UNIVERSIDAD DE SALAMANCA

FACULTAD DE BIOLOGÍA

Departamento de Biología Animal, Ecología, Parasitología, Edafología y Química Agrícola
(Área de Zoología)

LA ECOLOGÍA TRÓFICA DE LA LECHUZA COMÚN EN LOS ECOSISTEMAS AGRÍCOLAS DE GRECIA CENTRAL: SU APLICACIÓN A LA DISTRIBUCIÓN Y ABUNDANCIA DE SUS PRESAS

TESIS DOCTORAL
SALAMANCA 2009

VASILEIOS ANASTASIOU BONTZORLOS

UNIVERSIDAD DE SALAMANCA

FACULTAD DE BIOLOGÍA

Departamento de Biología Animal, Ecología, Parasitología, Edafología y Química Agrícola
(Área de Zoología)

LA ECOLOGÍA TRÓFICA DE LA LECHUZA COMÚN EN LOS ECOSISTEMAS AGRÍCOLAS DE GRECIA CENTRAL: SU APLICACIÓN A LA DISTRIBUCIÓN Y ABUNDANCIA DE SUS PRESAS

THE TROPHIC ECOLOGY OF BARN OWL IN THE AGRICULTURAL ECOSYSTEMS OF CENTRAL GREECE: ITS APPLICATION IN THE DISTRIBUTION AND ABUNDANCE OF ITS PREY

TESIS DOCTORAL
SALAMANCA 2009

VASILEIOS ANASTASIOU BONTZORLOS

El **Dr. D. José Salvador Peris Álvarez**, profesor titular del Departamento de Biología Animal, Parasitología, Ecología, Edafología y Química Agrícola de la Universidad de Salamanca, y director de la tesis con título “**La ecología trófica de la Lechuza común en los ecosistemas agrícolas de Grecia central: Su aplicación a la distribución y abundancia de sus presas**”, elaborada por **Vasileios Anastasiou Bontzorlos** en el Área de Zoología de la Universidad de Salamanca para optar al grado de doctor, considera que dicha tesis presenta los requisitos necesarios para ser defendida públicamente, por lo que:

Autoriza su presentación ante el tribunal correspondiente.

En Salamanca a ……………… de …………….. de 2008

Fdo.: José Salvador Peris Álvarez
(El Director)

Memoria presentada por el Licenciado
Vasileios A. Bontzorlos para aspirar al
Grado de Doctor por la Universidad de Salamanca.

Fdo.: Vasileios A. Bontzorlos
(El Doctorando)

Αφιερωμένο στους γονείς μου και στην αδερφή μου

Dedicado a mis padres y a mí hermana

Dedicated to my parents and to my sister

Contents

The Barn owl and the Small Mammal Fauna of Greece

Study Area

Page

The Trophic Guild of Barn owl in Greece: Review, Comparisons, Mainland - Insular Trends and Niche Breadth

The Feeding Ecology of Barn owl in Central Greece. Geographical Tendencies and Seasonal Comparisons

Page

Distribution and Structure of Small Mammal Populations in the Agricultural Ecosystems of Thessaly, Central Greece. Associations with Habitat, Soil Types and Land Uses

Small Mammal Populations in Mediterranean Agroecosystems. Seasonal Fluctuations, Temporal Space-Use Patterns, and Crop-Rotation Effect. The Case of Thessaly, Central Greece

Acknowledgements

First of all I would like to thank especially my mother and my father. Both of them supported strongly this long term project, which at many times through the years was not the easiest task to bear. Their love and understanding, always soothed the difficult moments, and always boosted up my broken motives. This thesis, first and above all, is dedicated to you.

Then I sincerely want to express my deep appreciation for the director of my thesis, Jose Salvador Peris Alvarez. Salvador, by accepting me to the University of Salamanca, you let me in into a world of knowledge, science and experiences that I could not have imagined before. So firstly, I thank you for receiving me as a graduate student from Greece, and transforming me into a Doctor. And secondly, because through this process, I came to Spain, lived there for years, I got to know its everyday life, I met its people, I made loving, lasting friendships, and that way this country, became my second home. A priceless, unique, lifetime's experience. I will always owe you, Salva.

There are two more professors in Greece, to whom I owe a great deal. Christos Vlachos and Dimitrios Bakaloudis. You were my University teachers and my first mentors. From you I firstly heard the meanings Wildlife Biology, Sustainable Management, Raptor Ecology. With you I firstly visited the biodiversity hot spots of Greece, to work as a volunteer; with you I firstly walked the path of investigation, and exhausting data field collection; with you I firstly experienced the unforgettable feeling, of working as a team in the field, and although tiredness was always adding up as the sun went down, I never wanted the day to end. Christos, exactly 10 years ago in the village of Stefanovikeio, you showed me the first pair of Barn owls that I had ever observed in the field. I'll never forget the feeling. I guess, by completing this thesis, I demonstrate among other things the impact that these moments had on me. Dimitris, I recall you with your father in the river of Evros, in the frontier with Turkey, recognizing raptors without binoculars, just by the way they were flying over us, and arguing, who was right, and who was wrong. All I can wish now is that projects will keep coming up!

During the realization of this thesis, two more people played a definitive and very essential role for its completion. Ignacio Torre Corominas and Jaime Madrigal Gonzalez. Ignacio, with your deep knowledge on small mammal behavior and ecology, and your long term recognized investigation in this field, you offered me great insight and new perspectives for my thesis, while at the same time your critic and statistical advices unblocked the path for me at very difficult times. Many thanks, and deep appreciation. Jaime, I will never forget these four days in Cuellar. You introduced me to the world of multivariate analysis of ecological data, a scientific field that you dominate, in which you are an expert. And your wonderful mother, calling us to lunch and dinner, for quick breaks away from our computer screens. You are an excellent investigator, and you offered me great help. But most of all, you are a dear and supporting friend. I thank you for the first. And I feel blessed and lucky for the latter. May your family, you and Tere, be always well, wherever your paths may lead you.

For the collection of data concerning the study area (the lowlands of Thessaly), a great deal of public services, offices, organizations, NGOs, ministries and investigation centers were visited. During these multiple visits, which quite often were proved to be very disappointing and frustrating, there were a few people who offered a great deal of help and I feel the need to thank them. In the Statistical Service of Larissa, the director in charge, Ms Rizou, was very kind and helped a lot with providing data. In the National Agricultural Research Foundation of Larisa, the investigators Leonidas Toulios, Margaritis Toulios and Tilemaxos Lelentzis, provided excellent help, maps and data, but above all their knowledge in edafological aspects of the region. Miguel Lizana, who was one of my professors during the first two years of my Phd studies in the University of Salamanca. He supported strongly my goal, and in certain difficult times his help was more than valuable. And finally Vasileios Goutner, who is a Full Professor in Aristotle's University of Thessaloniki in the Biology Department. He was a pioneer in publishing important Barn owl diet studies during the recent years in Greece, and he repeatedly accepted me in his office, to analyze with me various aspects of my thesis and answer my questions.

I also am deeply indebted to the Spanish Ministry of Foreign Affairs and the Department of International Cooperation, for granting me a scholarship in the beginnings of my Phd studies in Spain, and to Chloros Foundation and the National Metsoveio University, for granting me an additional scholarship to complete my research and Phd thesis.

Last but not least, I also wish to thank two more groups of people. At first, my dear friends in Greece. Real, considering, unique friends, who each one with his own special way, walked along with me this path that I chose, and was always there to share a laugh, a thought, a glass of wine, a tear, a moment. First of all Afroditi, who apart from being my sister, was also a real friend, always, in all circumstances. Sofia, Giannis and Themis, who always gave me the last hug before each trip to Spain, and always expected me back in Athens with a bottle of wine in the table. Giannis, Dora, Vasilis, Giorgos, Aggeliki and Fotis who live in Thessaloniki, the city where everything started, and will always be my favorite, as long as you are part of it. And finally in Larisa, my hometown, Achilleas and Aliki with her family. I love you all.

Secondly, I sincerely want to thank, all these people that I met during my three year field investigation, in the vast region of Thessaly. They changed the way I see things, life, they broadened my perspective, and they were always there, to bring a glass of water, to a sweating, strange guy with a helmet, who was visiting forgotten villages, searching all these abandoned houses, ready to collapse. Without trying, they showed me the other face of life; they showed me my land, my home, and I learned to appreciate it even more, through their eyes.

This Phd thesis is the fruit of a long race. Finally, I just wish, that it can be of some use, as a small help for others to step on, and reach beyond, even further, in this specific field of science. In Thessaly, in Greece, or in any other part of the world…

List of Tables

List of Figures

CHAPTER 1

Introduction, Part I

The Barn owl (*Tyto alba, Scopoli 1769*) and the small mammal fauna of Greece

1.1 OBJECTIVES AND STRUCTURE OF THIS THESIS

The main objectives of this thesis are five:

1). Collect and reanalyze all published studies in Greece concerning the Barn owl's (*Tyto alba*) diet. Compare the results with those of the present thesis, study the specie's trophic guild in the country and establish geographical differences, insular and continental diet variation.

2). Examine the Barn owl feeding ecology in the agricultural ecosystems of Thessaly where it hasn't been studied before until now, in a three year period (2003-2005). Explore geographical and seasonal patterns in the owl's prey use.

3). Establish predator – prey – habitat relationships and interactions. Test hypotheses in both spatial and temporal scales on a broad landscape context.

4). Study small mammals' distribution patterns, abundance, and space use in the dynamic Mediterranean agroecosystems of central Greece, along various environmental gradients.

5). Explore and define small mammal fluctuations in Thessaly, in respect to the seasonal change of agricultural landscape and evaluate the human impact.

The first Chapter of this thesis describes Barn owl's and small mammals' status in the country, and then describes the study area, climate, land uses, agricultural cultivations, geology, soil characteristics and finally the fauna of Thessaly. In the second Chapter, the first objective is met and answered respectively, by presenting a review of all publications that have been realized in Greece until now, and analyzing the feeding habits of Barn owl. Comparisons are made with results of this thesis. Chapter 3 sets the second and third objective analyzing Barn owl's diet in Thessaly.

Chapters 4 and 5, both answer to the questions set respectively in 4th and 5th objective. Chapter four deals with associations between small mammals and habitat, soil types, land uses and different cultivation types, whereas in the 5th Chapter, the effect of crop rotation on seasonal fluctuations of small mammals is discussed. Chapter 6 is a general summary and conclusion of all results and main parts from previous chapters' discussions along with implications for conservation, whereas the 7th and 8th parts of this thesis are bibliographical references and appendices respectively.

1.2 BARN OWL

The Barn owl (*Tyto alba*, Scopoli 1769), was first described as a new specie in 1769, from specimens collected for the first time in Italy (Mikkola, 1983; Burton, 1984). It belongs in the order of Strigiformes, and in the family Tytonidae, which includes two genera, Tyto and Phodilus, and approximately 16 species, though the taxonomy is under frequent revision (Del Hoyo, 1998). In Europe, it is the only representative of these 16 species (Feduccia, 1999), and it is also the specie with the broadest worldwide distribution, matched by very few others, if any (Burton, 1984; Taylor, 1994). In the Palearctic region two subspecies occur, *Tyto alba alba*, the white breasted race, and *Tyto alba guttata* (C.L. Brehm, 1831), the yellow breasted race. A total of 36 subspecies have been described worldwide, although some confusion still exists over the status of some (Sibley & Ahlquist, 1990; Taylor, 1994).

1.2.1 General description and biology

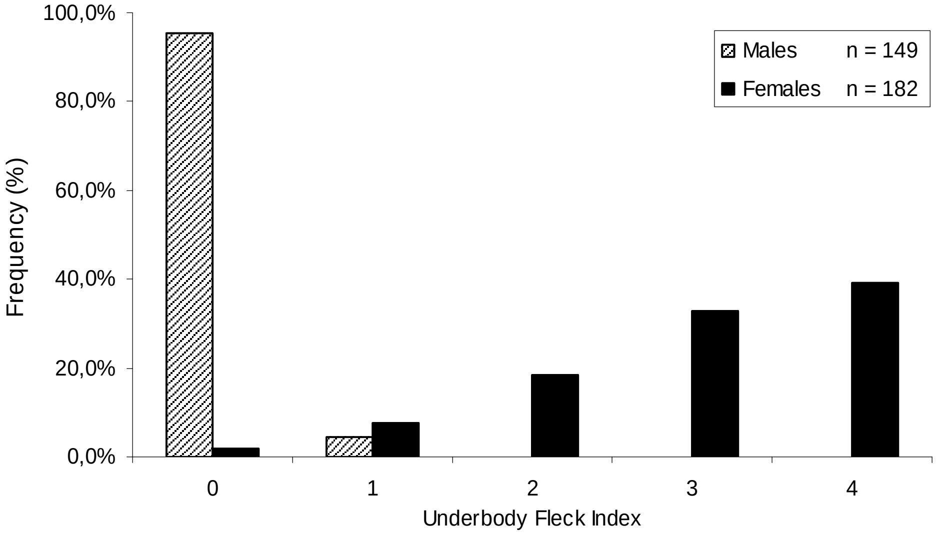
Barn owls are generally medium sized owls about 350 mm long, and their anatomy (long wings and legs) demonstrates that they are adapted to hunt over open habitats and to dive into vegetation in order to catch their prey (Everett, 1977; Taylor, 1994). They show insignificant size dimorphism between sexes (Table 1.1) however females tend to be heavier than males especially during the breeding season (Baudvin, 1975;

Cramp & Simmons, 1985; Taylor, 1994). Their upperparts are orange – buff and marked with black and grey, whereas face and underparts are colored white (Everett, 1977). Sex dimorphism according to Taylor (1994) makes it usually easy to separate males and females even from a distance, within most pairs of owls (Figure 1.1).

Table 1.1 Mean morphometric measurements of male and female Barn owls. Range (r) and sample sizes (n) are given in brackets.

		Male	**Female**
Weight (gr)	Baudvin, 1975	312 (n=17) (r: 280-365)	362 (n=55) (r: 290-450)
	Taylor, 1994	330 (n=361)	370 (n=445)
Wing length (mm)	Voous, 1950	286 (n=174) (r: 259-309)	286 (n=164) (r: 263–305)
	Cramp & Simmons, 1985	289 (n=18) (r: 279-299)	290 (n=13) (r: 280-300)
	Taylor, 1994	293 (n=139)	293 (n=110)
Tail length (mm)	Cramp & Simmons, 1985	115 (n=18) (r: 110-122)	115 (n=13) (r: 109-124)
	Taylor, 1994	115 (n=139)	115 (n=110)
Bill length (mm)	Cramp & Simmons, 1985	30.8 (n=9) (r: 30-32)	32.4 (n=4) (r: 31–33)
Tarsus length (mm)	Cramp & Simmons, 1985	57 (n=8) (r: 54-60)	56.8 (n=5) (r: 54-60)
	Taylor, 1994	57 (n=139)	58 (n=110)

Figure 1.1 Underbody fleck scores of breeding-age males and females. 0: Unmarked 1: Very lightly marked 2: Lightly marked 3: Medium marked 4: Strongly marked



Almost all females have at least some flecking on their underbody feathers, and many have their entire underparts densely covered with black flecks, whereas most males don’t even have underwing flecks. Females also tend to be darker, and become paler with age (Taylor, 1994).

Barn owls do not construct nests. In their natural state they are cavity nesters, depending upon tree holes, cliff faces, and nests of other birds (Haverschmidt, 1934; Sharrock, 1976; Taylor, 1991). In Europe and North America though, Barn owls have become highly dependent upon man made structures (Bunn et al., 1982; Seel et al., 1983; Juillard & Beuret, 1983; Baudvin, 1986). Therefore they can be found roosting, nesting and reproducing in ruins, churches, barns, outbuildings, storage silos and mostly agricultural constructions (Everett, 1977; Burton, 1984).

The Barn owl is strictly nocturnal, and begins to hunt with the set of the sun. When hunting, it catches a wide variety of prey, including small mammals, birds, reptiles, amphibians and insects, but worldwide they depend on a relatively small number of species (Taylor, 1994). In most areas, terrestrial small mammals and in particular rodents are by far the most important prey (Marti, 1988; Taylor, 1994).

During the breeding season, the female normally has clutches from 4 to 7 eggs, with extremes of 2 and 14 eggs mentioned (Shawyer, 1998). The eggs are laid with 2 days intervals, and it takes 30-33 days for the first egg to hatch, whereas fledging lasts for a 40 day period. The owlets leave the nest after 60 – 70 days, and in a year of good food supply, pairs may breed twice (Read & Allsop, 1994; Jones, 2002).

Barn owls are rather sedentary birds and no truly migratory populations are known. There is, however, a dispersal of young owls shortly after they become independent of their parents. Records from banded barn owls show that this may occur in any compass direction and may range from a few miles in most of the cases, to over a thousand miles in distance, in very few examples. Having completed their dispersal, barn owls select a home range and usually remain there for the rest of their lives (Marti, 1992; Marti, 1999).

1.2.2 World distribution, population trends & conservation status

An outstanding feature of Barn owl distribution is its' very wide world range (Figure 1.2), which includes North and South America, Europe, much of Africa, Arabia, India, South-east Asia and Australia, as well as many of the islands associated with these regions (Mikkola, 1983; Burton 1984). Consequently it is distributed in all continents except Antarctica, but it is also absent from the coldest parts of Eurasia and North America, and the driest Saharan and Middle Eastern deserts (Konig, 1999). Although Mikkola (1983) described it as cosmopolitan specie, this is slightly misleading since, apart from certain parts of Europe and the Americas, it is mainly a bird of tropical and sub-tropical regions and is essentially restricted to a band 40^o on either side of the Equator (Burton, 1984; Voous, 1989). Scottish Barn owls are the most northerly population in the world, whereas the southernmost outpost of the specie is Tierra del Fuego (Mikkola, 1983; Burton, 1984).

In Europe, *Tyto alba alba* is widely distributed in Ireland, Great Britain, in most central Europe and in the Mediterranean zone. It is slowly substituted from the dark breasted race *Tyto alba guttata* in the south of Sweden and Denmark, and from German, Poland and part of western Russia until Austria, Hungary, Rumania and Yugoslavia. Between western France and eastern German, in the borderline of the two subspecies' range, a hybrid race has occurred (Mikkola, 1983; Taylor, 1994). A third European race has also been located in Corsica and Sardinia, *Tyto alba ernesti* (Kleinschmidt,1901).

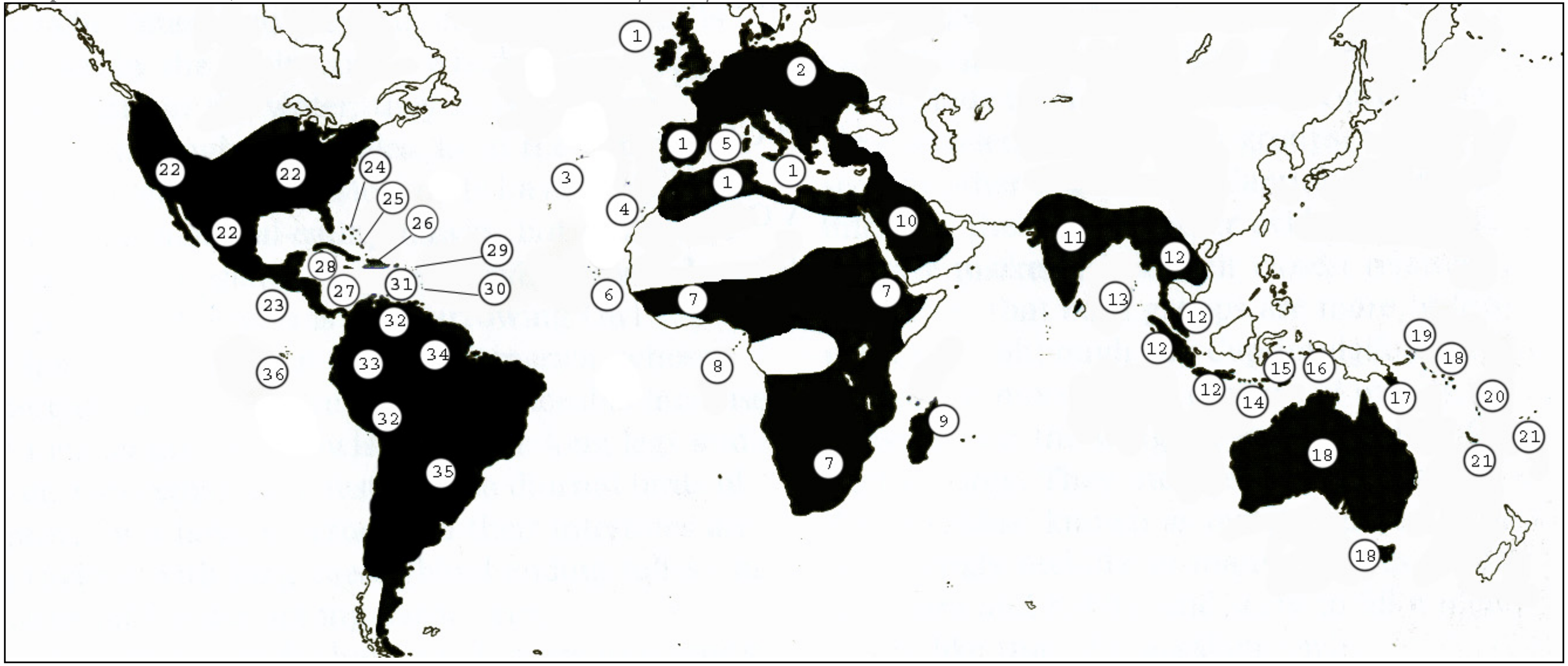


Figure 1.2 World distribution of Barn owl (black colour) and distribution of Barn owl subspecies (numbers).

1: *T.a.alba* (Scopoli): UK, Ireland, Channel Is., Spain, Portugal, west and south France, Italy, Yugoslavia, Greece, N. Africa. **2:** *T.a. guttata* (Brehm): Denmark, Netherlands, Belgium, Germany, eastern Europe. Hybrid zone with alba in eastern France western Germany. **3:** *T.a. schmitzi* (Hartet): Madeira. **4:** *T.a. gracilirostris* (Hartet): Canary Is. **5:** *T.a ernesti* (Kleinschmidt): Corsica, Sardinia. **6:** *T.a. detorta* (Hartet): Cape Verde Is. **7:** *T.a. affinis* (Blyth): Africa, south of Sahara. **8:** *T.a thomensis* (Hartlaub): Sao Thome. **9:** *T.a. hypermetra* (Grote): Comoros is., Malagasi. **10:** *T.a. erlangeri* (Sclater): Saudi Arabia, Oman, Gulf states north to Lebanon, Syria, Iraq, Iran. **11:** *T.a. stertens* (Hartet): India, Pakistan, Bangladesh, Sri Lanka, Assam, Sikkim, Nepal, Bhutan, Burma. **12:** *T.a javanica* (Gmelin): Thailand, Burma, Indo-China, Malaysia, Indonesia, Java, Flores, Timor. **13:** *T.a. deroepstorffi* (Hume): Andaman Is. **14:** *T.a. sumbaensis* (Hartet): Sumbe Is. **15:** *T.a. everetti* (Hartet): Savu Is. **16:** *T.a kuehni* (Hartet): Lesser Sunda Is., Flores to Timor; possible confusion with distribution of javanica and everetti. **17:** *T.a. meeki* (Rothschild & Hartet): South east New Guinea, Vulcan and Dampier Is. **18:** *T.a. delicatula* (Gould): Australia, Solomon Is. **19:** *T.a. crassirostris* (Mayr): Boang Is., Tanga Group, Bismark Archipelago. **20:** *T.a. interposita* (Mayr): Santa Cruz Is., Banks Is., northern New Hebrides. **21:** *T.a. lulu* (Peale): New Caledonia, south New Hebrides, Fiji, Loyalty, Tonga, Samoa, Society Is. **22:** *T.a. pratincola* (Bonaparte): North and Central America. **23:** *T.a. guatemalae* (Ridgeway): Panama to Guatemala. **24:** *T.a. lucayana* (Riley): Bahama Is. **25:** *T.a. furcata* (Temminck): Cuba. **26:** *T.a. niveicauda* (Parkes & Phillips): Is. Of Pines, Cuba. **27:** *T.a. bondi* (Parkes & Phillips): Bay Is. (off Honduras). **28:** *T.a. glaucops* (Kaup): Tortuga and Hispaniola, West Indies. **29:** *T.a. nigrescens* (Lawrence): Dominica, West Indies. **30:** *T.a. insularis* (Pelzeln): Lesser Antilles. **31:** *T.a. bargei* (Hartet): Curacao Is. (Off Venezuela). **32:** *T.a. contempta* (Hartet): Columbia, Ecuador, Peru, Venezuela. **33:** *T.a. subandeana* (Kelso): parts of Columbia, Ecuador. **34:** *T.a. hellmayri* (Griscom & Greenway): Guianas to Amazon. **35:** *T.a. tuidara* (Gray): Brazil (south of Amazon), Chile, Argentina. **36:** *T.a. punctatissima* (Gray): Galapagos Is.

The Barn owl population has suffered important declinations all over the world during the last century and especially after the 1930's (Mikkola, 1983; Taylor, 1994; Del Hoyo, 1998). In the United States, northern and mid-west populations have experienced long term reductions since 1930 (Stewart, 1980; Lerg, 1984; Mumford & Keller, 1984; Colvin, 1985). In Europe, Holland and England presented the greatest losses. During the last 50 years, Holland's population decreased for 2000 pairs (Braaksma & Bruijn, 1976), England's was reduced for 8000 pairs (Blaker, 1934; Prestt, 1965; Toms, 2000; Toms, 2001), whereas similar, but not that big decrease, also occurred in German (Güttinger, 1965; Krägenow, 1970) and Belgium (Straeten & Asselberg, 1973; De Wavrin, 1977). In a total of seven European countries the Barn owl population was reduced 50%, in another thirteen countries it reduced 20% (Table 1.2), and it disappeared completely from Malta (Tucker & Heath, 1994). The Barn owl is listed as a Species of Conservation Concern category 3, but not a priority species. Its' protection is regulated according to the European Community's Instruction 79/409, with which Greece is also in line.

