ABUNDANCE AND DIVERSITY OF EPIGEIC INVERTEBRATES IN AGRICULTURAL HABITAT MOSAIC: ORCHARD AREA CASE

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AGRICULTURAL, EN CONCRETO EN EL CASO DEL HUERTO

RESUMEN

El presente trabajo está basado en analizar y comparar la abundancia y diversidad de los invertebrados epigeos de distintos hábitats agrícolas. Además, tratamos de estimar si un hábitat agricultural heterogéneo mejora o empeora la diversidad biológica de la fauna epigea invertebrada del lugar. La recogida se realizó en la parte sur de Polonia, en una granja frutícola cerca de Cracovia. La fauna epigea se recolecta mediante el uso de trampas de fallas en cuatro tipos de hábitat: huerto, pradera, arbusto y bosque. En total se recolectaron 1695 ejemplares pertenecientes a 11 taxones. Los siguientes grupos fueron identificados en el material recolectado: Coleoptera, Hymenoptera, Araneae, Mollusca, Diptera, Crustacea, Diplopoda, Earthworms, Lepidoptera, Dermaptera y Chilopoda. La abundancia media de determinados taxones de invertebrados fue diversa entre los tipos de hábitat. En el caso de praderas y huertos, se observó la mayor abundancia de Coleoptera, Hymenoptera, Diptera, Lepidoptera y Araneae. Por otro lado, Mollusca, Crustacea, Diplopoda y Chilopoda fueron las más abundantes en arbustos y bosques. Según los parámetros de ensamblajes de Carabid que se utilizaron como bioindicadores, los resultados mostraron diferencias significativas entre los tipos de hábitat. Los resultados revelaron que el mosaico heterogéneo de hábitat en el paisaje agrícola desempeña una función importante en el mantenimiento de una alta diversidad biológica.

Palabras clave:

Invertebrado, Carabidae, huerto, prado, arbustos, bosque, trampa

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ABSTRACT

The present work is based on analyzing and comparing the abundance and diversity of the epigeic invertebrates in different agricultural habitats. In addition, the aim of the study was to estimate if a heterogeneous agricultural habitats improve the biological diversity of the invertebrate fauna. The survey was conducted in southern part of Poland, in fruit-growing farm near the Krakow. Epigeic fauna was collected by using pitfall traps in four habitat types: orchard, meadow, shrub and forest. In total 1695 specimen belonging to 11 taxa were collected. The following groups were identified in the collected material: Coleoptera, Hymenoptera, Araneae, Mollusca, Diptera, Crustacea, Diplopoda, Earthworms, Lepidoptera, Dermaptera and Chilopoda. The mean abundance of particular invertebrate taxa was diverse among habitat types. In case of meadow and orchard area the highest abundance was noticed for Coleoptera, Hymenoptera, Diptera, Lepidoptera and Araneae. On the other hand Mollusca, Crustacea, Diplopoda and Chilopoda were the most abundant in shrub and forest area. According to Carabid assemblages parameters which was used as bioindicators, the results showed significant differences among habitat types. The results revealed that heterogenous mosaic of habitat in agricultural landscape play important function in maintenance of high biological diversity.

Key Words:

invertebrates, Carabidae, orchards, meadows, shrubs, forest, pitfall traps.

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Table of contents

Figures

Tables

List of abbreviations

ANOVA: Analysis of variance

NMDS: Non-metric multidimensional scaling

SIMPER: Similarity percentage analyses

ANOSIM: Analysis of similarities

List of scientific names

Coleoptera

Carabidae

Formicidae

Halictidae Apidae

Asiliidae

Syrphidae

Cicindelidae

Hydrophilidae

Nitidulidae

Tenebrionidae

Chrysomelidae

Arctiidae

Notodontidae

Maculinea alcon

Scarabaeidae

Cerambycidae

Hymenoptera

Crustacea

Araneae

Diplopoda

Amphiphoda

Isopoda

Mollusca

Diptera

Dermaptera

Chilopoda

Lepidoptera

Elateridae

Curculionidae

Byrrhidae

Staphylinidae

Silphidae

Dermestidae

Leistus spinibarbis

Pseudoophonus rufipes

Carabus convexus

Chlaenius tibalis

Harpalus affinis

Trichotichnus laevicollis

Platinus assimilis

Microlestes maurus

Amara fluvipes

Bembidion pygmaeum

Carabus granulatus

Amara communis

Pterostichus melanarius

Carabus arvensis

Carabus nemoralis

Leistus assimilis

Pterostichus minor

Pterostichus oblongopunctatus

Amara lucida

Abax parallelepipedus

Harpalus latus

Harpalus griseus

Ophonus puncticollis

Pterostichus niger

Carabida larvae

Calathus erratus

Bembidion lampros

Amara aenea

Amara plebeja

Calathus fuscipes

Anisodactylus binotatus

Leistus spinibarbis

Harpalus affinis

Pterostichus oblongopunctatus

Pterostichus niger

1. INTRODUCTION

1.1. DIVERSITY OF CULTIVATED AGRICULTURAL LANDSCAPE

Nowadays, it is a fact that there is a negative impact on native species and habitats by the use of the agricultural landscapes, especially by introduction of exotic species, pesticides and fertilizers, grazing and modification of natural habitats (Pimentel et al.,1992; McLaughlin and Mineau, 1995). The alteration of the soil structure produced by agricultural activities has a significant influence on the diversity and abundance of the epigeic and soil invertebrates fauna, proof of this is that the major driver of recent arthropod species loss is the intensification of agricultural practices. There are so many things that influence on diversity of the agriculture land, like: habitat heterogeneity disturbance, fertilization, tillage, the use of herbicides, pesticides, type of farming system or, even, characteristics of field borders and border management.

Among the epigeic invertebrate fauna, ground beetles (*Coleoptera*, *Carabidae*) play an essential role in many ecosystems and they are influenced by agricultural practices, as several studies have hightlighted (Hance and Grégoire-Wibo, 1987; Kromp, 1999, Holland and Luff, 2000). They usually are found in higher diversity and abundance in less intensively using agricultural landscape or systems with reduced chemical input (Attwood et al., 2008). For example, ground beetle assemblages are affected by the system of farming (organic versus conventional farm), generally showing greater abundance and diversity in organic farms than in conventional (Kromp, 1989; Cárcamo et al., 1995; Bengtsson et al., 2005). Furthermore, ground beetle assemblages can be strongly influenced by tillage (Cárcamo, 1995; Menalled et al., 2007; Nash et al., 2008), crop rotation and land use (Booij and Noorlander, 1992; Ellsbury et al., 1998; Dauber et al., 2005), fertilization (Söderström et al., 2001) and the use of pesticides (Ellsbury et al., 1998; Epstein et al., 2001; Nash et al., 2008). Its assemblages in the border depend on the characteristics of field borders, it means width, richness and composition of the vegetation; and border management: mowing and fertilization (Sotherton, 1985; Woodcock et al., 2005; Griffiths et al., 2007; Woodcock et al., 2007). The adjacent field must be considered too (Lys et al., 1994; Varchola and Dunn, 2001). For instance, Van Alebeek et al. (2006) found twice as many ground beetles in uncut field borders than in bare soils, providing evidence for the need to conserve the vegetation beside fields. Landscape structure also affects ground beetle communities (Purtauf et al., 2005a). Referring to landscape structure, many studies have shown the positive effect of landscape heterogeneity (Weibull and Östman, 2003, Weibull et al., 2003, Ekroos et al., 2010) on ground beetle assemblage and non-crop areas (Purtauf et al., 2005a; Werling and Gratton, 2008; Perovic et al., 2010). In particular, Dauber et al. (2005) demonstrated that ground beetle richness was positively correlated with the length of forest edges, and Hendrickx et al. (2007) proved that ground beetle diversity increased with the proximity of semi-natural habitat patches, confirming the need to conserve non-crop areas in agricultural landscapes.

In addition, zones that may offer an opportunity to conserve biodiversity while maintaining food production are those agricultural landscapes where mosaics of farmland habitats and remnant natural habitats of woodlots, hedgerows, shelterbelts, and riparian have been maintained (Paoletti et al., 1992). It has to be mention that hedgerow and riparian habitats are especially valuable for conservation of plant diversity in agricultural landscapes (Bunce and Hallam, 1993; Boutin et al., 2002) and agricultural lands which have a huge variety of habitats help to maintenance beneficial invertebrates (Altieri and Nicholls, 1999), so diversity of plant species and its conservation is essential to improve habitats for terrestrial species in agricultural landscapes.

it needs to be highlighted that biological diversity plays such important role in agricultural landscape due to it provides us the food and the means to produce it. The diversity of plants and animals that we consume are components of agricultural diversity that we can appreciate with the naked eye. Equally important, although less visible, are the thousands of organisms present in the soil, pollinators and natural enemies of pests and diseases, whose regulatory function constitutes the support of agricultural production. One measure of diversity conservation is creating and preserving a heterogeneous habitat mosaic, which has been shown to be correlated in a positive way with diversity levels (e.g. Brose, 2003; Smith et al., 2004; Herzon & O'Hara, 2007). Increasing habitat diversity in agrarian landscapes is also regarded as a pest management practice by bolstering the diversity of natural enemy populations.

1.2. BIOINDICATION AS A METHOD OF ECOLOGICAL RESEARCH

We can estimate the diversity and ecological quality in agricultural areas with the use of bioindicators, they have proved to be a useful tool for monitoring and detecting changes in the environment. In this project, I decided to use the invertebrates as bioindicators of ecological quality of environment. One of the primary goals of research on bioindicators is to identify species or other taxonomic units that would reliably indicate disturbances in the environment as well as reflect the responses of other species or the overall biodiversity.

