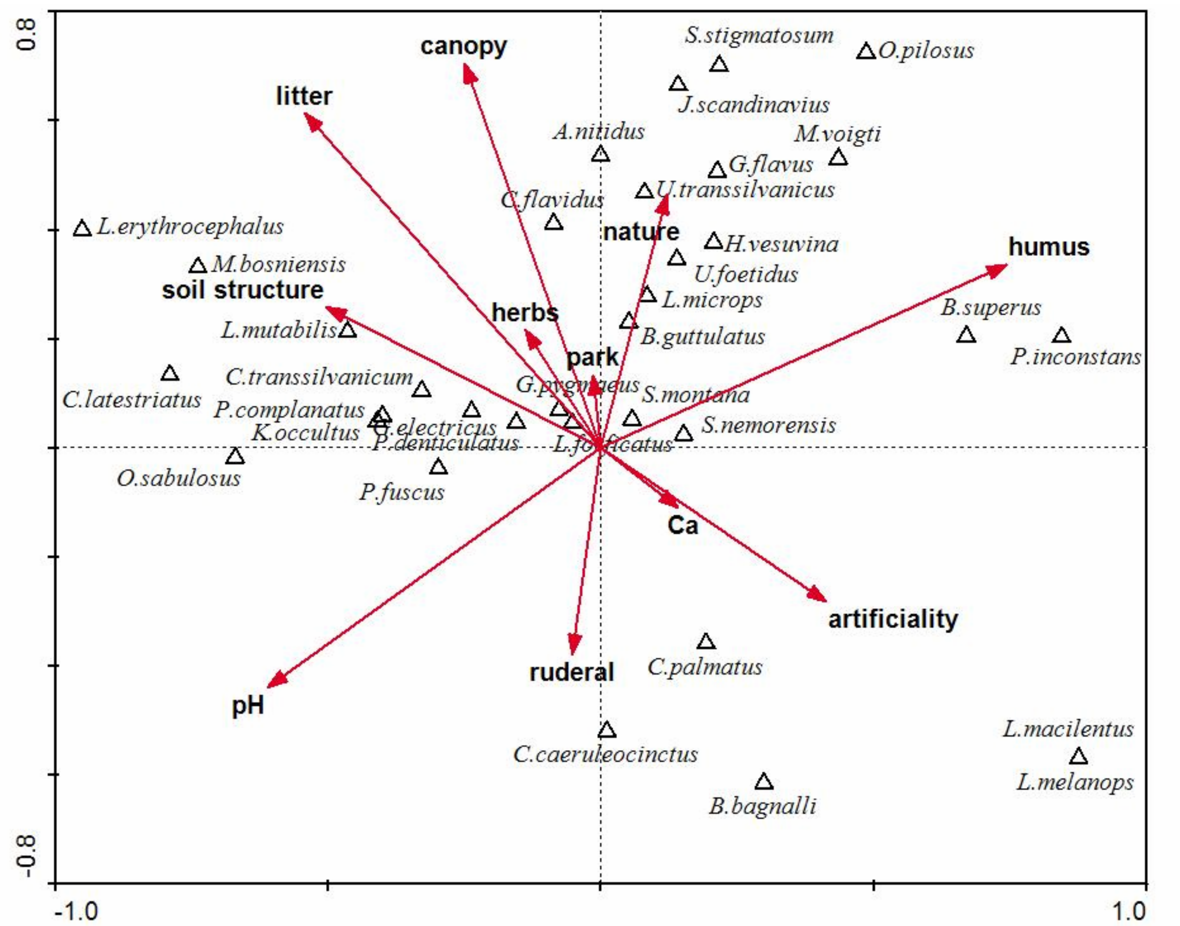


Fig. 2: Generalized additive model (GAM) for millipede species and the variable amount of humus