1.2.3 Threats in Europe and Greece

There are five major causes for the population decline of Barn owl in Europe. 1: Agricultural intensification, 2: Loss of hunting and nesting sites, 3: Pesticide use, 4: Traffic deaths and 5: Poor winter weather.

The evolution of agricultural methods in the 1940's, opened the way for the development of farm machinery and consequently the intensification of farming. To gain the maximum benefit from their farmland use, farmers enlarged their field units usually with financial assistance from governments, and they used sophisticated

Table 1.2 Population estimates (in pairs) and trends for Barn owl in Europe. **+1**: Light increase (20 - 40%). **-1**: Small decrease (20-40%). **-2**: Great decrease (>50%). **0:** Stable condition. **F:** Unclear trend. **():** Little evidence. **X**: Disappeared.

	1930's	1960's	1970's	1980's	1990's	Population trend
Albania	-	1,000-3,000[1]	-	-	-	-1
Austria	-	-	-	(10-20)[1]	-	-1
Belarus	-	-	-	(10-50)[1]	-	-1
Belgium	-	-	1,500[2]	650-1,000[1,2]	-	-1
Bulgaria	-	-	-	(20-50)[1]	-	0
Croatia	-	-	(3,000-4,000)[1]	-	-	-1
Cyprus	-	-	-	(200-600)[1]	-	0
Chez Republic	-	-	400-700[1]	-	-	-2
Denmark	-	-	75-100[3]	20-25[1]	-	-2
France	-	-	60,000[4]	-	20,000-50,000[1]	-1
German	-	-	-	5,000-15,000[1]	-	F
Greece	-	-	-	-	(2,000-5,000)[5]	0
Hungary	-	-	1,500-2,000[1]	-	-	-1
Ireland	-	3,000-4,000[6]	1,500-3,000[7]	550-800[1]	-	-2
Italy	-	-	(6,000-12,000)[1]	-	-	-1
Lithuania	-	-	-	10-50	-	+1
Luxemburg	-	1,600[2]	-	400-800[1]	-	-1
Malta	-	-	10-30[8]	1[8]	0[1]	X
Moldavia	-	-	-	30-50[1]	-	-1
Holland	-	1,800-3,500[9]	200-500[9]	(600-1000) [1]	-	-1
Poland	-	-	1,000-4,000[1]	-	-	-1
Portugal	-	-	-	1,000-10,000[1]	-	F
Madeira	-	-	-	100-200[1]	-	0
Rumania	-	-	-	(500-1,000) [1]	-	-1
Slovakia	-	-	-	400-500[1]	-	-2
Slovenia	-	-	(50-150) [1]	-	-	-2
Spain	-	50,000-90,000[1]	50,000-80,000[1]	-	-	0
Sweden	-	18[10]	5[10]	1[10]	1[1]	-2
Canary Islands	-	-	-	(400-500)[1]	-	0
Switzerland	-	-	-	500-800[1]	-	F
Turkey	-	-	(50-500) [1]	-	-	-1
Ukraine	-	-	-	(25-35)[1]	-	-2
Great Britain	12,000[11]	8,000[6]	6,000[7]	4,500[1]	3,000[12]	-2

1: Tucker & Heath, 1994; **2:** Lippens & Wille, 1972; **3:** Dybbro, 1976; **4:** Baudvin, 1975; **5:** Handrinos & Akriotis, 1997; **6:** Parslow, 1967; **7:** Sharrock, 1976; **8:** Sultana & Gauci, 1982; **9:** Braaksma & De Bruijn; **10:** Holmgren, 1983; **11:** Blaker, 1934 **12:** Toms, 2001 machinery for drainage, harvesting, ploughing and transporting the harvests (Taylor, 1994). That resulted in a widespread loss of hedgerows, ditches, small woodlands, and hollows and led to the loss of natural foraging habitat for the Barn owl. It also favoured the disappearance of both mosaic-habitats and edge habitat types which supported rich small mammal communities, and were available for perching and hunting (Blaker, 1934; Shawyer, 1987; Cayford, 1992; De Bruijn, 1994). Along with this change, nesting sites were also reduced after the agricultural evolution, since barns, small lofts, sheds, silo storages, stone buildings for animals and hay stocking constructions, started to be replaced by multipurpose constructions which were inaccessible to owls or just didn't offer available nesting sites (Krägenow, 1970; Kaus, 1977; Taylor, 1994).

In the 1960's, the second step of agricultural evolution was the introduction of inorganic fertilizers and organic pesticides (Taylor, 1994). Inorganic fertilizers removed the need for crop rotation to maintain fertility, and led to further loss of diverse habitat and to the enlargement of fields with specific monoculture crops (cotton, cereals etc). On the other hand, organic pesticides were responsible for second-level poisoning of Barn owls, since they could prey on poisoned small mammals (Newton, 1979; Newton et al., 1990; Newton et al., 1991). For more than two decades (1960-1980), pesticides like DDT, aldrin/dieldrin, Difenacoum and Brodifacoum, have been responsible for the death of Barn owls, and for the thinning of their eggshells, and consequently the failure of their breeding attempts (Jeffries & French, 1976; Klaas et al., 1978; Mendenhall & Pank, 1980; Cooke et al., 1982; Mendenhall et al., 1983; Colvin, 1984; Duckett, 1984).

The monitoring of mortality patterns for Barn owl populations in Europe has also revealed that the last two decades, car collisions hold a high percentage. After 1980 two human activities, road construction and transportation, have deeply invaded farmland habitats, and since the Barn owl is foraging and hunting in very low heights, deaths from traffic collisions have increased (Fajardo, 1990; Illner, 1992; Martinez & Lípez, 1992).

Last but not least, severe winters can be a cause of high mortality for Barn owl populations (Taylor, 1992). Prolonged snow, especially when it covers the ground uniformly at depths greater than about 7 cm and when accompanied by low temperatures, has often been identified with increased owl mortality because small mammals live and move below the snow and Barn owls can’t capture them (Honer, 1963; Güttinger, 1965; De Jong, 1983; Marti & Wagner, 1985).

In Greece, the modification and destruction of natural habitats is the biggest threat for Barn owl populations, and is mainly due to changes in the agricultural practices (Handrinos & Akriotis, 1997). As Greece is now a full member of the European Union, the country is subject to the CAP (Common Agricultural Policy), which aims to increase agricultural efficiency and which often means greater intensification (Tucker & Heath, 1994). Intensification of arable farmland in the form of monocultures of industrial crops and increased field sizes took place after the 1960’s (Handrinos & Akriotis, 1997) along with widespread hedge destruction and the use of fertilizers and pesticides. The lack of data on Barn owl populations in the country from the past makes it impossible to assess the long-term impact of habitat changes on its abundance and distribution (Handrinos & Akriotis, 1997). No census, no studies, or any kind of monitoring has been realized in Greece for the decrease or the actual status of Barn owl populations. Still, agricultural modernization and intensification seem to be the most obvious threats.

1.2.4 The Barn owl in Greece

Although Mikkola (1983), Burton (1984) and Cramp & Simmons (1985) have mentioned that Barn owl is very scarce in Greece, it is quite common all over the continental country, and it is also present in a great number of islands (Handrinos & Akriotis, 1997; Alivizatos et al., 2005). The subspecie *Tyto alba guttata* has been observed in northern Greece and in the island of Euboia, but the true distribution of the two subspecies remains unknown in Greece (Handrinos & Akriotis, 1997). Although the population is supposed to be stable between 2.000 and 5.000 pairs (Handrinos & Akriotis, 1997), very little is known about the Barn owl in Greece, and no serious censuses have ever been realized, so these numbers are mainly speculations, and they have inarguably decreased during the last decade.

1.2.5 The Barn owl population in Thessaly, central Greece

The plain of Thessaly, a region located in central Greece which is consisted of four prefectures, is the biggest plain of Greece, dominated from agricultural crops. Apart the fact that it is the centre of agricultural production of the country, it is also a very large area, with low altitude, low vegetation height and agricultural habitat structure, forming an ideal landscape for Barn owls. As mentioned before, Handrinos & Akriotis (1997) have estimated the Barn owl population of Greece to be somewhere between 2.000 and 5.000 pairs. Still, these numbers are mainly speculations since no organized census have ever been organized in Greece. Moreover, although some studies have verified the existence of Barn owl in various islands (Pieper, 1977; Akriotis, 1981; Niethammer, 1989; Angelici et al., 1994; Alivizatos et al., 2005) as well in other parts of continental Greece (Tsounis & Dimitropoulos, 1992; Vohralik & Sofianidou, 2000; Goutner & Alivizatos, 2003; Alivizatos et al., 2005; Alivizatos et al., 2006), no study has ever been realized in the plains of Thessaly, which probably hold the largest Barn owl population of the country. The only known data about Barn owl populations of central Greece is a preliminary research, realized as a pilot-study for this thesis, in three Barn owl breeding sites of Thessaly which was published by Bontzorlos et al. (2005). One of the aims of this work among others as stated before, is to locate and record an important part of the Barn owl population which is nesting and breeding in Thessaly, analyze its feeding ecology and niche breadth, compare it with the existing works of Greece, and once this thesis is completed and its objectives are met, continue with every year census, and further research.

1.3 SMALL MAMMALS

Various vertebrate groups, such as birds (Opdam, 1991; Wiens, 1995; Tucker et al., 1997) and amphibians (Dickman, 1987; Laan & Verboom, 1990; Vos & Stumpel, 1996) have been used to test various hypotheses at the landscape scale. However, small mammals are considered as the ideal taxonomic group to be used as model species in order to address questions at different spatial scales, ranging from small plots to landscapes (Barrett & Peles, 1999; Manning & Edge, 2004). Ecologists and wildlife managers already have command over a solid body of knowledge concerning small mammals' natural history, population dynamics, and community interactions. They have been the subject of numerous field investigations in which individual, population-level and community-level responses have been quantified.

For instance, biology and natural histories of numerous small mammal species have been studied and recorded, especially at the organismal, population, and community levels of organization. Roles and niches of member species functioning in old-field, grassland, and forest ecosystems are also explored in detail. Another advantageous point in small mammal studies is that they can be identified, marked, and their lives can be followed and record their movement patterns. That way, survivorship, reproductive success, size of home range, and trophic level dynamics at community, ecosystem, and landscape levels can be determined. Moreover, live-trapping studies in combination with radiotelemetry have permitted insights regarding dispersal behavior and why a particular species predominantly selects a particular ecosystem or patch type. Small mammals live in relatively small spatial areas, have short lives, they typically disperse from their natal areas on reaching adulthood, and frequently exhibit behavioral response to seasonal changes. Therefore, small mammal ecologists also managed to gain new insights into processes such as rates of colonization, extinction, dispersal and persistence.

Because of the good work and the sound research on all these aspects of small mammal ecology and biology, the last 15 years it was possible to move beyond description and test hypotheses which give insight into how landscapes operate. Most questions regarding population-level and community-level processes in small mammals were traditionally addressed from the perspective of individual habitat patches. Nevertheless, since the end of twentieth century many mammalian ecologists were led to consider the importance of surrounding landscape, when investigating relationships of ecological processes to population dynamics and survivorship in small mammals. Especially during the 90’s, small mammal ecology was increasingly studied from a landscape perspective. Addressed questions begun to focus on the effects of landscape elements on dispersal behavior (e.g. Henderson et al., 1985; Merriam & Lanoue, 1990; LaPolla & Barrett, 1993), the effects of habitat fragmentation on species success and abundance (e.g. Robinson et al., 1992; Diffendorfer et al., 1995; Collins & Barrett, 1997), or the role of patch quality as well as shape and size on small mammal population dynamics (e.g. Harper et al., 1993; Peles & Barrett, 1996).

Therefore, developing and testing hypotheses of how individual and population-level processes are influenced by features of the landscape will have an important impact on our understanding of landscape ecology as a whole. It has become increasingly clear in the dawn of 21st century that small mammals are among best organisms to help ecologists understand ecosystem and landscape processes because of their rich biotic diversity, and their small-scale spatial and temporal responses. A better understanding of large scale processes has become critical to both the development of theory on landscape ecology and, ultimately, to the management of natural systems in an ecological sensible and economically sustainable manner. In the past, small mammals served as a model group to advance our knowledge at the molecular and cellular level. Nowadays, they are considered the ideal experimental model group to advance our knowledge and understanding at community, ecosystem, landscape, and global levels.

1.3.1 Small mammals in the Mediterranean Basin and the particularities of Balkan Peninsula

During the last million years, various processes such as immigration, extinction, endemicity and many others have produced the extant biodiversity in the Mediterranean region (Blondel & Aronson, 1999). A total of almost 200 mammal species can be encountered, from which the 25% are endemic species (Cheylan, 1991). Moreover, non-flying small mammal fauna presents great differences within the Western Palearctic and among the four zones of Mediterranean Basin (Baquero & Telleria, 2001). Non-flying mammals have low dispersal abilities, a fact which along with the presence of physical barriers running East-West in the Mediterranean Basin, and the climatic along with land-use changes which occurred during the Holocene, are key factors in comprehending these patterns (Blondel & Aronson, 1999; Baquero & Telleria, 2001).

Many Palearctic mammal populations retreated to the Southern Peninsulas during glacial periods. These species are nowadays nearly absent and extinct from these areas due to post-glacial warming and to the negative human impact on both forest habitats and mammal populations from the Neolithic era and onwards (Blondel & Aronson, 1999). A few species though were able to maintain populations in southern mountainous regions, which were less affected by warming and human activities than the lowlands. Therefore, climatic and human effects increased the extinction rates of Palearctic species in the southern peninsulas, explaining the low species richness as compared to central Europe. On the other hand though, isolation during glacial periods along with the presence of warm refuges during the Tertiary, explains the high numbers of endemics and rare species in southern Europe (Blondel & Aronson, 1999; Baquero & Telleria, 2001).

As a result, western Mediterranean nowadays is the poorest region, with Iberian and Italian peninsulas holding less than 80 mammal species, (Blondel & Aronson, 1999), whereas central Europe presents the higher richness values. On the contrary, endemic and rare species demonstrate a reverse pattern, with the Iberian Peninsula being richer in endemic species, the Balkan Peninsula presenting higher values in rare species, and Central – Northern Europe having lower values in these terms. It has been shown that the hot spots of European rodent diversity are focused in the Balkan Peninsula (including the Carpathian Basin) and adjacent parts of southern Ukraine and

Ciscaucasia, where >80% of rodent genera and species occur on merely 11.4% of the continent's surface (Krystufek & Griffiths, 2002).

Among the eight mainland European rodents with particularly restricted distributional ranges (range encompassing <1% of the continent's surface), no less than five are from the Balkans: Romanian hamster (*Mesocricetus newtoni*), Balkan snow-vole (*Dinaromys bogdanovi*), Balkan pine-vole (*Microtus felteni*), Tatra vole (*Microtus tatricus*), Roach’s mouse-tailed dormouse (*Miomymus roachi*). Additionally, a number of other species have similarly narrow ranges such as European ground squirrel (*Spermophilus citellus*), Sandy mole-rat (*Nannospalax arenarius*), Thomas’s Pine vole (*Microtus thomasi*) and Western broad-toothed field mouse (*Apodemus epimelas*). Due to high chromosomal polymorphism in some taxa on one hand, particularly Lesser blind mole-rat (S*palax leucodon*) but also Common shrew (*Sorex araneus*) and Thomas’s Pine vole, and a lack of comprehensive taxonomic treatments on the other, the number of taxa with very restricted ranges is likely to be higher than actually recognised. In addition, the islands of Crete and Cyprus host two island endemics out of the three documented for Europe., the Crete white-toothed shrew (*Crocidura zimmermani*) and Cyprus spiny-mouse (*Acomys nesiotes)* respectively. That fact is coherent with the-oft suggested role of the Balkans as a Quaternary refugium, based on its age as a distinct landscape unit and also because of complex Plio-Pleistocene vicariant interactions, between the Balkans and Anatolia (Krystufek & Griffiths, 1999).

1.3.2 The status of non-flying small mammal fauna in Greece

As it has been already outlined in the previous two parts, mammalian distribution patterns and ecological processes in a broad landscape context, both in global level but also in Mediterranean Europe, have been poorly and only recently documented and studied. That fact in combination with the particularities of the Mediterranean basin and especially those of the Balkan Peninsula, outpoint the geographic region of Balkans as a hot spot for mammalian ecological studies. Greece moreover, apart from being the most southern outpost of Balkan Peninsula, it is also the least studied area from any small mammal aspect. Since this thesis is not dealing with any Chiroptera species, their status will not be analyzed hereafter. In respect to the non-flying small mammal fauna of Greece, a total of 43 species comprise it and inhabit the country. No matter the rich number of species, there is actually a complete lack of any kind of ecological studies concerning small mammals in Greece. The first Phd study based on live-trapping sessions which addressed ecological hypotheses about small mammal population dynamics, was conducted in the island of Lesbos by Papamichael (2007). Other than that, all the rest existing information for Greece, is dealing mainly with species' recordings concerning their distributional range (some from owl pellets), some publications focus on taxonomic arguments, and an important number of published studies deal with genetic analyses.

1.3.2.1 Order: Erinaceomorpha

1.3.2.1.1 Family: *Erinaceidae*

The order of Erinaceomorpha has only one representative of Erinaceidae family encountered in the country, the Southern white-breasted hedgehog (*Erinaceus concolor*), which is broadly distributed all over continental and insular Greece (Lapini, 1999). The first publications about the specie concerned its presence in certain islands (Wettstein, 1941; Niethammer, 1969, 1971). Its distribution was also studied in various mainland localities (Ondrias, 1965a), some genetic analyses were realized on various specimens from island locations (Giagia-Athanasopoulou & Ondrias, 1980; Giagia-Athanasopoulou & Markakis, 1996; Schaschil et al., 2002), and most of these studies are revised by Holz & Niethammer (1990). Recently two genotypes were discovered which distinguished the southern from the western race in Europe (Filippucci & Simson, 1996; Santucci et al., 1998; Seddon et al., 2002).

1.3.2.2 Order: Soricomorpha

1.3.2.2.1 Family: *Soricidae*

Eight more insectivorous species which are present in Greece belong to the order of Soricomorpha and the Soricidae family. Two of them belong to the genus Sorex: the Common shrew (*Sorex araneus*) and the Eurasian pygmy shrew (*Sorex minutus*), and both present a very limited distribution in northern Greece and Peloponnesus (Vohralik & Sofianidou, 1987; Andera, 1999; Hutterer, 1999). First recordings of Sorex species' distribution in the country were published from Chaworth (1932), Markov (1962), Kahmann, (1964), Ondrias (1965a), Felten & Storch (1965) and finally Vohralik & Sofianidou (1987), whereas all these studies are reviewed in Hausser et al. (1990) and Hutterer (1990). Since the realization of these works, three more recent ones were published concerning genetic analyses of the species (Catzeflis et al., 1982; Zima et al., 1996; Giagia-Athanasopoulou & Searle, 2003). Two co-generic Neomys species are also present in Greece, the Mediterranean water shrew (*Neomys fodiens*) and Eurasian Water Shrew (*Neomys anomalus*). Similarly to Sorex species, these two water shrews also present a limited distribution to northern Greece (Chaworth, 1932; Markov, 1962; Kahmann, 1964; Vohralik & Sofianidou, 1987; Spitzenberger, 1990a, 1990b; Sofianidou & Vohralik, 1991; Spitzenberger, 1999a, 1999b). Except these studies which focus on various recordings and distribution ranges of Neomys species in the country, two more have been published concerning the species’ genetic differentiation (Catzeflis, 1984; Zima et al., 1998).

From the Crocidurinae subfamily 4 species are present in Greece, three of them belonging to the Crocidura genus: the Bicolored shrew (*Crocidura leucodon*), the Lesser white-toothed shrew (*Crocidura suaveolens*) and the endemic Cretan shrew (*Crocidura zimmermanni*). The Cretan shrew was considered as separate specie after a series of publications (Richter, 1970; Kahmann & Vesmanis, 1975; Vesmanis & Kahmann, 1978; Reumer, 1986; Reumer & Payne, 1986; Vogel, 1986; Vogel et al., 1986) and a thorough review of these works is presented by Pieper (1990) and Vogel (1999). The other two Crocidura species have a broad distribution all over Greece, with Bicolored shrew being absent from western parts of the country (Krapp, 1999; Libois et al., 1999). Most publications concerning the two species also deal with their distributional range (Peus, 1954; Ondrias, 1965a, Pieper, 1966; Ondrias, 1969a, 1969b, 1970; Niethammer, 1971; Besenecker et al., 1972; Kock, 1974; Vohralik & Sofianidou, 1987; Vogel & Sofianidou, 1996) and some analyze the species’ genetic differentiation (Catzeflis, 1983a, 1983b; Catzeflis et al., 1985; Vogel, 1986). The mentioned studies are reviewed by Vlasak & Niethammer (1990) and Krapp (1990). The last representative of Soricidae family in Greece is the Etruscan shrew (*Suncus etruscus*), which has a very limited and scarce distribution (Libois & Fons, 1999), and all published studies up to date from Greece concern its distributional range and recordings from new localities (Pieper 1966; Spitzenberger 1970; Besenecker et al., 1972; Springhorn & Kachel, 1981; Reumer & Payne, 1986; Niethammer, 1989; Spitzenberger, 1990c; Vohralik & Sofianidou, 2000; Rottmann et al., 2003).

1.3.2.2.2 Family: *Talpidae*

The three last representatives of Soricomorpha order in Greece belong to the Talpidae family: Blind mole (*Talpa caeca*), European mole (*Talpa europaea*) and Balkan mole (*Talpa stankovici*). All three species have a very limited distribution in northern Greece (Chaworth, 1932; Niethammer, 1962; Stein, 1963; Vohralik, 1991; Krystufek, 1994; Krystufek, 1999a; 1999b, 1999c) whereas the genetic differentiation of the species was realized by Filippuci et al. (1987). These few publications concerning mainly the species' distribution are reviewed by Niethammer (1990a, 1990b, 1990c).

1.3.2.3 Order: Rodentia

Most small mammal species in Greece belong to the order of Rodentia which counts a total of 31. The Balkan snow vole (*Dinaromys bogdanovi*) and Muskrat (*Ondatra zibethicus*) could possibly be two more Rodentia species which are included in the Greek small mammal fauna as well, but surveys and further studies are required to affirm that speculation (Niethammer, 1963; Petrov & Todorovic, 1982; Pietsch, 1982; Jima, 1999a; Krystufek, 1999d; Shenbrot & Krasnov, 2005).

1.3.2.3.1 Family: *Sciuridae*

Three species of the Sciuridae family are present in Greece: the Caucasian squirrel (*Sciurus anomalus*) with a very limited distribution in the islands of eastern Greece (Hecht-Markou, 1995, 1999; Gavish & Gurnell, 1999), the Eurasian red squirrel (*Sciurus vulgaris*) with a broad distribution from central to northern Greece (Wiltafsky, 1978; Vohralik & Sofianidou, 1992; Gurnell & Waters, 1999) and the European ground squirrel (*Spermophilus citellus*) also with a limited distribution in the north (Niethammer, 1974; Ruzic, 1978; Krystufek, 1999e). Two more studies concerning the genetic differentiation of the latter have been published (Soldatovic et al., 1984; Fraguedakis-Tsolis & Ondrias, 1985), and since then no other publications concerning the species have been realized.

1.3.2.3.2 Family: *Gliridae*

Gliridae family in Greece includes 4 species: the Fat dormouse (*Glis glis*), the Hazel dormouse (*Muscardinus avellanarius*), the Forest dormouse (*Dryomys nitedula*) and the Roach's mouse-tailed dormouse (*Myomimus roachi*). Fat dormouse has a confined population in the north and in the islands of Ionian Sea, Andros and Crete (Niethammer, 1962; Storch, 1978a; Vohralik & Sofianidou, 1987; Vohralik & Sofianidou, 1992; Kurtonur, 1992; Dimaki, 1999; Krystufek, 1999f). The Hazel dormouse has a very scattered confirmed population in two locations of western Greece and is possibly also present in some mainland localities (Niethammer, 1962; Storch, 1978b; Morris, 1999), whereas the Forest dormouse has a very limited distribution in the north and unconfirmed populations in a few mainland locations (Ondrias, 1966; Kurtonur, 1975; Storch, 1978c; Vohralik & Sofianidou, 1987; Sofianidou & Vohralik, 1991; Vohralik & Sofianidou, 1992; Krystufek & Vohralik, 1994; Krystufek, 1999g). Finally the Roach's mouse-tailed dormouse is probably holding a population in Thrace near the borders with Turkey, but no recent studies have been realized to confirm it (Storch, 1978d; Kurtonur & Ozkan, 1990; Filippucci & Peshev, 1999). Few studies also analyze the genetic differentiation of the species including Greek specimens (Filippucci & Kotsakis, 1995; Filippucci et al. 1995).

1.3.2.3.3 Family: *Spalacidae*

There is only one representative of the Spalacidae family in Greece, the Lesser blind mole rat (*Spalax leucodon*), which presents a very limited distribution in parts of northern and western Greece, in the island of Samothraki and in Thrace (Ondrias, 1966; Savic, 1982; Vohralik & Sofianidou, 1992; Krystufek, 1999h), and in certain mainland localities where its presence is unconfirmed with recent studies (Krystufek, 1999h). Some publications also deal with genetic analyses of the specie including specimens from Greece (Giagia-Athanasopoulou et al., 1982; Peshev, 1983; Savic & Soldatovic, 1977, 1978; Yuksel & Gulkac, 2001).

1.3.2.3.4 Family: *Muridae*

The family Muridae in Greece includes a total of 13 species. The single-species genera of the family include the Tristram's jird (*Meriones tristrami*), the Harvest mouse (*Micromys minutus*) and the Crete spiny mouse (*Acomys minous*). The Tristram's jird is recorded to be present in Greece only in the Aegean island of Kos which is adjacent to the coasts of Turkey (Pieper, 1966; Pavlinov et al., 1990; Krystufek & Vohralik, 1999). The Harvest mouse has a limited distribution in northern Greece (Böhme, 1978a; Spitzenberger, 1986, Vohralik & Sofianidou, 1992; Spitzenberger, 1999c) and the specie's first recordings were published by Ondrias (1966) and Niethammer (1974), whereas the Crete spiny mouse is endemic to the island of Crete (Zimmermann et al., 1953; Dieterlen, 1963, 1978; Zima, 1999b). Various genetic studies have been realized about the Crete spiny mouse which are reviewed in the publications of Fraguedakis et al. (1993), Kunze et al. (2000) and Barome et al. (2001).