A bioindicator can be loosely defined as a species or a species group that reflects the abiotic or biotic state of the environment, represents the impact of environmental change on a habitat, community or ecosystems, or indicates the diversity of other species (McGeoch, 1998). Indicators can be: environmental indicator, used to monitor a specific ecosystem stress ecological indicator or biodiversity indicator (McGeoch 1998, 2007). All three categories of bioindicators may not necessarily be mutually exclusive. Uses of bioindicators may be combined into a bioindicator system (van Straalen and Krivolutsky, 1996) on which site management decisions may be based. Bioindicators may also be used for conservation prioritisation (assessments using spatial comparisons of site value), monitoring of ecosystem recovery, or response to management. The reliability of these indicators and resultant systems depends on their appropriateness to the issue being investigated, as well as the quality of the assessment or of the monitoring data. In view of this, we are only able to overview general guidelines on research undertaken to date on what appear to be suitable taxonomic groups (with associated functions) for activities such as prioritization of sites, determining the success of restoration, investigating effective conservation management. It is beyond this overview to be able to give specific recommendations on which actual species to use in particular geographic localities.

One example of a well know bioindicator are lichens. These plants are very sensitive to toxins in the air. This is because they obtain their nutrients mostly from the air. There is posibility to estimate the quality of air by the amount and types of lichens on the trees. Different species of lichens have different levels of susceptibility to air pollution, so it can be also get an idea of the level of pollution by observing which species are present.

Which species can be a good bioindicator? First of all, they should be species, in general, abundant, sensitive in certain aspects, easily and quickly identifiable, with little mobility and of course they must have been well studied beforehand, both their ecology and their biological cycle. Among very diverse and abundant group of biota invertebrates are very good bioindicators.

Invertebrates are more diverse and abundant than vertebrates, for that reason invertebrates can show species richness and community composition more accurately, moreover, they are more cost-effective to use (Kremen et al., 1993; Bisvac and Majer, 1999). In addition, their small size makes them sensitive to local conditions, while their mobility enables them to move in response to changing conditions. In turn, short generation times result in rapid numerical responses, and variability in ecological characteristics give a wide range of specific environmental response taxa (Samways et al., 2010a). Among epigeic invertebrates, carabid beetles are widely used as bioindicators because they are really well-known both taxonomically and ecologically, they are susceptible to standardised sampling by the use of pitfall traps, easy to preserve and they react sensitively to changes of their environment. However, there are some advantages and disadvantages of using bioindicators.

The most advantages are:

- One of the most important is their cost-effectiveness. By using bioindicators it is possible to evaluate how affected is the biota because of human activities, without the need of examining the entire biota. The species that have an early warning of change are more useful (Speller-berg, 1993).

- Bioindicators are used to assess species richness of the community. Using only a few species groups and estimating diversity of total biota e.g. through extrapolation is a quick technique (Colwell and Coddington, 1994). This is a great advantage especially in the tropics, where it is impossible to survey all species due to high species richness.

- The communities reflect many system conditions (physical, chemical, biological and ecological).

-The existence of manuals with established methods of collecting and recording information, make it possible to perform them by people without extensive knowledge of biology.

- The effects of toxic materials on organisms can be seen by bioindicators (Bridgham, 1988). This might be difficult to assess through direct toxicity level assessment in nature.

- Possibility of observing physiological effects.

- They provide data of past situations.

-Usually, easy identification of polluting sources.

The disadvantages of using bioindicators are:

-It exists the possibility that they have been previously exposed to certain elements.

-They can be influenced by the environment (soil, homogeneity of habitat structure, etc.)

-Sampling implies more time.

- Generalisation of results. A lot of terrestrial animal groups have been used as bioindicator because of their differences in the way of responding to changes (e.g. Rosenberg et al., 1986; Roth 1993; Kremen et al., 1994). In many cases selection is based more or less on personal preference (Andersen, 1999).

- Genotypic variation and age can make the study difficult.

- For taxonomic identification, experience is required.

Going back to the previous example, using invertebrates as bioindicators has also advantages and disadvantages. Species richness, species turnover and comparisons of community similarity between different landscape features are easily identified by invertebrates because they are collected in a great number. However, there are some disadvantages when using invertebrates as bioindicators. The biggest disadvantage is to recognise the taxa, because a very high number of species are unknown or are not described taxonomically, for example this is usual in tropics which are very biodiversity rich, although strategies such as parataxonomy, morphospecies, strictly designated voucher specimens (Samways et al., 2010a) and new improvements in molecular identification techniques (particularly DNA barcoding) help to solve this problem (Janzen et al., 2005).

As a result, biondicators are chosen from groups that share similar ecological characteristics around the world, such as ground beetles (Niemelä et al., 2000), dung beetles (Aguilar-Amuchastegui and Henebry, 2007) and tiger beetles (Pearson and Cassola 1992) as indicators of disturbance and habitat quality in the tropics and subtropics. Also ants have been widely used as biodiversity indicators (Majer, 1983; Alonso, 2000; Kasperi and Majer, 2000; Andersen et al., 2002), and bees to identify pollution impacts on pollinators (mainly honey bees) (Porrini et al., 2003).

1.3. CHARACTERISTIC OF INVERTEBRATES USED AS BIOINDICATORS

During the experiment, I have worked with many invertebrates, including ants, pill and sow bugs, spiders, millipedes, snails, flies, mosquitos, earthworms, wasps, bugs, earwigs, centipedes, ground beetles or butterflies. Below I would like to show an overview of the taxonomic groups which I collected.

Hymenoptera (ants and wasps)

Withing Hymenoptera, in this work we could find ants and wasps. Ants are very good bioindicators due to their high abundance, diversity and presence in almost every habitat, then are easy to capture and monitor (Majer, 1983) and because they are closely related to other organisms, mainly with vegetation, food or shelter. In addition, the ants have a direct relationship with vascular plants, so that by varying the structure of the vegetation will also change the composition of ant species or their abundance. They can also be used as indicators because they are very important in the ecosystems, because they act on many trophic levels, they are predators and prey, detritivores, mutualists, foragers, etc. (Alonso, 2000). Ants are ideal for monitoring environmental changes, because many species are little tolerant to these changes responding quickly to alterations (Kaspary and Majer, 2000), so they have been used to indicate disturbance levels (Alonso 2000; Kasperi and Majer, 2000; Andersen et al., 2002; Thomson et al., 2007; Paolucci et al., 2010), management success (Majer, 1983; Delabie et al., 2009; De Souza et al., 2010) and restoration (Dekoninck et al., 2008; Coelho et al., 2009). They may indicate invasive species (Yemshanov et al., 2011) and pollution (Pereira et al., 2010).

Ants are widely used as bioindicators, for that reason they have been divided into different functional groups, which may indicate different aspects of ecosystems (Majer et al., 1984). Most ant surveys have relied on pitfall trapping, however ant surveys can also be conducted using leaf-litter or vegetation sampling methods.

Hymenoptera are also very useful ecological indicators, with the honey bee *Apis mellifera* having been used to indicate the presence of the toxins chlorfluazuron, oxymatrine and spinosad (Rabea et al., 2010).

Table 1. Characteristics of Hymenoptera taxa group used as bioindicator

Taxa	Potential	Feeding guild	Current use	Problems
Hymenoptera	High variety, it allows a wide range of responses		Environmental and ecological indicators	Taxonomy
Formicidae	Very abundant and are known as ecological engineers	Herbivores, omnivores, fungivores, predators	They are good at determining the state of an environment which suffered any recent disturbance	Taxonomy: complex and high abundant groups
Halictidae *Apidae*	Important ecosystem providers	Nectarivores, pollenivores	They are important in agricultural landscape to monitor the health of pollination systems	Taxonomy

Crustacea (pill and bugs)

Terrestrial amphipods and isopods have been used as bioindicatos because they are often abundant. In the case of amphipods, they have been used as bioindicators in specific habitats for some characteristics because they are not very high diversity group in terrestrial habitats and they are only abundant in a few places, for that reason they are unsuitable as bioindicators of species richness. (Lawes et al., 2005; Kotze and Lawes, 2008). Their main use is in the presence of a single species as a habitat indicator rather than as a subtle indicator of system dynamics. Isopoda have higher potential due to their more widespread distribution and greater diversity. They are important for monitoring habitat restoration (Pryke and Samways, 2009; Riggins et al., 2009). They may take a long time to return to a recovered site and so indicate habitat quality or the advanced stages of habitat recovery (Pryke and Samways, 2009).

Table 2. Characteristics of Hymenoptera taxa group used as bioindicator

Taxa	Potential	Feeding guild	Current use	Problems
Crustacea				
Amphipoda	Very abundant and sensitive to desiccation	Scavengers and herbivores	None	Taxonomy
Isopoda	Abundant and important for leaf litter studies	Scavengers and herbivores	Environmental indicator in moist areas	Taxonomy

Araneae (spiders)

Spiders have been used as bioindicators in several locations due to their diversity and easy identification of some families, others are very difficult to recognize, that´s why only a few families have been used as bioindicators.

Spiders have been used as indicators of specific habitat characteristics (Jeanneret et al., 2003; Buchholz, 2010) or of habitat change (Perner and Malt, 2003; Kapoor, 2008; Magura et al., 2010). These studies usually use a group of species or families as indicators, but in exceptional circumstances a single species may have potential as an indicator when it is closely tied to specific ecological conditions; Doran et al. (1999) proposed that the Tasmanian cave spider Hickmania troglodytes may be a sensitive indicator of disturbance in and around cave entrances. In South Africa, the spider Ozyptilia sp. is indicative of disturbance ecotones (Magoba and Samways, 2012). The success of habitat management has also been indicated (Pozzi et al., 1998; Cattin et al., 2003; Cardoso et al., 2004a, b; Rodriguez et al., 2006; Scott et al., 2006; Rezac et al., 2007; Midega et al., 2008; Horvath et al. 2009), as has the success of habitat restoration (Gollan et al., 2010). As spiders are predators, they accumulate pollutants and pesticides from their prey and so can be used as ecological accumulators to indicate environmental toxin levels (Haughton et al., 2003; Jung et al., 2008; Seyyar et al., 2010). Lövei et al. (2002) have used the generalist wolf spider Pardosa amentata for screening the impacts of transgenic wheat.