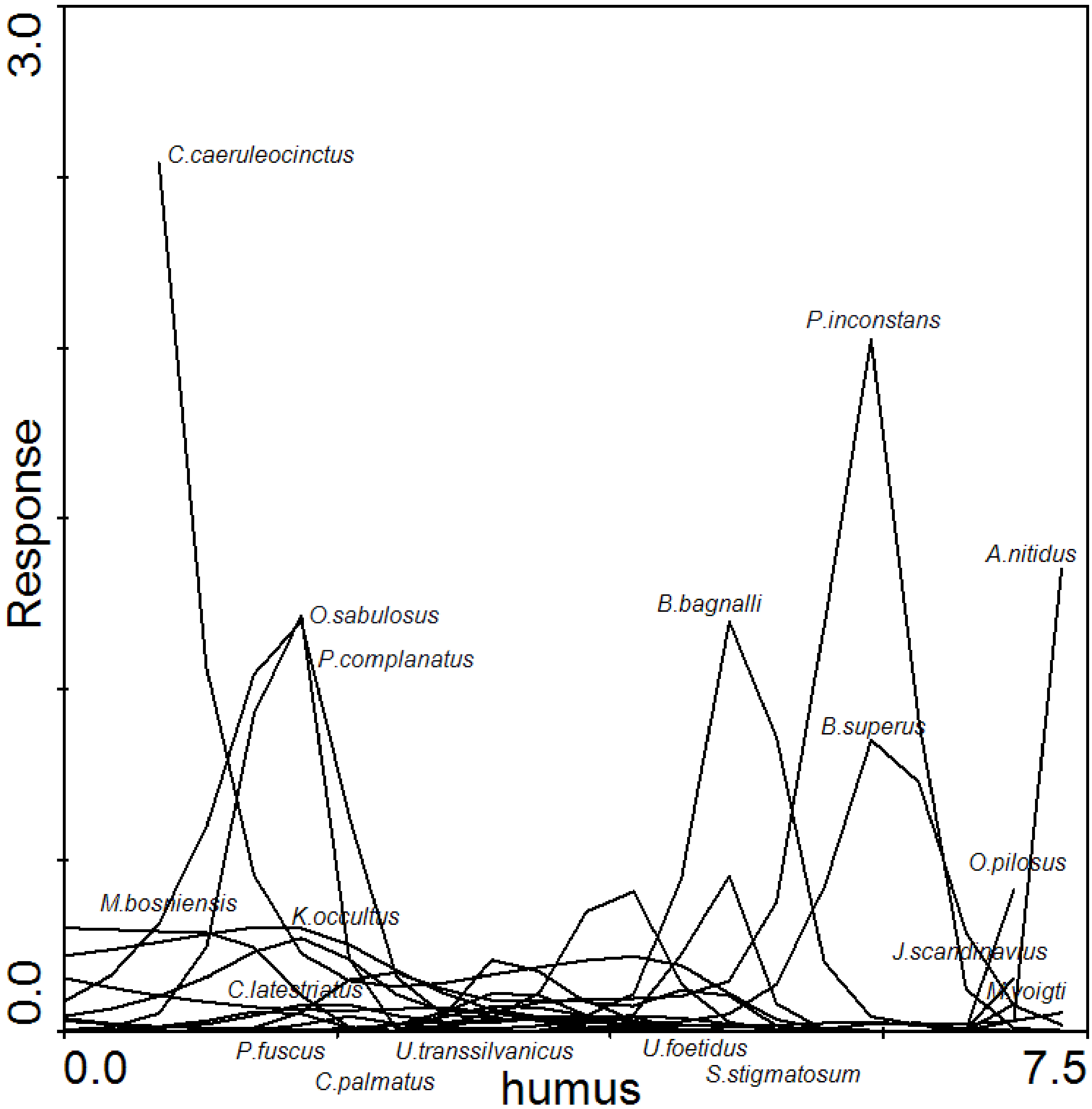


Fig. 3: Generalized additive model (GAM) for millipede species and the variable amount of litter