The Rattus genus in Greece has two representatives, the Brown rat (*Rattus norvegicus*) and the Black rat (*Rattus rattus*). Brown rat has a very restricted distribution in the north and also presents some island populations, along with some mainland localities where its presence hasn't been reconfirmed with more recent studies (Ondrias, 1966; Pieper, 1976; Niethammer, 1989; Vohralik & Sofianidou, 1992), and these works' results are analyzed and reviewed by Becker (1978a) and Amori & Cristaldi (1999a). As far as genetic analyses are concerned, those studies which have included specimens from Greece are reviewed and presented by Levan et al. (1991), Belcheva et al. (1992) and Behboudi et al. (2002). The Black rat on the other hand has a broader distribution in Greece mainly in western locations of the country and also presents confirmed populations in various islands (Wettstein, 1941; Niethammer, 1962; Becker, 1978b; Angelici & Riga, 1994; Amori & Cristaldi, 1999b; Masseti & Maurizio, 2003), whereas genetic analyses of the specie including Greek specimens are reviewed by Yosida (1980) and Baverstock et al. (1983).

Mus genus has three representatives in Greece: the House mouse (*Mus (Mus) musculus*), the Macedonian mouse (*Mus (Mus) macedonicus*) and the Mound-building mouse (*Mus (Mus) spicilegus*). House mouse in Greece is present with the subspecie *Mus musculus domesticus* (Mitchell-Jones et al., 1999; Wilson & Reeder, 2005). It was firstly treated as a subspecie in various studies and books (Macdonald & Barrett, 1993), then it was treated as a different specie (Mitchell-Jones et al., 1999), and the latest edition of Wilsong & Reeder (2005) treats it again as a subspecie. Therefore, when House mouse is mentioned in this study it actually refers to the subspecie *Mus (musculus) domesticus* (Auffray et al., 1990; Macholan, 1999a; Macholan et al., 2003), and it presents a broad distribution all over mainland and insular localities except some central Greece locations (Reichstein, 1978; Niethammer, 1989; Angelici et al., 1992; Angelici & Riga, 1994; Macholan, 1996;). The Macedonian mouse has a limited distribution in northern Greece and in very few western mainland localities and certain islands (Vohralik & Sofianidou, 1987; Auffray et al., 1990; Vohralik et al., 1996; Macholan, 1996; Vohralik et al., 1998; Macholan, 1999b), whereas the Mound-building mouse has a strictly confined distribution in a small part of western Greece (Macholan, 1996; Macholan & Vohralik, 1997; Macholan, 1999c). Various genetic analyses have been published about the differentiation of the species in the Balkans and in Greece specifically (Bonhomme et al., 1984; Fraguedakis et al., 1986; Fraguedakis et al., 1987; Giagia-Athanasopoulou et al., 1987; Tichy & Vucak, 1987; Winking et al., 1988; Niethammer, 1989; Zima et al., 1990; Fraguedakis-Tsolis, 1992; Haitlinger, 1993; Chondropoulos et al., 1994; Giagia-Athanasopoulou et al., 1995; Chondropoulos et al., 1996; Mitsainas & Giagia-Athanasopoulou, 2005; Tryfonopoulos et al., 2005). These studies are also the only works concerning Mus species that have been published from Greece up to day.

Finally, the five last representatives of Muridae family in Greece are all Apodemus species: the Striped field mouse (*Apodemus agrarius*), the Yellow-necked field mouse (*Apodemus flavicollis*), the Western broad-toothed field mouse (*Apodemus epimelas*), the Long-tailed field mouse (*Apodemus sylvaticus*) and the Steppe field mouse (*Apodemus witherbyi*). Western broad-toothed mouse was previously treated under the Latin name of *Apodemus mystacinus* and the common English name of Rock mouse (Macdonald & Barrett, 1993; Mitchell-Jones, 1999), but Wilson & Reeder (2005) reviewed genetic and morphometric studies of the specie which indicated two different Asian and Palearctic populations, and appointed as Western broad-toothed mouse (*Apodemus epimelas*) the European population. The Striped field mouse has a very limited distribution in north-western Greece (Ondrias, 1966; Böhme, 1978b;

Vohralik & Sofianidou, 1992; Vohralik & Sofianidou, 1993; Hille & Meinig, 1996; Gliwicz & Krystufek, 1999), whereas the Yellow-necked field mouse has a broad distribution in various islands (Crete excluded) and all over mainland country except some central localities (Kahmann, 1964; Niethammer, 1978a; Montgomery, 1999a). The Western broad-toothed field mouse has a broad distribution in southern Greece and in various islands, and also presents a confined population in northern Greece (Ondrias, 1966; Niethammer, 1971, 1978b; Kock, 1974; Storch, 1977, Cheylan, 1991; Storch, 1999), whereas the Long-tailed field mouse has a very broad distribution all over mainland and insular Greece except some central localities (Ondrias, 1966; Pieper, 1966; Niethammer, 1971, 1978c, 1989; Cheylan, 1991; Montgomery, 1999b; Ozkan & Krystufek, 1999; Krystufek, 2002). Genetic analyses that indicated and treated *Apodemus epimelas* and *Apodemus mystacinus* as separate species were realized just recently (Mezhzherin, 1997; Filippucci et al., 2002; Michaux et al., 2002), whereas numerous studies have been realized with specimens from Greece in order to differentiate genetically the 5 Apodemus species and establish their populations in the country (Fraguedakis et al., 1983; Giagia-Athanasopoulou et al., 1985; Fraguedakis & Chondropoulos, 1986; Krystufek et al., 2002; Vohralik et al., 2002). Very recently, the Steppe field mouse was discovered to be a part of the European small mammal fauna, and it specifically was captured and studied in the island of Rhodes in Greece by Krystufek & Francky (2005). One unique study has also been published exploring the habitat use of Long-tailed field mouse and Yellow-necked field mouse in Dadia Forest Reserve, in north-eastern Greece (Bousbouras, 1999).

1.3.2.3.5 Family: *Cricetidae*

Voles in Greece are present with a total of 9 species, and possibly include two more as mentioned in paragraph 1.3.2.3 (p: 21). The single-species genera of the family include the Gray dwarf hamster (*Cricetulus migratorius*), the Bank vole (*Myodes glareolus*), the Eurasian water vole (*Arvicola terrestris*) and the European snow vole (*Chionomys nivalis*). The status of Gray dwarf hamster population in Greece is poorly known (Nechay, 2000), but according to old recordings it is limited in Attica and in north-eastern Greece (Kahmann, 1964; Ondrias, 1966; Niethammer, 1974; Niethammer, 1982a; Vohralik, 1999). No other studies have been realized about the specie in the country. The Bank vole (*formerly known as Clethrionomys glareolus*) has a very limited distribution in northern Greece (Peus, 1964; Ondrias, 1966; Viro & Niethammer, 1982; Vohralik & Sofianidou, 1992; Spitzenberger, 1999d; Shenbrot & Krasnov, 2005), and similarly the Eurasian water vole is also confined in a few northern locations (Ondrias, 1966; Osborn, 1966; Reichstein, 1982; Saucy, 1999; Shenbrot & Krasnov, 2005). Up to day, for the mentioned three species, no genetic analyses or other type of studies have been published concerning Greek populations. Finally, the European snow vole has a very small population in northern Greece and probably also presents some fragmented populations in central locations (Ondrias, 1966; Krapp, 1982; Amori, 1999; Shenbrot & Krasnov, 2005), but more recent surveys and studies are required to corroborate the later. Genetic analyses of the specie including specimens from Greece have been published by Chaline & Graf (1988) and Filippucci et al. (1991).

The remaining 5 species of Cricetidae family are all co-generic and belong to the genus Microtus: the Balkan pine vole (*Microtus (Terricola) felteni*), Guenther's vole (*Microtus (Microtus) guentheri*), East European vole (*Microtus (Microtus) levis,* *formerly known as M. rossiaemeridionalis*), Common pine vole (*Microtus (Terricola) subterraneus*) and Thomas's pine vole (*Microtus (Terricola) thomasi*). The Balkan pine vole is found only in Europe and is specifically an endemic specie of the Balkan Peninsula. In Greece it has a very limited distribution in the north (Niethammer, 1982b; Krystufek, 1999i; Shenbrot & Krasnov, 2005) and genetic analyses of the specie were realized by Zima & Kral (1984), Gill et al. (1987) and Jaarola et al. (2004). Guenther's vole has a limited distribution in eastern mainland Greece, which is unconfirmed though with recent studies, and is also present in the island of Lesvos (Ondrias, 1964, 1965a, 1965b; 1966; Niethammer, 1982c; Stamatopoulos & Ondrias, 1995; Krystufek, 1999j; Shenbrot & Krasnov, 2005) and genetic analyses including Greek specimens were published by Zima & Kral (1984) and Jaarola et al. (2004). East European vole was formerly treated in various reviews and studies as *Microtus epiroticus* (Petrov & Ruzic, 1982), *Microtus rossiaemeridionalis* (Macdonald & Barrett, 1993; Zima, 1999c) and also as *Microtus arvalis* (Niethammer & Krapp, 1982b), and was often referred to with the common english names "Common vole", "Sibling vole" and "Southern vole". Genetic analyses which were realized on *Microtus arvalis* species indicated *Microtus rossiaemeridionalis* as a different species, and the latest taxonomic revised edition of Wilson & Reeder (2005) cleared that taxonomic fuss and unclear status of the specie, and proposed the common name of East European vole and the scientific Latin name "*Microtus levis*", which is used in this thesis. East European vole in Greece has a confined population in northern Greece (Felten & Storch, 1965; Petrov & Ruzic, 1982; Zima, 1999c; Goutner & Alivizatos, 2003; Shenbrot & Krasnov, 2005), and although numerous genetic approaches have been realized for the specie only a few include specimens from Greece (Ruzic et al., 1975; Zima & Kral, 1984; Zima et al., 1991; Jaarola et al., 2004).

The Common pine vole has similarly a limited distribution in northern Greece (Ondrias, 1966; Niethammer, 1982d; Vohralik & Sofianidou, 1992; Krystufek, 1994, 1999k; Shenbrot & Krasnov, 2005), whereas Thomas's pine vole has a reverse distribution pattern extending from central Greece to Peloponnesus (Ondrias, 1966; Kratochvil, 1971; Niethammer, 1974, 1982e; Krystufek, 1999l). Genetic analyses including Greek specimens of Common and Thomas's pine vole were published by Giagia-Athanasopoulou & Ondrias (1973), Zima & Kral (1984), Giagia-Athanasopoulou et al. (1995), Giagia-Athanasopoulou & Stamatopoulos (1997), Tsekoura et al. (2002), Jaarola et al. (2004) and finally Rovatsos et al. (2008).

1.3.3 Small mammals and the agroecosystems of Thessaly

All publications mentioned in part 1.3.2, form the existing core of information concerning non-flying small mammal fauna of Greece. As it can be observed they are divided in two groups of studies: one is analyzing the distribution and taxonomy of the species and the other deals with genetic analyses for species differentiation. Although both are necessary and useful, there is a complete lack of information dealing with ecological hypotheses tested in specie, community or population level. Except the work of Papamichael (2007) which was realized in an island ecosystem, no other study has been published from Greece concerning population dynamics, seasonal fluctuations, community structure, habitat and space use. Moreover, since most small mammal species in Greece present a limited distribution in the north, it is quite possible that this is due to the lack of detailed national surveys in further central and southern locations. It is also possible that the species' distribution patterns in Greece have changed since most studies on which these maps are based are outdated and published before the 80's.

In the dawn of 21st century where small mammal researchers have started to study the species' ecology in a broad landscape context, Greece still lacks any kind of field work with ecological hypotheses, and no detailed national survey has ever been realized in the country. Additionally, in the agroecosystems of Thessaly according to the recent works of Mitchell-Jones et al. (1999) and Wilson & Reeder (2005), most small mammal species seem to be absent or just present in the mountainous regions which surround the plain. As it will be demonstrated in 4th Chapter, new data on the geographical distribution of 15 small mammal species are presented for the lowlands of Thessaly, along with answers for concrete ecological hypotheses concerning space use, habitat selection, and seasonal fluctuations. Furthermore, the dynamic agroecosystems which comprise the lowlands of Thessaly hold a high interest, since every year crop rotations cause a strong change of habitat between seasons, and certainly create an effect on small mammal population dynamics which is very different from stable ecosystems such as forests or natural grasslands. The 5th Chapter of this thesis makes a first approach in order to factor in these processes as well. In conclusion, the second part of this thesis which deals with small mammals in Thessaly, is actually the first long term study of small mammal populations in Greece, realized in the largest agricultural plain of the country, which addresses concrete ecological hypotheses, in a broad landscape context.

1.5 RESUMEN

1.5.1 Lechuza común

La Lechuza común fue descrita la primera vez como especie por Scopoli, en el año 1769, con ejemplares colectados en Italia. Pertenece al orden de los Strigiformes y la familia Tytonidae, la cual incluye dos géneros y aproximadamente 16 especies. En

Europa, es el único representante de dichas 16 especies, y también es la especie con la distribución más amplia a nivel mundial. Un total de 36 subespecies han sido descritas hasta hoy en el mundo, aunque su taxonomía esta bajo revisión frecuente. La Lechuza común es una rapaz estrictamente nocturna de tamaño medio (350mm), la cual se nutre principalmente de micromamíferos. Su anatomía demuestra que es adaptada para forrajear y cazar en hábitats abiertos. El dimorfismo sexual permite la separación entre machos y hembras, de una manera fácil en la mayoría de las regiones europeas.

La Lechuza común no construye nidos. En su estado natural anteriormente, anidaba en cavidades naturales como huecos en arboles y superficies rocosas verticales, o nidos abandonados construidos por otras especies. Por otra parte, especialmente en Europa y Norteamérica es dependiente de construcciones humanas, y se puede encontrar reproduciendo y posando en ruinas, iglesias, construcciones agrícolas, casas abandonadas y grandes almacenes.

1.5.2 Distribución mundial, tendencias de población y status de conservación

Una característica de la Lechuza común es su amplia distribución global. Se puede encontrar en toda Europa, Norteamérica y Sudamérica, gran región de África, Arabia, India, Australia y en el sureste de Asia, excepto Antárctica y las partes más frías de Norteamérica y los desiertos de Medio Oriente.

Durante el último siglo y desde 1930, pero especialmente a partir de 1970, la población de la Lechuza común ha sufrido mermas importantes a nivel mundial. En un total de 7 países europeos su población se ha reducido un 50%, en otros 13 hasta un 20%, y ha desaparecido totalmente de Malta. Como especie esta enlistada en la categoría 3 de las Especies con Interés Europeo para Conservación. Su protección en

Europa esta regulada por la Instrucción de la Comunidad Europea 79/409, la cual Grecia también tiene que cumplir.

1.5.3 Amenazas

Las amenazas principales que causan el decrecimiento de la población de la Lechuza común, se pueden centralizar en cinco. 1) Intensificación de la agricultura, 2) Perdida de sitios de anidamiento naturales, 3) Uso de pesticidas, 4) Muertes por causa de colisiones con trafico, 5) Temperaturas bajas y severos inviernos.

La pérdida de los márgenes naturales de las parcelas agrícolas y de los bosques islas, y la substitución de pequeñas parcelas por monocultivos de gran extensión, afectaron negativamente a las comunidades de micromamíferos, a los hábitos alimentarios de la Lechuza común y su éxito reproductor. La aplicación de pesticidas, ha reducido más la diversidad de hábitat y además durante los años 60 y 70 ha producido muertes por envenenamiento de según nivel.

1.5.4 La Lechuza común en Grecia

En Grecia hasta el día de hoy, ningún censo nacional se ha realizado para presentar información sobre la población actual de la Lechuza común en el país. Por lo tanto, tampoco se puede evaluar el tamaño del impacto que tuvieron las cinco amenazas mencionadas, durante las últimas decenas de años. Se había estimado en el año 1997 que la población en Grecia estaría entre 2.000 y 5.000 parejas, pero estos números han sido solamente especulaciones, y seguramente son diferentes, y además sin duda han cambiado a lo largo de estos años. Específicamente, en la llanura de Tesalia, situada en Grecia central, donde se llevo a campo la investigación del presente trabajo, y que es el ecosistema agrícola más grande del país, es donde posiblemente se sostiene la población más grande de Lechuza común. Uno de los objetivos de esta tesis ha sido desde el principio, el censo de la población en la región de Tesalia donde no se ha estudiado antes, el estudio de la ecología trófica de la especie, y su comparación con otros resultados en el país y otras regiones agrícolas similares.

1.5.5 Los micromamíferos de la Cuenca Mediterránea y la Península Balcánica

Los micromamíferos son considerados como el grupo taxonómico ideal para dirigir hipótesis en diferentes escalas espaciales. Hasta recientemente, la mayoría de las preguntas a nivel de población de micromamíferos, ha sido tradicionalmente dirigida desde la perspectiva de pequeñas parcelas de hábitat individuales. Por otra parte, desde principios del siglo XXI, cuando se realizan investigaciones de procesos ecológicos sobre la dinámica de poblaciones y supervivencia de micromamíferos, la importancia del paisaje ha sido de importancia principal. Así, durante los últimos 10 años, la ecología de los micromamíferos ha sido estudiada cada vez más desde una perspectiva de paisaje.

Especialmente en la Cuenca Mediterránea, la biodiversidad existente se ha formado a través de un largo proceso de millones de años, de extinción, inmigración, emigración y endemismo. Por lo tanto, hoy en día, Europa Central presenta diversidad más alta con respecto a las especies de micromamíferos, y la Península Ibérica e Italia presentan valores más altos en especies endémicas; mientras la Península Balcánica sostiene más especies raras. Formando Grecia parte de ambas, la Cuenca Mediterránea y la Península Balcánica, sostiene un ensamblaje de micromamíferos que incluye especies raras y endémicas.

1.5.6 El status de la fauna de los micromamíferos no voladores en Grecia

La fauna de micromamíferos no voladores en Grecia, esta constituida por un total de 43 especies. Aunque es un número importante, hay un desconocimiento total sobre su ecología y biología en el país. Todos los estudios que se han publicado hasta hoy, presentaron información solamente sobre su distribución. El único trabajo que dirigió hipótesis ecológicas ha sido una tesis doctoral realizada por Papamichael Georgios en la isla de Lesvos, y defendida en el año 2007. Menos esta, las demás han sido publicaciones sobre argumentos taxonómicos, nuevos datos de distribución y análisis genéticos.

CHAPTER 1

Introduction, Part II

Study Area

1.5 STUDY AREA

The region of Thessaly is one of the thirteen regions of the country. It is located in the central-eastern part of continental Greece (39° 30’ 00” N, 22° 00’ 00” E) and it is comprised of four prefectures: Karditsa, Larisa, Magnesia and Trikala (Figure 1.2). It is characterized by a highly variable landscape which has a total area of 14.036 square kilometres, being the fourth biggest of Greece in size, which is roughly 10% of the area of the entire country. It borders on the north with the districts of West and Central Macedonia, on the south with the region of Sterea Hellas, on the west with Ipirou district and on the east with Aegean Sea.

The terrain of Thessaly has a double identity. It is such that tall mountains surround the plain and they comprise the natural borders with the mentioned regions. Olympus and Kissavos are found in the north, part of the Pindos mountain range in the west, Itamos, Pelion and Mavrovouni in the east, and Othris situated in the south. In the centre, mainly the lowlands of Larisa and Karditsa, and a small part of Trikala and Magnesia regions, comprise the biggest plain in Greece. Three main rivers traverse across Thessaly: Pinios (205 km), Enippeas (84km) and Titarisios (56km).

The present study was carried out in the Thessaly plain, mostly in the lowlands of Karditsa and Larisa, with heights which range from 0 to 300m. These lowlands comprise 36% of the total Thessaly region, an area of approximately 5.053 square kilometres. The rest semi-mountainous (17.1%) and mountainous (44.9%) parts which surround the study area were excluded from the study. The population of Thessaly region is 753.888 habitats and represents the 6.9% of the total population of the country, and remains the third largest region in Greece population-wise.

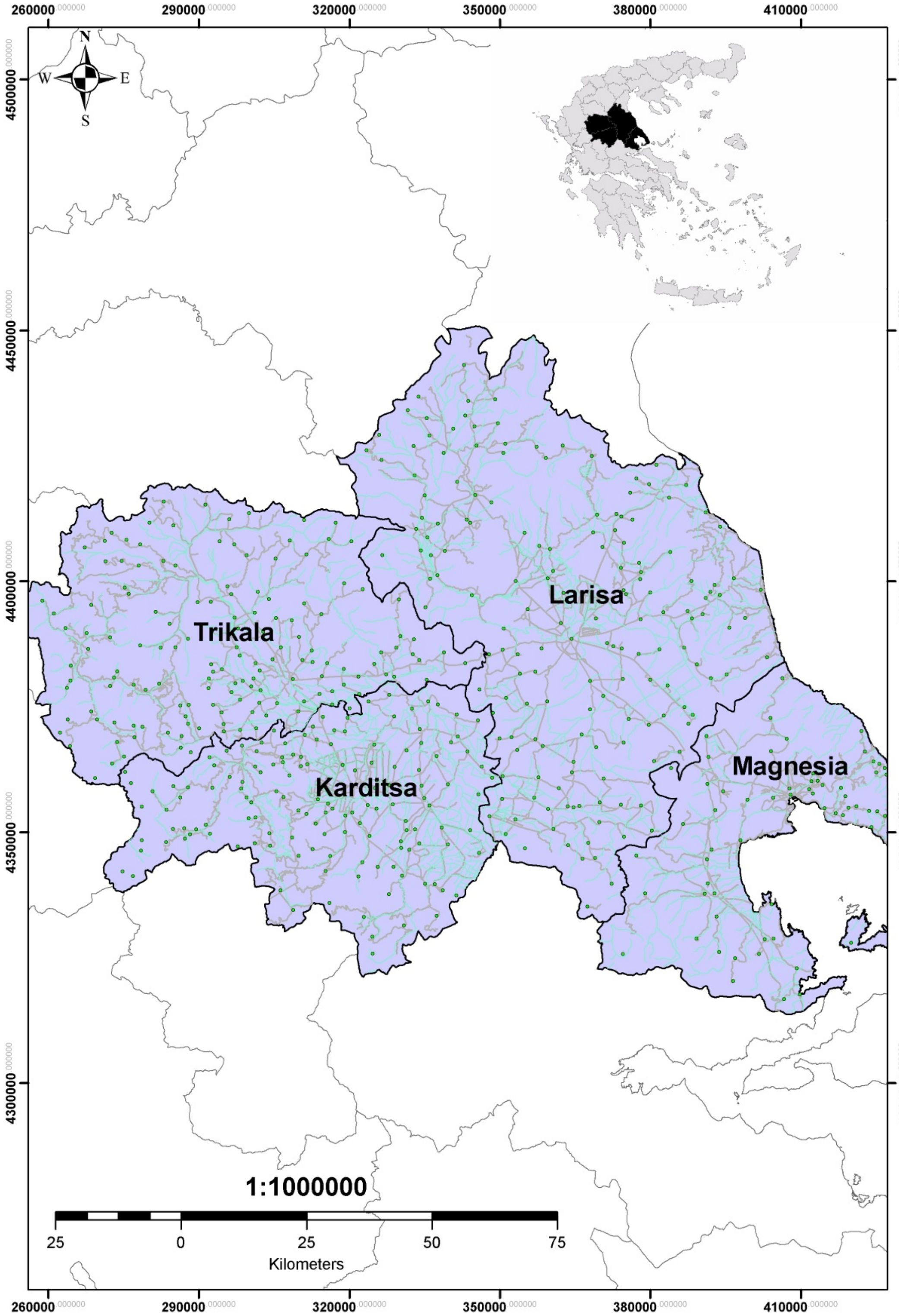


Figure 1.3 Map of study area. The region of Thessaly in central Greece, which is consisted of the four prefectures of Karditsa, Larisa, Magnesia and Trikala. Reference map of Thessaly in respect to Greece located in upper right corner.

The population break-down is 44% urban, 40% agrarian and 16% semi-urban. The urban population is concentrated in the capitals of the four prefectures, and the rest of the area is very sparsely populated from semi-urban and rural population.

1.5.1 Climate

Many classifications of climate types have been proposed in order to determine the relationships between climate and vegetation in the Mediterranean region. Nevertheless, the commonest indices used are the pluviothermic quotient (Q_2) of Emberger (1955), and the xerothermic coefficient (x) of Bagnouls & Gaussen (1952). Emberger’s index is:

$$Q_2 = \frac{2000 \text{ x } P}{M^2 - m^2}$$

P = average annual precipitation in mm,

M = monthly mean maximum temperature of the warmest month in ^{o}C, and

m = montly mean minimum temperature of the coldest month in ^{o}C

and ranges from 20 to over 250 in the Mediterranean region. According to these Q-values four main Mediterranean bioclimatic types are considered: 1) arid with $20 < Q_2 < 30$, 2) semi-arid with $30 < Q_2 < 50$, 3) sub-humid with $50 < Q_2 < 90$ and 4) humid with $Q_2 > 90$. In addition, six subdivisions have been introduced with reference to m: a bioclimatic type is considered warm if m exceeds 7 ^{o}C, temperate when 3 ^{o}C < m < 7 ^{o}C, cool with 0 ^{o}C < m < 3 ^{o}C, cold with -3 ^{o}C < m < 0 ^{o}C, very cold with -7 ^{o}C < m < -3 ^{o}C and extremely cold when m < -7 ^{o}C. The last three subdivisions have been suggested by Nahal (1972). Generally, m is an index of the relative duration of frosts; the lower m is, the longer the frost lasts (Nahal, 1981).

The Hellenic National Meteorological Service could only provide meteorological data about three of the four prefectures consisting Thessaly, therefore, the prefecture of Karditsa is excluded from the climatic classification of the study area. According to Emberger's classification, the bioclimatic types existing in the study area are the following: Larisa is subhumid (Q_2 = 62,43) and cold (m = -0,55), Trikala is humid (Q_2 = 106,1) and cool (m = 0,07), and Magnesia is subhumid (Q_2 = 80,48) and cool (m = 1,92).