Table 3. Characteristics of Araneae taxa group used as bioindicator

Taxa	Potential	Feeding guild	Current use	Problems
Araneae	Environmentally sensitive	Predators	Ecological, diversity	Identification difficult within some families

Diplopoda (millipedes)

Millipedes are good bioindicators of diversity in tropical or subtropical forests. The big problem of them is that they are very difficult to recognize. Millipedes have been used particularly as bioindicators of habitat characteristics (Kappes et al., 2009; Uys et al., 2010) and the effects of management (Halaj et al., 2009) and restoration (Snyder and Hendrix, 2008). Futhermore, they can be used as bioindicators, to a lesser extent, of the diversity of the decomposer communities.

Dispersal ability varies with family, with some being highly mobile and able to recolonize disturbed areas rapidly, whereas others are much more sedentary and sensitive to local conditions. Use of millipedes as indicators should divide the local fauna into these two dispersal and adaptation categories. In some areas, a small number of invasive species dominate the millipede assemblages (Shelley and Lehtinen, 1999) and may affect indicator reliability.

Table 4. Characteristics of Diplopoda taxa group used as bioindicator

Taxa	Potential	Feeding guild	Current use	Problems
Diplopoda	Important in wooded areas	Herbivores that prefer dead and decaying plant material	Wooded habitats	Taxonomy

Mollusca (snails)

They are not usually used as bioindicators, although they are easy to identify and easy to record in some areas. However, there are some important studies using these as bioindicators. This is the case of Sauberer et al. (2004), who indicated a correlation between Australian gastropod snail species richness and other ground-living animals like spiders, grasshoppers, ground beetles and ants.

Molluscs include both adaptable generalist species and highly sensitive taxa. They have low dispersal abilities so will reflect local conditions but not colonisation, so may be good indicators of habitat quality but not of the early stages of recovery. Many species are highly sensitive to local geological factors and this sensitivity needs to be taken into account when using molluscs as biodiversity indicators (Foeckler et al., 2006). The tissue of mussels can be used to test for toxins locally, as mussels are sessile and accumulate toxins and thus are good accumulator species (Irato et al., 2003).

Table 5. Characteristics of Mollusca taxa group used as bioindicator

Taxa	Potential	Feeding guild	Current use	Problems
Mollusca	Easy to record and easy to identify	Predators, detritivores, herbivores	Sensitive for soil and litter studies and good accumulator species	Identification in tropics

Diptera (flies and mosquitos)

Diptera are good as bioindicators due to their ecological diversity. Sometimes, the big problem is that family identification becomes very difficult, that is the reason why are rarely used as bioindicators. However, there are some families useful for the use as bioindicators. They are predators such as *Asiliidae* and pollinators such as *Syrphidae*. Some flies have been found to be sensitive to climate factors and may be used to indicate climate change (Ciamporova-Zat'ovicova et al., 2010), although this has not been investigated for most fly taxa.

Table 6. Characteristics of Diptera taxa group used as bioindicator

Taxa	Potential	Feeding guild	Current use	Problems
Diptera	High variety, it allows a wide range of responses	Various	Larvae are important indicators in freshwater systems.	Taxonomy

Chilopoda (centipedes)

The use as bioindicators of Centipede is not too high due to their low diversity in most habitats, furthermore they are poorly known in southern and lower latitudes. Centipede diversity has correlations with scorpions, some beetle taxa (*Cicindelidae, Hydrophilidae, Nitidulidae, Tenebrionidae, Chrysomelidae*) and Lepidoptera as Fattorini et al. (2011) demonstrated in Turkey. Centipedes are predators of the litter and soil fauna and are well suited to indicate diversity of organisms restricted to these systems, such as the scorpions, *Cicindelidae* and *Tenebrionidae*, as identified by Fattorini et al. (2011). Most centipedes are highly mobile, and little is known of their microhabitat sensitivity but they have been used in habitat quality indication (Kappes et al., 2009).

Table 7. Characteristics of Chilopoda taxa group used as bioindicator

Taxa	Potential	Feeding guild	Current use	Problems
Chilopoda	Keystone predator	Predators	Ecological	Taxonomy

Lepidoptera (butterflies)

Within *Lepidoptera*, butterflies are good bioindicators because of their conspicuousness and easy identification (Pollard and Yates, 1993; Dennis, 2010; Dover et al., 2011). Butterflies are used to denote changes in habitats (Hayes et al., 2009; Uehara-Prado and Freitas, 2009), changes of management, one of the most important are those changes associated with woodcutting in tropical forest (Haughton et al., 2003; Kadlec et al., 2009; Summerville et al., 2009) or changes in pollution levels (Hilbeck et al., 2008). They can be used also for indicate the quality and area of a habitat, this fact was shown by Maes and Van Dyck (2005) in Belgium with the Alcon blue butterfly *Maculinea alcon*.

Lepidoptera can correlate with other taxa, as found by Fattorini et al. (2011), this is the case of Bhardwaj et al. (2012) who discovered that butterflies were good indicators of beetle richness in the western Himalayas. They have other correlations with scorpions, centipedes or beetles. On the other hand, Predergast (1997) showed that between butterflies, dragonflies and bird species richness were poor correlations in the UK. Furthermore, Kremen demonstrated in Madagascar that butterflies are similarly poor predictors of plant diversity. Another example is given by *Arctiidae*, who indicated that correlation to ground beetles and plants was also a poor correlation (Axmacher et al., 2011). In the case of moths, moths and butterflies may have only weak correlations, the moth families *Arctiidae* and *Notodontidae* are the best indicators of total lepidopteran richness in North America (Summerville et al., 2004).

Maes and Van Dyck (2005) showed that the threatened Alcon blue butterfly *Maculinea alcon* in wet heathland in Belgium was a good indicator of the quality and area of habitat.

Table 8. Characteristics of Lepidoptera taxa group used as bioindicator

Taxa	Potential	Feeding guild	Current use	Problems
Lepidoptera	Sensitive, easy to identify	Nectivores, herbivores	Environmental and ecological indicators	Loss of sensibility due to their high mobility

Coleoptera (ground beetles)

Beetles can be considered as the representatives of insects (Hutcheson 1990) because of their diversity and their widely used as bioindicators (New 2010). However, this fact has also disadvantages, such as because it is sometimes too diverse for sampling in many habitats. Beetles have been used for too many objectives, for example to indicate specific habitat characteristics (Bishop et al., 2009), also to know disruptions of a habitat (Niemelä et al., 2000; Pearson and Cassola 2005, 2007; Kaiser et al., 2009; Song et al., 2009; Negro et al., 2010; Vasquez-Velez et al., 2010) or monitoring habitat management (Jacobs et al., 2010) and restoration (Babin-Fenske and Anand, 2010; Paoletti et al., 2010). Depending on the species, they have different functions when used as bioindicators, for instance some species are sensitive indicators of pollution, so are used for that and *Tenebrionidae* are used for post-fire recovery (Fattorini, 2010).

Within the family, the tiger beetles (*Cicindelidae*) are good bioindicators because of their easy recording, their stable taxonomy and because they are ecologically very well-known including their widespread and specialised species and their diversity patterns that correlate with other taxa (Pearson and Cassola, 1992; Fattorini et al., 2011). There are some families like *Nitidulidae*, *Tenebrionidae* and *Chrysomelidae* which are useful bioindicators. They have correlation with other taxa, like scorpions, centipedes and moths (Fattorini et al., 2011). Dung beetles (*Scarabaeidae*) are good indicators to show the diversity, they are a family quite sensitive and also dependent of present animals that can produce dung (Davis et al., 2001; Nichols et al., 2008). Dung beetles show high species turnover rates along habitat gradients (Davis et al., 1999; Spector and Ayzama, 2003; Louzada et al., 2010; Filgueiras et al., 2011), making them sensitive to habitat change (Gardner et al., 2007; Nielsen, 2007) and even to subtle changes in land use (Almeida et al., 2011). Fragmentation and isolation are also important determinates of dung beetle species distribution (Klein, 1989; Andresen, 2003; Nichols et al., 2007; Escobar et al., 2008), making them useful indicators in transformed landscapes. *Cerambycidae*, because of their easy identification, have been used as bioindicators in forest, but the correlations between saproxylic beetles and other taxa may be poor (Sverdrup-Thygeson, 2001).

