BABEŞ-BOLYAI UNIVERSITY
FACULTY OF BIOLOGY AND GEOLOGY
DOCTORAL SCHOOL

Ioan TĂUŞAN

Ant community succession (Hymenoptera: Formicidae) of deciduous forests clear-cuts in Transylvania

Summary of the PhD thesis

Doctoral supervisor

Univ. Prof. László RÁKOSY, PhD

Cluj-Napoca, 2013

CONTENTS

KEY WORDS

ANT COMMUNITIES

SECONDARY SUCCESSION

CLEAR-CUTS

DECIDUOUS FORESTS

INTRA AND INTERSPECIFIC RELATIONS

PLANT COMMUNITIES

TRANSYLVANIA

ROMANIA

INTRODUCTION

The Formicidae family includes over 12,700 described ant species, inhabiting all continents except Antarctica. Numerous studies, ranging from genetics to phylogeny, behavioural ecology to community ecology, have been undertaken in order to clarify the mechanisms behind these social insects.

In ecology, the importance of ants is reflected by their ubiquity and the great number of interactions within an ecological community. Moreover, ant studies have led to significant advances in our understanding of insect evolution, global diversity patterns, competitive interactions, mutualisms, ecosystem responses to change, and biological invasions (WILSON, 2010). Ant communities play a vital role within forest ecosystems as part of the food chain, seed dispersal (myrmecochory) and by modifying the soil structure and pH.

Interesting, in terms of ant communities mechanisms research, is the impact of extreme disturbances (fires, deforestation, mining exploitation) upon these communities and their general reaction.

Clear-cutting consequences on ants, especially in the case of ants inhabiting deciduous forests, are poorly studied in comparison to other invertebrates, large mammals or upon plant associations.

Therefore our aim was to study ant community succession of deciduous clear-cuts, by investigating chronosequence in Transylvania. The thesis brings new insights regarding changes underlying ant communities after clear-cutting. Moreover, composition and structure of the ant communities were researched in correlation to plant associations during secondary succession. Intra and interspecific relations within ant communities were studied within chronosequence in Transylvania.

Finally, comparative analysis of ant community composition was investigated in deciduous forests from different regions in Romania (Transylvania, Banat and Dobrogea) in order to establish ground rules for community composition in these forest ecosystems.

CHAPTER 1: ECOLOGICAL SUCCESSION

"An understanding of ecological succession provides a basis for resolving man's conflict with nature" Eugene Odum (1969)

According to MCINTOSH (1980): "*Succession is one of the oldest, most basic, yet still in some ways most cofounded of ecological concepts. Since its formalization as the premier ecological theory by H.C. Cowles and F.E. Clements in the early 1900s, thousand of descriptions of commentaries about and interpretations of succession have been published and extended inconclusive controversy has been generated*".

Ecological succession can be defined as the irreversible process in which an ecological system is undergoing different phases from initial stages throughout climax as a result of interactions between biocenosis and biotope. This process is characterized by species replacement, changes of environmental factors, species colonization or quantitative reshuffle of the community structure. In general, in every ecological succession there are different stages that can be theoretically recognized in any chronosequence. Each stage represents a development unit characterized by physical and chemical conditions and by its own special and distinct communities (ODUM 1971).

Despite the fact that the concept of ecology was proposed by a zoologist (E. Haeckel), botanists were the first to describe and characterize the ecological succession.

According to CLEMENTS, (1916) there are six stages: 1. **Nudation**; 2. **Migration**; 3. **Colonization** (Ecesis); 4. **Competition**; 5. **Reaction** and 6. **Stabilization** (climax).

In 1926 GLEASON stated that "an association is not an organism, scarcely even a vegetation unit, but merely a coincidence." The model proposed by Gleason was more complex and less deterministic than Clements. In this context, the species appear together in a given area, as a result of their ecological valence, and not because they form a superorganism.

Over time, TANSLEY (1935), WHITTAKER (1953) have developed approaches based on Gleason concept of succession where as ODUM (1969) continued Clements ideas, and proposed the ecosystem development theory.

CONNELL & SLATYER (1977) have suggested a number of models regarding succession. These were based on the concept that the initial composition of communities is determined by pioneer species that produce many seeds that germinate and have a rapid growth rate.

TILMAN (1985) proposed the theory of resource share, which assumes that each plant species is a superior competitor for a certain proportion of a limited resource and it predicts that changes in community composition should take place when the relative availability of two or more limited resources change.

Recent studies on succession, at least in the case of vegetation, considers that soil biology, ecology of invasive species, community ecology, landscape ecology, and studies on resilience should be emphasized (HASTINGS et al. 2007, HOBBS et al. 2007, WALKER et al. 2007).

According to classical theories, succession stops when it reaches a steady state of both biotic and abiotic factors. This final point is called climax. However, this is not a static endpoint, but rather a dynamic state of equilibrium. An ecosystem that has reached at least in theory, the climax stages, is characterized by high stability, except in case of major extreme disturbances (POJAR et al. 1991).

In fact, it is very difficult to identify stable climax communities in nature. Abandoned grasslands need 100-500 years to reach climax, but disturbance such as fire or extreme weather may occur and have a negative impact, so that the process will not be complete. It's the case of the northern temperate or tropical forests that are still regenerating after the last glaciations. This leaves an open question whether the climax vegetation is often achieved in nature (BEGON et al. 2009).

Today, a number of theories have been developed regarding the climax and succession mechanisms. In ecology, the alternative stable stages theory predicts that ecosystems can exist in multiple states (unique sets of biotic and abiotic factors).

These alternative states are non-transitional stages, thus considered stable for significant periods. Ecosystems can shift from one state to another, whenever there is a disturbance.

This theory was proposed by LEWONTIN (1969, ap. SCHEFFER et al., 2001), but authors such as HOLLING (1973), SUTHERLAND (1974), MAY (1977), and SCHEFFER et al. (2001) share the same vision.

Checking these alternative stable states has a direct effect on ecosystem management. When these conditions exist, gradual changes in environmental factors tend to have little effect on the system until a threshold is reached, at which point it could lead to catastrophic changes. Understanding the nature of these thresholds can support the development of monitoring programs, environmental restoration and other management decisions on ecosystems (BEISNER et al. 2003).

All ecosystems are exposed to gradual changes of climate, nutrients, habitat fragmentation or biotic exploitation. In general, it is assumed that nature changes gradually and responds in a predictable manner. However, studies on lakes, coral reefs, oceans, forests and arid areas showed that these predictable changes can be stopped abruptly and it can be driven by a contrasting state. A series of events can trigger these permutations, but it has been recently shown that loss of resilience is one that allows an alternative state permutation (SCHEFFER et al. 2001).

One of the most used models to explain and describe successional chronosequence was the forest ecosystem. It is well known that when disturbance (fire, clear-cutting) affects a forest, it will trigger a secondary succession. First, pioneer species with *r* strategies, will try to colonize the new formed habitat. The canopy closure influences the regime light and has an impact these pioneer species. Therefore tolerant species, with *k* strategy, will benefit from this and will compete with the pioneer species. There are multiple models that can characterize forest succession duet to the variety of factors that influence this process.

It is widely known that the forest is one of the most complex terrestrial ecosystems. Pop in 1973 stated the followings: "No other terrestrial ecosystems have realized such a complex and comprehensive equilibrium, achieving important correlations with its flora, fauna, soil and climate, as the forest itself. Its disturbance unleashes repercussions on the ecological network "(POP 1973, ap GIURGIU 1978).

In this highly complex ecosystem, beyond the obvious stratification of the vegetation, invertebrates play an important role (NIEMELÄ 1997).

In this context, ant communities are an important part of the system. It is well known that these communities are considered "ecosystem engineers" (FROUZ & JILKOVÁ

2008) having a range of both positive and negative effects on forest ecosystems. In general, species *Formica s. str.* can change the soil pH towards a neutral value.

Recently, DEL TORO et al. (2012) reviewed the services that ants provide or mediate in different ecosystems. Among them, we emphasize the biological control of pests, nutrient cycling, biomarkers, pollination, seed dispersal, etc.

CHAPTER 2: ANT COMMUNITY SUCCESSION

"From scorching, barren deserts to humid tropical forests, from deep in the soil to high in the tree canopies, ants are everywhere!"

E.O Wilson (2010)

Ants are an interesting case of succession. Co-occurring species have similar ecological requirements, and competition for space and resources is as pronounced as in the case of plants (HÖLLDOBLER & WILSON 1990, ANDERSEN 1995).

Ant community succession is generally studied by simultaneous comparisons of habitats representing different successional stages. In literature it is known as **SFT** (Space for Time substitution, PICKETT sensu1989). This method has enabled numerous studies (BOOMSMA & VAN LOON 1982, VESPÄLÄINEN & PISARSKI 1982, ZORRILLA et al. 1986, GALLÉ 1991, ACOSTA et al. 1992, JÁRDÁN et al. 1993, MARKÓ 1999, VESPÄLÄINEN et al. 2000, ZETTLER et al. 2004, DAUBER & WOLTERS 2005, DAUBER & SIMMERING 2006, PALLADINI et al. 2007, DEKONINCK et al. 2008, BABIK et al. 2009, VELE et al. 2011, CZECHOWSKI et al. 2013). Another method to study succession requires long-term studies on the successional changes of ant populations' dynamics in particular habitats. This approach has generated few studies in Europe (GALLÉ 1981, GALLÉ et al. 1993).

Despite that ants play an important role in soil processes in the western and central European forests (CZECHOWSKI et al. 1995) and are take part in the biological decomposition processes (SEIFERT 1996, GOTELLI & ELLISON 2002) seed dispersal (GORB & GORB 1999), long term studies regarding the effect of forest succession after afforestation or other management treatments are rare (CZECHOWSKI et al. 1995, SCHLICK-STEINER et al., 2005).

One of the classical approaches to community ecology is to identify relationships between communities composition and environmental properties of their habitats (ALVARADO 2000). Landscape determines the presence of potential colonizers, population dynamics and their ability to colonize different fragments of landscapes. Local factors determine the suitability of habitats (EGGLETON et al. 2005, SUMMERVILLE & CRIST 2008).

In the clear-cuts, communities are not only affected by habitat age. The history of logging in the surrounding areas is of great importance. Ant species are more abundant in young forest habitats, and ant communities were affected habitat conditions at higher regional scale (VELE et al. 2011).

Important factors affecting succession are local factors such as food sources, the amount of available light, age of the site, and regional factors acting such as distance to the nearest forest or open habitat (VELE et al. 2011).

Ant community succession has been extensively studied in the case coniferous forests (PUNTILA et al. 1991, CZECHOSWKI et al. 1995, VEPSÄLÄINEN et al. 2000, ZETTLER et al. 2004, PALLADINI et al. 2007, VELE et al. 2011, etc.).

Clear-cuts generally have significant effects on ant communities. PALLADINI et al. (2007) showed that the abundance and number of species were significantly higher in the clear-cuts and young sites, being correlated with canopy variability.

Clear-cutting has a negative effect on colonies of dominant ant species of the genus *Formica s. str*. Thus, changes in the size of individuals (e.g. head width) occurred after clear cutting. This is caused by a substantial reduction in trophic resources (e.g. aphids) along with removal of the trees (PUNTTILA et al., 2004), causing a decrease in body fat content of ant workers (SORVARI & HAKKARAINEN, 2009). Therefore, the overall size of ant mounds is affected and hence the sexual offspring production (SORVARI & HAKKARAINEN, 2005).