Bagnouls & Gaussen's xerothermic coefficient (x) takes into account the annual average number of biologically dry days per year. Four main types of Mediterranean climate are considered: 1) submediterranean ($0 < x < 40$), 2) mesomediterranean ($40 < x < 100$), 3) thermomediterranean ($100 < x < 150$) and 4) xeromediterranean ($150 < x < 200$). The climate of the study area is characterised as submediterranean for all three prefectures of Larisa (x = 21,2), Trikala (x = 21,91) and Magnesia (x = 21,8) according to Bagnouls & Gaussen xerothermic coefficient.

Climatic data for the study area were obtained for the last 50 years from the Hellenic National Meteorological Service (H.N.M.S.) and reflect the measurements from three meteorological stations (Larisa, Trikala and Magnesia) located within the study area.

1.5.1.1 Temperature

Mean monthly summer temperatures present their peaks in July and August, in all three prefectures of Larisa, Trikala and Magnesia (Figures 1.4, 1.5 and 1.6). Larisa presents the highest values of mean monthly highest temperatures, ranging from 32 to 35, although the absolute maximum temperatures during daytime often exceed 38 ^{o}C. Mean summer temperatures range between 21 and 26 ^{o}C in all three prefectures and mean winter temperatures typically average 3 ^{o}C - 9 ^{o}C. A typical climatic feature of the study area is the large discrepancy between night and day temperatures which often exceed 20 ^{o}C. This often causes late frost in spring, usually in April and forward frost in autumn, mainly in October.

1.5.1.2 Precipitation

The mean annual precipitation for the years 1970 – 2004 is about 477 mm for Magnesia (ranging from 288 mm in 2000 to 753 mm in 2002), for Larisa it is 414 mm (ranging from 211 mm in 1970 to 704 mm in 1982) and finally for Trikala it is 704 mm (ranging from 378 mm in 1989 to 1070 in 1982). In all three prefectures precipitation is concentrated in the cold season from autumn to spring, with two peaks during November and a lower second peak during February. In contrast, the summer is dry and lasts from June to the end of September. The snow usually falls from November to March in all three prefectures.

1.5.2 Geology and Soil

The Thessaly plateau has a varied geology, both in terms of rock types and structural complexity, and it also presents a high complexity of soil types. According to Van Zeist & Bottema (1982), two were the main factors that formed the geology of the Thessaly plain. Firstly, about 5 million years ago certain geological realignments created a lake over the lowlands of Thessaly.

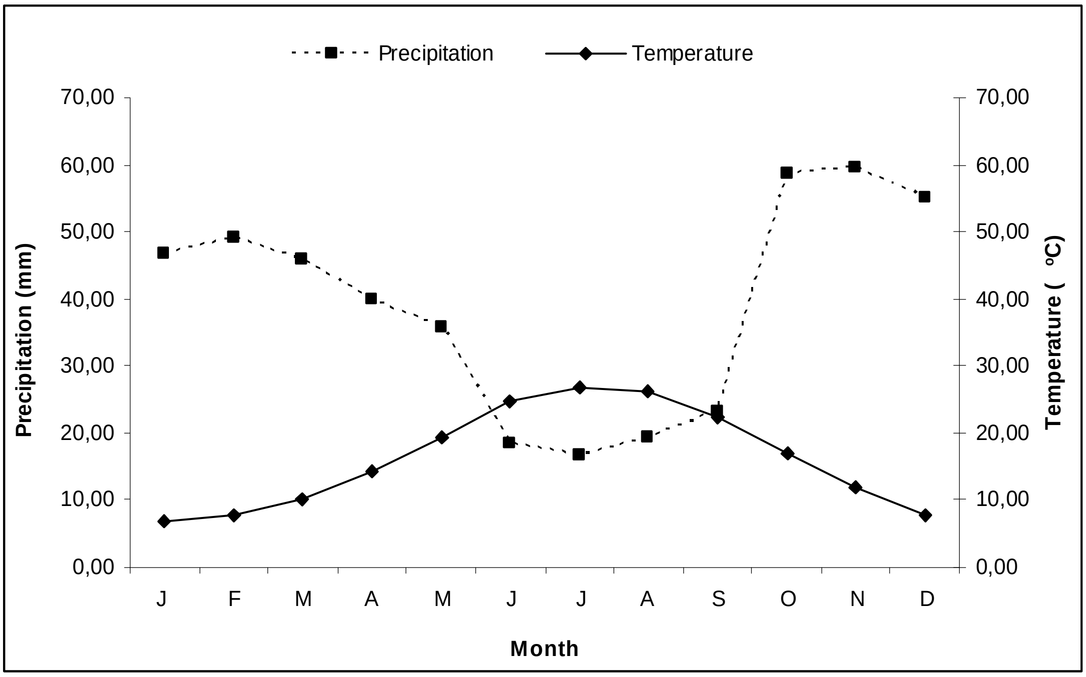


Figure 1.4 Ombrothermic diagram of Magnesia meteorological station (1970 – 2001). The area between the two intersecting curves indicates the dry period.

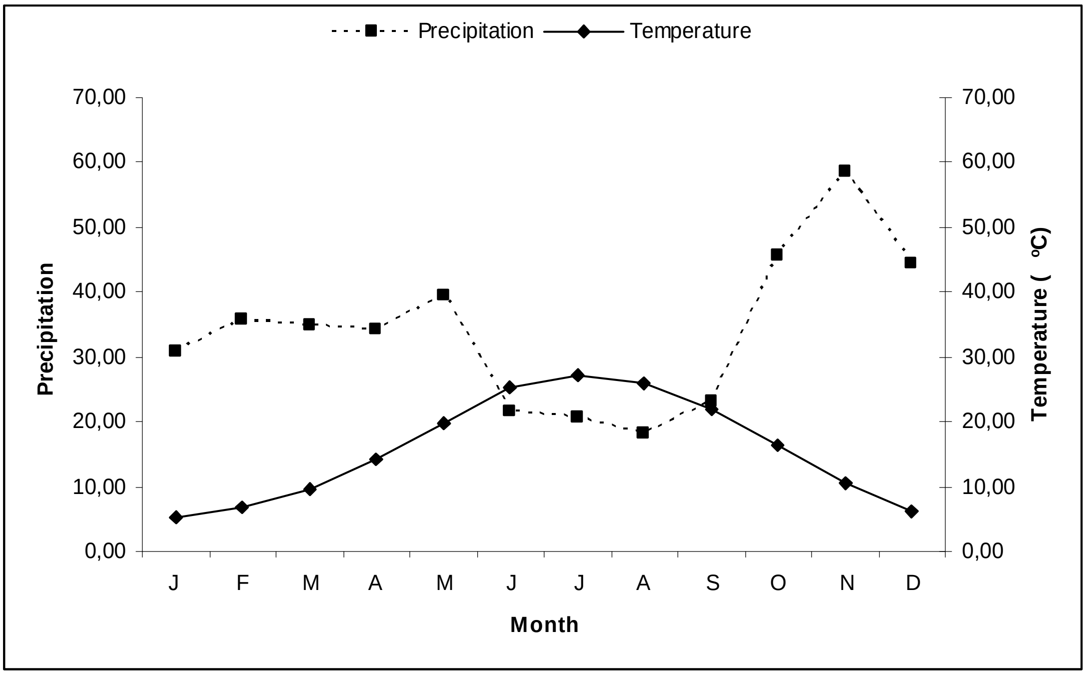


Figure 1.5 Ombrothermic diagram of Larisa meteorological station (1970 – 2001). The area between the two intersecting curves indicates the dry period.

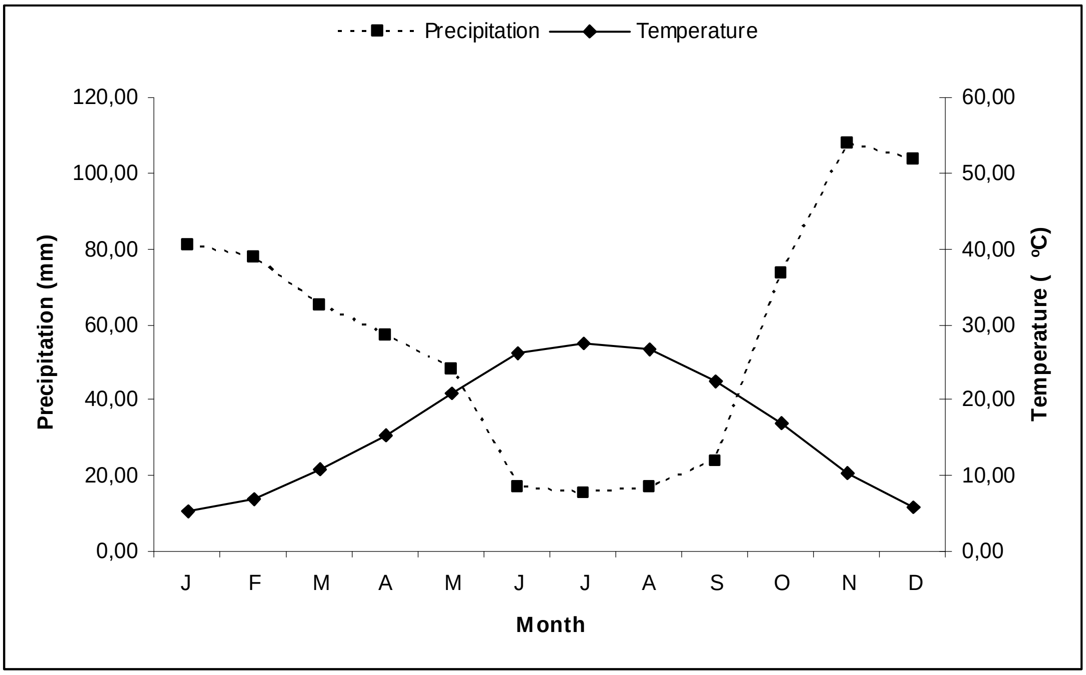


Figure 1.6 Ombrothermic diagram of Trikala meteorological station (1970 – 2001). The area between the two intersecting curves indicates the dry period.

Numerous rivers flowing from the surrounding mountains were transporting brought material to that lake until 100.000 years ago, when the Tempi canyon emerged and the waters of the lake found their way to the sea. The second important factor after the drainage of the lake was the climatic change combined with human impact such as fires, cultivations, livestock and the destruction of deciduous forests that dominated the area.

1.5.2.1 Geological formations

The northern parts of Thessaly are comprised mainly of carbonic rocks of great thickness, such as crystalline carbons and dolomites of Mesozoic era. Formations of Middle Eocene underlie most of the eastern parts of the study area, comprised from transformed rocks of sedimental origin such as siltstones and metagravouvakes. In addition, the river Pineios crosses along its' route from western to eastern Thessaly a great rock variety, such as peridotite, diabase, pyroxenit, serpentine, flysch and limestones. Marbles dating to the Middle Superior Triadic underlie and often overlie most of the western part of the study area. The marbles are densely layered and intensely karsted and plicated. Sometimes dolomite marbles and crystalline dolomites interject the marble layers. The central part of the study area dates to the Palaeozoic period, and it presents a uniformity of rock types such as compact micaclous gneiss rich in granite web. Magnetite is also located in the area. Finally, in the northern and north-eastern part of the study area underlie metaflyschic rocks over transformed formations of a corroded area of the Pelagonian zone.

1.5.2.2 Soil classification

The main factors that determine the soil types in the Mediterranean region are the nature of the parent material, the amount of organic matter present and their degree of development (Archibold, 1995). In addition, the climate and the topography control soil formation. As a result of these factors, a diversity of soils has developed in the study area.

For the soil-mapping of Thessaly, the National Agricultural Research Foundation (N.Ag.Re.F.), used maps of the Geographical Army Service in a 1:5.000 scale. The plains of Thessaly and especially the agricultural areas were mapped in detail during a period of ten years, and the mapped area includes approximately a total of 500.000 hectares. In order to determine the soil units and their limits, numerous openings with soil drills were realized all over the area. The density of the soil sections depended on the uniformity of the land and the depth of each opening was usually 1.5 m. The characterization of each map unit was based on the system of symbolisms according to Yassoglou (1964), the description of the soil sections was realized according to U.S Department of Agriculture Soil Taxonomy (1975) and the colours of the soil were determined according to Munsell (1954) system. Finally, detailed edafological maps of Thessaly were manufactured from the National Agricultural Research Foundation on a 1:20.000 scale. The symbolisms used to describe the soil units on the maps, include inclination, erosion, carbonic salts, soil texture, edafological order and sub-order, and hydric soil indicators (Figure 1.7).

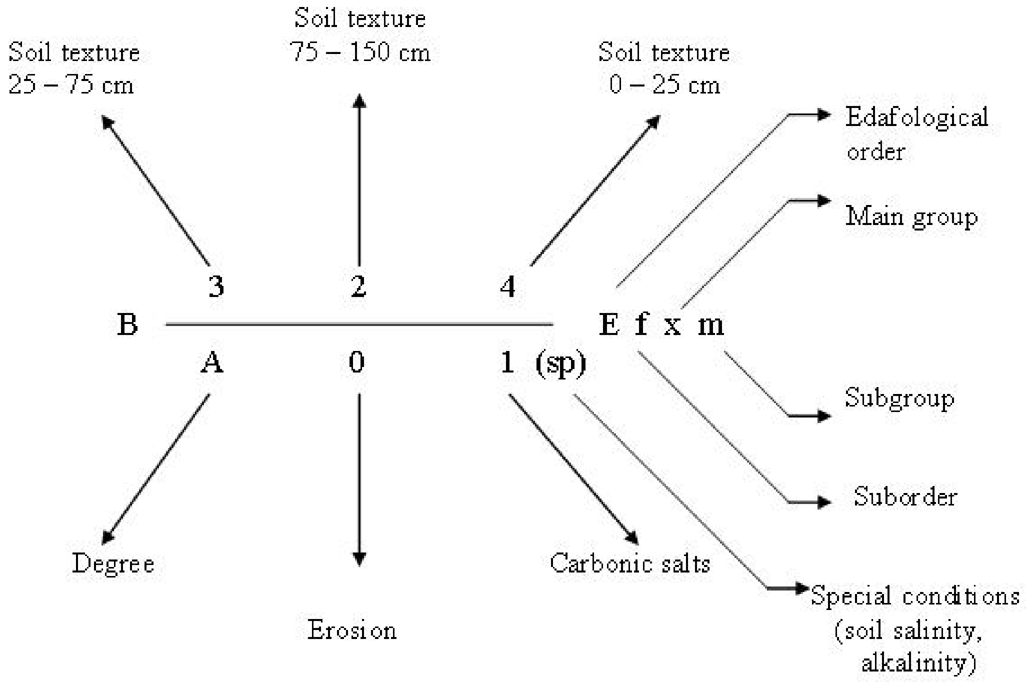


Figure 1.7 Symbolisms used in edafological maps constructed from the National Agricultural Research Foundation (N.Ag.Re.F.) for the region of Thessaly, in order to describe various soil units in the study area.

For the present study the National Agricultural Research Foundation provided the necessary edafological maps which included all the locations where barn owls nests were present and pellet samplings were realized. In order to estimate the percentage of each soil unit within the study area of each sampling site, a grid of dots with a 2 km radius on a transparent sheet (scale 1:20.000) was used on each sampling point. The 2 km radius coincides with the average radius of Barn owl hunting distance (Taylor, 1994; Martínez & López, 1999; Martínez & Zuberogoitia, 2004). The grid was laid over the 1:20.000 scale edafological maps, using as centre each sampling point, and the number of dots which occurred in each soil unit, were counted for each one of the sampling sites. The percentage cover for a particular soil unit was calculated in each sampling point by dividing the number of dots which fell into soil unit i by the total number of dots for the whole area included in the 2 km radius. Each dot corresponded to 4 ha. By multiplying the number of dots for each soil unit by 4 the total area of each soil unit in the total study area could be calculated.

As a result, 5 main soil types were located in the study area: Alfisols, Entisols, Inceptisols, Mollisols and Vertisols. Alfisols occupy 12,85% of the study area and they are mineral soils relatively low in organic matter, with light-coloured surface layers and relatively high base saturation. They contain a horizon of alluvial clay and their moisture is available to mature a crop. Entisols form 31,75% of the study area and they are mineral soils which lack developed soil horizons and their moisture content varies. They may have thin surface horizons with some accumulation of organic matter, but they lack enough alteration of parent materials to form other horizons. Entisols generally are in young landscapes where time has not been sufficient for soils to develop. 19,66% is occupied by Inceptisols, which are also mineral soils containing some developed horizons other than one of illuvial clay, and their moisture is available to mature a crop. They differ from Entisols because of weak to moderate profile horizonation. A small percentage (4,89%) is formed by Mollisols, which are mineral soils with thick, dark surface horizons relatively high in organic matter and with high base saturation. Finally Vertisols occupy 25,37% of the study area and they are clayey soils with deep wide cracks at some time in most years, whose moisture content varies. Vertisols are troublesome for engineering uses and can seriously affect the growth of trees. Building foundations on Vertisols may crack, and fences, power lines, highways and trees often become misaligned or variously tilted. The remaining 5.49% of the study area is semi-mountainous, occupied by low hills.

Most small mammal species are subterraneous and build their nest chambers and corridors underneath the ground surface. Therefore, the soil texture in the first 25 centimetres was also accounted as an independent variable in this study, except the more general soil types explained previously. In order to calculate the percentage of the study area which is covered by different types of soil texture (in a depth from 0 to 25 centimeters), the same grid of dots with a 2 km radius on a transparent sheet (scale 1:20.000), was also used on the 1:20.000 scale edafological maps. There were also two more similar categories referring to different soil depths (Fig. 1.6), but since they exceeded 25 cm in depth, and therefore were not related with small mammal activity, they were not accounted nor included as independent variables concerning soil units.

Hence, there are in total six different categories of soil texture from 0 to 25 cm which cover the study area, and can actually be pooled in two general categories according to Yassoglou et al. (1964). These two categories are: 1). Sandy-Clay soil texture which covers the 25.43% of the study area and 2). Argillaceous-Clay soil texture which covers the 69.09% of the study area. The remaining 5.49% of the study area are mountains and hills or areas beneath water (ditches, rivers, irrigation canals etc.).

1.5.3 Agricultural cultivations

The plains of Thessaly have been intensively used since 1950 for the cultivation of agricultural products. Being the biggest plain of Greece, agriculture was by far and still remains the first choice for rural and semi-urban populations. Since 1965 when the intensification of agriculture slowly begun in Thessaly, until nowadays, 40 years later, various changes have been realized. Firstly, the most important change concerns the two dominating cultivations of Thessaly, cereals and cotton. Cereals were slowly but steadily replaced through the years by the intensified cultivations of cotton (Fig. 1.8), a cultivation whose needs' exceed much more in both fertilizers and irrigation. Secondly, intensification is not only observed in terms of area expansion for intensified cultivations, but it is also obvious if observed the continuous increase of total irrigated land during the last 40 years (Fig. 1.9). Although the cultivated land in Thessaly remains the same in extension with slight changes through the years, occupying a total of 500.000 hectares, the total irrigated land increases from less than 100.000 hectares in 1965 up to 300.000 hectares in 2005.

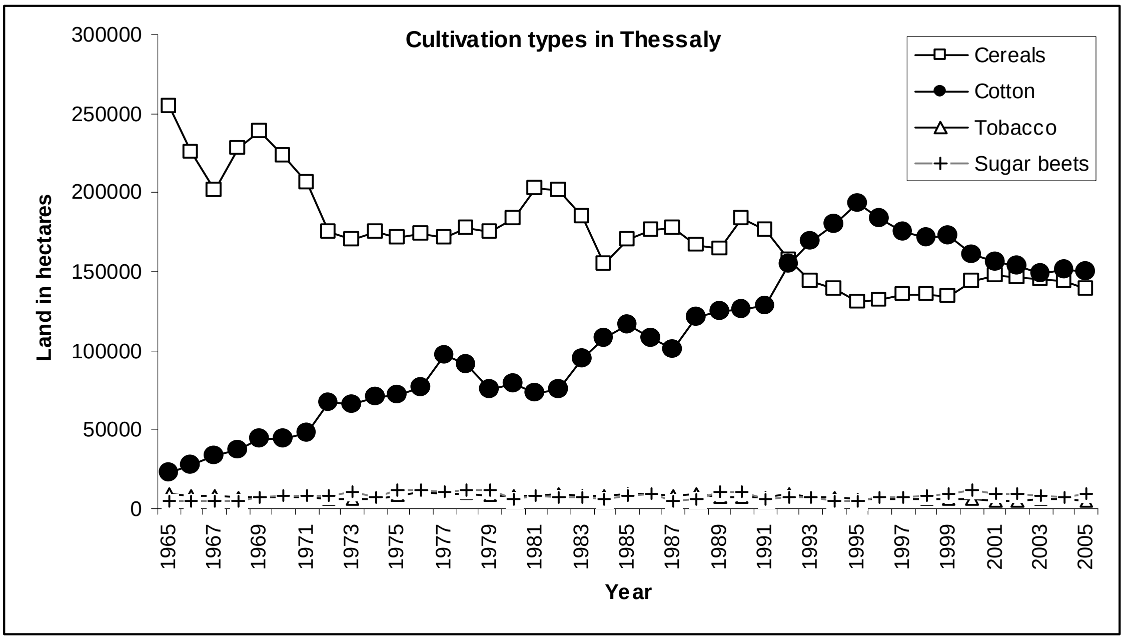


Figure 1.8 Changes in the extension of cultivation types in Thessaly plains during the last 40 years.

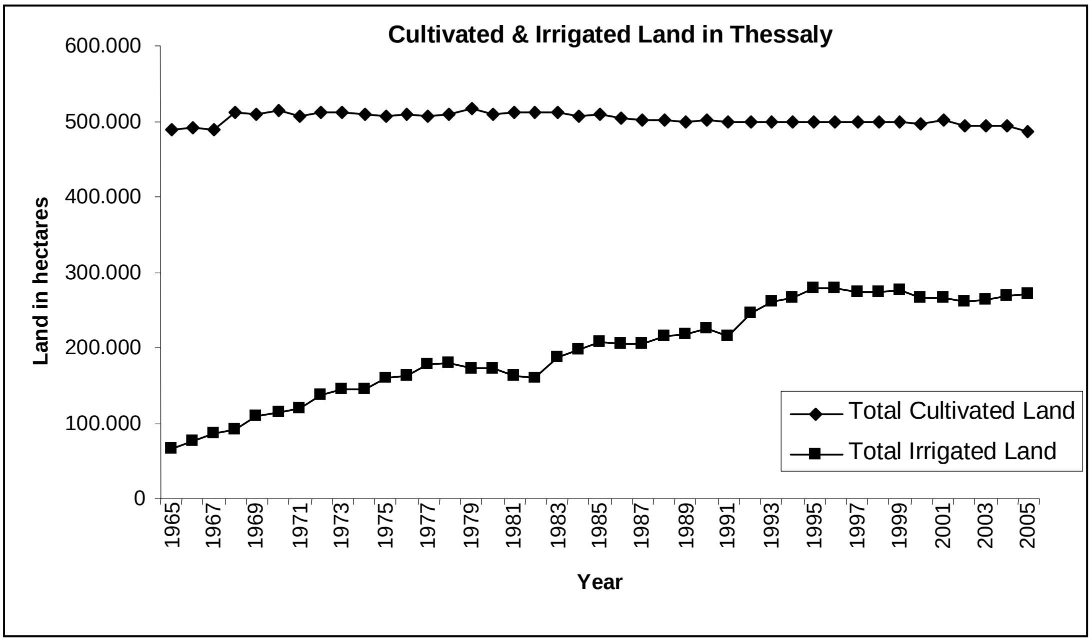


Figure 1.9 Comparison between total cultivated land and total irrigated land in the lowlands of Thessaly, from 1965 to 2005.

1.5.3.1. Habitat Classification and Land Uses

The topography of the villages where samplings were realized through the three-year study, present an altitude which ranges from 55 to 306 m, in an area which is strictly agricultural. Therefore, structure, vegetation and habitat-composition of the study area are characteristic of an agricultural Mediterranean plain of low altitude. Climate, soil, intensive human influence and agricultural intensification have formed a landscape which morphologically is highly agriculturally homogeneous. Agricultural crops dominate most of the study area and natural vegetation is practically inexistent. Only a few fragments of natural vegetation like trees and bushes are located in certain river banks, some natural grassland can be found near some areas with a semi-mountainous character, and finally patches of small forest-islands which are combined with religious architecture, can be located near every village's church. Field units with different cultivation types or owned by different landlords, are no longer separated by natural hedgerows, natural vegetation or bush-lines, except in a minimum of cases. The transition between field units of different crop types or of different ownership is abrupt. In numerous occasions that transition is facilitated by a field road which is used for the transportation of heavy agricultural machinery. Therefore the precise discrimination of habitat type in the study area, is dealing exclusively with the classification of the agricultural landscape and its land uses.

In order to classify the agricultural landscape of Thessaly, official data were collected from various sources. The National Statistic Service of Greece provided data about cultivations, area extensions, crop types, livestock and land uses for each one of the 31 villages where samplings were realized for three consequent years, 2003, 2004 and 2005. The Hellenic Ministry for the Environment, Physical Planning and & Public Works provided a number of maps of the study area on a scale 1:5000 and the rest maps were provided from the Topographic Services of each prefecture of Thessaly (Karditsa, Larisa, Magnesia and Trikala). These maps included all the locations where Barn owl nests were present and pellet samplings was realized, but their disadvantage was that they presented field units according to ownership and not according to cultivation type. Therefore after the study of the maps, the results had to be combined with a database held in the Ministry of Agriculture where agricultural applications are presented each year in order to specify cultivation types. Finally, in order to estimate the percentage of each field unit and cultivation types in the study area, a grid of dots with a 2 km radius on a transparent sheet was used on each map over the sampling points. The 2 km radius as mentioned coincides with the average radius of Barn owl hunting distance (Taylor, 1994; Martínez & López, 1999; Martínez & Zuberogoitia, 2004). The grid was laid over the 1:5.000 scale topography maps, centred on each sampling point, and the number of dots which occurred in each field unit, were counted for each one of the sampling sites. The percentage cover for a particular land unit was calculated in each sampling point by dividing the number of dots which fell into field unit i by the total number of dots for the whole area included in the 2 km radius. Each dot corresponded to 4 ha. By multiplying the number of dots for each land unit by 4, the total area of each land unit in the study area could be calculated. From the combined analysis of the mentioned data, the following habitat classification derived:

(1) Cereals cultivated for their seeds:

In the total region of Thessaly as well as in the study area, this group of cultivations is the second dominating group in terms of area extension. It is divided into 4 subcategories:

1a. Wheat (*Triticum aestivum* & *Triticum durum*), ***1b.*** Barley (*Hordeum vulgare*), ***1c.*** Oat (*Avena sativa*) and ***1d.*** Corn (*Zea mays ssp*).