Table 9. Characteristics of Coleoptera taxa group used as bioindicator

Taxa	Potential	Feeding guild	Current use	Problems
Coleoptera	Allows for a wide range of responses	Predators, nectarivores, herbivores, fungivores, detritivores, gramnivores		Taxonomy, particularly the groups of *Curculionidae* and *Chrysomelidae*
Carabidae	Predators and environmentally important	Predators	Environmental	More important in the northern hemisphere because of the scarce in southern hemisphere environments
Scarabaeidae	Sensitive to landscape changes	Nectarivores, herbivores, fungivores, detritivores	Ecological and environmental	

One of the best described group of epigeic beetle bioindicators are carabid beetles (Coleoptera, Carabidae) (Koivula, 2011). Carabids are highly diverse and sensitive to disturbances. Their taxonomy and ecology are well known. They are top predators in the soil layer with diverse habitat preferences (from very narrow to very broad) and they participate in several ecosystem processes such as herbivory, predation, granivory and mediate nutrient flows. It has been shown that the structure of carabid assemblages responds to diverse disturbances such as river degradation (Kędzior et al., 2016), agricultural practices (Kosewska et al., 2016), or forest management (Skłodowski, 2014). Most often community indices such as species composition and diversity, abundance or species richness have been used to determine the state of the natural environment (Kędzior et al., 2014). Moreover, high dispersal power (most species with flight abilities), body size modifications (toward smaller species) or reproductive potential (most species with flexible spring breeding strategy) indicate the high disturbance level in ecosystem. Moreover, focusing an attention on trophic relationships where decrease of predators abundance in relation to extinction of detritivores (e.g. earthworms and springtails) as well as increase of herbivore proportion in community is observed. It indicates the disruptions in the food webs and the slowdown of decomposition rate. They are important element of efficient matter circulation and energy flow (Loreau, 1995; Schirmel et al., 2012).

2. AIM OF THE STUDY

The overall objective of this project is to analize and compare the abundance and diversity of epigeic invertebrate assemblages from different habitats in agriculture land (orchards, meadows, shrubs and forest).

Moreover, in the study I set out to estimate if the habitat heterogeneity of agriculture land improve the biological diversity of epigeic invertebrate fauna. Increasing habitat diversity can be pointed as a pest management practice by improving the diversity of natural enemy populations, which in turn limit colonisation rates of herbivorous pests.

3. MATERIALS AND METHODS

3.1. STUDY SITE

Field studies were conducted during June of 2019 on a fruit-growing farm belonging to the University of Agriculture in Krakow. The farm is situated in the southern part of the Krakowsko-Częstochowska Plateau, in the south of Poland, in a small rural village, Garlica Murowana (Figure 1).

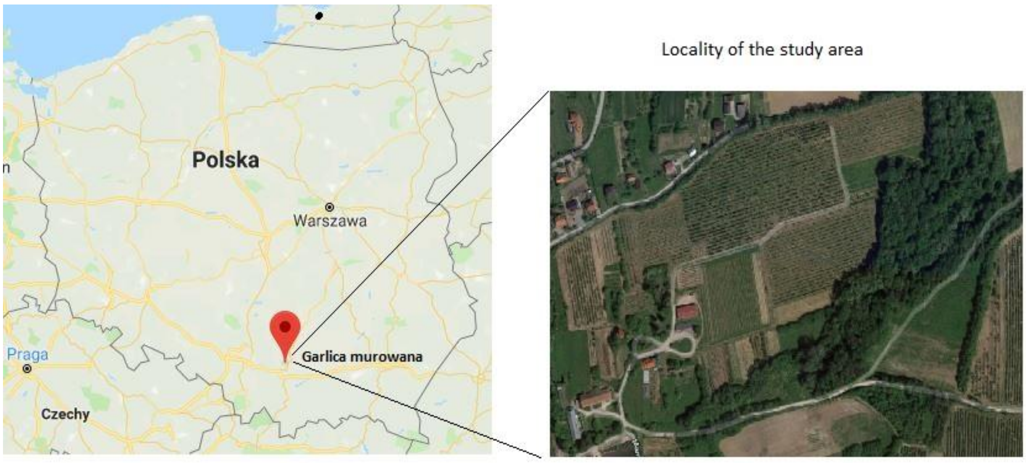

Figure 1. The map of the study area

The studied area is relatively small (~80ha), nevertheless it is characterized by distinct heterogenity of land use, which is typical for that part of the Plateau. It should be mentioned that the farm area is used by the Department of Fruit Farming and Apiculture Agricultural University in Krakow. In the studied fruit-growing farm area pesticide (Mospilan 20 SP, Karate Zeon 050 CS) and fungicide (Cuprate, Sylit 65wp, Delan 700 wg) application during growing season reached 2-4 times in the orchards, the mowing reached 2 times in meadow and 4 times in orchards.

3.2. STUDY DESIGN AND EPIGEIC FAUNA SAMPLING

Epigeic fauna was collected by using pitfall traps, in a convenient and easy to operate method (Greenslade and Greenslade, 1971) yielding highly standardized samples (Thiele, 1977; Southwood, 1978). The following equipment was used to collect invertebrates:

- Garden digger
- Plastic glass
- Sieve (Figure 4)
- Propylene glycol
- Boxes
- Drill
- Tweezers
- Magnifying glass
- Microscope
- Plastic try

To estimate the abundance and diversity of epigeic invertebrate fauna four habitat types were chosen: meadow, orchard, shrub and forest. Each kind of habitat creates heterogenous patches on the whole fruit-growing farm. For each habitat three sampling transect was randomly established for collecting epigeic invertebrates (Figure 2). In total 12 sampling transects were located in four habitats (forest, meadow, shrub, orchard).

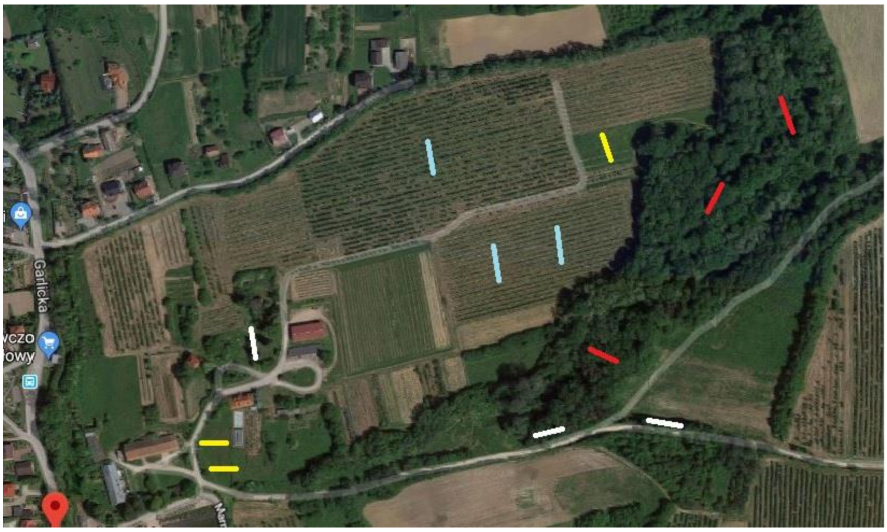

Figure 2. Sampling study design with visualization of pitfall trap transect in each habitat type (red-forest, yellow- meadow, white- shrub and blue- orchard).

Each transect consisted of three traps that were positioned 10 meters apart. The traps were plastic cups, 7 cm in diameter and 10 cm high, placed flush with the soil surface and 1/3 filled with ethylen glycol (Figure 3).

Figure 3. Setting up pitfall traps in transect (photo taken by Jorge Blanco Fuentes)

Overall 36 pitfall traps were installed at the end of the May. After two weeks they were emptied, collected, biological material were rinsed on the sieve, placed in plastic containers and preserved with alcohol (Figure 3).

Figure 4. Rinsed invertebrate sample collected from three pitfall traps belonging to individual sampling transect (photo taken by Jorge Blanco Fuentes)

3.3. LABORATORY METHODS

For comparing results of abundance and diversity, in laboratory the branches, sticks, leaves and other elements were removed from the samples and only invertebrates were selected and sorted to individual taxon groups. The results were entered to a sheet with a reference table where the sample numbers and the collected taxa of the invertebrates were written, what made the monitoring and counting of insects easier. The collected invertebrates were identified to general taxonomy level, with the exception of beetles, which have been marked to family level (White, 1983; Chinery, 1993; Hurka, 2005). Because the carabid beetles were chosen as bioindicators they were identified to species level according to specialised key (Hurka, 1996).

3.4. DATA ANALYSIS

Specimens caught at the individual sampling transects (3 traps per 1 transect) were pooled for statistical analysis. The following carabid assemblage parameters were calculated: The Shannon diversity index and Berger - Parker dominance index as well as the mean abundance and species richness.

The Shannon index is a popular diversity index in the ecological literature, and it is calculated according to the following formula:

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Where, pi is the proportion of characters belonging to the ith type of letter in the string of interest. In ecology, pi is often the proportion of individuals belonging to the ith species in the dataset of interest.

The Berger - Parker index represents the proportion of the most dominant species in the overall sample, with high levels of dominance odf a single species generally representing low levels of diversity.

Non-metric multidimensional scaling (NMDS) was performed to obtain an overview of the differences in composition of the beetle assemblages of the four habitat types: forest (F), meadow (M), shrub (S) and orchard (O). Significance of dissimilarity differences between ecosystem types was tested by ANOSIM on the Bray-Curtis dissimilarities matrix with 499 permutations of the data. The NMDS and ANOSIM were done using PAST software (version 3.13) (Past for Windows, Hammer et al., 2001).

A one-way ANOVA was carried out for ground beetle from carabids structure (abundance, species richness, Shannon and Berger- Parker index) to evaluate if significant differences exist between the diversity of carabid species assemblages recorded at different habitats (forest, meadow, shrub and orchard). This analysis was done using Statistica software (StatSoft, 12).

Similarity percentage analyses (SIMPER) were performed to determine the relative contribution of the various species to habitat types (Past for Windows, Hammer et al., 2001). It enabled the identification of species that are specific to each individual habitats.

4. RESULTS

During the field research a total of 1695 epigeic invertebrates, belonging to 11 taxes, were collected and identified. A total of 527 *Hymenoptera* (Ants and wasps), 53 *Crustacea* (Pill and bugs), 225 *Araneae* (Spiders), 10 *Diplopoda* (Millipedes), 215 *Mollusca* (Snails), 93 *Diptera* (Flies), 6 Earthworms, 1 *Dermaptera* (Earwigs), 1 *Chilopoda* (Centipedes), 6 *Lepidoptera* (Butterflies) and 558 *Coleoptera*. These 558 *Coleoptera* belonged to 8 families (Figure 5).