In the case of deciduous forests, where species of the genus *Formica s. str*. are less dominant or absent, the effects of clear-cutting on ant assemblages are less known (SZUJECKI et al. 1978, LYNCH 1981, DEKONINCK et al. 2008, BABIK et al. 2009). In those forests, dominant ant species belong to the subfamily Myrmicinae, *Myrmica ruginodis* being one of the most common ant species (Dekoninck et al. 2008).

BABIK et al. (2009) showed that diversity was higher in clear-cuts compared with to inner forest sites. An important factor responsible for this was the high heterogeneity of the habitats: high insolation areas with scarce vegetation, alternating with areas shaded by shrubs or dense vegetation.

In late stages of succession, in mature forests, a number of factors are essential in structuring ant communities: tree and shrubs coverage and litter development. In young forests, herbaceous vegetation coverage is essential for ants (DEKONINCK et al. 2008).

An extremely limiting factor in the stabilization of typical forest species in a new forest after 50-100 or even 150 years is the lack of dead wood or fallen trees and lack of resources (PUNTILLA et al. 1994).

The role of intra-and interspecific relationships in structuring ant communities is well known (SAVOLAINEN & VEPSÄLÄINEN 1988, SAVOLAINEN et al. 1989, PUNTILA et al. 1991, 1996, CZECHOWSKI 2000, VEPSÄLÄINEN et al. 2000, CZECHOWSKI & VEPSÄLÄINEN 2001, CZECHOWSKI & MARKÓ 2006), although it has recently been questioned (LESSARD et al. 2012, CERDA et al. 2013).

The main enemies of ants are ... other ants. Most species are omnivorous and generalist in all aspects.

Given the fact that ants are social species, characterized by an established hierarchy and a great division of labour. While foraging ants usually meet competitors. High abundance of ants and activities requires a great consumption of energy which causes immense pressure on the environment and hence on other ant species. Ants are competing for space, anthills and spatial distribution of colonies which adds up to their competitive actions (CZECHOWSKI & MARKÓ 2005).

In evolutionary terms, competition leads to the development of territorialism and a dominant interspecific hierarchy. Ant species are distributed on the basis of their hierarchical organization of the colonies (colony size, density of foragers, recruitment effectiveness). According to SAVOLAINEN et al. (1989) there are three levels of competition hierarchy: dominant, subdominant and subordinate. It is notable that subdominant species, although not territorial, can become aggressive when it comes to exploitation of trophic resources, being able to reach high densities where the dominant species are absent or are in a mosaic spatial distribution (ARNAN et al. 2011). Furthermore, where local territorial species are species shift up one level in the hierarchy of competition (SAVOLAINEN et al. 1989, ARNAN et al. 2011).

Ant colonization of post-mining sites under different forest management regimes indicates that these assemblages are able to "catch up" and settle in such habitats (BISEVAC & MAJER 1999, DUNGER et al. 2001, HOLEC & FROUZ 2005, OTTONETTI et al. 2006). However, there are few studies that deal with how social insects respond to restoration measures such as natural succession (DUNGER et al., 2001), reforestation (WATT et al. 2002) and other forest management measures (MAETO & SATO 2004, DECKONICK et al. 2008).

Other studies however showed that clear-cutting have a significant impact on colonies of dominant species such as *Formica s.str*. In the case of *F. aquilonia* high aggressiveness between neighbouring colonies was observed. The aggression may be a result of increased intraspecific resource competition or alienation of neighbouring colonies caused by the loss of visual orientation cues. In the late stages of succession this aggressiveness has low values (SORVARI & HAKKARAINEN 2004).

The first study of ant communities of succession was undertaken by MARKÓ (1999). He studied changes in diversity in of spruce forests clear-cuts in the Eastern Carpathians. Successional pathways were studied and changes occurring in the structure of ant communities. Correlations between ants and plants during succession were also studied. KISS & MÁTIS (2002) published a study of parallel succession of ants and plants communities after mining.

The last study regarding succession was focused on old fields (NÉMET et al., 2007). The authors analyzed changes in diversity of ant communities along vegetation changes during old fields' chronosequence.

AIM AND GOALS

The aim of our research was to elucidate the mechanisms and phenology underlying ant communities succession in the case of deciduous forests clear-cuts. To achieve this purpose, we set the following goals:

- **O1**: What are the characteristics of the ant community succession of deciduous clear-cuts?

- **O2**: Are there any correlations between ants and plants communities succession, and at what level?

- **O3**: Which are the internal and external factors that influence the ecological succession pathways?

- **O4**: Are there any intra-regional (within Transylvania) or inter-regional (Dobrogea and Banat region) differences in terms ant community structure?

- **O5**: What will be the impact of clear cutting on ant communities?

CHAPTER 3: STUDY AREA, MATERIAL AND METHODS

3.1. STUDY AREA

In order to achieve our research goals, we chose to study ant community succession in two areas within Transylvania, in Dumbrăveni (Sibiu County) and in the surroundings of Cluj-Napoca (Cluj County). Within these areas we investigated two chronosequence consisting of different-aged sites (Fig. 3.1).
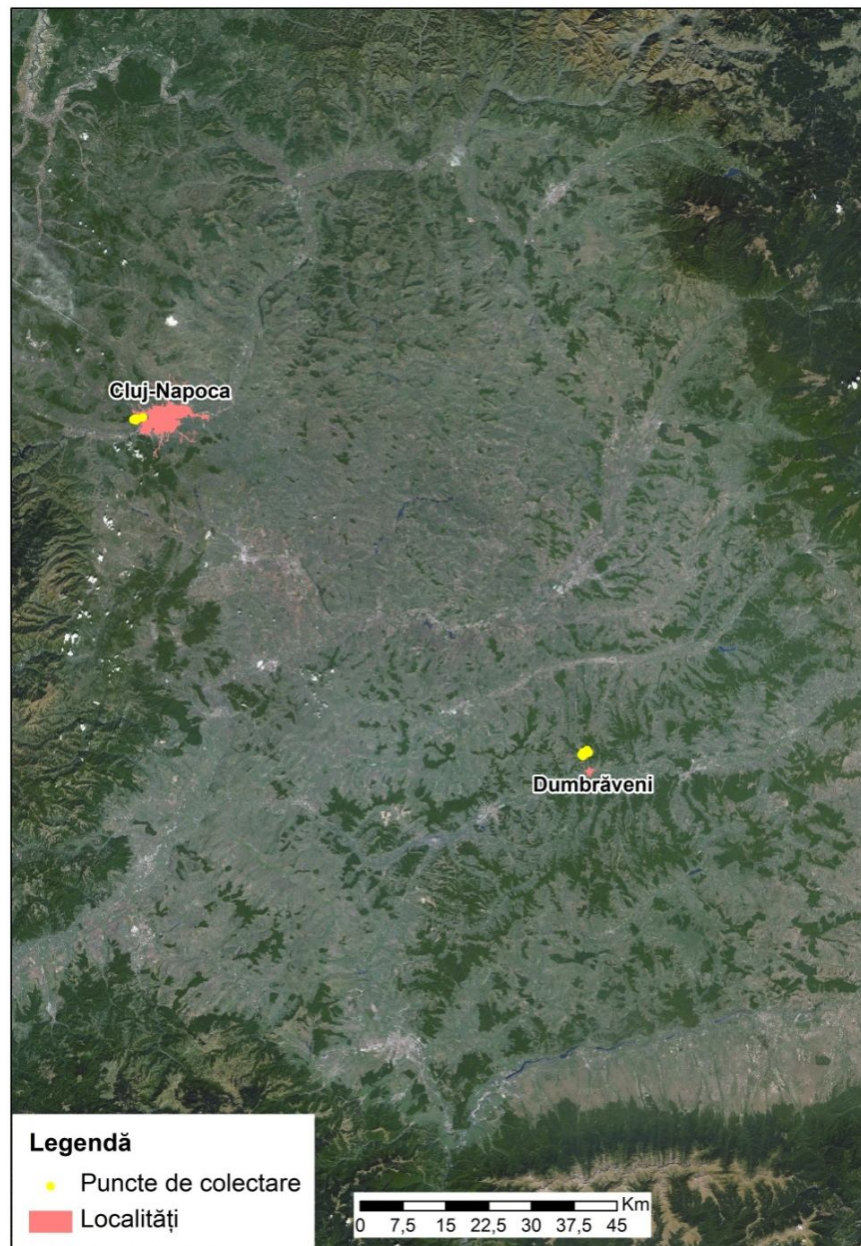
Fig. 3.1. Sampling areas in Transylvania

3.1.1 Forest sites in the surroundings of Dumbrăveni

The study sites are located in the so-called Mediaş Plateau micro region (Fig. 3.2).

Fig. 3.2. Sampling sites in Dumbrăveni (modified after google.earth, the codes are explained in text)

Sampling sites

The investigated habitats of different ages are the following: **age class 1 [AC1]** – clear-cut site; **age class 2 [AC2**] – 2 years clear-cut; **age class 15 [AC15]** –15 years old forest; **age class 35 - [AC35]** – 35 years old forest; **age class 55 [AC55]** – 55 years old forest; **age class 70 [AC70]** – 70 years old forest; **age class 120 - [AC120]** – 120 years old forest; Two secondary meadows were also sampled (**F1** and **F2**). It is considered to be the sites where propagula (young queens) can come and invade freshly installed new habitats, (e.g. clear-cuts). In addition a 120 years old forest with *Quercus pubescens* **[AC120*]** was also sampled (Fig. 3.3 -3.7.).

Fig. 3.3 AC1 (left) and AC2 (right) sites

Fig. 3.4 AC15 (left) and AC35 (right) sites

Fig. 3.5 AC55 (left) and AC170 (right) sites
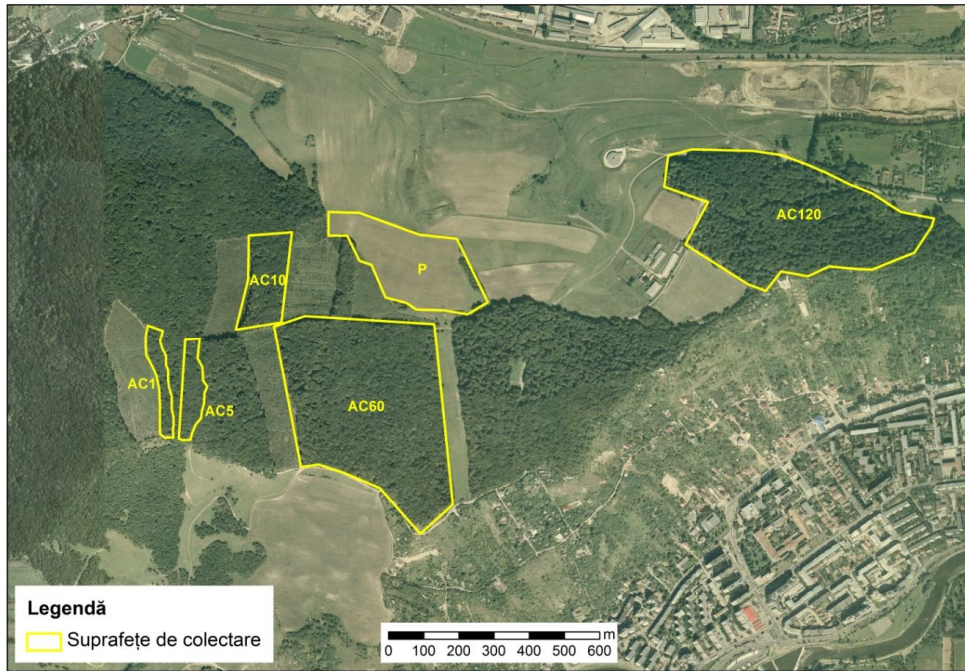
Fig. 3.6 AC120 (left) and AC120* (right) sites

Fig. 3.7. F1 (left) and F2 (right) sites

3.1.2 Forest sites in the surroundings of Cluj-Napoca

The second chronosequence was investigated in Hoia forest, near Cluj-Napoca (Fig. 3.8).