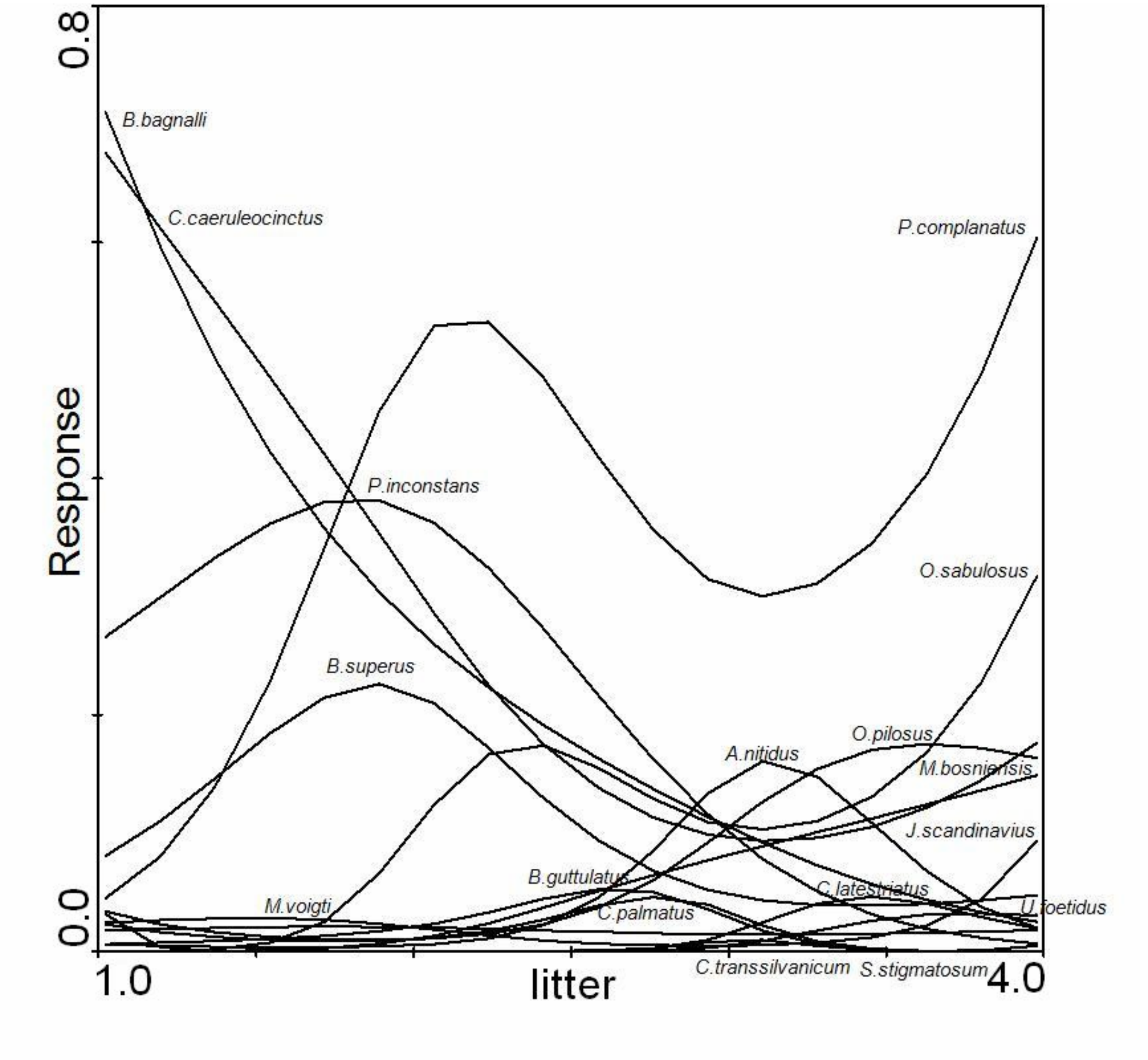
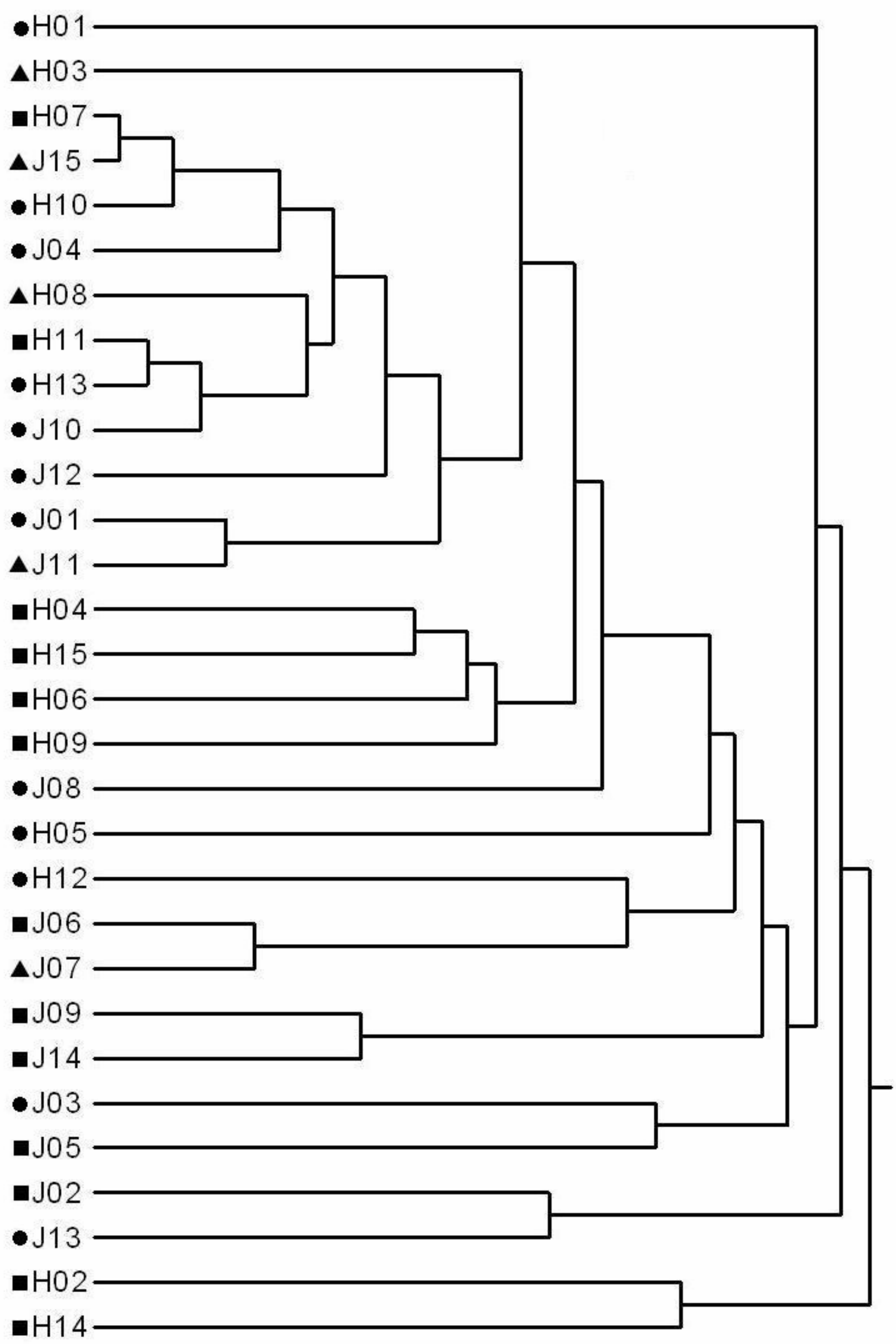