Wheat is the crop type which occupies the greatest percentage of cultivated cereals. It is planted in January, and harvested in June.

(2) Industrial Cultivations:

This group of cultivations is the one dominating the study area. It is comprised from cultivation types which are all destined for industrial exploitation, and it is divided into three subcategories:

2a. Tobacco (*Nicotiana tabacum*), ***2b.*** Sugar beets (*Beta vulgaris*) and ***2c.*** Cotton (*Gossypium herbaceum*).

Cotton is planted in April and harvested in September and October. It is the dominating cultivation in Thessaly, which covers the greatest percentage of land in comparison with other crop types.

(3) Pasture Cultivations:

The cultivations which belong in this category are used for livestock grazing. They also produce crops which after their harvesting are used as livestock food, once combined and enriched. This specific group includes a large number of subcategories, but in the study area the most important of them are:

3a. Alfalfa (*Medicago sativa*), ***3b.*** Fresh corn (*Zea mays*) and ***3c.*** Vetch (*Vicia sativa*)

(4) Mpostanika:

This specific group of cultivations is poorly represented in the study area. It is divided into three categories:

4a. Watermelon (*Citrullus lanatus*), ***4b.*** Melon (*Cucumis melo*) and ***4c.*** Potatoes (*Solanum tuberosum*).

(5) Legumes:

Cultivations like bean (*Vica faba*), pea (*Pisum sativum*) and lentil (*Lens culinaris*) are only the most representative from this group of cultivations. The total of these species cultivated in the study area form quite a large group, but since none of them presents high percentages, and most of them are poorly represented they will be dealt as a whole group.

(6) Horticultural cultivations:

There are various cultivation types which are included in this general one such as: tomatoe (*Solanum lycopersicum*), onion (*Allium cepa*), aubergine (*Solanum melongena*), leek (*Allium ampeloprasum*), lettuce (*Lactuca serriola*), okra (*Abelmoschus esculentus*) and many more. Treating each one of these cultivation types separately is meaningless because they are poorly represented, therefore they will be presented and treated as a whole group. This category as a total is also poorly represented in the study area in comparison to the dominating ones.

(7) Tree cultivations:

A large variety of tree species can be found in this category such as lemon (*Citrus lemonium*), mandarin (*Citrus reticulata*), orange (*Citrus sinensis*), pear (*Pyrus communis*), cherry (*Prunus avium*), apple (*Malus domestica*), olive (*Olea europaea*) or trees which produce "hard" seeds like almond (*Amygdalus communis*), walnut (*Juglans regia*) and chestnut (*Castanea sativa*). Many more are included and they will be treated as a whole group.

(8) Vineyards:

Only a minor extension of the study area in its southwestern part is occupied by them.

(9) Fallow land:

Agricultural land left to rest for one or more years depending on the previous cultivations and on its general exploitation.

(10) Mountain areas:

In a number of cases, sampling points located in the borderline of Thessaly plain, are close to semi mountainous and mountainous areas, and parts of them are included in the 2 km radius used in the data analysis.

(11) Urban area:

That part of the area included within the 2 km radius that is used by man for structures like houses, storage facilities, roads, squares etc.

(12) Natural grasslands:

That type of land is used neither for agricultural practices nor for human structures, and is poorly represented in the study area.

In conclusion, each one of the above land uses and cultivation types, and their respective occupied areas in each sampling site, are demonstrated in Appendix A.

1.5.4 Fauna

The double identity of Thessaly, with high mountains surrounding the plain, a great number of streams, rivers and a few lakes, the agricultural habitat mosaic and the combination of different climates appoint the area a complicated ecosystem supporting a valuable number of wildlife species and densities. The analytical tables which are presented in Appendix B, include the species found strictly in our study area, and not in the total of Thessaly region, excluding the mountainous areas and part of the lowlands that were not studied.

According to the European Directive 92/43/EE, a dense ecological network of Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) was created in Greece and was named “Natura 2000”. A total of 359 areas are included in the “Natura 2000” network and 15 of them occur in the Thessaly region. Four of them include part of the plain which comprises the study area, and therefore the Special Environmental Studies that were realized for each one of them, were taken into account in order to list the number of species found in it. The studies that were used in specific are the following: 1) Special Environmental Study of the Delta of Pineios river and Tempi valley, (N.Ag.Re.F., 1999), 2) Special Environmental Study of lake Karla, Mavrovouni and Kefalovriso Velestinou, (N.Ag.Re.F., 2002), 3) Special Environmental Study of the forest of Tempi valley, (N.Ag.Re.F., 2000), 4) Special Environmental Study of Antixasia mountains and Meteora region, (N.Ag.Re.F., 2000).

1.5.4.1 Amphibians and Reptiles

The herpetofauna of the area has been surveyed from a group of scientists in the recent years of 2000 and 2002. They have recorded a total of 15 amphibian and 26 reptile species (Appendix B, Table I), and described the area as having a rich herpetological species assemblage. Still, not too much credit should be given to that rich assemblage, since the extension of the area is quite large (5.053 square kilometres approximately) and therefore the rich herpetological biodiversity is more or less expected.

From the 15 amphibian species observed, 2 are newts and belong to the family Salamandridae, 8 are frogs and toads and belong to five families, and 5 species are tortoises and terrapins forming two families (Emydidae & Testudinidae). European green toad (*Bufo viridis*), European tree frog (*Hyla arborea*), Spur-thighed tortoise (*Testudo graeca ibera*) and Marginated tortoise (*Testudo marginata)* which are also found in the study area, are considered as rare species in Europe. In addition 9 species are listed under Appendix II of Bern Convention (Council of Europe, 1979) and therefore merit strict protection. Reptiles count 26 species and eight families. Colubridae includes most of the species (11), whereas thirteen are listed under Appendix II of Bern Convention. A total of 12 amphibian and 9 reptile species are listed in the IUCN Red Data Book (IUCN, 1996).

1.5.4.2 Birds

Although the study area is situated in the lowlands of Thessaly (0 – 300m), and is comprised mainly from the lowlands of Karditsa and Larisa, it covers a quite large area and includes highly diverse habitats: Three main rivers (Pineios, Ennipeas and Titarisios) along with many smaller traverse the study area and favour riparian vegetation and little forest-lines at the sides of their banks. Two lakes exist in Thessaly, and one of them is almost entirely included in the study area, the Karla Lake. Small forest-islands are usually and often combined with religious architecture.

And finally, ditches, irrigation canals, and various agricultural cultivations. Therefore, an important number of bird species occur in the area as well. As expected, raptors do not present a rich assemblage, since the lowlands only give adequate food, foraging and nesting sites to a small number of raptor species (Bousbouras, 2005). Nevertheless, non-raptorial birds present a rich assemblage, and especially riparian bird-species, due to the existence of rivers and lakes.

In total, 163 of the 514 native European species have been recorded in Thessaly plain; 102 (63%) breed and 61 (27%) use the area during their seasonal movements (non-breeders and migrants). Nineteen of these species are birds of prey (diurnal and nocturnal), whereas 144 are non-raptorial birds, which belong to 4 and 42 families respectively. Fifty five (34%) species are resident, 47 (29%) are summer visitors, 42 (26%) are winter visitors and nineteen (12%) are only passage visitors from the study area. According to the classification of Tucker & Heath (1994) and Hagemeijer & Blair (1997), 60 (37%) species have an unfavourable conservation status in the study area. Two of these species are of global conservation concern (SPEC category 1), one of them is a raptor and one of them a duck. Thirteen species (8%) fall into SPEC category 2 (unfavourable conservation status, and more than half of the global breeding or wintering population concentrated in Europe), and only one of them is a raptor. Forty five species (28%) are classified as SPEC category 3 (unfavourable conservation status with less than half of the global breeding or wintering population concentrated in Europe), and 31 (19%) species in SPEC category 4 (favourable conservation status and more than half of the global breeding or wintering population concentrated in Europe). Finally, 72 (44%) species are classified as non-SPEC species (secure and with more than half of the global breeding or wintering population concentrated in Europe). Of those species with an unfavourable conservation status

(60 species in SPEC categories 1-3) in the Thessaly plain, six species are considered to be endangered, 25 vulnerable, 3 rare and 24 are declining in Europe. Finally, of the 102 breeding species in the study area, 54 (33%) are resident.

1.5.4.2.1 Birds of Prey

A relatively good raptor assemblage is present in the lowlands of Thessaly, although the study area has an altitude of no more than 300 metres, and therefore isn't exactly adequate to support rich raptor communities (Bousbouras, 2005). In total, 19 raptor species occur in the area out of the 38 European species (Appendix B, Table II). The diurnal raptors of the area belong in two families, namely Accipitridae and Falconidae, which are represented by 8 and 4 species respectively. In addition, 7 nocturnal birds of prey are present in the area and belong to two families: Tytonidae which includes one specie, and Strigidae which includes the remaining six. Thirteen raptor species currently breed in the study area, from which 4 are summer visitors and 9 are present throughout all the year. The other 4 are winter or passage visitors.

Fourteen (74%) raptor species in the area qualify as Species of European Conservation Concern and 11 (58%) of those have an unfavourable conservation status (SPEC 1-3), because their populations are vulnerable, endangered or declining. Five (26%) birds of prey are finally classified as non-SPEC species.

Only one species, Lesser kestrel (*Falco naumanni*) is of global conservation concern (SPEC 1). The lowlands of Thessaly support the most important population of Lesser kestrel in Greece, and of course one of the most important in Europe, after Spain (Vlachos et al., 2003). In most of the study area, Lesser kestrel is sympatric with Barn owl, and in some cases they were found nesting in the same abandoned buildings, a coexistence which sometimes is common but also difficult (Vlachos et al., 2004). The

Thessaly plain is also very important for Scops owl (*Otus scops*), which is a summer visitor and breeds in great numbers throughout the study area (personal observations).

From the 14 species that are classified with unfavourable conservation status, Levant Sparrowhawk (*Accipiter brevipes*) is the only one considered to be rare. Long-legged Buzzard (*Buteo rufinus*) and Saker Falcon (*Falco cherrug*) have populations endangered with extinction, whereas Common Kestrel (*Falco tinnunculus*), Little owl (*Athene noctua*), Barn owl and Scops owl have populations which are listed to be declining throughout Europe. From the raptor species, eight (42%) are considered to have stable populations.

Finally, all of the 19 birds of prey present in the study area are cited in Annex II of Bern convention, whereas only 7 are listed in Annex II of Bonn Convention, all of them being diurnal raptors.

1.5.4.2.2 Non-Raptors

Although the lowlands of Thessaly present a raptor community not quite rich in species terms, they hold a remarkable diversity and a considerable number of non-raptorial birds which occur in the region. A total of 42 non-raptorial bird families, which belong to 17 orders and count 144 different species, are present in the plain of Thessaly (Appendix B, Table III). 79 (55%) species are aquatic birds occurring mainly in the riparian habitat of Lake Karla, and along the sides of the three main rivers traversing Thessaly, and the rest 65 (45%) species are observed throughout the rest of the area, in diverse habitats. Passeriformes is the order which includes the majority of species [17 families and 47 (33%) species], Charadriiformes is second counting 6 families and 37 (26%) species, whereas the orders Coraciiformes and Ciconiiformes include 3 families each one, 3 (2%) and 11 (8%) species respectively.

From the total 144 species, 90 (62%) of them are breeding in the study area with forty-four (30%) being only summer visitors and breeders. The rest 54 (37%) species are passage or winter-visitors.

According to their conservation status, 48 (33%) species have an unfavorable status (SPEC categories 1-3), twenty seven (19%) are listed in SPEC category 4 and 67 (46%) are classified as non-SPEC species. Twelve (8%) species are listed under SPEC category 2, whereas only the Ferruginous duck (*Aythya nyroca*) is classified as a SPEC 1 category species. Baillon's crake (*Porzana pusilla*) and Black stork (*Ciconia nigra*) are considered to be rare whereas Caspian tern (*Sterna caspia*), Spoonbill (*Platalea leucorodia*), Collared pratincole (*Glareola pratincola*) and Gull-billed tern (*Gelochelidon nilotica*) have populations which are considered to be endangered throughout Europe. Twenty one (7%) species are classified as vulnerable and the populations of 20 (14%) species are declining. Furthermore, species such as Nightjar (*Caprimulgus europaeus*), Woodlark (*Lullula arborea*), Little bittern (*Ixobrychus minutus*) and Ortolan bunting (*Emberiza hortulana*) which are present in the study area are worth mentioning for their vulnerability. Also, species that breed in the area and present an international interest include the Syrian woodpecker (*Dendrocopos syriacus*), Calandra lark (*Melanocorypha calandra*), Barn swallow (*Hirundo rustica*) and Tawny pipit (*Anthus campestris*).

1.5.4.3 Mammals

In the plateau of Thessaly, birds and reptiles present quite a rich assemblage whereas mammals are represented with a fewer number of species. Although a systematic survey has never been carried out in the study area, scientists who studied certain Areas of Special Conservation which are included in the study area, through direct personal observations and indirectly from footprints and raptor pellet analysis, came through with a list of 53 different mammal species (Appendix B, Table IV). Eight insectivores, 17 bats, one lagomorph, 18 rodents and eight carnivores. No ungulates are present in the study area.

Fifteen species are listed under Appendix III and nineteen mammals are listed in Appendix II of Bern Convention (Council of Europe, 1979) respectively. 18 species are listed in the IUCN Red Data Book (IUCN, 1996), from which seven are considered to have vulnerable populations throughout Europe.

Small packs of wolves (*Canis lupus*) approach the Thessaly plains from time to time since livestock can provide food resources for them, but the jackal (*Canis aureus*) holds a higher population in the study area. Numerous attacks occur each year in the livestock in various villages of Thessaly. The Otter (*Lutra lutra*) had completely disappeared from the study area for more than 40 years, since the lake Karla was dried out in 1963 in order to use its 9.000 ha for agricultural practices. The last five years, after it was decided to reconstruct the lake Karla, the specie has appeared again in very small populations.

The carnivores that occur in the area in large numbers include the Red fox (*Vulpes vulpes*), Stone marten (*Martes foina*) and the weasel (*Mustela nivalis*). In addition, other less common carnivores such as the Wild cat (*Felis silvestris*), and the Bagder (*Meles meles*) are also inhabitants of the Thessaly region.

Dormice, mice, rats and voles of several genera also occur in the region. The most widespread of the rodents are Guenther’s vole (*Microtus guentheri*), East European vole (*Microtus levis*), Long-tailed field mouse (*Apodemus sylvaticus*) and the House mouse (*Mus (Mus) musculus [domesticus]*). Furthermore, a great variety of insectivores are distributed in the region, with the Western hedgehog (*Erinaceus* *europaeus*) and Lesser white-toothed shrew (*Crocidura suaveolens*) occurring in large numbers across different habitats. Finally, the order Chiroptera is represented in the Thessaly plateau by few species, but more studies are necessary in order to record in detail the Chiroptera fauna of Thessaly.

There are no records neither studies about the insect fauna of Thessaly.

1.6 RESUMEN

1.6.1 Área de estudio

Tesalia es una de las 13 regiones de Grecia. Esta localizada en la parte centro-oriental del país, y esta constituida por 4 prefecturas, Karditsa, Larisa, Magnesia y Trikala. Se extiende en una área total de aproximadamente 14.000 kilómetros cuadrados. La región tiene una identidad doble. Esta rodeada por montañas en todas las direcciones, en el centro se situa la llanura que ocupa el 35% de toda la región, formando el ecosistema agrícola mas grande del país, con altitudes entre 0 y 300 m.s.n.m.. Esta área, ha sido el área de estudio en la presente tesis doctoral, la cual ocupa aproximadamente un total de 5.500 kilómetros cuadrados. La atraviesan tres ríos, y aparte de las cuatro capitales de cada una de las prefecturas, esta bastante despoblada.

1.6.2 Clima, precipitación y temperatura

Según los tipos de Emberger y datos del Servicio Nacional Meteorológico, se ha calculado que el clima de Tesalia es sub-húmedo y frio en Larisa, húmedo y fresco en Trikala y en Magnesia sub-húmedo y fresco. Además, según los tipos del clima Mediterráneo de acuerdo a Bagnouls & Gaussen, Larisa, Trikala y Magnesia demuestran un tipo climático sub-mediterráneo. No hay datos meteorológicos fiables para la prefectura de Karditsa. Las temperaturas medias mensuales presentan sus valores máximos durante los meses de Julio y Agosto en todas las prefecturas, con un rango grande entre noche y día. Respecto a los datos analizados para los años 1970-2005, la precipitación media anual en Larisa ha sido 414 mm, en Magnesia 477 mm y en Trikala 704 mm. En toda la región de Tesalia, los valores máximos de la precipitación media anual han ocurrido durante Noviembre y la segunda mitad de Febrero.

1.6.3 Geomorfología y tipos de suelo

La parte norte de la llanura de Tesalia esta constituida por rocas carbónicas de gran capa, como los carbones cristalinos y dolomitas de la era Mesozoica. En la parte oriental hay formaciones del Medio Eoceno como “metagravouvakes” y otras rocas arcillosas dominan el área. Adicionalmente, a lo largo del río Pineios que atraviesa Tesalia con dirección de oeste al oriente, hay gran variedad de formaciones de rocas como peridotitas, diabasas, pyroxenitas, serpentinas, flysches y piedras de caliza duras. Mármoles de la era del Medio Tríasico Superior se encuentran en el oeste de Tesalia, mientras la parte central y norte tiene su origen geológico en la era Paleozoica, y presentan una uniformidad de rocas de granito.

El Instituto Nacional de Investigación Agrícola de Grecia central, ha realizado a lo largo de los últimos 20 años, detallados y múltiples análisis edafológicos en toda la llanura de Tesalia; construyendo mapas analíticos de los tipos del suelo presentes en la región. Sin embargo, al no estar todavía digitalizados dichos mapas y sus bases de datos, para cuantificar los tipos del suelo en cada lugar de muestreo, se han ubicado dentro de un cuadriculado con un radio de 2 km en una hoja transparente, -que coincide con el radio medio de la distancia de caza de la Lechuza común-, y aplicado en los mapas edafológicos, utilizando como centro cada lugar de muestreo. El numero de cuadriculas, que ocurren dentro de cada unidad del suelo, ha sido calculada en cada lugar. Al final, el porcentaje de cada unidad particular del suelo ha sido calculada, dividiendo el numero de cuadriculas que forman cada unidad diferente, con el total del número del cuadriculado dentro del radio de 2 km. Cada cuadrícula corresponde a 4 hectáreas.

En conclusión, 5 tipos del suelo están presentes en el área del estudio. Los Alfisoles ocupan el 12.85% de la llanura estudiada, y son suelos minerales con relativamente poca materia orgánica, y saturación de bases. Los Entisoles formaron el 31.75%, y son suelos minerales a los que les faltan horizontes del suelo y su humedad es variable; en general aparecen en paisajes nuevos donde no han tenido el tiempo adecuado para formarse. Inceptisoles ocupan el 19.66% y son suelos minerales con horizontes del suelo desarrollados, y un porcentaje de humedad que permite el crecimiento de cultivos. Un pequeño porcentaje ha sido formado por Mollisoles, que son también suelos minerales pero con horizontes superficiales de capa grande, y color oscuro. Finalmente, los Vertisoles ocupan el 25.37% de las localidades estudiadas, y son suelos de arcilla inestables para construcciones mecánicas.

La mayoría de los micromamíferos construyen sus nidos en los primeros 25 centímetros bajo la superficie del suelo, y por lo tanto la textura del suelo en estos 25 cm ha sido calculada también del mismo modo, como una variable independiente. Como resultado, la textura del suelo arenosa ocupa el 25.43%, mientras que la textura del suelo arcillosa ocupa el 69.09%.

1.6.4 Cultivos agrícolas, clasificación de hábitat y de usos de tierra

La llanura de Tesalia ha sido cultivada extensivamente desde los años 1950. Siendo la llanura más grande de Grecia, a lo largo de los años ha sido explotada costeantemente y la agricultura ha sido intensificada gradualmente. Los dos cambios más grandes que tuvieron lugar en la región, han sido en primer lugar la substitución de cultivos cereales por cultivos industriales y especialmente el algodón, y paralelamente a este cambio el aumento general de los cultivos de regadío. Los cultivos de regadío aumentaron de 100.000 hectáreas en 1965 a 300.000 en 2005.

Con el mismo modo explicado anteriormente, y con el uso de mapas y bases de datos que facilitados por el Ministerio de Medio Ambiente, el Servicio Nacional de Estadística, el Servicio Topográfico de cada prefectura y el Ministerio de Agricultura, se calcularon y cuantificaron en un radio de 2 km alrededor de cada lugar de muestreo, los tipos de hábitat, los diferentes cultivos, y los usos de la tierra. Las categorías mas importantes que se obtuvieron son las siguientes 12 en total: 1) Cereales, 2) Cultivos industriales, 3) Pastos, 4) Hortalizas (sandia, melón, patatas), 5) Legumbres, 6) Vegetales, 7) Cultivos de árbol, 8) Viñedos, 9) Barbecho, 10) Área montañosa, 11) Área urbana, 12) Praderas naturales.

1.6.5 Fauna

Según estudios realizados en ciertas zonas de Tesalia, las cuales pertenecen a espacios naturales protegidos y a la red de regiones Natura de Grecia, la fauna de la región incluye gran cantidad de especies de aves, mamíferos, reptiles y anfibios. Todas las especies acompañadas por su status Europeo según las convenciones internacionales, están detalladamente presentadas en el Apéndice B, al final de la presente tesis. En total, 15 anfibios, 26 reptiles, 144 aves y 19 aves rapaces están presentes en la llanura de Tesalia.

CHAPTER 2

The Trophic Guild of Barn owl (*Tyto alba, Scopoli 1769*) in Greece: Review, Comparisons, Mainland - Insular Trends and Niche Breadth

2.1 INTRODUCTION

Among the rich diversity and high species' richness that characterizes the Greek avifauna, 9 nocturnal raptors are also included in it (Handrinos & Akriotis, 1997). From the total of nine species, 4 of them have only been recorded as present in the country, but no studies concerning any of their ecological or biological aspects have been published. These species are the Short-eared owl (*Asio flammeus*), Pygmy owl (*Glaucidium passerinum*), Tengmalm's owl (*Aegolius funereus*) and Tawny owl (*Strix aluco*). For the remaining five species, a limited number of studies have been published up to day, most of them dating before the 90's, and all of them analyzing their feeding habits. In specific, Scops owl (*Otus scops*) was the least studied nocturnal raptor in the country, whose identified prey items are just 52 and were collected from the island of Evoia (Akriotis, 1981). Long-eared owl's (*Asio otus*) diet was studied in two wetlands of northern Greece, Porto Lagos and Nestos Delta (Alivizatos & Goutner, 1999; Alivizatos et al., 2005), and in the island of Evoia (Akriotis, 1981), whereas a total of 1382 prey items were identified. Eagle owl's (*Bubo bubo*) feeding habits were assessed through the identification of 783 prey items from two islands (Evoia: Akriotis, 1981; Lesvos: Pieper, 1982) and two mainland localities, a forest ecosystem in northern Greece (Dadia: Papageorgiou et al., 1993) and a wetland in western Greece (Amvrakikos: Alivizatos et al., 2005). Little owl (*Athene noctua*) was more broadly studied in Greece, from the mentioned species. A total of 7737 prey items were identified from a total of 9 different geographic regions. The specie's diet was studied in mainland Greece in five important wetland ecosystems, and also in four different islands: Two river Deltas of northern Greece (Evros Delta: Goutner & Alivizatos, 2003; Alivizatos et al., 2005; Alivizatos et al., 2006; Axios Delta: Alivizatos et al., 2005), and three lake ecosystems comprised of one or more lagoons, all located in northern Greece as well (Porto Lagos & Lafres Lagoon: Goutner & Alivizatos, 2003; Kitros Lagoon: Alivizatos et al., 2005), and in respect to insular studies, diet analyses were realized in the islands of Evoia (Akriotis, 1981), Astipalaia (Angelici et al., 1997), Tilos and Psara (Alivizatos et al., 2005).

Nonetheless, similarly to the European and global trends of raptor diet studies, Barn owl in Greece was the most studied nocturnal raptor as well. Its feeding habits were studied in 13 different geographical locations, some from northern, central and southern mainland areas in the country, along with various studies from islands, forming a total of 13483 identified prey items. This relatively large number of identified prey items in combination with the different geographical locations from which the studies originated, offers a fertile terrain for comparisons, exploration of geographical trends and a deeper insight on the specie's diet spectrum in a broad latitudinal and longitudinal gradient. In the past decades, very important and highly referenced papers have been published exploring geographical trends in Barn owl diets. For example, the specie's diversity and trophic relationships were assessed and compared in European level (Herrera, 1974; Herrera & Hiraldo, 1976), works which indicated that Barn owl as a specie demonstrates stenophagous diets in central Europe because of the higher mammal diversity, whereas in southern areas and in the Mediterranean basin Barn owl is more euryphagous due to lower mammal diversities. Other authors have used Barn owl's prey to study geographical trends in small mammals included in its diet, and explored their latitudinal and longitudinal patterns (Clark & Bunck, 1990; Barbosa et al., 1992; Korpimaki & Marti, 1995; Torre, 2001). Barn owl's feeding habits were also compared between similar Mediterranean habitats belonging to different European, Nearctic and Neotropic regions (Herrera & Jaksic, 1980; Jaksic et al., 1982), a type of study which was applied from the same group of authors in other owl species as well (Jaksic & Marti, 1981, 1984; Donazar et al. 1989). Moreover, the specie's diet was also assessed in large geographical areas testing habitat, latitudinal and longitudinal effects (Herrera, 1974; Campbell, 1987; Torre et al., 1997; Varuzza et al., 2001), the effect of altitudinal gradient was also explored in various cases (Alegre et al., 1989; Travaini et al., 1997), other reviews analyzed diet studies in large geographical areas or even whole countries (Bellocq, 2000), and comparisons were also realized between decades to explore differentiation in the occurring trends (Alasdair et al., 2000).