Sampling sites

The investigated habitats of different ages are the following: **age class 1** [AC1] – clear-cut site; **age class 5** [AC5] – 5 years clear-cut; **age class 10** [AC15] –10 years old forest; **age class 60** [AC55] – 60 years old forest; **age class 120** - [AC120] – 120 years old forest. One secondary pasture was also sampled (Fig. 3.9 -3.11.).

Fig. 3.8. Sampling sites in Cluj-Napoca (modified after google.earth.com) (the codes are explained in text)

Fig. 3.9. AC1 (left) and AC5 (right) sites

Fig. 3.10. AC10 (left) and AC60 (right) sites

Fig. 3.11. AC120 (left) and P1 (right) sites

3.1.3 Deciduous forest from different regions in Romania

In order to achieve our 4th goal, we studied deciduous forest from different regions in Romania (Fig. 3.12). Therefore in Transylvania we investigated Dumbrava Sibiului forests, in Banat, "Izvoarele Nerei" and Anina forests, and in Dobrogea, forest sites from Niculiţelului hill.

Dealurile Niculiţelului (Dobrogea)

In Dobogrea we sampled forest sites from an area where two protected areas: ROSCI0201 (North Dobrogean Plateau) and ROSPA0073 (Măcin-Niculiţel) overlap (Fig. 3.13).

Izvoarele Nerei and Anina (Banat)

One of the last primeval forests from Europe is „Izvoarele Nerei" forest, which is part of the Semenic – Cheile Caraşului National Park. The nature reserve covers approximately 5,000 ha and is characterized by the exclusive presence of beech (*Fagus sylvatica*) (TURCU 2012). However, beside beech some other herbaceous species are present: *Athyriumfilix-femina* and _Luzula sylvatica_ (Fig. 3.13).

Dumbrava Sibiului forests (Transylvania)

Dumbrava Sibiului forest is a part of Sibiului depression, situated in the south-western part of Sibiu at an altitude range between 433 m and 604 m (BUCŞA 1998). According to SCHNEIDER-BINDER (1973) the dominant plant association of the forest is *Querco robori-Carpinetum* Soo et Pocs (1931, 1957) (Fig. 3.14)
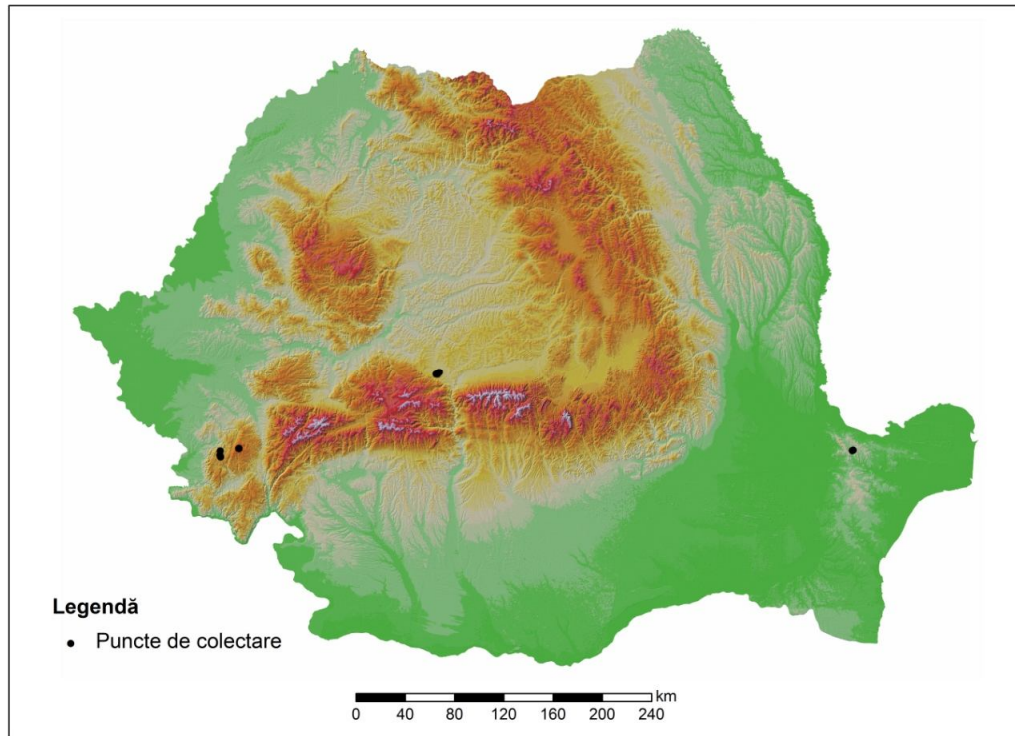
Fig. 3.12 Sampling sites of ant communities in different deciduous forests in Romania

Fig. 3.13 Forest sites in Niculițelului hill (left) and in Izvoarele Nerei (right)

Fig. 3.14 Forest site in Anina (left) and in Dumbrava Sibiului (right)

3.2 MATERIAL AND METHODS

3.2.1 Ant community composition analysis

In order to study ant community composition within the two chronosequence, we sampled ants with pitfall traps in all successional stages in Dumbrăveni and Cluj-Napoca. 16 pitfall traps were installed in all sites, in a 4 X 4 network, with 5 meters distance between traps. Traps were filled with glycol (antifreeze: water, 1:1) and were retrieved after 10 days. Sampling was carried out in three periods of time (May, July and September 2011). Similar sampling design was applied in deciduous forests from Romania (Banat, Transylvania and Dobrogea). In each of the three regions, three forest sites were sampled with 16 pitfall traps/ site. The sampling campaign in 2012 was undertaken in one period (July).

Ants were identified to species level using available keys: CZECHOWSKI et al. (2002), SEIFERT (2007) and CZECHOWSKI et al. (2012). The ants are to be found in the personal collection of the author and for statistical analysis only workers were considered.

3.2.2 Plant community composition analysis

In parallel with ant community succession, plant communities were analyzed in the same sites and in the same sampling periods. Three vegetation quadrates were applied (25 m^2 for grasslands and 400 m^2 for forest sites). Plant species were identified using CIOCÂRLAN (2009) and SPETA & RÁKOSY (2010).

3.2.3 Interspecific relations analysis

In 2011, in the same place where pitfall traps were installed we analyzed species interactions with baiting observations. The artificial bait consisted of a mix of tuna and honey (2:1). Number of species and individuals and type of the interactions were observed for 1 minute in each site in two observation sessions: 9:00 - 10:00 - 11:00 and 17:00 -18:00 - 19:00.

3.3 DATA MANAGEMENT

Data from both chronosequence were analyzed as following: ant community composition, diversity analysis and multivariate analysis. Differences between forest sites along succession were tested using a permANOVA (5000 permutations, Poisson distribution). Similarities between successional stages were analyzed using a NMDS analysis (Bray-Curtis similarity index). Similar analysis was conducted for plant communities. Correlations between ant and plant communities were analyzed using a Mantel Test. For all statistical analysis we used PAST (HAMMER et al. 2001) and R (R CORE TEAM 2012).

CHAPTER 4: RESULTS

4.1. FAUNISTICS

During the 2011 and 2012 campaigns, we identified 35 ant species belonging to 15 genres and 3 subfamilies.

Most of the species are common for Romania. However there are some faunistical novelties for Transylvania and Romania. First record of *Myrmica gallienii* in Romania was recently published (CZEKES et al. 2012). We also published the first record of *Aphaenogaster subterranea* in Transylvania (TĂUȘAN et al. 2011). One last novelty is represented by the first record of *Tetramorium sp C* from the *Tetramorium* cf. *caespitum* group (TĂUȘAN et al. in prep b).

4.2. ANT COMMUNITY SUCCESSION OF DECIDUOUS FOREST CLEAR-CUTS

### 4.2.2 Chronosequence in Dumbrăveni

Altogether **22** ant species were identified in Dumbrăveni. Based on pitfall traps, *Myrmica ruginodis* was the most abundant species which was present in all sites, except AC15. *M. ruginodis* dominance is confirmed by its presence on artificial baits. Beside *M. ruginodis,* some other species occurred in pitfall: *Temnothorax crassispinus, Lasius platythorax* and *Stenamma debile*.

An interesting finding was recorded in AC120*, where due to its thermophilic character we collected *Aphaenogaster subterranea*. Up-to-date it is considered to be the north-most record of the species (Fig. 4.1). However, there is a northern record of the species in a mountain area near Poiana Stampei (CÎRDEI et al. 1969). Due to the species requirements of temperature and humidity the species presence there is ruled out. (TĂUȘAN et al. 2011). Moreover, there is a strong possibility that the authors misidentified the species with a more common ant species *Stenamma debile*. The presence of species occurred in other two sites in Dumbrăveni (AC1 andAC55).
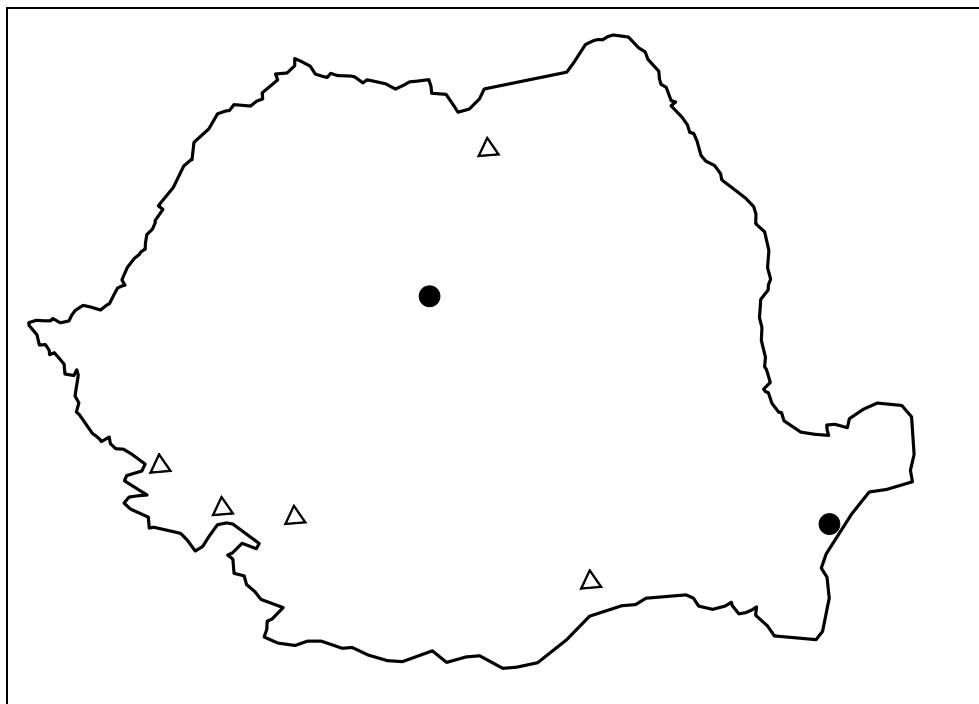
Fig. 4.1 Known distribution of *Aphaenogaster subterranea* in Romania (black circles – new records, triangle – published data) (modified after TĂUȘAN et al. 2011)