Fig. 4: Dendrogram of localities classified according to catches of centipede and millipede species trapped using pitfall traps (J – Jičín, H – Hodonín; ● park locality, ■·ruderal locality, ▲ natural locality).



4 Summary

The submitted thesis presents a part of a wider research project, conducted in three Czech cities lying in different parts of the Czech Republic: Olomouc, Jičín and Hodonín. The objects of research were communities of centipedes, millipedes and terrestrial isopods. The aim of the study was contribution to knowledge about how these animals respond to urbanization and what conditions and habitats they prefer in urban area. The benefit of the research is also knowledge of species spectrum of investigated cities.

Individuals were obtained using pitfall traps, heat extraction and individually collected by hand. Totally 90 traps were installed in Olomouc, 45 in Jičín and 45 in Hodonín in various localities, subsuming parks, built up areas and ruderal grounds. Basic environmental characteristics of these localities were evaluated.

The first manuscript (accepted for publication in Contributions to Soil Zoology in Central Europe) deals with distribution of terrestrial isopods and millipedes in the city of Olomouc. Studied animals were collected during 9 months (2006). Environmental conditions were evaluated using following variables: amount of litter, coverage by herbal and canopy layer, structure of soil and rate of artificiality of locality.

The highest mean number of trapped isopods was in ruderals; the lowest in natural sites. Quite the contrary, the highest values of Shannon-Weaver index of biodiversity were reached in natural sites and the lowest in ruderal sites. Distribution of millipedes showed the exactly converse pattern; millipedes were the most abundant in natural sites where the diversity was the lowest. The most important factor for both groups appears to be artificiality; the response is mostly negative.

The most interesting faunistical records from Olomouc were *Armadillidium nasatum* (Mediterranean species found in the greenhouses of the Botanical Garden), *Androniscus roseus* and *Haplophtalmus danicus* (the second known locality from Moravia). The most interesting millipede species was *Oxidus gracilis* (exotic species probably originating from Japan, in Olomouc recorded also outside the greenhouse).

The second manuscript is devoted to centipede and millipede faunas of Jičín and Hodonín, medium-sized settlements in Central European conditions. Animals were collected during 12 months (2006-07). The evaluated environmental characteristics were amount of litter, herbal coverage, canopy coverage, pH, amount of humus, amount of calcium, soil structure, and artificiality.

Centipedes were the most ground-active in parks and the highest mean catches of millipedes were typical at ruderal sites; while the highest abundances in soil were found at natural sites for both groups. The communities were the most diverse at natural sites (S-W index of biodiversity), followed by parks and ruderals. Evaluation of myriapods obtained using pitfall traps showed that the amount of humus in soil and amount of litter were the most important environmental factors predicting their distribution.

The most interesting faunistical records from Jičín were *Henia vesuviana* (the first record for the Czech Republic) and specimens of genus *Brachychaeteuma* (the first record in CR out of caves). From Hodonín we recorded *Geophilus pygmaeus* (the second record in CR after more than 100 years) and *Schendyla montana* (the first record for Moravia). Other interesting species were *Craspedosoma transsilvanicum*, *Allajulus nitidus*, *Geophilus oligopus*, and *Lithobius burzenlandicus*.

Results from all three cities show that urban areas are occupied chiefly by adaptable or eurytopic species, only few species may by considered as relics, i.e. inhabitants of undisturbed areas. On the other hand, city ecosystem is also often enriched with exotic species and thus affords a chance for interesting faunistic records.