In Greece however, except the 13 published studies which provide valuable but scattered information, never before has been intended a synthesis of information in order to combine the existing data in a thorough analysis, and produce a general view of the specie's feeding habits in the country. Therefore, the aims of this chapter are:

1). Collect all the published data about Barn owl diet in Greece up to date, reintroduce them in statistical and ecological softwares, and reanalyze thoroughly all the existing information.

2). Explore different geographical trends, test for longitudinal or latitudinal effects, and compare mainland with insular diets.

3). Define species richness and diversity patterns among diets, explore differences in prey use, and try to combine it with habitat mosaics when possible, and geographical effects.

4). Compare these review analyses with the results of the present thesis which are also analytically presented in Chapter 3.

2.2 STUDIED AREAS

As mentioned before, the Barn owl diet was studied in 13 different geographical locations in Greece. In some of these 13 locations, as it will analytically be demonstrated afterwards, pellets were usually collected from various localities. All these studied regions are demonstrated analytically in Figures 2.1 to 2.13.

2.2.1 Mainland diet studies

In mainland Greece, a total of 7 Barn owl diet studies have been realized. Four of them analyzed the raptor's feeding habits in northern and north-eastern Greece, and three presented data collected from eastern-central areas of the country, whereas no diet study has been realized until today in Peloponnesus, in southern Greece.

2.2.1.1 Evros Delta

Three different publications analyzed Barn owl's diet in the Evros Delta. The Evros Delta is probably the most important wetland ecosystem in the country, located in the further north-eastern region of Greece, and is shared by both Turkey and Greece. It is actually functioning as a natural border between the two countries, and the river's Delta is comprised by a great variety of habitats such as extensive saltmarshes, sand dunes and sandy islands, mudflats, lagoons, reed beds, tamarisk, riverine and riparian forests, permanent and temporary freshwater marshes and extensive cultivations. Most Barn owl pellet samples were opportunistically collected from various roosting sites. The first sampling was realized in 1987 (Goutner & Alivizatos; 2003), then the same team of authors collected mores samples during two more periods, from 1997 to 2001 (Alivizatos et al., 2005), and from 2002 to 2004 (Alivizatos et al., 2006). The geographical location of Evros Delta and sampled areas are indicated in Figure 2.2.

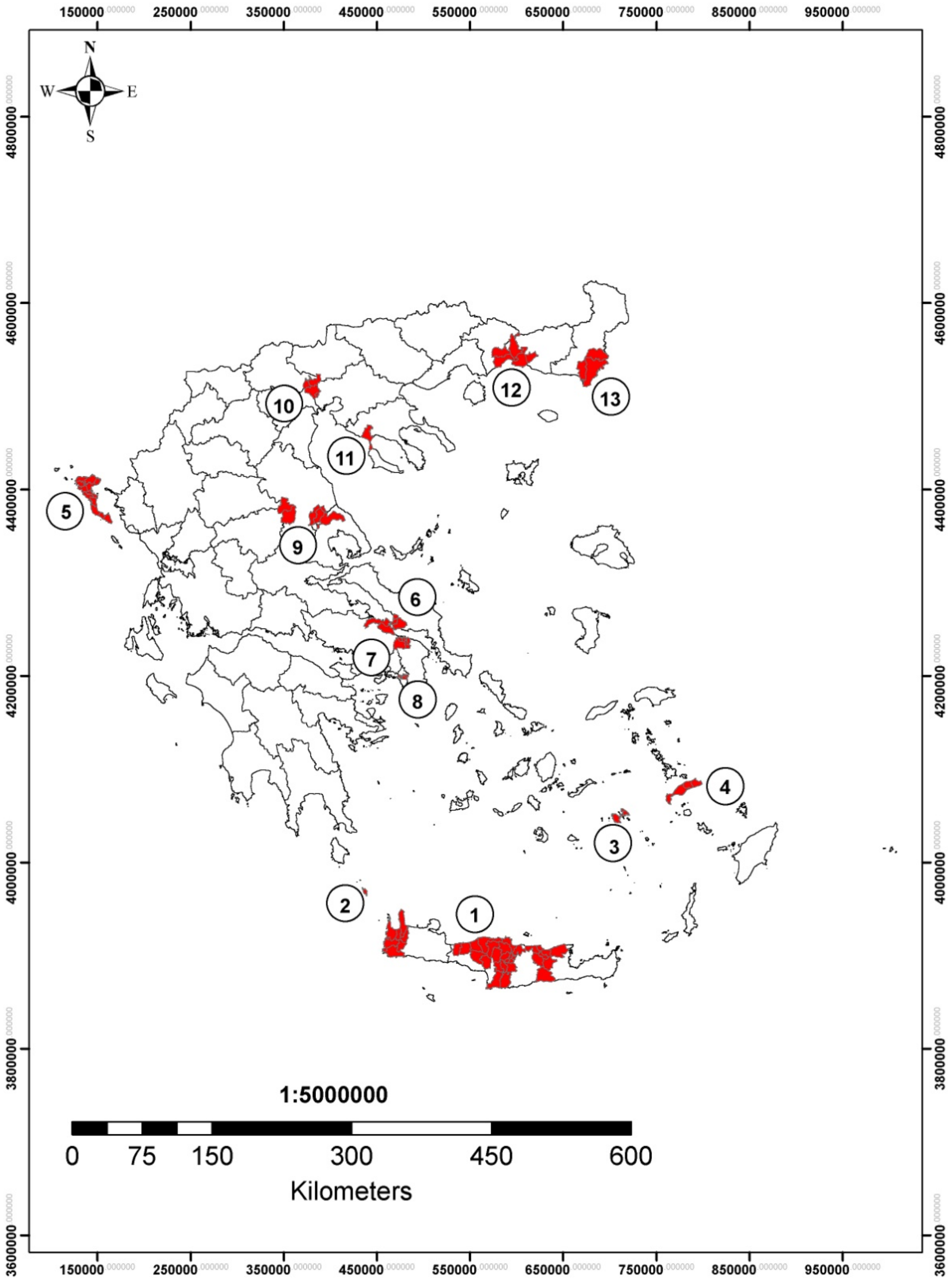


Figure 2.1 Geographical regions in Greece (indicated in red) where Barn owl diet studies have been realized up to date: 1) Crete, 2) Antikythera, 3) Astipalaia, 4) Kos, 5)Corfu, 6) Evoia, 7) Avlona, 8) Attica, 9) Thessaly, 10) Parthenio, 11) Potidaia, 12) Wetlands of northern Greece (P. Lagos, Mitrikou, Lafres), 13) Evros Delta.

2.2.1.2 Wetlands of northern Greece (P. Lagos, Lafres and Mitrikou)

Except the Evros Delta, another important complex of wetlands in northern Greece is located in the borders between the prefectures of Xanthi and Rodopi (Fig. 2.3). Three major wetlands comprise this ecosystem in northern Greece, named Porto Lagos, Lafres and Mitrikou. Porto Lagos is a small village situated within a wide wetland complex including the shallow, polluted, brackish Lake Vistonis on the north, surrounded by reed beds and forest remnants. Extensive coastal lagoons are fringed marginally with saltmarshes, sandy beaches and livestock, and grazing fields extend to the southwest. Lafres comprises a complex of two coastal lagoons close to each other named “Lafri” and “Lafrouda” surrounded by rocky cliffs with Quercion ilicis vegetation. Extensive grasslands, saltmarshes, sandy beaches and cultivation areas occur mainly to the north of the lagoons. Finally, lake Mitrikou is a shallow freshwater lake extending over 2.3 km^2 which is surrounded by extensive reed beds and cultivation areas, situated in the vicinity of a coastal wetland complex. The Barn owl diet was studied in this wetland complex in a total of two articles published by Goutner & Alivizatos (1987) and Alivizatos et al. (2005). The wetlands complex along with the sites where Barn owl pellets were collected are indicated in Figure 2.3.

2.2.1.3 Parthenio

The village Parthenio is located in central Macedonia, in the eastern part of Thessaloniki prefecture, bordering from south-western direction with the prefecture of Imathia, from west with the prefecture of Pella and in the north it is adjacent to the prefecture of Kilkis, as can be observed in Figure 2.4. It is surrounded by typical agricultural habitats, from which the greater percentage is dominated from cotton cultivations forming almost 60%, cereal crops comprise another 20% of crops in the

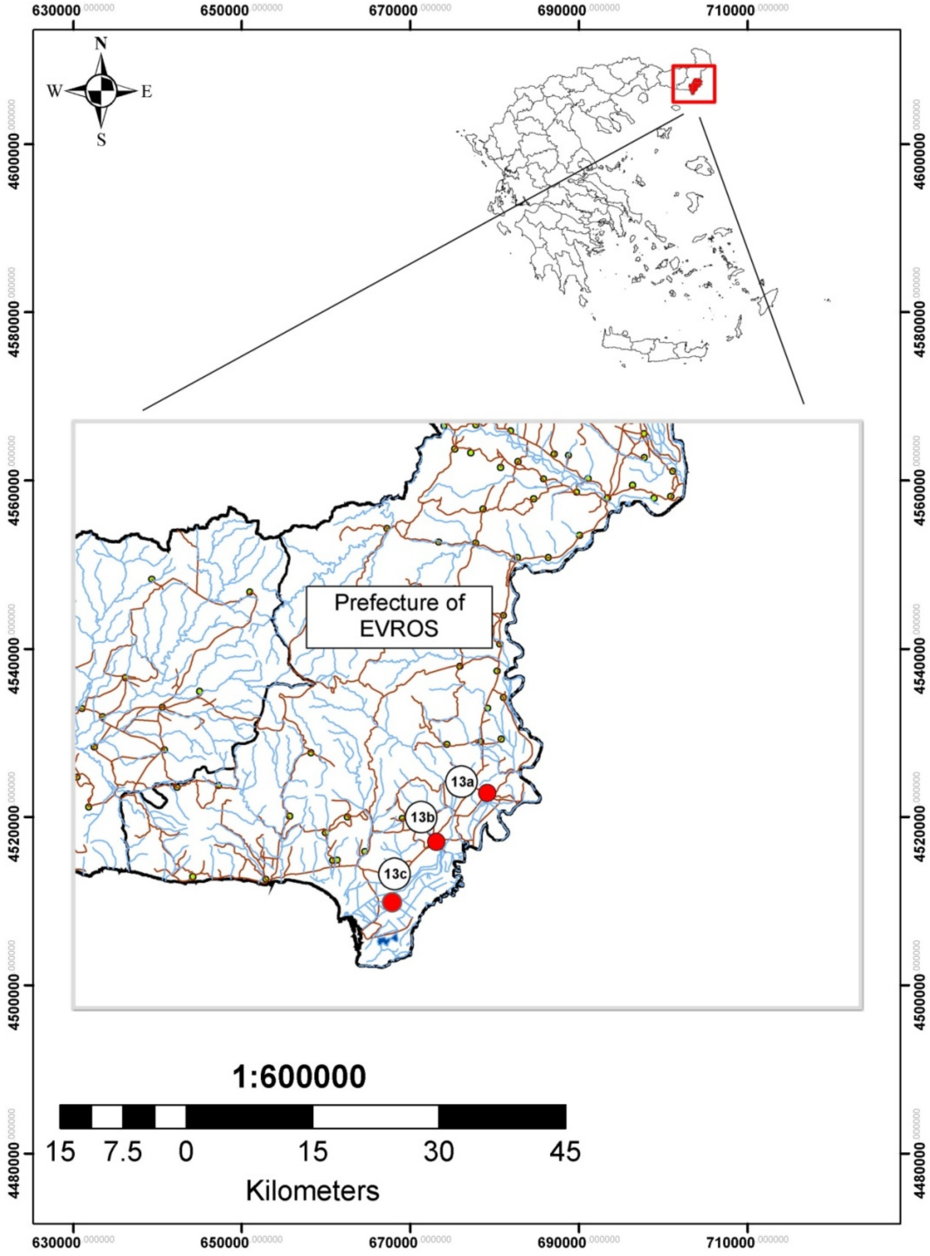


Figure 2.2 Geographical region of Evros Delta (*indicated with number 13 in general map, Fig. 2.1*). Reference map in respect to Greece located in upper right corner, and localities in the region where Barn owl pellet samples were collected are indicated in red dots. (*13a: Ferres, 13b: Korneofolia, 13c: Delta*).

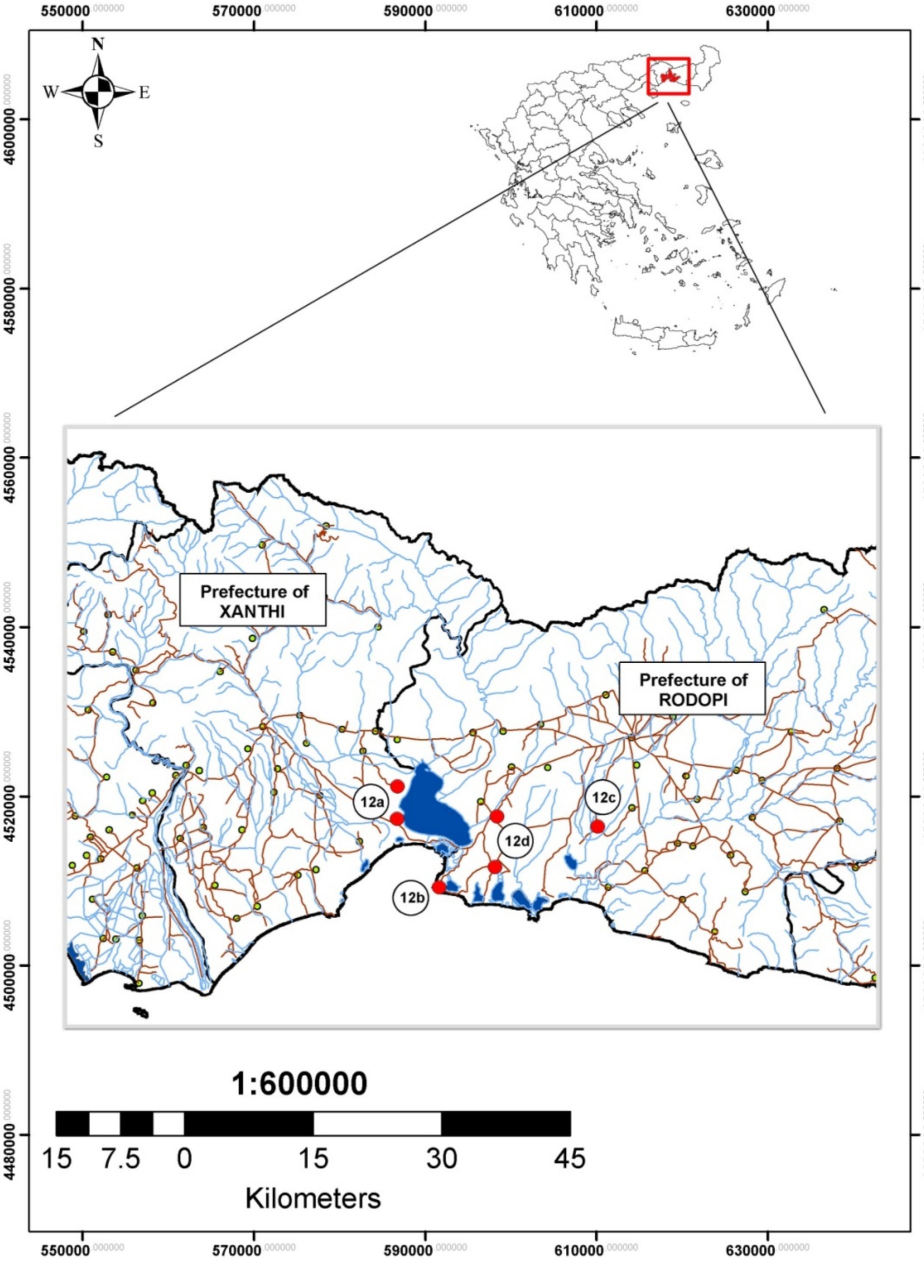


Figure 2.3 Geographical region of wetlands in northern Greece (*indicated with number 12 in general map, Fig. 2.1*). Reference map in respect to Greece located in upper right corner, and localities in the region where Barn owl pellet samples were collected are indicated in red dots. (*12a: Porto Lagos, 12b: Mitrikou, 12c & 12d: Lafres*).

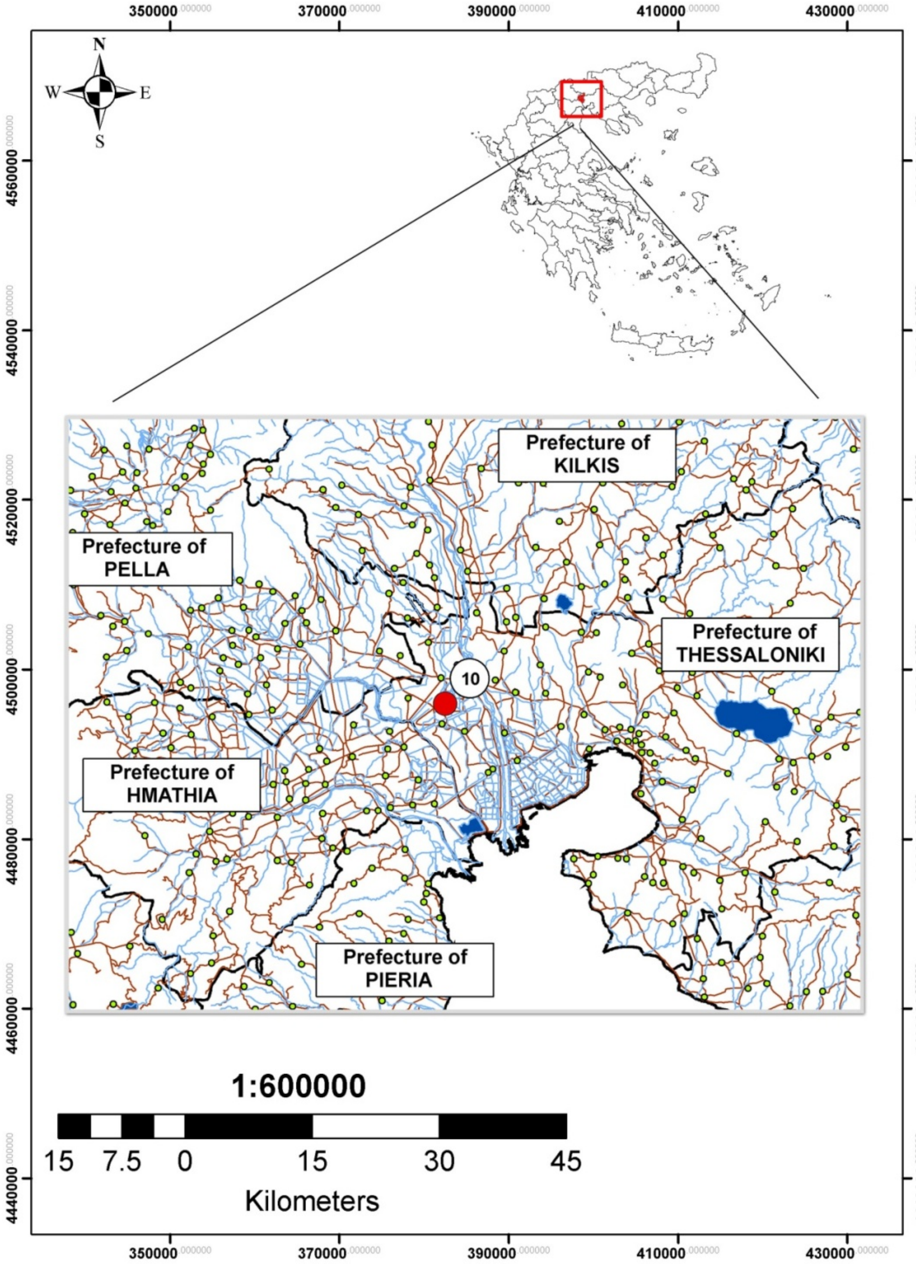


Figure 2.4 Geographical region of Parthenio (*indicated with number 10 in general map, Fig. 2.1*). Reference map in respect to Greece located in upper right corner, and localities in the region where Barn owl pellet samples were collected are indicated in red dots.

area, and the remaining 20% is occupied by different crop types and habitats. Only one published study included Barn owl pellet analysis collected from the area of Parthenio (Alivizatos et al., 2005).

2.2.1.4 Potidaia

The village Potidaia can be found in a distance of 50 km from the town of Thessaloniki, further down in a south-eastern direction. It is located in central Macedonia in the prefecture of Chalkidiki, built in the narrowest point of the Kassandra peninsula in its western part (Fig. 2.5). The village is actually also functioning as the enter point to the first of the three peninsulas that comprise Chalkidiki, and it is surrounded by sea. The surrounding habitat is a typical agricultural habitat, also dominated by cotton cultivations, with cereals and also an important percentage of vineyards. Its geographical location is demonstrated in Figure 2.5, and Barn owl diet was studied only once in Potidaia with pellet samples which were gathered opportunistically during the period 1997 to 2001 (Alivizatos et al., 2005).

2.2.1.5 Thessaly

A pilot study was realized prior to the present thesis, during which three small villages located in the plain of Thessaly were sampled for Barn owl pellets, and the results were published by Bontzorlos et al. (2005). Thessaly is the largest agricultural plain in the country, located in central Greece. Agricultural practices are mainly oriented in arable crops, from which cotton cultivations dominate, cereal crops come second, and other habitat types such as vineyards, fallow land, mountainous areas and natural grasslands form minor percentages. For a detailed analysis Chapter 2 offers a

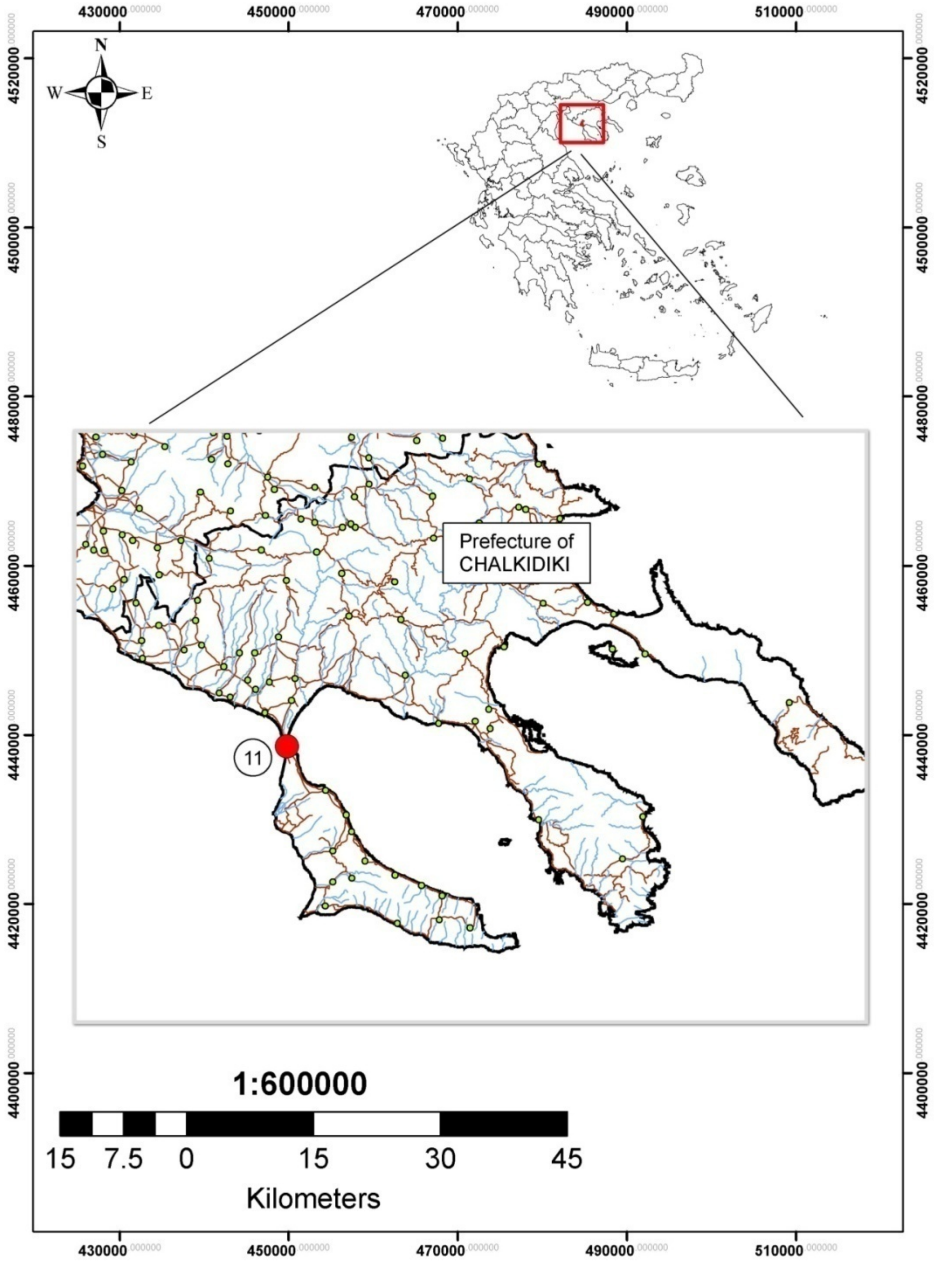


Figure 2.5 Geographical region of Potidaia (*indicated with number 11 in general map, Fig. 2.1*). Reference map in respect to Greece located in upper right corner, and localities in the region where Barn owl pellet samples were collected are indicated in red dots.