Analyzing the species number in the Dumbrăveni chronosequence we can state that the higher number of species was recorded in the clear-cuts (9 species). The number of species decreases in the all of the sites, except AC55 (9 ant species. The number of individuals follows the same trend of species number. In the last site AC120, there are 4 species represented by a high number of individuals (Fig. 4.2).
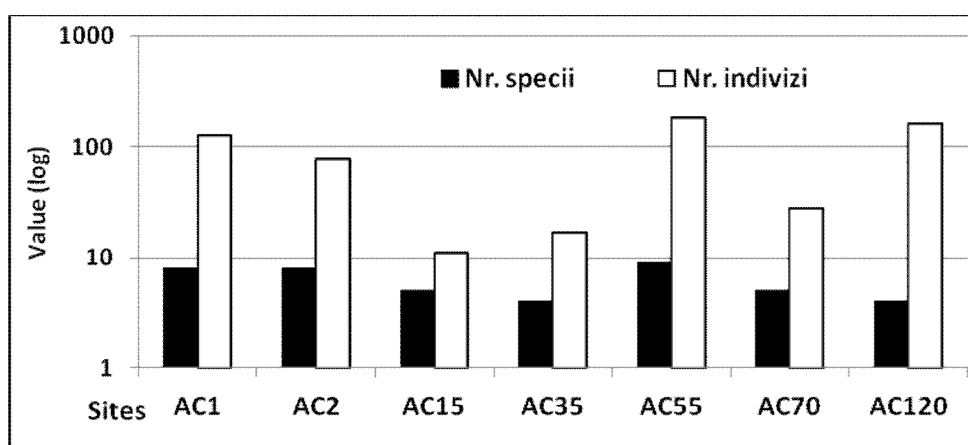

Fig. 4.2. Changes in ant species number and individuals in different stages of succession in Dumbrăveni (the codes are explained in text)

The 7 forest sites are significant different in terms of species composition (permANOVA, 5000 permutations, p=0.00039, F=5.9, Df=6).

Regarding phenology, the number of individuals registers the highest value in spring. In the AC1 site, based on pitfall traps, the highest number of individuals was registered. For AC35 there are similar results, but with lower abundance. AC15 and AC70 are characterized by a maximum value in the autumn season (Fig. 4.3).
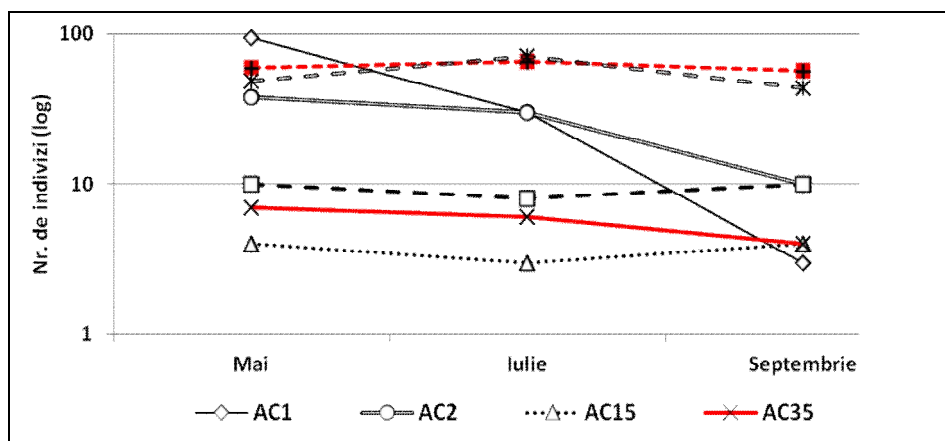
Fig. 4.3 Seasonal changes of ant communities in different successional stages in Dumbrăveni (the codes are explained in text)

4.2.3 Chronosequence in Hoia forest (Cluj-Napoca)

Altogether **18** ant species were identified in Cluj-Napoca. In Cluj-Napoca sites, *Myrmica ruginodis,* was replaced by *M. rubra.* However, *M. ruginodis*, was collected in all the sites, but its abundance was lower than *M. rubra.* Moreover, *M. ruginodis*, was present on baits in AC1, but was absent in all of the other sites.

In the clear-cuts, AC1 and AC5, the presence of *Camponotus vagus* and *Formica sanguinea* is notable. Along succession this species are eliminated. In the AC5 site, 4 species of *Myrmica* were present: *M. gallienii, M. rubra, M. ruginodis* şi *M. scabrinodis. M. gallienii* and *M. scabrinodis.* AC10 is similar with AC15 from Dumbrăveni in terms of species presence and abundance. In the last site, AC60 and AC120, the ant fauna is represented by forest species: *M. rubra, M. ruginodis, Stenamma debile* and *Temnnothorax crassispinus.*

Concerning diversity, the highest value was recorded in the AC5 site (13 species). After canopy closure (more than 10 years) the species number decreases. The AC120 is

represented by 5 species. Changes in number of individuals follow the species number trend. However, the lowest value is recorded in the AC10 site (Fig. 4.4).
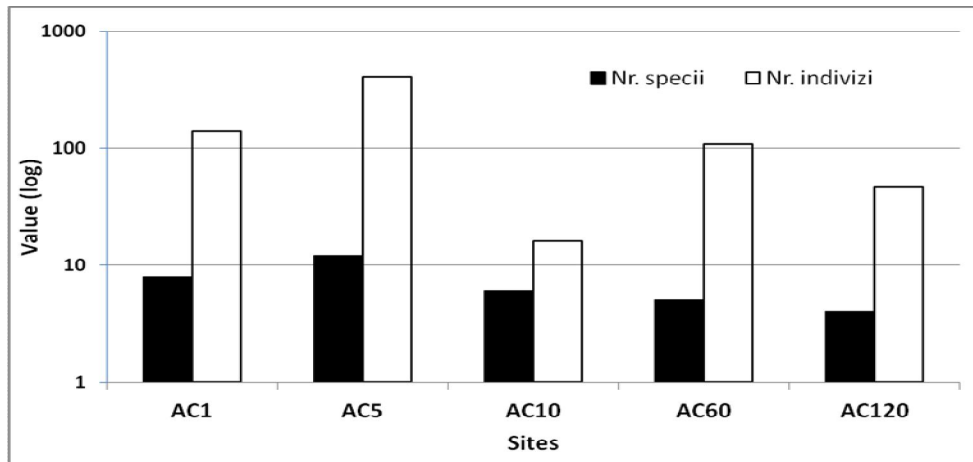
Fig. 4.4 Changes in ant species number and individuals in different stages of succession in Cluj-Napoca (the codes are explained in text)

There were significant differences in species composition within the 5 forest sites (permANOVA, 5000 permutations, p=0.06, F=2.05, Df=4).

Analysing community dynamic one can observe that beside AC1, in all of the sites the highest abundance was recorded in the summer season, followed by autumn. In AC1, the pick of activity was recorded in spring. In contrast, in the same period no individual was collected from AC10 (Fig. 4.5).
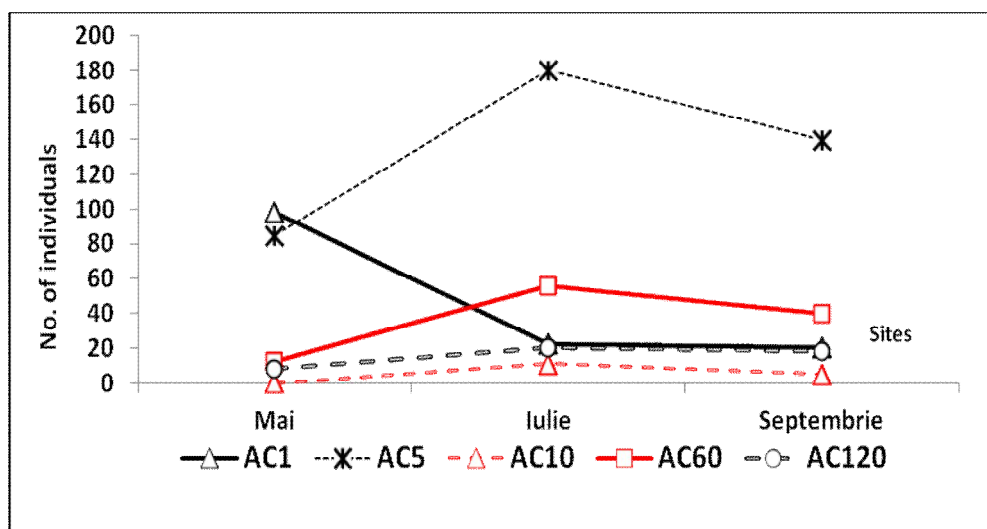

Fig. 4.5 Seasonal changes of ant communities in different successional stages in Cluj-Napoca (the codes are explained in text)

4.3. CORRELATIONS BETWEEN ANT AND PLANT COMMUNITY SUCCESSION

The chronosequence from Dumbrăveni, shows a clear trend for the richness of plant species, with a decrease towards the mature sites (AC120, 23 plant species), whereas for the ant species, a similar trend was not found (Fig. 4.6).

Similar results were obtained for the chronosequence of Cluj-Napoca, with the lowest number of plant species in the AC120 site (19 species). However, for ants, the highest number of species was recorded in AC5. In the following stages of succession, the species number follows a similar trend with the plant species (Fig. 4.7).

The plant communities of Cluj-Napoca are significant different in terms of species composition (permANOVA, 5000 permutations, $p < 0.02$; $F = 3.06$, Df=5). Similar results were observed in the chronosequence from Dumbrăveni (permaANOVA, 5000 permutations, $p = 0.018$; $F = 2.25$, Df=6).
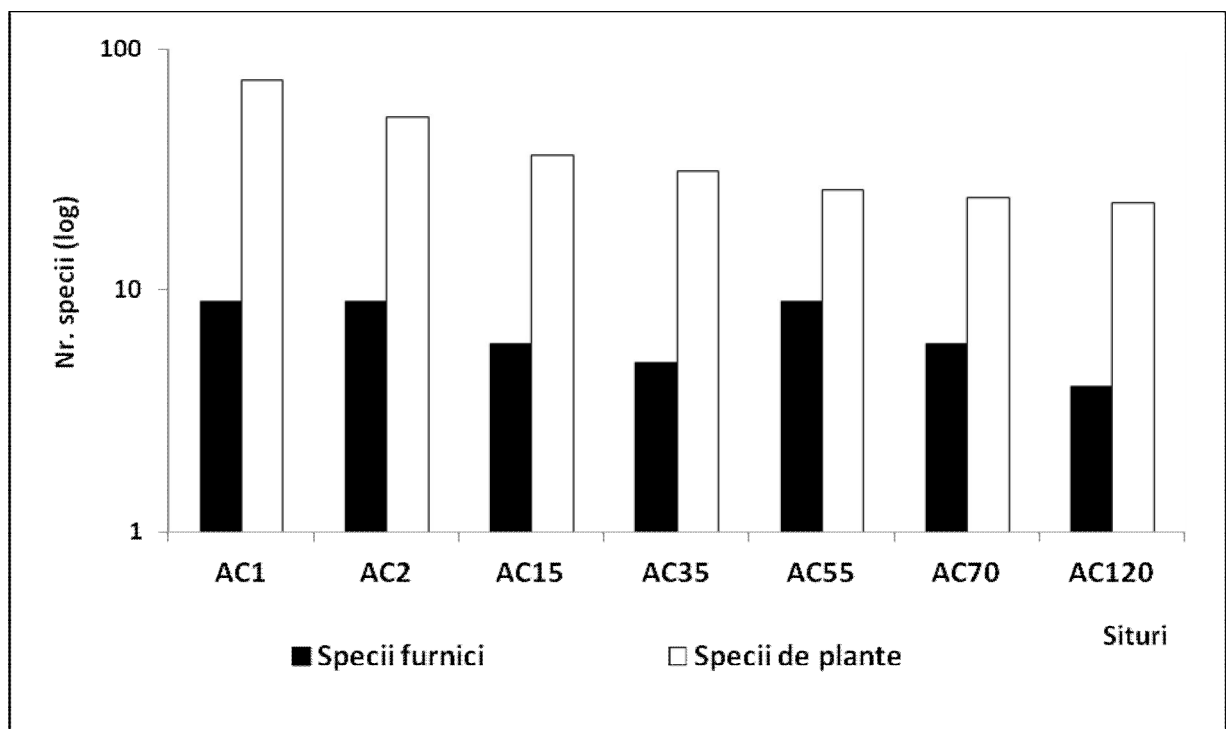
Fig. 4.6 Comparative analysis of ants and plants species number in Dumbrăveni (the codes are explained in text)