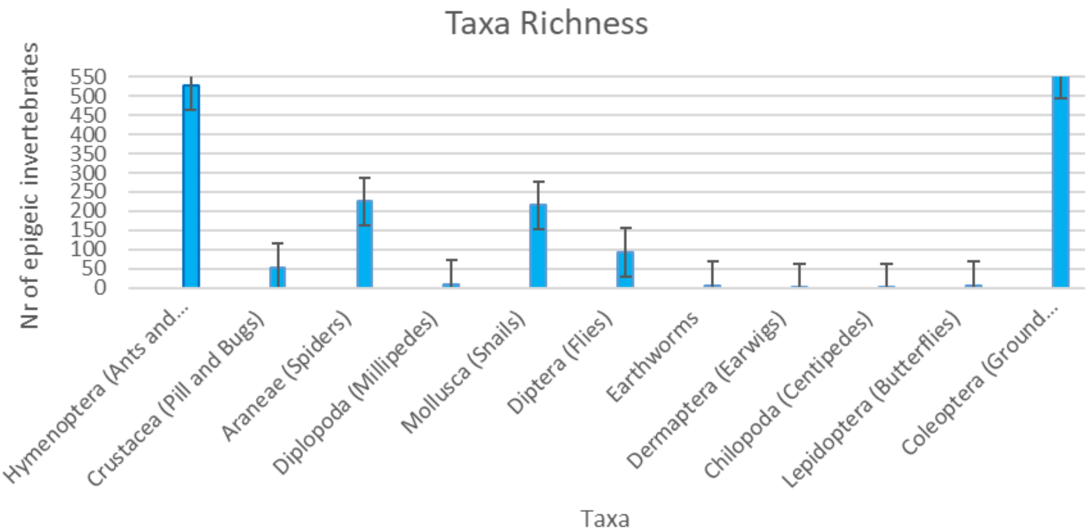

Figure 5. Number of epigeic invertebrates from each taxa group

Distribution of particular invertebrate taxa (without *Dermaptera*, *Chilopoda* and *Lepidoptera* because of their very low abundance) was differed according to habitat type. In Figure 6, the distribution of mean abundance of *Crustacea* was illustrated for all habitats (forest, meadow, shrub and orchard). It is cleary visible that forest and shrub patches are characterised by highest abundance of pill and bugs. On the other hand, the lower abundance was observed in meadow and orchard.

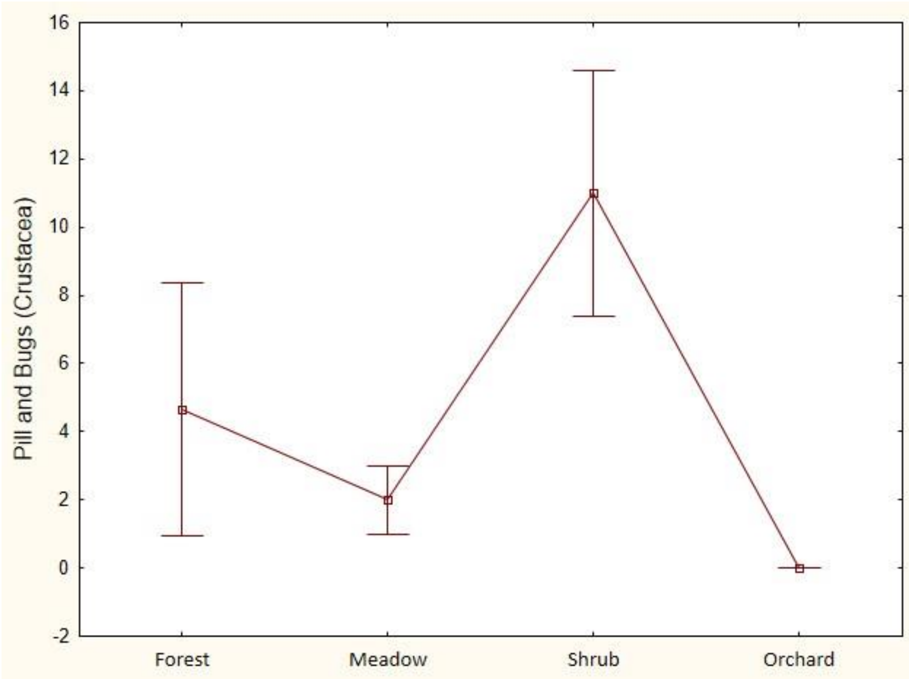

Figure 6. Mean abundance of Crustacea in researched habitats

Different pattern of abundance distribution was noted for spiders (Figure 7). This taxa group was the most abundant in meadow and next in orchard sites because of the predatory food preferences. This habitats with high diversity of potential prey were much favorable, compared to shrubs and forest.

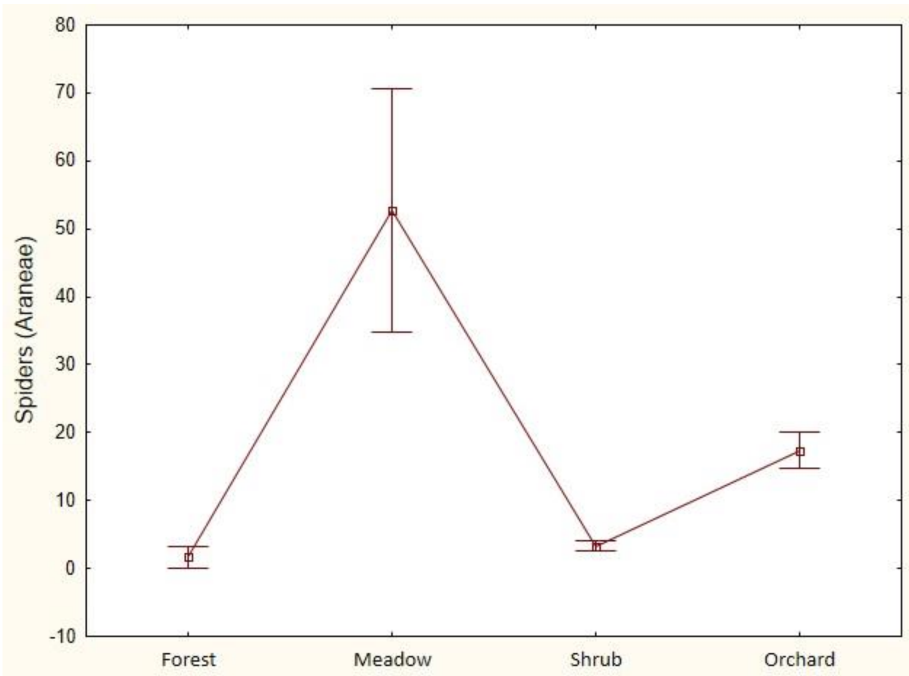

Figure 7. Mean abundance of spiders in researched habitats

In case of *Hymenoptera* abundance in the particular habitats it was observed similar pattern of abundance distribution as for spiders (Figure 8). The *Hymenoptera* is a very important group of insects which play a key role in the functioning of ecosystems in agrocenosis (e.g. pollination). In researched habitats they were the most abundant in meadow and orchard sites.

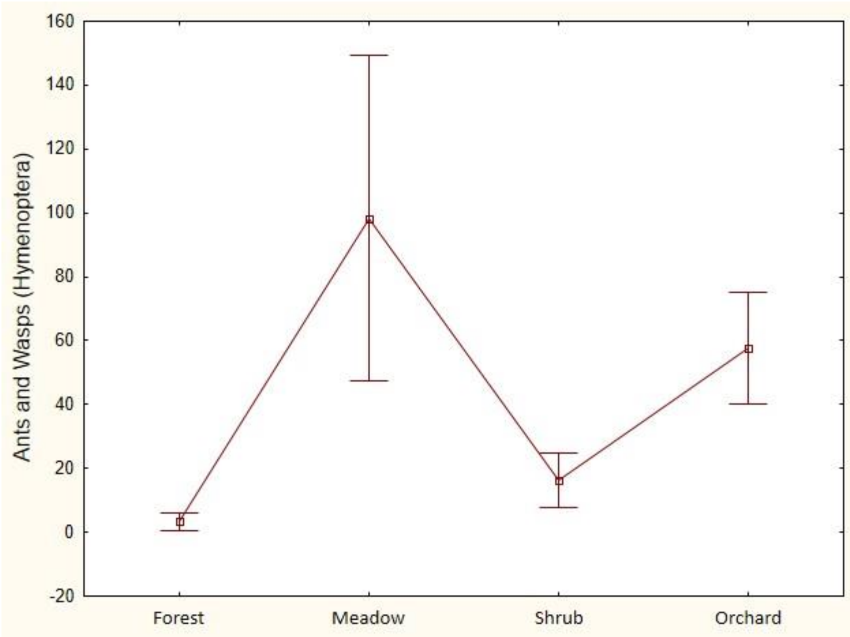

Figure 8. Mean abundance of Hymenoptera in researched habitats

The distribution of mean abundance of *Diplopoda* taxa was not differed between particular habitats. In most cases the standard deviation was very big, which may indicate the randomness of these invertebrates during the first sampling period.