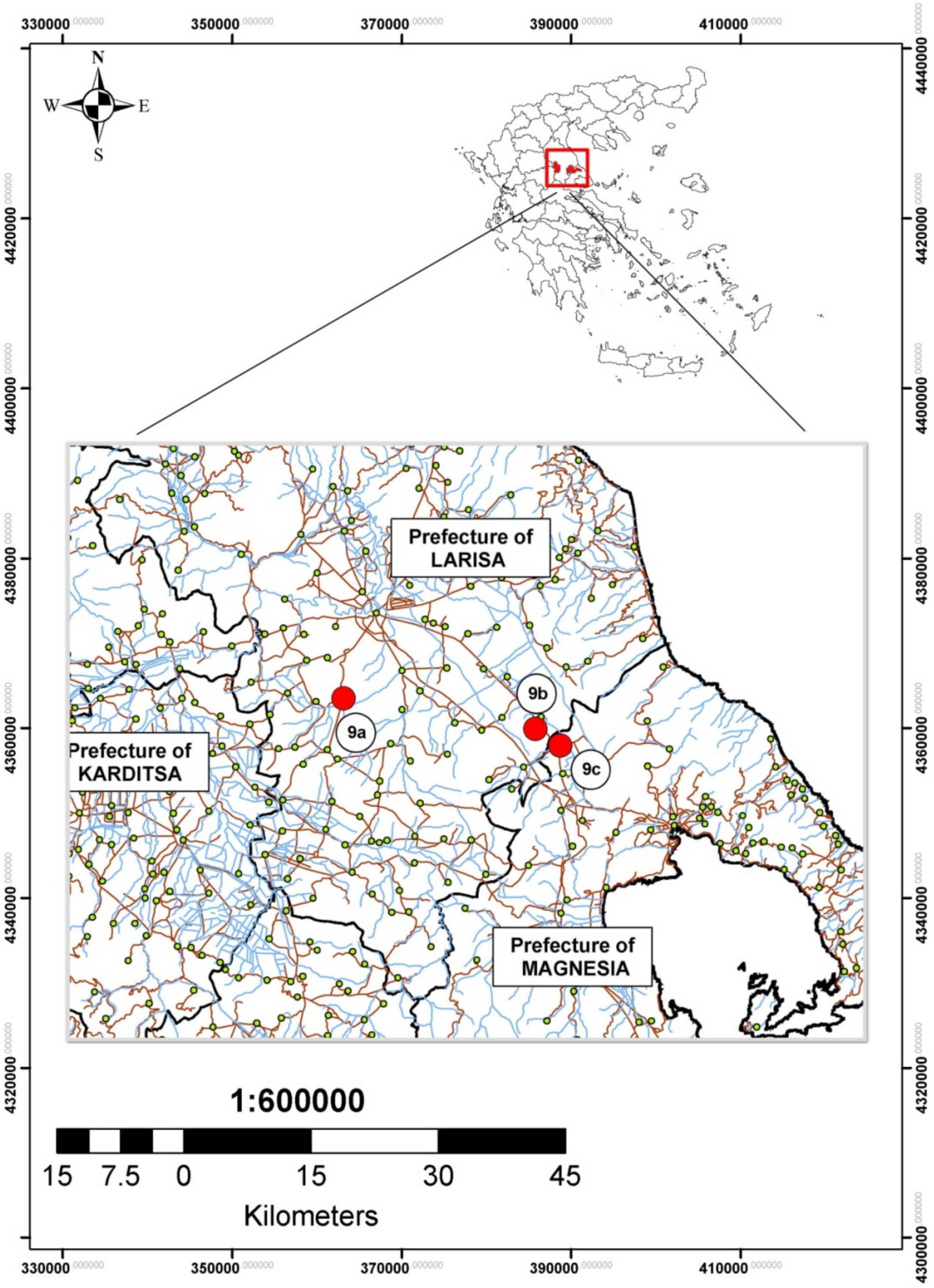


Figure 2.6 Geographical region of Thessaly (*indicated with number 9 in general map, Fig. 2.1*). Reference map in respect to Greece located in upper right corner, and localities in the region where Barn owl pellet samples were collected are indicated in red dots. (*9a: Mesoraxi, 9b: Armenio, 9c: Stephanovikeio*).

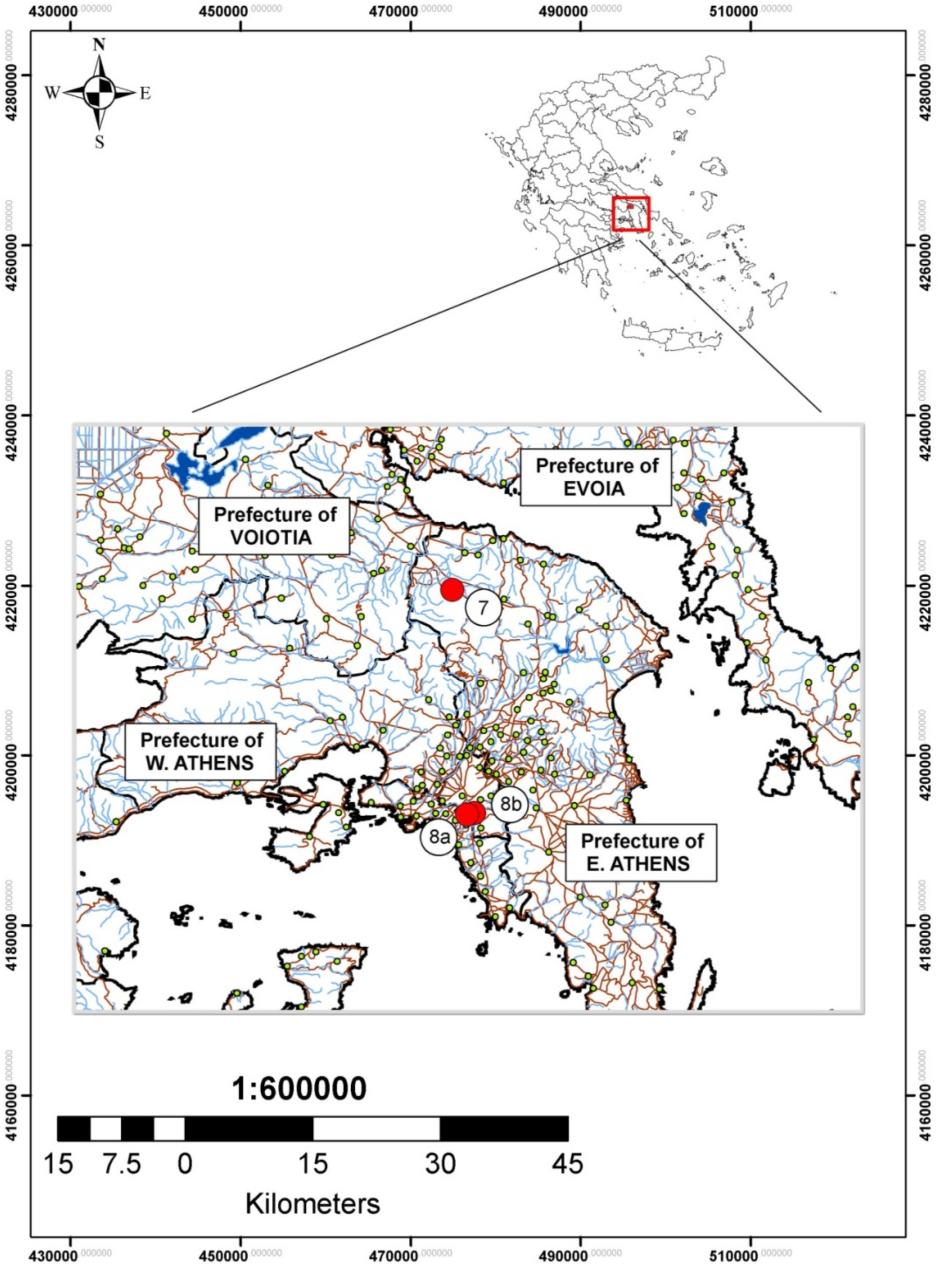


Figure 2.7 Geographical region of Attica (*indicated with numbers 7 & 8 in general map, Fig. 2.1*). Reference map in respect to Greece located in upper right corner, and localities in the region where Barn owl pellet samples were collected are indicated in red dots. (*7: Avlona, 8a: Dafni, 8b: Hymettus*).

a complete image.

2.2.1.6 Avlona

Avlona is an area located in the prefecture of Attica, 48 km north of Athens, bordering in the north with the prefecture of Voiotia. Barn owl's diet was studied in Avlona from Alivizatos et al. (2005), with samples collected during the period 1997 to 2001. The dominating habitat type in the area is open scrubland comprised mainly of phrygana, and secondly agricultural crops which complete the habitat structure. The exact location of the area is indicated in Figure 2.7.

2.2.1.7 Dafni & Hymettus

Dafni is a municipality which belongs to the prefecture of Attica, bordering to the north with the capital of Attica, Athens, and is also one of the smallest municipalities belonging to the southern municipalities' complex. To the east, Dafni is bordering with Hymettus, another small municipality which is located in the feet of mountain Hymettus. Barn owl's diet was studied in Dafni from pellet samples which were collected during 1972 (Cheylan, 1976), and in the mountain Hymettus from pellet samples which were collected from a cave during 1989 (Tsounis & Dimitropoulos, 1992). The main habitat in Hymettus mountain is Mediterranean maquis, with most common plants the Mastic tree (*Pistacia lentiscus*), Kermes oak (*Quercus coccifera*), Strawberry tree (*Arbutus unedo*) and Aleppo pine (*Pinus halepensis*), whereas the habitat of Dafni surrounding the sampled locality is not indicated from the author. Both sampled locations of Dafni and Hymettus, are demonstrated in Figure 2.7 along with the location of Avlona, since all three of them belong in the prefecture of Attica.

2.2.2 Insular diet studies

In Greece Barn owl diets where also studied in six islands. One of them belonged in the complex of Ionian islands, two in Dodecanese complex, one in Sterea Hellas, and two in the Cretan complex.

2.2.2.1 Corfu

Corfu is the northernmost island encountered in the complex of seven islands of Ionian Sea, in western Greece. It is located in the entrance of Adriatic Sea, near the coasts of Epirus district and the prefectures of Ioannina and Thesprotia, and the island's northwestern coasts approach the coasts of Albania (Fig. 2.8). It is mainly a mountainous island especially in its northern part, with a habitat structure dominated from olive trees and vineyards, and a very rich fauna counting more than 150 bird species. Barn owl diet was studied in Corfu with pellet samples which were collected in a total of 9 localities scattered all over the island's surface, from Bohr (1962) and Niethammer (1962). No other more recent studies have been realized in the island since, and the total of 9 locations where pellets were collected are demonstrated in Figure 2.8.

2.2.2.2 Kos

The island of Kos belongs to the complex of Dodecanese islands, it is the third larger in the Dodecanese complex after Rhodes and Karpathos, and it is situated between Nissiros and Kalymnos, near the coasts of Minor Asia (Fig. 2.9). It is an island with rich flora, flat in most of its extension with two low mountains in the southern part, Dikaio and Sympatro. Barn owl diet was studied in Kos with pellet samples which were collected in 1978, and the results were published by Niethammer (1989).

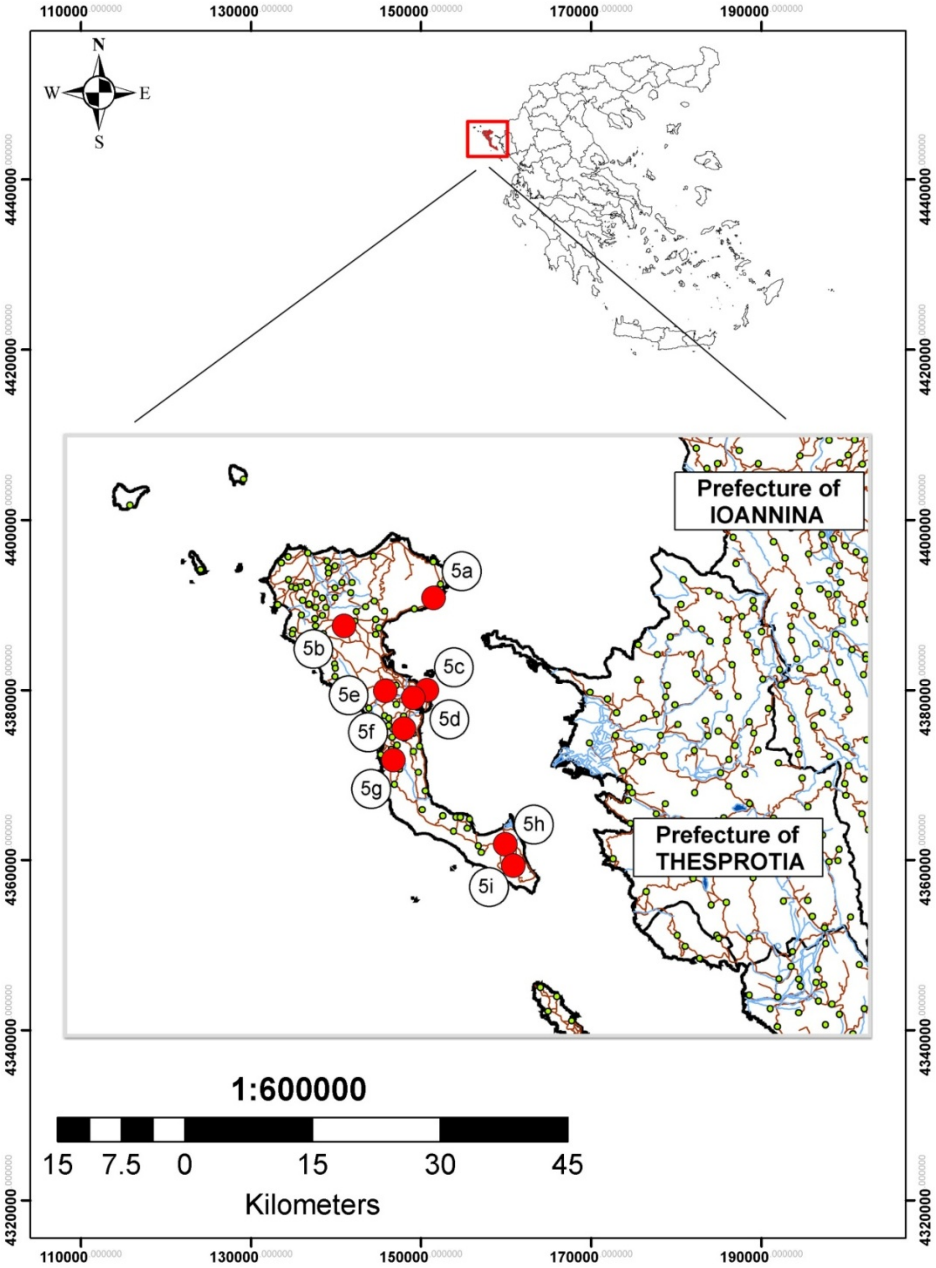


Figure 2.8 Geographical region of Corfu island (*indicated with number 5 in general map, Fig. 2.1*). Reference map in respect to Greece located in upper right corner, and localities in the region where Barn owl pellet samples were collected are indicated in red dots. (*5a: Synies, 5b: Dukades, 5c: Ag. Ioannis, 5d: Kanalia, 5e: Triklino, 5f: Pondi, 5g: Agioi Deka, 5h: Dragotina, 5i: Spartero*).

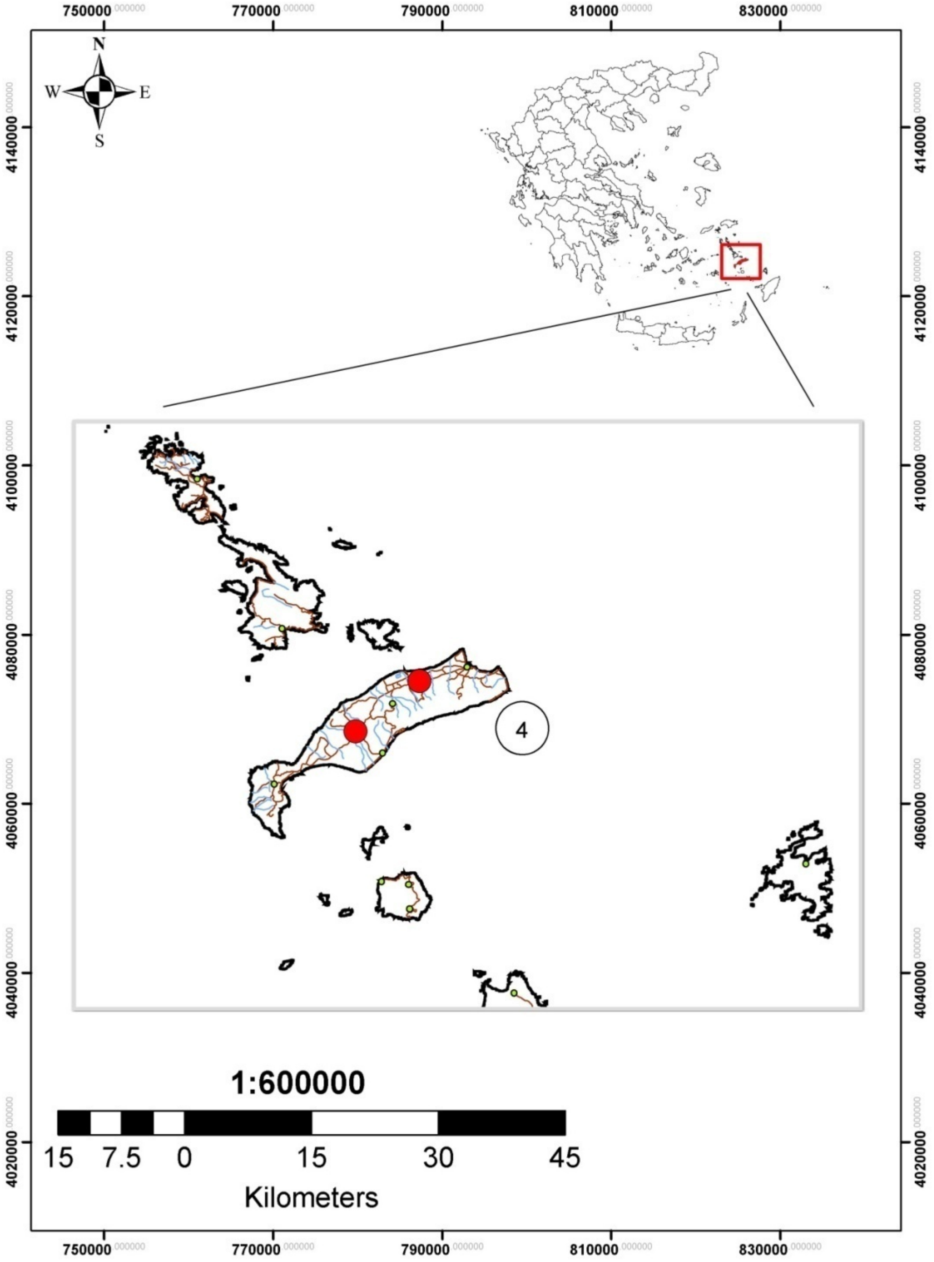


Figure 2.9 Geographical region of Kos island (*indicated with number 4 in general map, Fig. 2.1*). Reference map in respect to Greece located in upper right corner, and localities in the region where Barn owl pellet samples were collected are indicated in red dots.

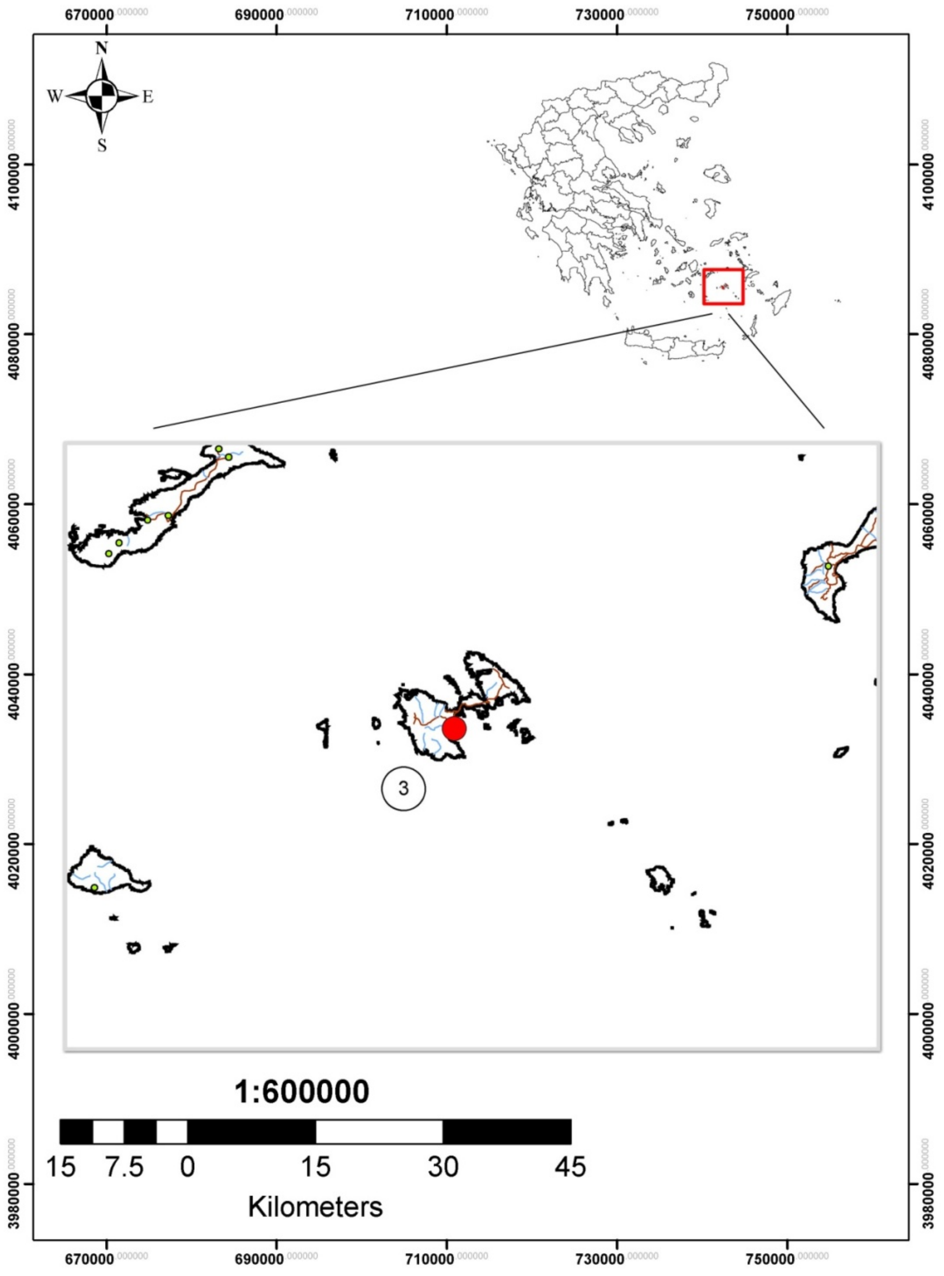


Figure 2.10 Geographical region of Astipalaia island (*indicated with number 3 in general map, Fig. 2.1*). Reference map in respect to Greece located in upper right corner, and localities in the region where Barn owl pellet samples were collected are indicated in red dots.

2.2.2.3 Astipalaia

The island of Astipalaia is the western border of Dodecanese complex, and is actually the bridge between the two island complexes, Dodecanese and Cyclades. Although it belongs legislatively to Dodecanese, geographically it is actually part of Cyclades islands. In its south-eastern part, Astypalaia is bordering with smaller islands such as Agia Kyriaki, Xondros, Kounoupi and Koutsomitis, and in the west even smaller islets surround it like Ofidousa, Xtenia, Pontikousa and many more (Fig. 2.10). A short land zone of just 10 km length and 100 m in amplitude divides the island in the western and eastern part, and the island's surface which in total occupies 96.22 km^2 is actually mountainous, naked with rocks and rock debris, no vegetation, and no other characteristic habitat types exist than just a few orchards. Barn owl diet in the island of Astipalaia was studied with pellet samples which were collected during 1988 and 1990, and were published by Angelici et al. (1992) and Angelici & Riga (1994).

2.2.2.4 Evoia

The island of Evoia is the second largest in Greece after Crete. It is located in the centre of Aegean Sea, and it belongs to Sterea Hellas prefecture. It is actually attached to the mainland and Sterea Hellas prefecture with a bridge which is lifted when boats traverse the Evoian bay. It is a long island with direction from north-west to south-east, and it is comprised by a great variety of different habitats, and a very rich flora and fauna. Nonetheless, Barn owl's diet was studied by Akriotis (1981) only in the locality of Halkida which is the capital of Evoia, as demonstrated in Figure 2.11. The habitat in the locality where the author realized the pellet sampling is mainly occupied by limestone hills, where phrygana and maquis vegetation dominate, pine woods come second and cultivated land occupies a minimum percentage.