We tested the correlations between plant and ant communities in both chronosequence with a Mantel Test. In the case of Dumbrăveni we did not find any correlations ($p = 0.564$). In contrast, for Cluj-Napoca chronosequence, we found significant correlations between the two communities ($p = 0.033$).
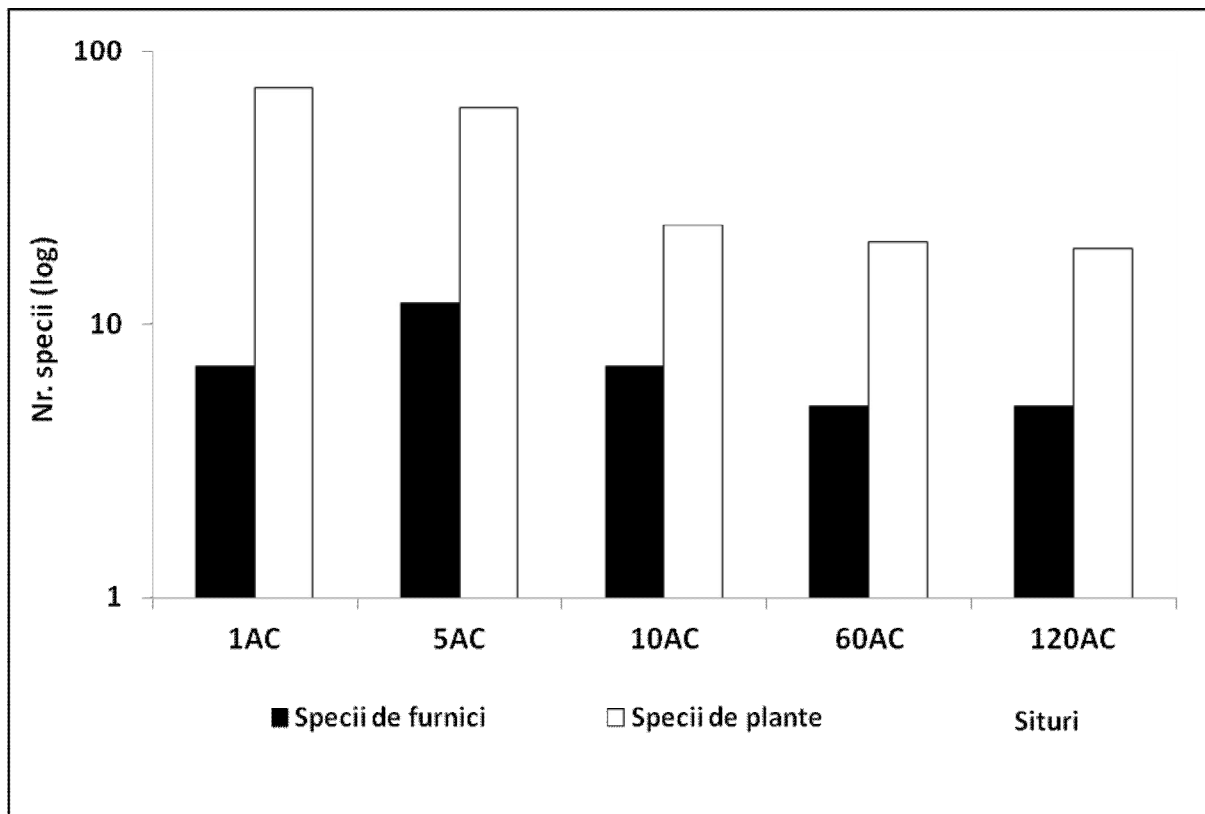
Fig. 4.7 Comparative analysis of ants and plants species number in Cluj-Napoca (the codes are explained in text)

4.4. INTERNAL FACTORS THAT INFLUENCES ANT SUCCESSION

4.4.1 Intra and interspecific interactions within ant communities

Analyzing the type of interactions (aggression, tolerance-avoidance) we observed, in the clear-cuts from Dumbrăveni (AC1 and AC2), a maximum of aggressive interactions. Intraspecific aggression was also manifested (in the case of *Myrmica ruginodis*) and in some cases aggressive behavior of *M. ruginodis* towards *Temnothorax crassispinus* was recorded. However, we observed non-aggressive interactions between the *M. ruginodis* and *T. crassispinus.*

In the mature sites, AC120 and AC120* aggressive behavior was recorded, particularly intraspecific competition, but also from *Lasius platythorax* towards *M. ruginodis.* In the AC120*, we observed a high number of non-aggressive interactions between *Aphaenogaster subterranea* and *M. ruginodis.* Towards the last hour of

observations and due to strong recruitment from *A. subterranea,* we noticed aggressive behavior between the two species.

In the Cluj-Napoca chronosequence similar results were obtained. However, in the AC1 site, we observed only non-aggressive interactions, especially between *M. ruginodis* and *T. crassipinus*.

The AC5 site recorded interesting results from baiting observations. Moreover, we noticed a mosaic of interactions. Aggressive interactions were recorded between *M. rubra* and *Lasius platythorax/Camponotus vagus*. *L. platythorax* was aggressive to *C. vagus,* and *C. vagus* was aggressive to *Tapinoma subboreale.* In the last stages of succession we observed mainly non-aggressive interactions.

4.5. INTRA-REGIONAL (WITHIN TRANSYLVANIA) AND INTER-REGIONAL (TRANSYLVANIA, BANAT AND DOBROGEA) DIFFERENCES IN TERMS OF SPECIES COMPOSITION OF DECIDUOUS FORESTS

Studying forest habitats (> 60 years old) in order to establish general rules of ant community composition in Romania we analyzed deciduous forests of different geographical areas. A total number of 15 ants species were identified, mainly forest species.

4.5.1 Ant fauna of deciduous forests from different regions of Romania

Dumbrava Sibiului forests (Transylvania)

In the three forest sites we investigated we identified 6 ant species. The most abundant species was *Myrmica ruginodis*, followed by *M. rubra* and *Temnothorax crassispinus.*

Anina and Izvoarele Nerei forests (Banat)

In the old-growth forest "Izvoarele Nerei", we identified, only one spices, sporadic *M. ruginodis.* Based on pitfall traps, but also on baiting observations, no other species was sampled. Moreover, the species occurred on forest edges, correlated with *Luzula sylvatica* patches and lower canopy shading.

In Anina sites, we identified 4 species, namely *M. ruginodis* and *T .crassispinus, L. platythorax* and disturbance-tolerant *Lasius paralienus.*

Niculiţelului Hill forests (Dobrogea)

Predictably, the ant fauna from Dobrogea compared to the other studied was clearly different. Species sucha as *M. ruginodis* and *T. crassispinus* are replaced by *Aphaenogaster subterranea* and *T. parvulus.* Thus, the most common species was *A. subterranea* (80% frequency), followed by *T. parvulus* (15% frequency) and *Tetramorium* cf. *caespitum* (17% frequency). Due to its dryer and thermophilic character species such as *Camponotus truncatus* or *Dolichoderus quadripunctatus* were sampled.

4.5.2 Intra-regional differences of ant communities in Transylvania

Analysing the species richness from the 8 forest sites within Transylvania, one can observe that most of the sites are characterised by a low number of ant species. However, in the AC120* site, due to its thermophilic character 10 ant species were identified (Fig. 4.8).

In terms of species composition, significant differences were recorded between the investigated forest sites (permANOVA, 5000 permutations p=0.06 F=3.92, Df =6).
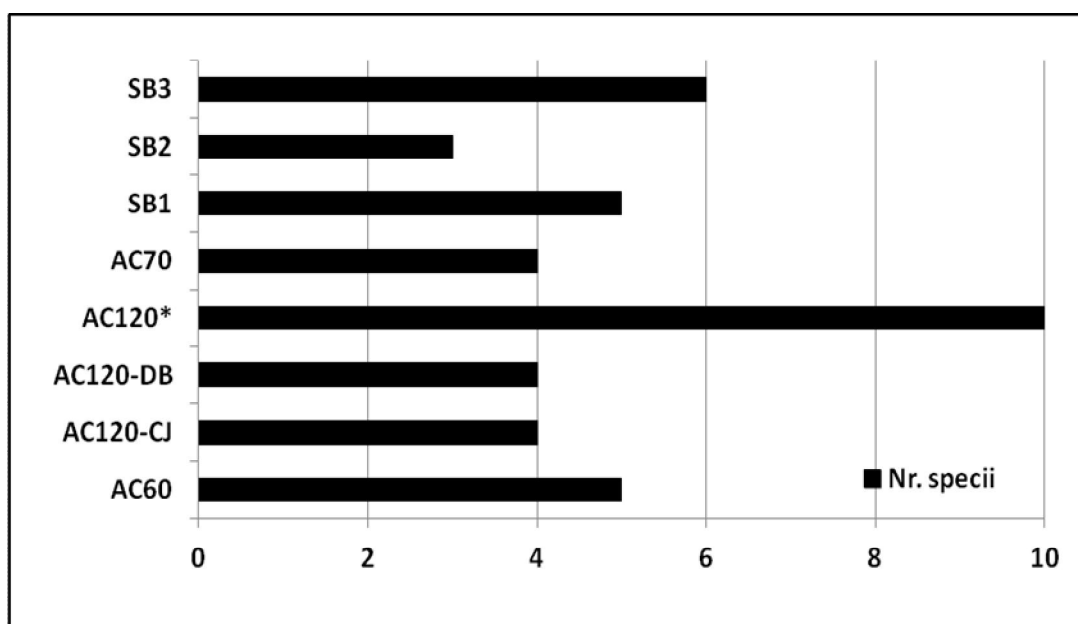
Fig. 4.8 Comparative analysis of ant species number of different deciduous forest from Transylvania (the codes are explained in text)