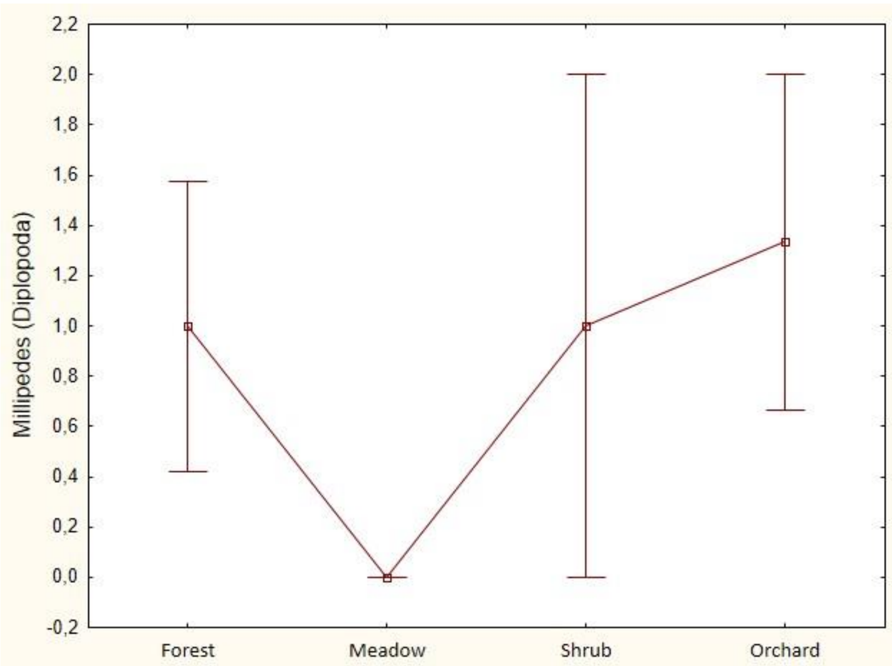

Figure 9. Mean abundance of Diplopoda in researched habitats

Coleoptera taxa are a good bioindicators, so it is important to know how it varies. Analysis of the abundance distribution was also done for *Coleoptera* taxa, first in general way, next for particular *Coleoptera* families. In the figure 10 its are clearly visible the differences between abundance from particular habitat types. The most abundant were meadow and orchard as well as shrubs. The lowest abundance of *Coleoptera* was noted for forest sites.

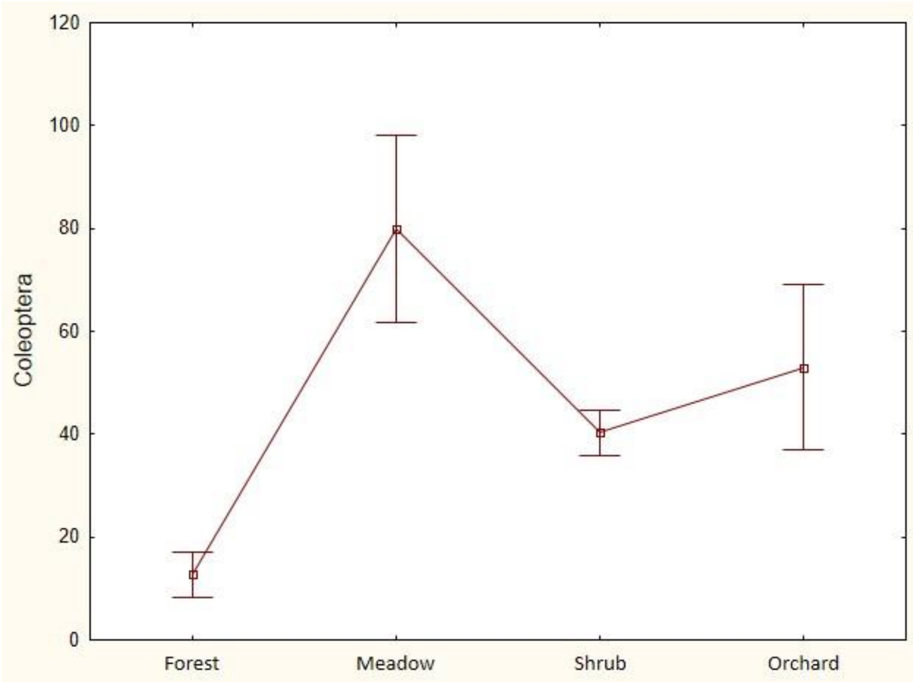

Figure 10. Mean abundance of Coleoptera in researched habitats

The next group of epigeic invertebrates which were caught in the pitfall traps was *Mollusca*. The highest abundance was observed in shrub patches (Figure 11). In the others habitats the mean abundance was relative in similar level.

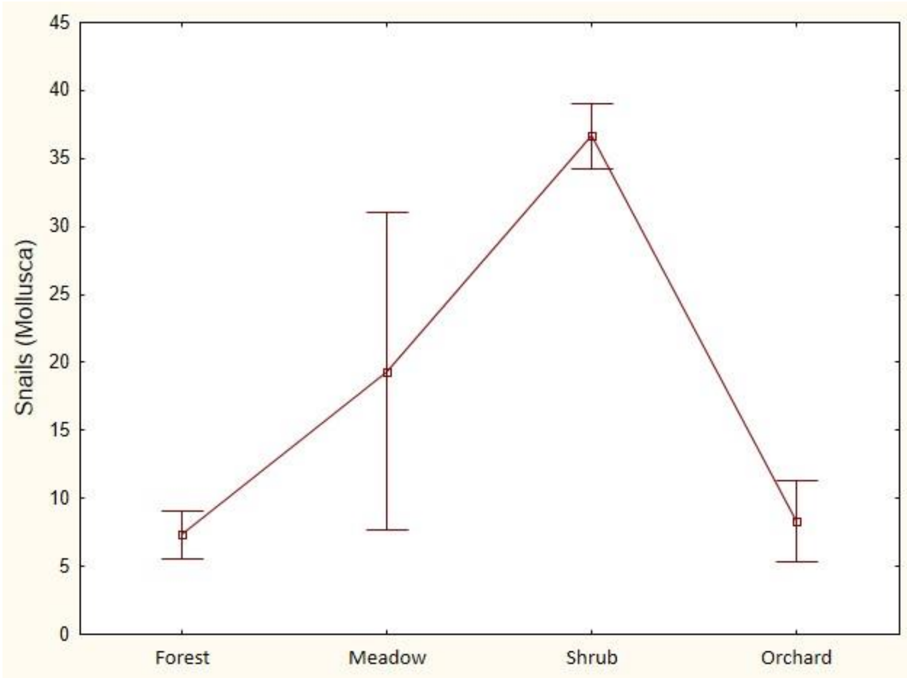

Figure 11. Mean abundance of Mollusca in researched habitats

The last group of epigeic invertebrates which were observed in material was *Diptera*. Generally, they had low total abundance. There are not big differences between habitats, but it is remarkable that it´s less common to find them in forest habitats (Figure 12).

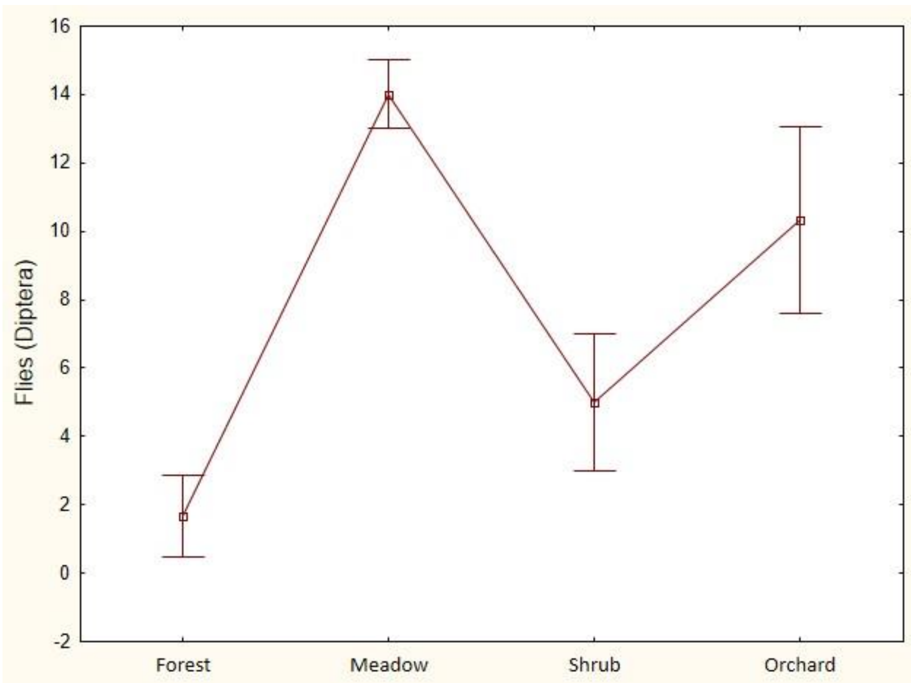

Figure 12. Mean abundance of Diptera in researched habitats

Referring to ground beetles, there was a total of 5 ground beetles belonged to *Elateridae*, 58 to *Curculionidae*, 77 to *Nitidulidae*, 3 to *Byrrhidae*, 16 to *Staphylinidae*, 16 to *Silphidae*, 106 to *Dermestidae* and 277 to *Carabidae*. As carabid family is a good bioindicator we decided to make a more specific study and to recognize the species collected from this family. The results were 30 different species in the following numbers: 81 *Leistus spinibarbis*, 11 *Pseudoophonus rufipes*, 1 *Carabus convexus*, 7 *Chlaenius tibalis*, 27 *Harpalus affinis*, 1 *Trichotichnus laevicollis*, 1 *Platinus assimilis*, 1 *Microlestes maurus*, 7 *Amara fluvipes*, 1 *Bembidion pygmaeum*, 2 *Carabus granulatus*, 6 *Amara communis*, 1 *Pterostichus melanarius*, 4 *Carabus arvensis*, 11 *Carabus nemoralis*, 7 *Leistus assimilis*, 3 *Pterostichus minor*, 17 *Pterostichus oblongopunctatus*, 2 *Amara lucida*, 3 *Abax parallelepipedus*, 3 *Harpalus latus* , 2 *Harpalus griseus*, 1 *Ophonus puncticollis*, 12 *Pterostichus niger*, 24 Carabida larvae, 1 *Calathus erratus*, 7 *Bembidion lampros*, 22 *Amara aenea*, 8 *Amara plebeja*, 2 *Calathus fuscipes* and 1 *Anisodactylus binotatus*. The most abundant species were *Leistus spinibarbis* and *Harpalus affinis*.