4.5.3 Inter-regional differences of ant communities in Romania

Within Romania there are significant differences between forest sites, in terms of species composition (permANOVA, 5000 permutations, p=0.00059, F=4.91, Df=7). The ant fauna from Dobrogea was the most different, due to the presence of *Aphaenogaster subterranea* and *Temnothorax crassispinus.* In contrast, the sites from Banat are similar to those of Transylvania due to presence of *M. ruginids, T. crassipinus* and *L. platythorax* Fig. 4.9).
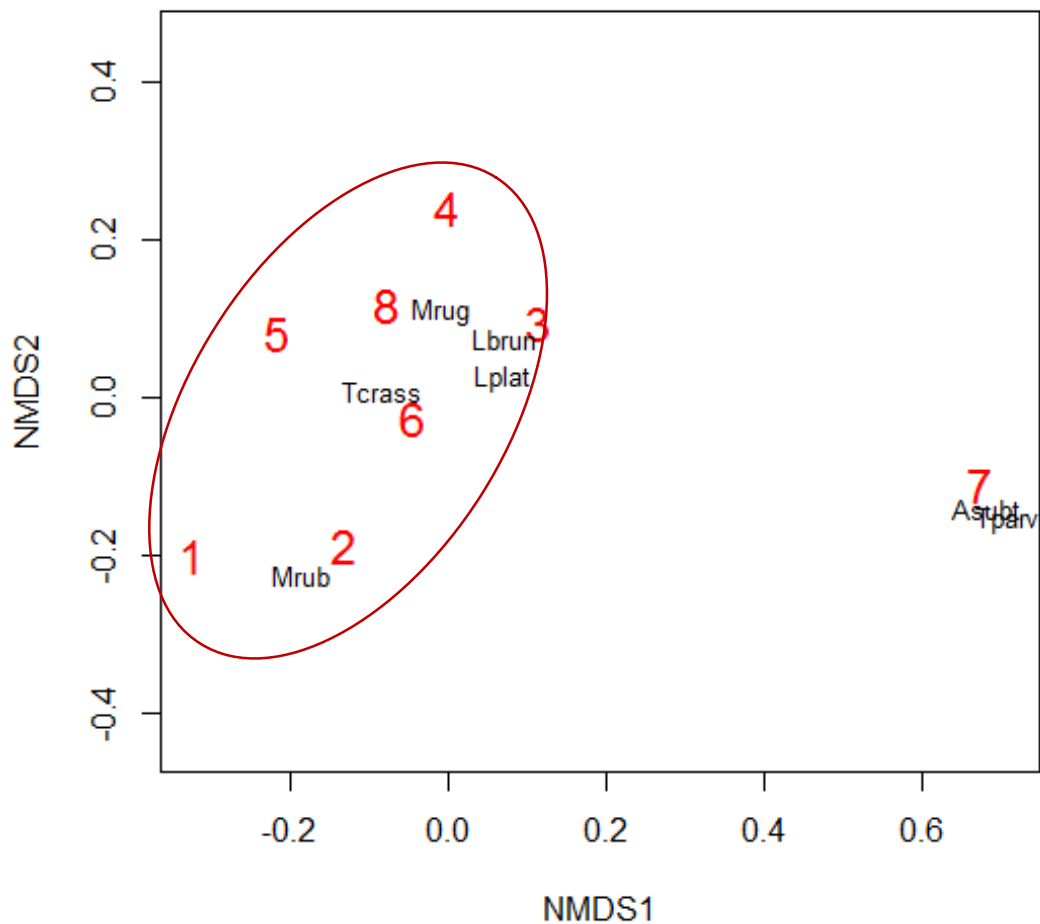
Fig. 4.9 NMDS ordination of ant communities from deciduous forest from different regions of Romania (Bray-Curtis Index of similarity, Stress= 0.084, 1-AC120 from Cluj-Napoca, 2-AC60 , 3-AC120*, 4- AC120 from Dumbrăveni, 5- AC70, 6- Dumbrava Sibiului, 7- Niculițelului hills, 8,- Anina, Mrub - *Myrmica rubra*, Mrug, *M. ruginodis,*Tcrass- *Temnothorax crassispinus*, Tparv -*T. parvulus*, Lplat - *Lasius platythorax,* Lbrun- *L. brunneus,* Asubt - *Aphaenogaster subterranea*)

CHAPTER 5: DISCUSSION

5.1 MECHANISMS OF ANT COMMUNITY SUCCESSION OF DECIDUOUS FORESTS

Following our research in 2011 we identified 21 ant species in all sites investigated in both chronosequence. Other studies from coniferous forests in different regions indicate similar results (LYNCH 1981, MARKÓ1999, PALLADINI et al. 2007, BABIK et al. 2009). In Dumbrăveni forest sites, we identified 14 ant species. The value is quite low, considering that an exhaustive study on the myrmecofauna of Sibiu County revealed 75 species (TĂUŞAN et al. 2012).

Mature stages (> 100 years), AC120 (Cluj-Napoca), AC120 and AC120* (Dumbrăveni) were characterized by the almost exclusive presence of forest ant specie. In Dumbrăveni sites, the dominant species was *Myrmica ruginodis*, whereas in Cluj-Napoca, *M. rubra* (TĂUŞAN et al. 2013). The two species are common in Transylvanian forests (CZEKES et al. 2012).

It is worth mentioning that although the two forests Dumbrăveni, AC120 and AC120* have different exhibitions (north and south), they are more similar than Cluj-Napoca forest which has a north exhibition (TĂUŞAN et al. 2013). These results may indicate the effect of landscape on ant communities. VELE et al. (2011) obtained similar findings, who considered that local dynamics is determined by the composition and structure of the landscape.

Species temperature requirements could have an important role in structuring communities (CERDÁ et al. 1998). In the clear-cuts, the temperatures are noticeably higher, which would allow the dominant species with a narrow ecological valence, be active in cooler periods and subordinate species may be more active during the day (RETANA & CERDA, 2000).

In our case, we did not find any dominant species according to SAVOLAINEN (et al. 1989) hierarchical classification. However, *Myrmica ruginodis* (in Dumbrăveni) and *M. rubra* (in Cluj) were present in traps and present on baits. In the AC1 and AC2 sites (Dumbrăveni) *M. ruginodis* was active during the morning and in the last hour of the evening observations due to requirements for temperature and humidity (CZECHOWSKI et

al. 2012). Instead when temperatures were higher species such as *Lasius platythorax* were more active. These conclusions are also valid in the case of AC1 and AC5 sites in Cluj-Napoca. In AC5, T*etramorium* cf. *caespitum* or *Tapinoma subboreale* were more active during periods with high temperatures.

5.2 ANT COMMUNITY RESPONSE TO CLEAR-CUTTING

Based on the results from Dumbrăveni, the ant communities of the AC1 and AC2 sites are not different from those of mature forests such as AC55 or AC120. Ant communities tend to react more slowly to disturbance than plant species. Contrasting results were obtained from the chronosequence in Cluj-Napoca, where the two clear-cuts AC1 and AC5 were characterizes by a different species composition than the mature sites. Moreover, in AC5 were identified four species of *Myrmica,* otherwise the only site where this was observed (TăușAN et al. *in prep* a).

The clear-cutting effects on *Formica s.str* colonies are known (SORVARI & HAKKARAINEN 2004, 2005, 2007, ŻMIHORSKI, 2010). In our research dominant species such as *Formica s. str.* were absent, but aggressive interactions were observed in three of the four clear-cuts. But their number decreased along succession stages in both study locations. Despite the existence of aggressive interactions, their number is much lower than that of avoidance/tolerance ones, emphasizing that the effects clear-cutting did not have drastic effects on the community structure.

We can conclude that clear-cutting had a negative effect on ant communities through changes in species composition, and by an increase in the intra-and interspecific aggression. However, analyzing both chronosequence, ant communities tend to recover. This is easily supported by the fact that in stages such as AC55, AC70 (Dumbrăveni) and AC60 (Cluj-Napoca), the ant fauna is dominated by forest species (TăușAN et al. *in prep* a).

CONCLUSIONS

➢ Following field campaigns conducted in 2011 and 2012, we identified 35 ant species belonging to 15 genera and three subfamilies. Most species are common in Romania. However, _Myrmica gallienii_, was recently published as first record in Romania (CZEKES et al. 2012) and _Aphaenogaster subterranea_ which was first reported in Transylvania (TĂUȘAN et al. 2011). The last faunistical novelty is the first record of T_etramorium_ sp C. (_sensu_ Schlick-Steiner et al. 2006).

➢ In Dumbrăveni, altogether 22 ant species were identified. Based on pitfall trap data, the most abundant species was _Myrmica ruginodis_, which was present in all of the sites except AC15. The highest diversity value, in terms of species richness, was recorded in the clear-cut sites (9 species).

➢ In Cluj-Napoca altogether 18 ant species were identified. The most abundant species was _M. rubra. M. ruginodis_ occurred in all site, but with lower abundance than _M. rubra._ Similar to Dumbrăveni, the highest diversity value, in terms of species richness, was in the clear-cut sites (12 species in AC15).

➢ In both chronosequence, the mature forest sites were characterized by the presence of forest species: _M. rubra, M. ruginodis, Stenamma debile, T. crassispinus_ and _L. platythorax._ Thus, ant communities tend to recover after clear-cutting. However, significant differences were found between successional stages in terms of species composition.

➢ Regarding the ant and plant community correlations during secondary succession, our results are contradictory. In Dumbrăveni, the two communities seem to have different trajectories regarding succession, where as in the case of Cluj-Napoa, significant correlations were found between the two communities.

➢ The intra and interspecific relations showed an increase of aggressive interactions in three out of four clear-cut sites. However, these interactions seem to decrease during succession, being replaced by a higher frequency of tolerance/avoidance interactions.

➢ Based on our data, the *Myrmica ruginodis / Temnothorax crassispinus* group which was observed in Transylvania, is replaced by the <u>*Aphaenogaster subterranea / T. parvulus*</u> group in deciduous forest from Dobrogea. The same interaction categories of tolerance/avoidance within the pair of species were observed in both regions, implying that there could be a co-adaptation of the two categories, only compositional changes occurring due to biogeographical influences.

SELECTED REFERENCES

1. ACOSTA, F. J., ZORRILLA, J. M., LOPEZ, F. & SERRANO, J. M. (**1992**): Progressive coupling of ant community topography with environment geomorphology in post perturbed slopes. *Acta Entomologia Bohemoslovaca*, 89: 157–167;

2. ALVARADO, M. (**2000**): Habitat correlates of ant assemblages in different forests of the South Pannonian Plain. *Tiscia,* 32: 35-42;

3. ANDERSEN, A.N. (**1995**): A classification of Australian ant communities, based on functional groups which parallel plant life-forms in relation to stress and disturbance. *J. Biogeogr*, 22: 15-29;

4. ARNAN, X., GAUCHEREL, C. & ANDERSEN, A.N. (**2011**): Dominance and species co-occurrence in highly diverse ant communities: a test of the interstitial hypothesis and discovery of a compe-tition cascade. *Oecologia,* 166: 783-794;

5. BABIK, H., CZECHOWSKI, W., WŁODARCZYK, T. & STERZYŃSKA, M. (2009): How does a strip of clearing affect the forest community of ants (Hymenoptera: Formicidae)? *Fragmenta Faunistica,* 52 (2): 125–141;

6. BEGON, M., TOWNSEND C.R. & HARPER J.L. (**2009**): Ecology, from individuals to ecosystems. Wiley. com;

7. BEISNER, B. E., HAYDON, D. T. & CUDDINGTON, K. (**2003**): Alternative stable states in ecology. *Frontiers in Ecology and the Environment*, 1(7): 376-382;

8. BISEVAC, L. & MAJER, J.D., (**1999**): An evaluation of invertebrates for possible use as success indicators for minesite rehabilitation, In: Ponder, W. & Lunney, D., (eds.): The other 99%: The conservation and biodiversity of invertebrates. *Royal Zoological Society of NSW,* 46-49;

9. BOOMSMA, J.J. &VAN LOON, A.J., (**1982**): Structure and diversity of ant communities in successive coastal dune valleys. *J. Anim. Ecol.,* 51: 957-974;

10. BUCŞA C., (**1999**): Coleoptere xilofage din Pădurea Dumbrava şi Muzeul Tehnicii Populare Sibiu. Studiu sistematic, biologic şi ecologic. Universitatea Babeş-Bolyai, Cluj-Napoca (manuscris);

11. CERDÁ X., ARNAN X. & RETANA J (**2013**): Is competition a significant hallmark of ant (Hymenoptera: Formicidae) ecology? *Myrmecological News*,18: 131-147;

12. CERDÁ, X., RETANA,J. & MANZANEDA, A. (**1998**): The role of competition by dominants and temperature in the foraging of subordinate species in Mediterranean ant communities. *Oecologia,* 117: 404-412;

13. CIOCÂRLAN V., (**2009**): Flora ilustrată a României - Pteridophyta et Spermatophyta, III ed., Ed. Ceres, Bucureşti;

14. CÎRDEI, F., BULIMAR, F. & BOIŞTEANU, T. (**1969**): Contribuţii la studiul formicidelor (Fam. Formicidae) din Carpaţii Orientali. *Studii şi comunicări ale Muzeului de Ştiinţele Naturii Bacău*, 151-156;

15. CLEMENTS, F. E. (**1916**): Plant succession: an analysis of the development of vegetation (No. 242). *Carnegie Institution of Washington,* Publication No. 242.

16. CONNELL, J.H. & SLATYER, R.O., (**1977**): Mechanisms of succession in natural communities and their role in community stability and organization. *American Naturalist* 111: 1119–1144;

17. CZECHOWSKI, W., (**2000**): Interference of territorial ant species in the course of raids of *Formica sanguinea* Latr. (Hymenoptera, Formicidae). *Annales Zoologici*, 50: 35–38;

18. CZECHOWSKI, W. & VEPSÄLÄINEN, K., (**2001**): *Formica rufa* L. protects indirectly *F. fusca* L. against raids of *F. sanguinea* Latr. (Hymenoptera, Formicidae). *Annales Zoologici*, 51: 267–273;

19. CZECHOWSKI, W. & MARKÓ, B. (**2005**): Competition between Formica cinerea Mayr (Hymenoptera: Formicidae) and co-occurring ant species, with special reference to Formica rufa L.: direct and indirect interferences. *Polish Journal of Ecology,* 53: 467-487;

20. CZECHOWSKI, W. & MARKÓ, B., (**2006**): Uncomfortable protection: *Formica polyctena* Först. shelters *Formica fusca* L. from *Formica sanguinea* Latr. (Hymenoptera: Formicidae). *Annales Zoologici,* 56(3): 539-548;

21. CZECHOWSKI W., PISARSKI B. & YAMAUCHI K. (**1995**): Succesion of ant communities (Hymenoptera, Formicidae) in moist pine forests. *Fragm. Faun.,* 24: 447–488;

22. CZECHOWSKI W., RADCHENKO A. & CZECHOWSKA W. (**2002**): The ants (Hymenoptera, Formicidae) of Poland. Museum and Institute of Zoology PAS, Warszawa, Poland;

23. CZECHOWSKI W., VEPSÄLÄINEN, K. & RADCHENKO A. (**2013**): Ants on skerries: *Lasius* assemblages along primary succession. *Insectes Sociaux,* 60(2): 147-153;

24. CZECHOWSKI W., RADCHENKO A., CZECHOWSKA W. & VEPSÄLÄINEN K. (**2012**): The Ants of Poland with Reference to the Myrmecofauna of Europe. *Fauna Poloniae* (New Series) Vol. 4. Museum and Institute of Zoology PAS, Warsaw, 496 pp

25. CZEKES Z., RADCHENKO A., CSŐSZ S., SZÁSZ-LEN A., **TĂUŞAN I**., BENEDEK K. & B. MARKÓ (**2012**): The genus *Myrmica* Latreille, 1804 (Hymenoptera: Formicidae) in Romania: distribution of species and key for their identification. *Entomologica Romanica,* 17: 29-50;

26. DAUBER J. & SIMMERING D. (**2006**): Ant assemblages in successional stages of Scotch Broom stands (Hymenoptera: Formicidae; Spermatophyta). *Myrmecol. Nachr.,* 9: 53–64;

27. DAUBER, J., & WOLTERS, V. (**2005**): Colonization of temperate grasslands by ants. *Basic and Applied Ecology*, 6, 83–91.

28. DEKONINCK, W., DESENDER, K. & GROOTAERT, P. (**2008**): Establishment of ant communities in forests growing on former agricultural fields: Colonisation and 25 years of management are not enough (Hymenoptera: Formicidae). *Eur. J. Entomol.,* 105: 681–689:

29. DEL TORO I., RIBBIONS R.R. & PELINI S.L. (**2012**): The little things that run the world revisited: a review of ant-mediated (Hymenoptera: Formicidae) ecosystem services and disservices. *Myrmecol. News,* 17:133–146;

30. DUNGER, W., WANNER, M., HAUSER, H., HOHBERG, K., SCHULZ, H.-J., SCHWALBE, T., VOIGTLÄNDER, K., ZIMDARS, B. & ZULKA, P. (**2001**): Development of soil fauna at mine sites during 46 years after afforestation. *Pedobiologia*, 45, 243–271;

31. EGGLETON P., VANBERGEN A.J., JONES D.T., LAMBERT M.C., C. ROCKETT, P.M. HAMMOND, J. BECCALONI, D. MARRIOTT, E. ROSS & A. GIUSTI (**2005**): Assemblages of soil macrofauna across a Scottish land-use intensification gradient: influences of habitat quality, heterogeneity and area. *J. Appl. Ecol.*, 42:1153-1164;

32. FROUZ, J., & JILKOVÁ, V. (**2008**): The effect of ants on soil properties and processes (Hymenoptera: Formicidae). *Myrmecological News*, 11, 191-199;

33. GALLÉ, L. (**1979**): Formicoidea Populációk denzitása és produktivitása gyepcönózisokban. (Density and Productivity of Ant Populations in Grasslands, Thesis, (in Hungarian), Szeged;

34. GALLÉ, L. (**1981**): The formicoid fauna of the Hortobágy. *The fauna of the National Park*, 307-311;

35. GALLÉ, L. (**1991**): Structure and succession of ant assemblages in a north European sand dune area. *Holarctic Ecology,* 14: 31–37;

36. GIURGIU V. (**1978**): Conservarea pădurilor. Edit. Ceres Bucureşti;

37. GLEASON, H.A. (**1926**): The individualistic concept of the plant association. *Bulletin of the Torrey Botanical Club* 53: 7–26;

38. GORB S.N. & GORB E.V. (**1999**): Effects of ant species composition on seed removal in deciduous forest in Eastern Europe. *Oikos,* 84: 110–118;

39. GOTELLI N.J. & ELLISON A.M. (**2002**): Assembly rules for New England ant assemblages. *Oikos,* 99: 591–599;

40. HAMMER, Ø., HARPER, D.A.T. & RYAN, P.D. (**2001**): PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica 4(1): 9pp. http://palaeo-electronica.org/2001_1/past/issue1_01.htm

41. HASTINGS, A., BYERS, J.H., CROOKS, J.A., CUDDINGTON, K., JONES, C.G., LAMBRINOS, J.G., TALLEY, T.S. & WILSON, W.G. (**2007**): Ecosystem engineering in space and time. *Ecology Letters*, 10: 153–164;

42. HOBBS, R. J., WALKER, L. R., & WALKER, J. (**2007**): Integrating restoration and succession. *In Linking restoration and ecological succession* pp. 168-179. Springer New York;

43. HOLEC, M. & FROUZ, J. (**2006**): The effect of two ant species *Lasius niger* and *Lasius flavus* on soil properties in two contrasting habitats. *European Journal of Soil Biology,* 42: 213-217;

44. HÖLLDOBLER, B. & WILSON, E.O., (**1990**): The ants – Belknap Press of Harvard University Press. *Cambridge*, MA, 732 pp;

45. HOLLING, C.S. (**1973**): Resilience and stability of ecological systems. *Annual review of ecology and systematics*, 4, 1-23;

46. JÁRDÁN, CS., GALLÉ, L. & MARGÓCZI, K., (**1993**): Ant-assemblage composition in a successional Hungarian sand dune area. *Tiscia,* 27: 9–15;

47. KISS, K. & MÁTIS, A. (**2002**): Párhuzamos szukcessziós folyamatok – növényzet és hangyaközösségek – a kőbányák meddő-hányóin. [Parallel successional processes – vegetation and ant communities – on minesites] *Collegium Biologicum,* 4: 23-39.

48. LESSARD, J.P., BORREGAARD, M.K., FORDYCE, J.A., RAHBEK, C., WEISER, M.D., DUNN, R.R. & SANDERS, N.J. (**2012**): Strong in-fluence of regional species pools on continent-wide structur-ing of local communities. *Proceedings of the Royal Society B-Biological Sciences,* 279: 266-274;

49. LYNCH J.F. (**1981**): Seasonal, successional and vertical segregation in a Maryland ant community. *Oikos,* **37:** 183-198;

50. MAETO K. & SATO S. (**2004**): Impacts of forestry on ant species richness and composition in warm-temperate forests of Japan. *Forest Ecol. Manag.,* 187: 213–223;

51. MARKÓ, B. (**1999**): Ant community succession and diversity changes in spruce forest clearcuts in Eastern Carpathians, Rumania. In: Tajovsky, K., Pizl, V., (eds.): Soil Zoology in Central Europe. *České Budèjovice*, pp. 203-210;

52. MAY, R. M., (**1977**): Thresholds and breakpoints in ecosystems with a multiplicity of stable states. *Nature*, 269(5628):471-477;

53. MCINTOSH R.P. (**1980**): The relationship between succession and the recovery process in ecosystems. In: *The Recovery Process in Damaged Ecosystems* (eds. J. Cairns). *Ann Arbor-Michigan*: 11-62;

54. NÉMET, E., MARKÓ, B., RUPRECHT, E. & GALLÉ, L. (**2007**): Succession of ant communities on old-fields (Hymenoptera: Formicidae; Spermatophyta). *Myrmecological News*,10: 114;

55. NIEMELÄ, J. (**1997**): Invertebrates and boreal forest management. *Conservation biology*, 11(3), 601-610;

56. ODUM E.P. (**1969**): The Strategy of Ecosystem Development. *Science,* 164: 262-270;

57. ODUM E.P. (**1971**): Fundamentals of ecology. 3rd edition. W. B. Saunders Co., Philadelphia and London. 544 pp;

58. OTTONETTI, L., TUCCI, L. & SANTINI, G. (**2006**): Recolonization Patterns of Ants in a Rehabilitated Lignite Mine in Central Italy: Potential for the Use of Mediterranean Ants as Indicators of Restoration Processes. *Restoration Ecology* ,Vol. 14, No. 1, pp. 60–66;

59. PALLADINI J. D., JONES M.G., SANDERS N. J. & JULES E.S. (**2007**): The recovery of ant communities in regenerating temperate conifer forest. *For. Ecol. Manage.*, 242: 619–624;

60. PICKETT S.T.A. (**1989**): Space for time substitutions as an alternative to long-term studies. In Likens G.E. (eds). *Long-Term Studies in Ecology*. Springer, New York, pp. 110–135**;**

61. POJAR, J., KLINKA, K., & DEMARCHI, D. A. (**1991**): Coastal western hemlock zone. Ecosystems of British Columbia, 95-112;

62. PUNTTILA, P., HAILA, Y. & TUKIA, H. (**1996**): Ant communities in taiga clearcuts: habitat effects and species interactions. *Ecography,* 19: 16–28;

63. PUNTTILA, P., HAILA, Y., PAJUNEN, T. & TUKIA, H., (**1991**): Colonisation of clearcut forests by ants in the southern Finnish taiga: a quantitative survey. *Oikos,* 61:250–262;