More detailed analyses have been done for assemblages of ground beetles (*Coleoptera*, *Carabidae*). The results of NMDS showed that there are significant differences in ground beetle species composition in relation to the type of habitat (Figure 13). These differences are high, especially between meadow and forest. As we can see in the figure 13, the forest habitat is the one with less assemblages and not clearly separated to shrubs assemblages, and meadows have the highest number of ground beetle assemblages. However, the orchard assemblages of the ground beetles are closely to the meadow habitat.

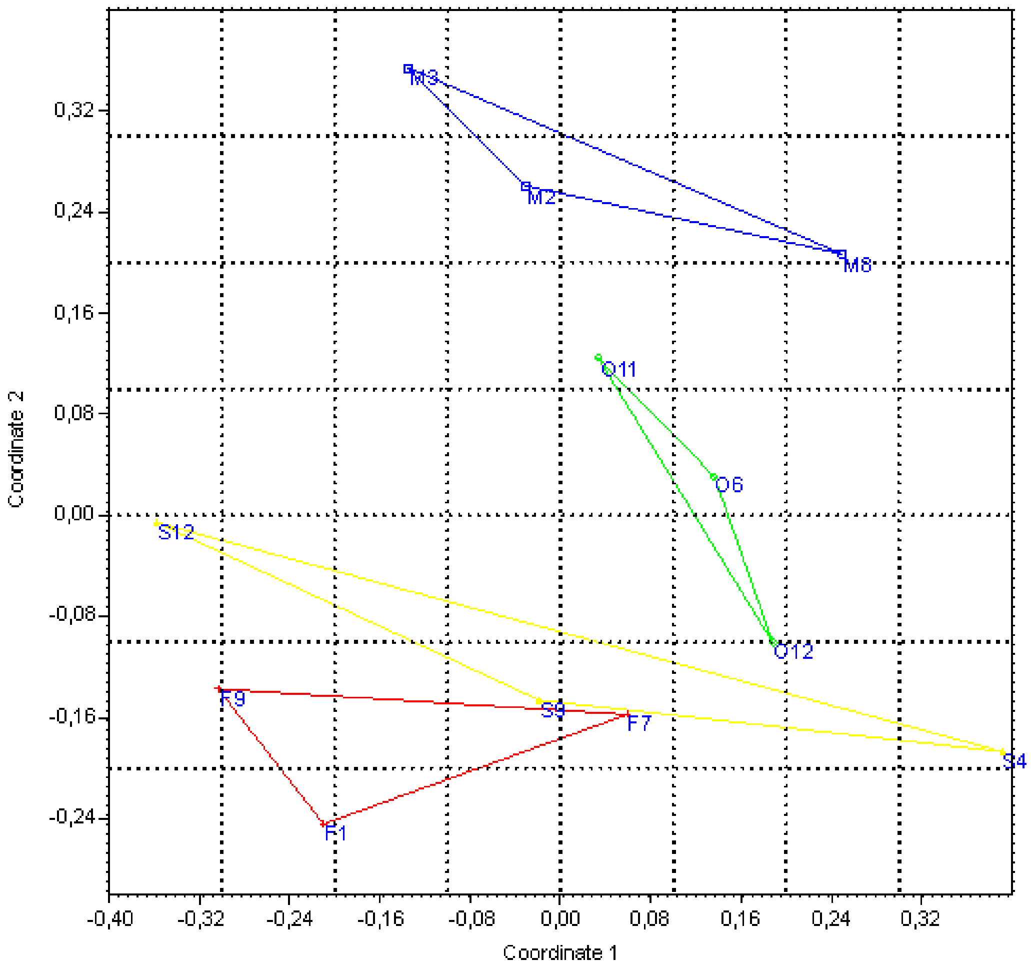

Figure 13. NMDS for ground beetle assemblages in relation to habitat type (F- forest, S-shrubs, M-meadow, O-orchards)

The assemblages of ground beetles from the forest and from the meadows are clearly significant (Table 10). In orchard and in meadow the differences are significant between them and the rest of habitats (p value is almost 0.05 if it is compared orchard to forest).

Table 10. R statistics of Anosim analysis comparing ground beetle variation between habitat types (bold indicates p<0.05, significance after Bonferroni correction)

R				
	F	M	S	O
F	0	**0.8889**	0.09259	**0.7963**
M	**0.8889**	0	**0.7222**	**0.6481**
S	0.09259	**0.7222**	0	**0.7667**
O	**0.7963**	**0.6481**	**0.7667**	0

The calculations for obtaining the p value are provided in the table below (Table 11).

Table 11. p value calculations

p				
	F	M	S	O
F	0	**0.01005**	0.399	**0.0499**
M	**0.01005**	0	**0.01046**	**0.03102**
S	0.399	**0.01046**	0	**0.03071**
O	**0.0499**	**0.03102**	**0.03071**	0

The difference between habitat types and species number of carabids are significant because the p value is lower than 0.05, the same happens with the abundance, Shannon diversity and Berger-Parker dominance index (Table 12).

Analyses of ground beetle assemblage parameters showed significant differences according to habitat types. The one-way Anova analysis reveald that species number, abundance, Shannon diversity and Berger-Parker index were significantly differ among particular habitats (Table 12).

Table 12. Results of one-way Anova for carabid assemblage structure parameters in relation to habitat type. Statistically significant results printed in bold for carabids assemblage parameters

Ground beetle assemblage parameter	**SS**	**df**	**MS**	**F**	**p**
Species number					
Residual	341,3333	1	341,3333	78,76923	2,05E-05
Habitat type	30	3	10	2,307692	**0,015318**
Error	34,66667	8	4,333333		
Abundance					
Residual	3434,083	1	3434,083	25,21971	0,001024
Habitat type	319,5833	3	106,5278	0,782334	**0,053637**
Error	1089,333	8	136,1667		
Shannon diversity					
Residual	21,30294	1	21,30294	151,2633	1,78E-06
Habitat type	0,872005	3	0,290668	2,063914	**0,018352**
Error	1,126668	8	0,140834		
Berger-Parker dominance index					
Residual	2,416878	1	2,416878	107,7647	6,42E-06
Habitat type	0,053162	3	0,017721	0,790134	**0,043259**
Error	0,179419	8	0,022427		

Ground beetles (*Coleoptera*, *Carabidae*) were very common in orchard and in meadow habitats and not so abundant in the case of forest habitat (Figure 14). Interesting is quite high abundance also in the shrub patches.

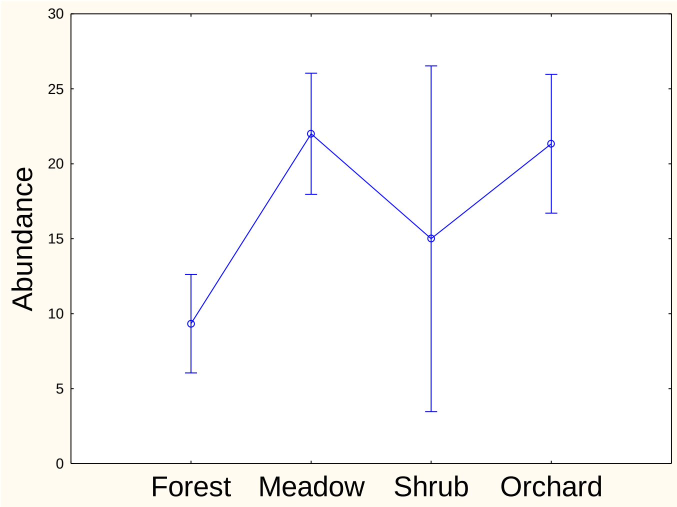

Figure 14. Average abundance of ground beetles (Coleoptera, Carabidae) in particular habitat type

In case of species richness the highest values was observed in orchard and meadow sites (Figure 15). In more stable habitats (e.g. forest, shrubs) the mean species number decreased.

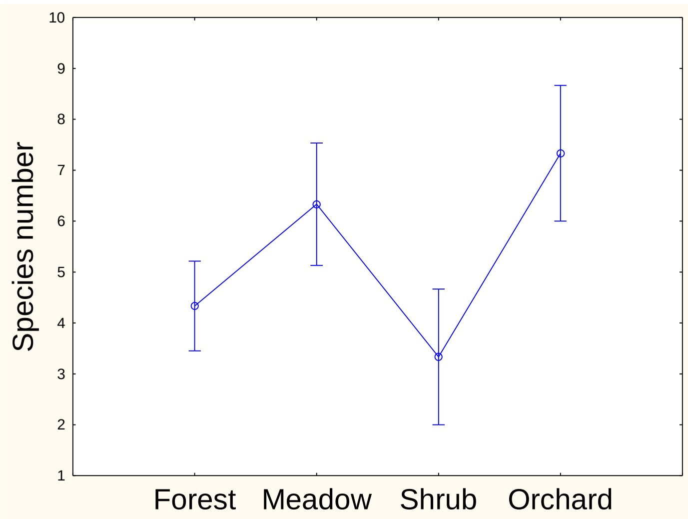

Figure 15. Average species number of ground beetles in particular habitat type

Shannon diversity index showed clearly that in more disturbed habitats like orchard or meadow the mean values of index was significantly higher than in reference, undisturbed forest and also shrubs (Figure 16). At the same time, the dominance Berger-Parker index was lower there (Figure 17).