64. PUNTTILA, P., HAILA, Y., NIEMELÄ, J. & PAJUNEN, T. (**1994**): Ant communities in fragments of old-growth taiga and managed surroundings. *Ann. Zool. Fennici,* 31: 131–144;

65. R DEVELOPMENT CORE TEAM (**2012**): R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.

66. RETANA, J., & CERDÁ, X. (**2000**): Patterns of diversity and composition of Mediterranean ground ant communities tracking spatial and temporal variability in the thermal environment. *Oecologia*, 123(3), 436-444;

67. SAVOLAINEN, R., & VEPSÄLÄINEN, K., (**1988**): A Competition Hierarchy among Boreal Ants: Impact on Resource Partitioning and Community Structure. *Oikos,* 51(2): 135-155;

68. SAVOLAINEN, R., VEPSÄLÄINEN, K. & WUORENRINNE, H. (**1989**): Ant assemblages in the taiga biome: testing the role of terri-torial wood ants. *Oecologia,* 81: 481-486;

69. SCHEFFER, M., CARPENTER, S., FOLEY, J. A., FOLKE, C. & WALKER, B. (**2001**): Catastrophic shifts in ecosystems. *Nature,* 413(6856), 591-596;

70. SCHLICK-STEINER B.C., STEINER F.M. & STEINER H. (**2005**): Effect of extensification of coppice management on central European ant assemblages (Hymenoptera: Formicidae). *Entomol. Gener.,* 28: 23–37;

71. SCHNEIDER-BINDER, E. (**1973**): Pădurile din Depresiunea Sibiului şi dealurile marginale *Studii şi comunicări, Muzeul Brukenthal, seria Ştiinţe naturale*, 18: 71-100;

72. SEIFERT, B. (**1996**): Ameisen, bestimmen, beobachten. Naturbuch Verlag, Berlin, 352 pp;

73. SEIFERT, B. (**2007**): Die Ameisen Mittel-und Nordeuropas (pp. 204-320). Tauer: Lutra Verlags-und Vertriebsgesellschaft;

74. SORVARI J. & HAKKARAINEN H. (**2004**): Habitat-related aggressive behaviour between neighbouring colonies of the polydomous wood ant *Formica aquilonia. Animal Behaviour,* 67: 151-153;

75. SORVARI J. & HAKKARAINEN H. (**2005**): Deforestation reduces nest mound size and decreases the production of sexual offspring in the wood ant *Formica aquilonia. Ann. Zool. Fenn.,* 42**:**259–267;

76. SORVARI, J., & HAKKARAINEN, H. (**2007**): Wood ants are wood ants: deforestation causes population declines in the polydomous wood ant Formica aquilonia. *Ecological Entomology*, 32(6), 707-711;

77. SPETA, E., & RÁKOSY, L. (**2010**): Wildpflanzen Siebenbürgens. Plöchl;

78. SUMMERVILLE, K. S., & CRIST, T. O. (**2002**): Effects of timber harvest on forest Lepidoptera: community, guild, and species responses. *Ecological Applications*, 12(3), 820-835;

79. SUTHERLAND, J.P. (**1974**): Multiple stable points in natural communities. *American Naturalist*, 859-873;

80. SZUJECKI A., SZYSZKO J., MAZUR S. & PERLINSKI S. (**1978**): A succession of ants (Formicidae) on afforested arable land and forest soil. *Memorabilia Zool.,* 29: 183–189;

81. TANSLEY, A. G. (**1935**): The use and abuse of vegetational concepts and terms. *Ecology*, 16(3), 284-307;

82. **TĂUŞAN,** I., BOTA, O.T., ŞTEFU, A.A. & CRAVĂ, A.V., (**2011**): *Aphaenogaster subterranea* (Latreille, 1798) (Hymenoptera: Formicidae) in Romania: new records, distribution and habitat preferences. *Brukenthal Acta Musei,* VI.3: 459-464;

83. **TĂUŞAN,** I., JERPEL, M.M., PUŞCAŞU, I.R., SĂDEANU, C., BRUTARU, R.E., RĂDUŢIU, L.A. & GIURESCU, V., (**2012**): Ant fauna (Hymenoptera: Formicidae) of Sibiu County (Transylvania, Romania). *Brukenthal Acta Musei,* VII.3: 499-520;

84. **TĂUŞAN,** I, BOTA, O.T., TRICĂ, M.R. (**2013**): Comparative analysis of ant assemblages (Hymenoptera: Formicidae) of old Transylvanian deciduous forests. *Brukenthal Acta Musei,* VIII.3 (in press).

85. TILMAN, D. (**1985**): The resource-ratio hypothesis of plant succession. *American Naturalist*, 827-852;

86. TURCU, D.O (**2012**): Cercetări privind dinamica structurii făgetelor virgine şi a mortalităţii arborilor din Rezervaţia Naturală „Izvoarele Nerei". Universitatea "Transilvania", Braşov (rezumat);

87. VELE A., HOLUSA J., FROUZ J., KONIVCKA O. (**2011**): Local and landscape drivers of ant and carabid beetle communities during spruce forest succession. *European Journal of Soil Biology,* 47: 349-356;

88. Vepsäläinen, K. & Pisarski, B., (**1982**): Assembly of island ant communities. *Ann. Zool. Fennici,* 19: 327–335;

89. Vepsäläinen K., Savolainen R., Tiainen J. & Vilén J. (**2000**): Successional changes of ant assemblages: from virgin and ditched bogs to forests. *Ann. Zool. Fenn.,* 37: 135–149;

90. Walker, L.R., Walker, J. & Hobbs, R.J., (**2007**): Linking restoration and succession in theory and practice. *Springer*, New York;

91. Watt A.D., Stork N.E. & Bolton B. (**2002**): The diversity and abundance of ants in relation to forest disturbance and plantation establishment in southern Cameroon. *J. App. Ecol.,* 39: 18–30;

92. Whittaker, R. H. (**1953**): A consideration of climax theory: the climax as a population and pattern. *Ecological monographs*, 23(1), 41-78;

93. Wilson E.O. (**2010**): Foreward. In: Ant Ecology, Lach, L. Parr, C. & Abbott K. (eds.), Oxford University Prees, 432 pp.

94. Zettler J.A., Taylor M.D., Allen C.R. & Spira T.P. (**2004**): Consequences of forest clear-cuts for native and nonindigenous ants (Hymenoptera: Formicidae). *Ann. Entomol. Soc. Am.*, 97: 513-518;

95. Żmihorski, M. (**2010**): Distribution of red wood ants (Hymenoptera: Formicidae) in the clear-cut areas of a managed forest in Western Poland. *Journal of Forest Research*, 15(2), 145-148;

96. Zorrilla, J.M., Serrano, J.M., Casado, M.A., Acosta, F.J. & Pineda, F.D., (**1986**): Structural characteristics of an ant community during succession. *Oikos,* 47:346–354.

97. *** http:// earth.google.com

TABLE OF CONTENTS

LIST OF PUBLICATIONS

- **Published articles in international data bases journals (Zoological Records, Index Copernicus, EBSCOHost):**

1. **Tăuşan, I.,** Bota, O.T., Ştefu, A.A. & Cravă, A.V., (2011): *Aphaenogaster subterranea* (Latreille, 1798) (Hymenoptera: Formicidae) in Romania: new records, distribution and habitat preferences. *Brukenthal Acta Musei,* VI.3: 459-464;

2. **Tăuşan, I.,** Jerpel, M.M., Puşcaşu, I.R., Sădeanu, C., Brutaru, R.E., Răduţiu, L.A. & Giurescu, V., (2012): Ant fauna (Hymenoptera: Formicidae) of Sibiu County (Transylvania, Romania). *Brukenthal Acta Musei,* VII.3: 499-520;

3. Czekes, Z., Radchenko, A., Csősz, S., Szász-Len, A., **Tăuşan I**., Benedek, K. & Markó, B. (2012): The genus *Myrmica* Latreille, 1804 (Hymenoptera: Formicidae) in Romania: distribution of species and key for their identification. *Entomologica Romanica,* 17: 29-50;

4. **Tăuşan, I.,** Bota, O.T., Trică, M.R. (2013): Comparative analysis of ant assemblages (Hymenoptera: Formicidae) of old Transylvanian deciduous forests. *Brukenthal Acta Musei,* VIII.3 (in press).

- **Manuscripts in preparation**

1. **Tăuşan, I.,** Dauber, J., Trică, M.R., Markó, B. – Impact of clear-cutting on ant communities (Hymenoptera: Formicidae) of deciduous forests – A case study from Romania;

2. **Tăuşan, I.**, C*sősz,* S., Markó, B. – The genus *Tetramorium* (Hymenoptera: Formicidae) in Romania.

- **International conferences**

1. **Tăuşan, I.,** Sădeanu, C., Bota, O.T. Trică, M.R., Markó, B. (2013): Ant assemblages (Hymenoptera: Formicidae) of deciduous forests in Romania: differences at regional scale. 5th CEWM Central European Workshop of Myrmecology, Innsbruck Vienna.

2. **Tăuşan, I.,** Dauber, J.,Trică, M.R., Markó, B. (2013): Clear-cutting – not the end of the story for ant communities (Hymenoptera: Formicidae) – A case study from Transylvanian deciduous forests (Romania)*. 3rd Central European IUSSI Meeting,* Cluj-Napoca, Romania

3. **Tăuşan, I.,** Trică, M.R., Anghel, C.L., Ştefu A.A., Bota O.T., Cravă, A.V, Markó, B. (2012): Ant community structure retains the past for a while... Ant community succession (Hymenoptera: Formicidae) on deciduous forest clear-cuts in Romania, *5th Congress of European Section of the I.U.S.S.I.* Tuscany, Italy

4. **Tăuşan, I.,** Markó, B., Bota, O.T., Ştefu, A.A., Cravă, A.V. (2011): Comparative analysis of ant communities (Hymenoptera: Formicidae) in Transylvanian deciduous forests: structure and mechanisms. *Integrated Management of Environmental Resources,* Suceava, Romania

- **National conferences**

1. **Tăuşan, I.**, Ştefu, A.A., Sădeanu, C., Trică. M.R. (2013): Comunităţi de furnici (Hymenoptera: Formicidae) din păduri de foioase din România. *Al 23-lea Simpozion al Societăţii Lepidopterologice Române,* Cluj-Napoca, România.

2. **Tăuşan, I.,** Ştefu, A.A., Bota, O.T., Cravă, A.V., Markó, B., (2012): Succesiunea comunităţilor de furnici (Hymenoptera: Formicidae) pe tăieturi de păduri de foioase din sudul Transilvaniei: fenologie şi mecanisme, *Al 22-lea Simpozion al Societăţii Lepidopterologice Române,* Galaţi, România.

3. Trică, M.R., **Tăuşan, I.,** Ştefu, A.A., Anghel C.L., Cravă, A.V., Bota, O.T. (2012): Comunităţi de plante vs. comunităţi de furnici (Hymenoptera: Formicidae) în diferite pajişti din Transilvania: structură, compoziţie şi diversitate, *Al 22-lea Simpozion al Societăţii Lepidopterologice Române,* Galaţi, România

4. **Tăuşan, I.,** Ştefu, A.A., Bota, O.T., Cravă, A.V., (2011): New data concerning the distribution of some sub – Mediteranean ant species (Hymenoptera: Formicidae) from Romania, *The Third Annual Zoological Congress of "Grigore Antipa" Museum (CZGA 2011),* Bucharest, Romania