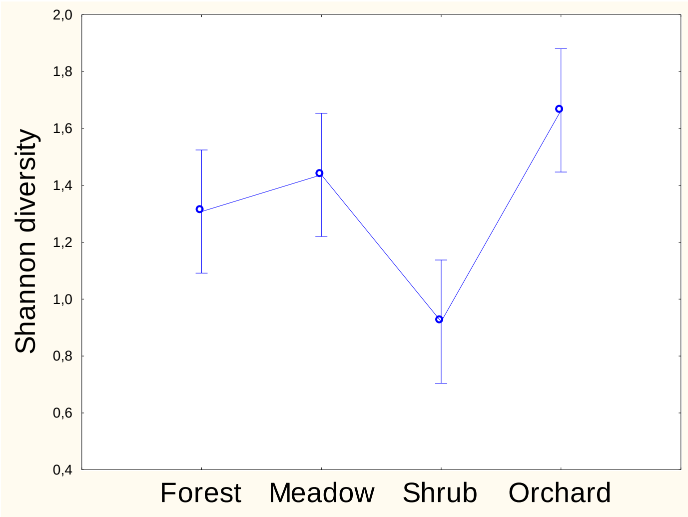

Figure 16. Average diversity of ground beetles in particular habitat type

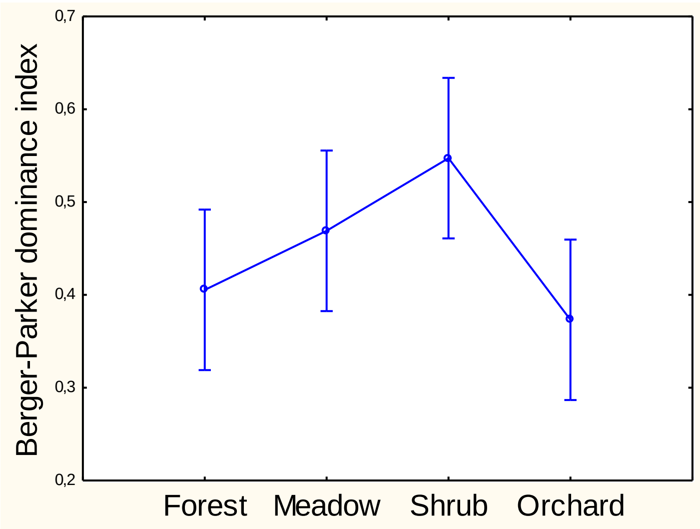

Figure 17. Average dominance of ground beetles in particular habitat type

SIMPER analysis, based on the degree of similarity explains which species indicate higher or lower abundance in particular assemblages (Table 18). *Carabus nemoralis*, *Leistus assimilis*, *Carabus arvensis*, *Abax parallelepipedus*, *Pterostichus minor* and *Amara lucida* were present in higher densities on the stable area of the forest. *Amara lucida* is also common in open spaces and *Carabus nemoralis* is typical from forest but also from shrubs. *Amara aenea*, *Bembidion lampros*, *Amara communis*, *Chlaenius tibalis* and *Amara fluvipes* clearly preferred meadow habitats. *Pterostichus oblongopunctatus*, *Pterostichus niger* and *Ophonus puncticollis* were more common in shrub than others areas, but, actually they usually can live also in forests. *Leistus rufomarginatus*, *Harpalus affinis*, *Amara plebeja*, *Harpalus latus* and *Harpalus griseus* would rather have been in disturbed habitats than the other, so they are better adopted to open spaces. Other species were studied but didn´t have a clear preference where to live, so it can indicate their randomness occurrence.

Table 13. Simper analysis for the ground beetles species contributing more than 1% to the dissimilarity between four assemblages. The colours indicate higher abundance in particular assemblages (red-forest, blue- meadow, yellow- shrub and green-orchard)

Species	Average dissimilarity	Contribution %	Mean abundance Forest	Mean abundance Meadow	Mean abundance Shrub	Mean abundance Orchard
Carabus_nemoralis	4.933	5.356	2.33	0	1.33	0
Leistus_assimilis	4.437	4.818	2.33	0	0	0
Carabus_arvensis	1.798	1.953	0.667	0	0.333	0.333
Abax_parallelepipedus	1.587	1.723	1	0	0	0
Pterostichus_minor	1.412	1.533	0.667	0	0.333	0
Amara_lucida	1.058	1.149	0.667	0	0	0
Amara_aenea	10.27	11.15	0	5.67	0	1.67
Bembidion_lampros	3.145	3.415	0	2.33	0	0
Amara_communis	3.068	3.331	0	2	0	0
Chlaenius_tibalis	2.725	2.958	0	2	0	0.333
Amara_fluvipes	2.64	2.866	0	1.67	0	0.667
Pterostichus_ oblongopunctatus	5.854	6.356	0.333	0	4.33	1
Pterostichus_niger	5.505	5.977	0	0	4	0
Ophonus_puncticollis	0.9536	1.035	0	0	0.333	0
Leistus_rufomarginatus	10.76	11.68	0.667	0	3.33	6.33
Harpalus_affinis	10.21	11.09	0	4.33	0	4.67
Amara_plebeja	3.332	3.618	0	1	0	1.67
Harpalus_latus	1.715	1.862	0	0	0	1
Harpalus_griseus	1.257	1.365	0	0	0	0.667
Pseudoophonus_rufipes	3.329	3.614	0.667	1	1	1
Carabus_granulatus	0.9419	1.023	0	0.333	0	0.333

5. DISCUSSION

It is a fact that biodiversity is really important in agriculture lands and varies depending on the habitat. For example studies show that agricultural intensification leads to landscape simplification and loss of biodiversity, this is the case of orchard. A higher diversity than expected in this area proves that do not need to be incompatible the conservation of biodiversity and agricultural landscapes if it is managed in a good way and may even supports a substantially higher biodiversity than pristine habitats (Pimentel et al., 1992; Tscharntke et al., 2005; Ameixa and Kindlmann, 2008).

Biodiversity is responsible for ensuring the balance of an ecosystem, for that reason biodiversity losses lead to losses of ecosystem function, compromise the surrender of ecosystem services, and reduce the resilience of these systems to disturbance. A good way to preserve the biodiversity is to increase the habitat heterogeneity, in fact, habitat loss supposes a big threat to biodiversity because it can cause the loss of the biotic interactions between some important insects and the ecosystem. So, habitat heterogeneity should be maintained or increased to protect the loss of these important insect which play an essential role in the environment, such as Hymenoptera, *Coleoptera* or *Araneae*. As my results show, they have very similar pattern in the distribution of abundance (they are more abundant in meadow, next is orchard, then shrub and forest). The biotic interactions mentioned before were pollination (in the case of Hymenoptera), which is really necessary in orchards and predation (*Coleoptera* and *Araneae*). The abundance of these important three groups are also fundamental for pest management, so increasing the diversity of the habitat can be indicated as a pest management practice.

Pest management with these insects is important because the more population of beneficial predators insects we have, a quicker detection of colonies. And that is why we are interested in having these groups in an abundant number and high diversity. For example, there are some species of *Colepotera* which are the most well-known in the fight against aphids, such as *Coccinella Septempunctata*.

In relation to ground beetles, those that live in forest are mostly bigger, brachypterous predators. They live in stable environmental conditions. They also can play important role as predators in intensively cultivated agricultural landscape, where they can be useful tool in pest management practice. Moreover, presence of shrub patches in the direct neighbourhood of orchard area can play a crucial role as refuges and sources of colonisation. NMDS analysis showed that Carabidae assemblages from shrub patches had a short distance from forest assemblages. In addition, in the shrub patches some of the forest spacialists species were observed as a *Pterostichus oblongopunctatus* and *P. niger*.

In the orchard and meadow sites the results showed the highest diversity, richness and abundance of carabid species. These habitats are characterised by high variation of environmental conditions, so among diverse group mostly smaller, macropterous species were observed. They are characteristic for open areas and they have high ecological plasticity which allows them adapt to agricultural management.

During the interpretation of the results of this study, it is important to mention that the overall diversity of ground beetles (558 individuals and 8 families) was high, considering that 36 pitfall traps were used for a total of 14 sampling days. This proves the validity of using these organisms in ecosystem functioning assessment studies in agriculture landscape.

6. CONCLUSION

- It is proved that heterogeneity of agriculture land can play important role in maintenance of a high diversity of epigeic invertebrates fauna. I analyzed and I compared abundance and diversity of epigeic assemblages in different habitats of agricultural land and my results indicated that there are very visible differences between particular groups.
- There are some groups that are more diverse in meadow and orchard, as well as there are some groups more diverse in shrub and forest. In the case of *Hymenoptera*, *Araneae* and *Coleoptera* they have a very similar pattern in abundance distribution (meadow, orchard, shrub and forest), *Crustacea* (shrub, forest, meadow, orchard), *Diplopoda* (orchard, shrub, forest, meadow), *Mollusca* (shrubs, meadow, orchard, forest) and *Diptera* (meadow, orchard, shrub, forest). In these groups, there are some of them that deserve a special importance due to their potential in the environment as pest management activity: *Hymenoptera*, *Coleoptera* and *Araneae*. These can be used as biological pest management because they are predators and less inputs are requested to kill pests. The abundance of them brings benefits like the improvement of soil quality and pollination.
- The area which I observed the highest number of ground beetles assemblages was in the meadow and in the orchard where I observed also the highest diversity.
- The results showed that abundance and diversity of epigeic invertebrates assemblages differ according to heterogeneous environment.

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