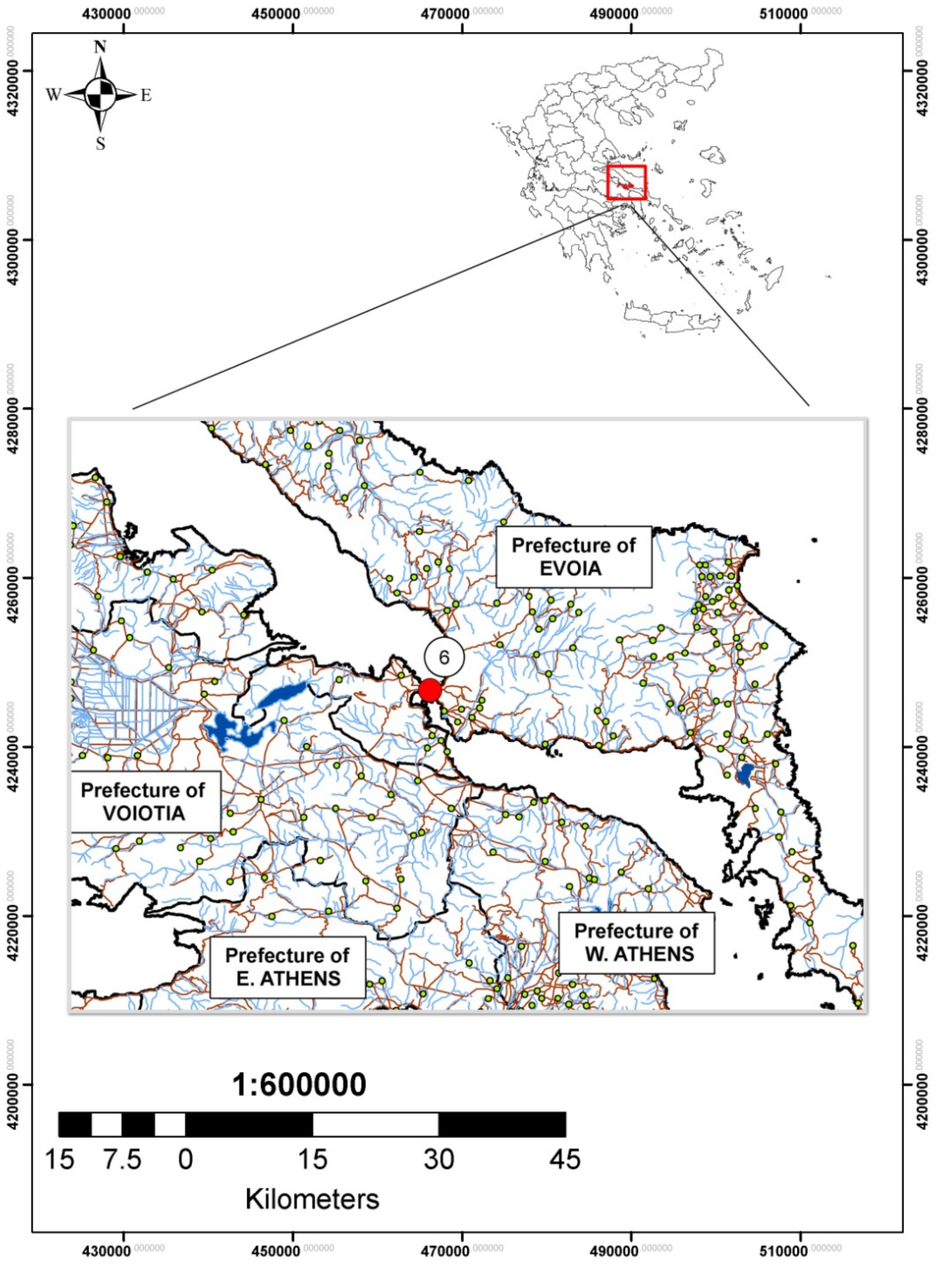


Figure 2.11 Geographical region of Evoia island (*indicated with number 6 in general map, Fig. 2.1*). Reference map in respect to Greece located in upper right corner, and localities in the region where Barn owl pellet samples were collected are indicated in red dots.

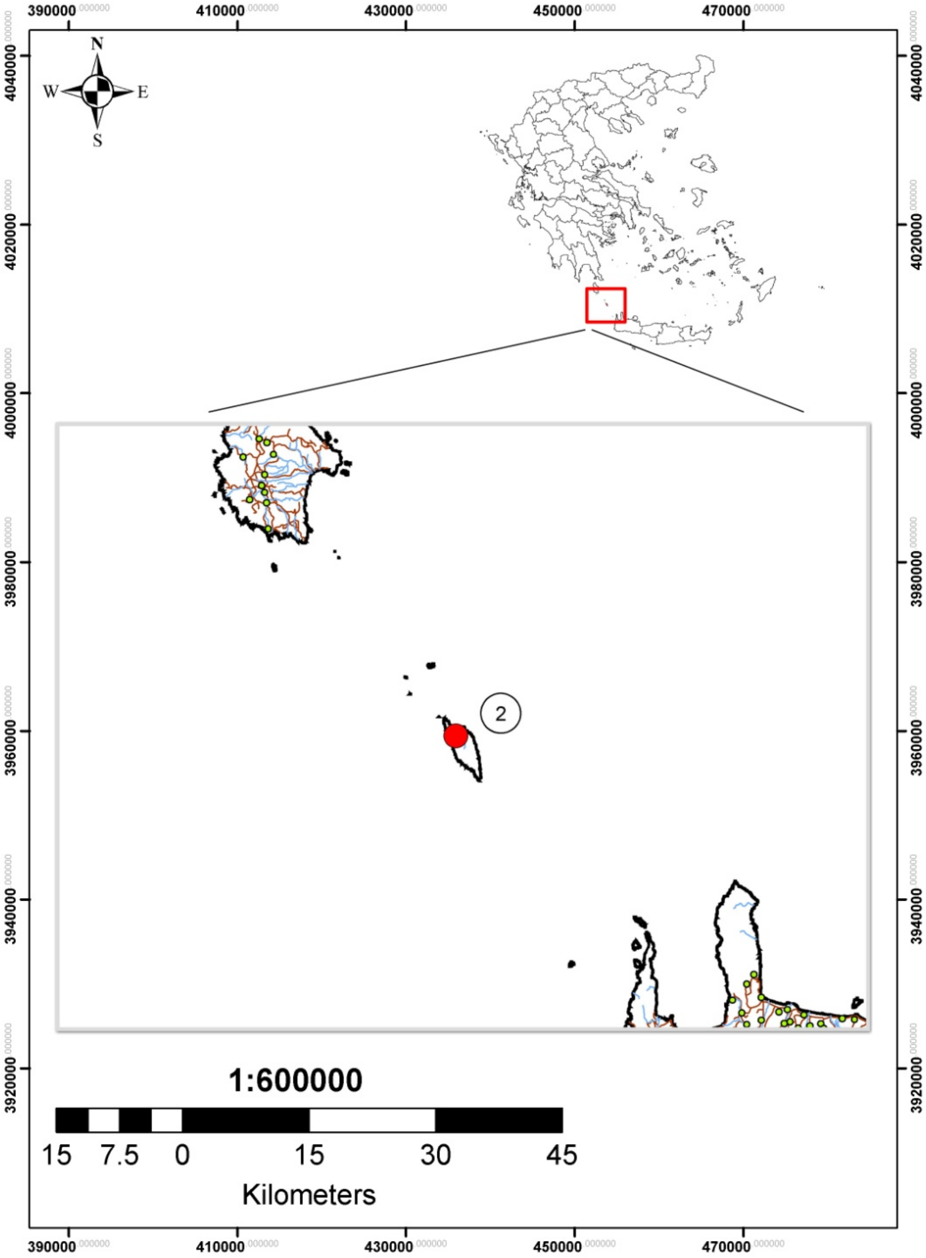


Figure 2.12 Geographical region of Antikythera island (*indicated with number 2 in general map, Fig. 2.1*). Reference map in respect to Greece located in upper right corner, and localities in the region where Barn owl pellet samples were collected are indicated in red dots.

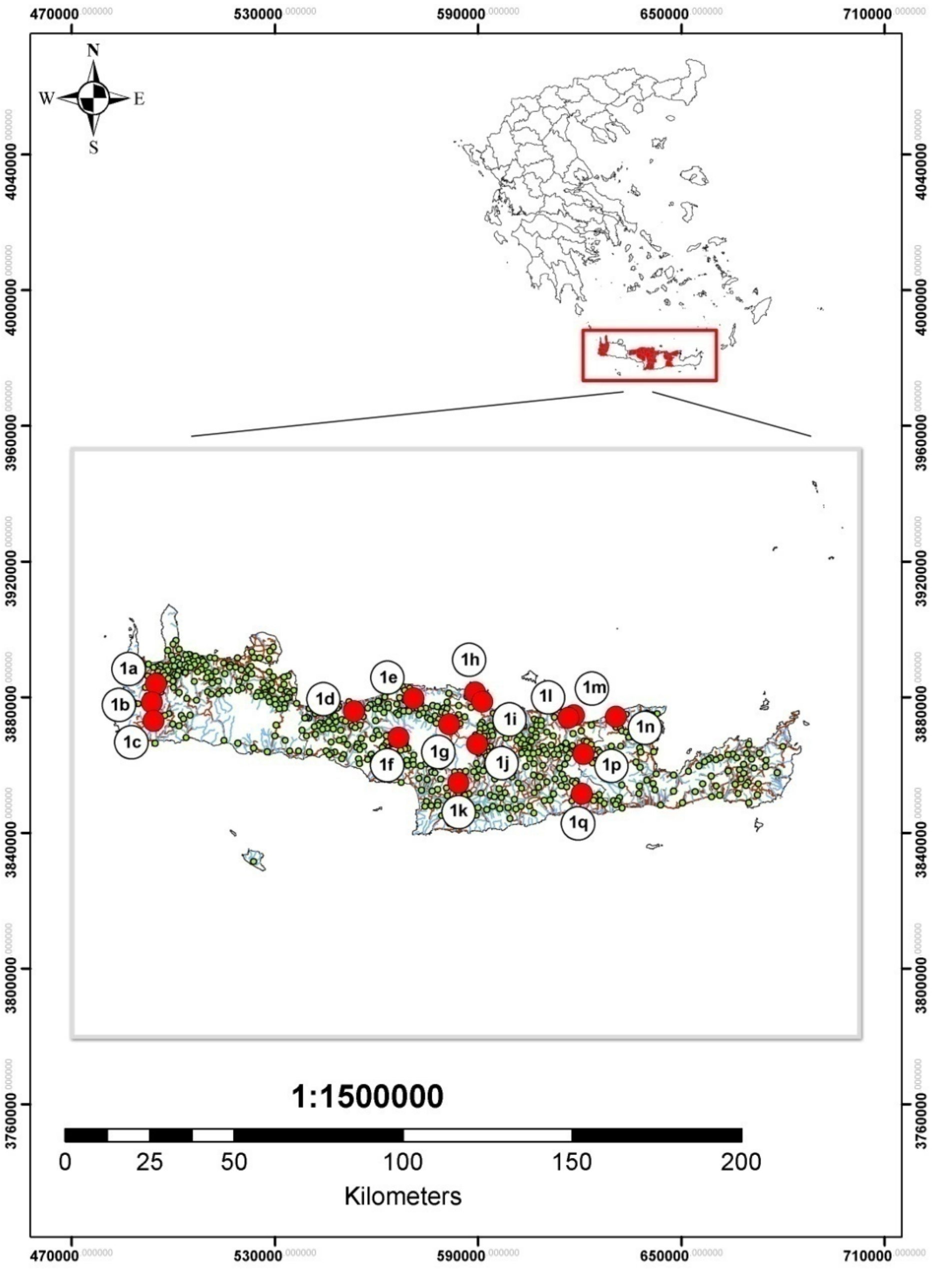


Figure 2.13 Geographical region of Crete island (*indicated with number 1 in general map, Fig. 2.1*). Reference map in respect to Greece located in upper right corner, and localities in the region where Barn owl pellet samples were collected are indicated in red dots. (*1a: Topolia, 1b: Strovles, 1c: Voutes, 1d: Pervolia, 1e: Melidoni, 1f: Platania, 1g: Axos, 1h: Skotino, 1i: Kato Metochi, 1j: Sarxos, 1k: Almiros, 1l: Agio Pnevma, 1m: Aloni, 1n: Milatos, 1p: Ag. Titos, 1q: Ano Viannos*).

2.2.2.5 Antikythera

Antikythera is a very small island of just 20 km^2 in extension and 24 km of coastal line. It belongs legislatively in the prefecture of Attica, geographically in Peloponnesus, and it is located below Peloponnesus, between the island of Kythera and the north-eastern edge of Crete (Fig. 2.12). The main habitat type in the island is phrygana and to a much lesser extent cultivated farmland. During the last decade, the island has been continuously observed from the Hellenic Ornithological Society, due to the high avian diversity that exists on it, and the great numbers of migratory species which use it as intermediate stop during their movements. Almost 200 hundred species have been recorded in Antikythera, many of them are studied in long term basis, and the greatest colony of Eleonora’s falcon (*Falco eleonorae*) in the Mediterranean basin is located there. Barn owl diet was studied in the island with pellet samples collected during the period 1997 to 2001, and the results were published by Alivizatos et al. (2005). The island’s exact location is indicated in Figure 2.12.

2.2.2.6 Crete

Crete is the largest island of Greece occupying an extension of 8.336 km^2, and it is the southern border of Aegean islands. With an extent of 260 km from west to east, it presents a very high diversity of habitats, flora and fauna. Crete is considered a predominantly mountainous island, with three main mountain series traversing it from west to east, and specifically the White Mountains, Psiloreitis and Dikti. Barn owl diet was studied in the island in numerous sites (16) located in all four prefectures (Fig. 2.13). Pellets samples were collected during the period 1972 to 1976, and were published afterwards by Cheylan (1976) and Pieper (1977).

2.3 METHODS AND MATERIAL

As mentioned before, the Barn owl diet was studied in 13 different geographical locations in Greece. In each one of these 13 locations, as was priorly stated and analytically demonstrated, pellets were usually collected from more than one locality. Of course, pellets from various localities belonging in the same geographical region were pooled and treated as a sum in posterior analyses, in order to produce meaningful results which reflect the owl's diet in specific geographical areas. It would also be very interesting to present analyses about Barn owl's diet during breeding and non-breeding seasons as well, a method followed by other authors which published owl review studies (Holt, 1993). Nevertheless, some Greek papers included pellet samples which were collected uniquely at specific times of the year (Bohr, 1962; Niethammer, 1962a; Cheylan, 1976; Akriotis, 1981; Alivizatos & Goutner, 1999; Goutner & Alivizatos, 2003), some were opportunistically collected without a clear methodology (Pieper, 1977; Niethammer, 1989; Angelici & Riga, 1994; Alivizatos et al., 2005), and finally those studies which actually treated Barn owl diet through seasonal analysis had small samples (Tsounis & Dimitropoulos, 1992), whereas these papers which analyzed good samples were limited to a total of 2 studies (Bontzorlos et al., 2005; Alivizatos et al., 2006). Therefore, in the present review chapter a breeding/non-breeding view cannot be offered from the existing data, and thus only geographical trends will be explored.

At that point it is also necessary to outline that from the island of Crete, although only a total of 3180 prey items are included and analyzed in the present chapter, a total of 12842 prey items have been identified from Barn owl pellet analysis, as mentioned by Pieper (1976). Nonetheless, from that amount of 12842 identified prey items, only 3180 have been published with analytical references to specie level, part of them by

Pieper (1976) and the rest is included as scattered information in the collective works of Niethammer & Krapp (1977, 1982, 1990). Therefore, although there is a great surplus of 9662 more indentified prey items from the island of Crete, since they were never published analytically by any of the mentioned authors, they will not be included in the present analyses. It is quite certain thus, that Barn owl's diet in Crete is biased since only ¼ of its diet is included in the present chapter, but unfortunately no official source could provide the remaining information.

Niche breadth was defined with the calculation of three indices. Firstly, species richness which is the oldest and simplest concept of species diversity was calculated as the number of species in a community or in a sample. Secondly, the Shannon-Wiener diversity index which was calculated according to Pianka (1980) as:

$$H' = -\sum_{i=1}^{n} pi \ln pi$$

pi = proportion of species i in each sample (seasonal or total)

ln = natural logarithm (base e)

Nonetheless, before pooling the data as well as afterwards, sample sizes as it was expected varied among geographical regions in respect to their prey item numbers. Therefore, in order to calculate niche indices for comparisons among regions with equal samples and avoid bias, the rarefaction method was applied according to Sanders (1968), Hurlbert (1971), Simberloff (1972) and Krebs (1999). Rarefaction was applied both in species richness and diversity indices, which were calculated in respect to the smallest sample. Rarefaction calculations were realized with the software packages Past (Hammer et al., 2001), Biodiversity Pro (McAleece et al., 1997) and Ecosim version 7.0 (Gotelli & Entsminger, 2001). Since trophic diversity was calculated for different geographical regions within the country, it wasn't necessary to calculate it in relation to the number of individuals contributed by each higher taxonomic category as in other papers which realized Neotropic, Nearctic and Palearctic comparisons (Jaksic & Marti, 1981, 1984; Jaksic et al, 1982). Therefore, diversity index was calculated with all prey categories included and in specie level. For furthermore comparisons between small mammal taken by the owls, the fraction Insectivora/Rodentia was calculated in each case, and simple descriptive statistics in small mammal genus level, provided the necessary information. Thirdly, although no available software could calculate a rarefied equitability index, evenness was calculated according to Shannon-Wiener function J' (Krebs, 1999) without prior rarefaction, with the software Biodiversity Pro (McAleece et al., 1997) according to the equation:

$$J' = \frac{Observed\ Shannon\ Measure\ of\ \ Niche\ Breadth\ H'}{Maximum\ Possible\ Shannon\ Measure}$$

Although the evenness index J' cannot be calculated after rarefying the results, so there may be bias in some sites, it is the most common index of evenness in raptor diet literature (Krebs, 1999), and allows various comparisons with other diet studies.

Small mammal species' biomass was based to bibliographical references (Niethammer & Krapp, 1977, 1982, 1990; Macdonald & Barrett, 1993; Alcantara, 1998; Moreno & Balbontin, 1998; Krystufek & Vohralik, 2005), and avian species' weight was calculated according to Hume (2002). The biomass contribution to the owl's diet was calculated as the percentage biomass, multiplying the number of each species' individuals in each sample by the estimated body mass of each species respectively and then divided by the total sum of biomass in the sample. The average weight of mammalian prey (MWMP) in each sample and in totals was also obtained by multiplying each prey item by its average weight, summing the products, and dividing the sum by the total number of mammalian prey in the sample (Marks, 1984). Insects' biomass wasn't calculated due to their minor contribution in the Barn owl diet, and therefore they were considered as non significant, as in other authors' methodology (Goutner & Alivizatos, 2003; Alivizatos et al., 2005).

In order to perform comparisons between the different geographical regions where Barn owl diet was studied, and explore various trends in the existing niche breadth, a grouping of regions was applied. Insular diets were grouped (but not pooled) together, and similarly mainland diets were also grouped together with the exception of Thessaly, which was pooled with the results of this thesis (see Chapter 2) in order to observe separately its niche among Greek diets. The comparisons between different geographical regions concerning the two diversity indices (diversity H' and evenness J') were realized with non parametric statistical tests, and specifically Kruskal Wallis test, and the respective comparisons concerning species richness and mean weight of mammalian prey among regions, were realized with one-way ANOVA tests.

2.4 RESULTS

2.4.1 General overview and descriptive statistics

The Barn owl diet in Greece was studied in a total of 13 geographical regions as demonstrated analytically in Figure 2.1, whereas in certain cases some regions also included more adjacent localities. Six studies were realized in islands and seven more in mainland areas, which produced a total of 13483 identified prey items up to date in the country. As expected, mammals dominated Barn owl's diet in all regions, ranging from 73.58% (Antikythera) to 99.3% (Crete), and in the great majority of studied areas they formed more than 90% of preyed items in terms of percentage of frequency (Tab. 2.1). A total of 41 species comprised the owl's mammalian intake, nonetheless only 5 to 6 species were heavily preyed which formed the main bulk of Barn owls' diet (Tab. 2.1). In specific, although bats participated with 15 different species they

Table 2.1 Geographical localities where Barn owl diets were studied in Greece up to day, and percentages of frequency (n%) of prey items which comprised them

	Crete	***Antikythera***	***Astypalaia***	***Kos***	***Corfu***	***Evoia***	***Avlona***	***Attica***	***Thessaly***	***Parthenio***	***Potidaia***	***P. Lagos***	***Lafres***	***Mitrikou***	***Evros Delta***
	n %	n %	n %	n %	n %	n %	n %	n %	n %	n %	n %	n %	n %	n %	n %
Suncus etruscus	15.47			1.91	4.13	3.20	3.16	0.82			0.68	1.27	1.16	6.36	0.41
Neomys anomalus															2.54
Crocidura leucodon									24.48	0.43	0.68	1.53	7.95	23.31	3.83
Crocidura suaveolens	68.05		24.22	30.89	11.27	6.40	9.47	11.04	0.79	9.07	13.18	16.69	17.63	15.25	25.32
Crocidura zimmermani	4.72														
Soricidae	**88.24**		**24.22**	**32.80**	**15.40**	**9.60**	**12.63**	**11.04**	**25.27**	**9.50**	**14.53**	**19.49**	**26.73**	**44.92**	**32.11**
Talpa europaea										0.65					
Talpidae										**0.65**					
Soricomorpha	***88.24***		***24.22***	***32.80***	***15.40***	***9.60***	***12.63***	***11.86***	***25.27***	***10.15***	***14.53***	***19.49***	***26.73***	***44.92***	***32.11***
Apodemus sylvaticus	0.63			4.78	50.66	15.2	4.21	20.04	15.50	11.66	3.38	8.54	6.94	5.08	5.44
Apodemus flavicollis									2.47		1.35				0.47
Apodemus epimelas	0.03			4.99	7.27	0.80		16.56	0.39						
Rattus rattus	0.25	51.89	1.56	9.87	3.04		1.05	0.41	1.09	3.02	0.68	0.89			0.21
Rattus norvegicus						19.2			9.87	1.51					
Mus mus (domesticus)	4.56	20.75	60.16	21.66	12.27	32.8	31.58	23.93	26.26	0.43		33.63	28.18	28.39	8.18
Mus macedonicus							9.47	4.91		32.61	76.01	2.17			22.68
Micromys minutus										1.51		1.02	0.14		
Acomys minous	0.06														
Meriones tristrami				4.35											
Muridae	**5.53**	**72.64**	**61.72**	**45.65**	**73.23**	**68.00**	**46.32**	**65.85**	**69.20**	**50.76**	**81.42**	**46.24**	**35.26**	**33.47**	**36.98**
Arvicola amphibius										0.65		0.13			0.41
Cricetulus migratorius						0.80	1.05	0.61							
Microtus levis						14.4			1.38	32.40	0.34	28.03	34.10	8.47	28.07
Microtus guentheri									4.34						0.47
Microtus thomasi							36.84	9.82	7.90						
Microtus felteni								0.20							
Cricetidae						**15.20**	**37.89**	**10.63**	**13.62**	**33.05**	**0.34**	**28.15**	**34.10**	**8.47**	**28.95**
Muscardinus avellanarius					1.13				0.39						
Glis glis	1.07				0.03										
Gliridae	**1.07**				**1.16**				**0.39**						
Rodentia	***6.60***	***72.64***				***83.20***	***84.21***	***76.48***	***69.60***	***83.80***	***81.76***	***74.39***	***69.36***	***41.95***	***65.92***
Oryctolagus cuniculus	0.19	0.94													
Lagomorpha	***0.19***	***0.94***													
Mustela nivalis															0.05
Carnivora															***0.05***

Table 2.1 (continued)

	Crete	*Antikythera*	*Astypalaia*	*Kos*	*Corfu*	*Evoia*	*Avlona*	*Attica*	*Thessaly*	*Parthenio*	*Potidaia*	*P. Lagos*	*Lafres*	*Mitrikou*	*Evros Delta*
	n %	n %	n %	n %	n %	n %	n %	n %	n %	n %	n %	n %	n %	n %	n %
Rhinolophus ferrumequinum	0.79				0.06										
Rhinolophus hipposideros	0.03														
Rhinolophus blasii	0.06														
Rhinolophidae	**0.88**				**0.06**										
Eptesicus serotinus	0.16				0.03										
Miniopterus schreibersi	0.35				0.03										
Myotis mystacinus					0.03										
Myotis emarginatus	0.28				0.03										
Myotis oxygnathus					0.06										
Myotis myotis					0.06										
Myotis blythi	2.17														
Pipistrellus pipistrellus												0.25			
Pipistrellus kuhli	0.22														
Pipistrellus savii	0.19														
Plecotus austriacus	0.38														
Vespertilionidae	**3.74**				**0.26**							**0.25**			
Tadarida teniotis	0.13														
Mollosidae	**0.13**														
Chiroptera	***4.75***				***0.32***							***0.25***			
MAMMALIA	**99.30**	**73.58**	**85.94**	**78.45**	**90.12**	**92.80**	**96.84**	**88.34**	**94.87**	**93.95**	**96.28**	**94.14**	**96.10**	**86.86**	**98.08**
Limosa limosa					0.03										
Gallinago gallinago															0.05
Charadriiformes					***0.03***										***0.05***
Tyto alba				0.11											
Otus scops		0.94			0.03										
Strigiformes		***0.94***		***0.11***	***0.03***										
Alectoris chukar		0.94													
Galliformes		***0.94***													
Porzana porzana		0.94													
Gruiformes		***0.94***													
Alcedo atthis															0.05
Coraciiformes															***0.05***
Streptopelia decaocto															
Streptopelia turtur										0.22					
Columbiformes										***0.22***					

Table 2.1 (continued)

	Crete	***Antikythera***	***Astypalaia***	***Kos***	***Corfu***	***Evoia***	***Avlona***	***Attica***	***Thessaly***	***Parthenio***	***Potidaia***	***P. Lagos***	***Lafres***	***Mitrikou***	***Evros Delta***
	n %	n %	n %	n %	n %	n %	n %	n %	n %	n %	n %	n %	n %	n %	n %
Pica pica															
Corvidae															
Hirundo rustica		1.89			0.06										
Delichon urbica				0.11											
Hirundinidae		**1.89**		**0.11**	**0.06**										
Alauda arvensis				0.21											
Galerida cristata				0.11											
Alaudidae				**0.32**											
Parus major					0.13						0.34		0.72	2.12	
Parus caeruleus					0.10										
Paridae					**0.23**						**0.34**		**0.72**	**2.12**	
Turdus merula	0.03				0.06	1.60		0.61					0.29		0.05
Turdus philomelos				0.32											
Monticola solitarius					0.03										
Turdidae	**0.03**			**0.32**	**0.10**	**1.60**		**0.61**					**0.29**		**0.05**
Anthus campestris					0.16										
Anthus cervinus					0.03										
Motacilla alba					0.10										
Motacillidae					**0.29**										
Lanius senator		1.89			0.03										
Laniidae		**1.89**			**0.03**										
Ficedula parva		1.89													
Erithacus rubecula							1.05	0.20				0.13			0.05
Muscicapidae		**1.89**					**1.05**	**0.20**				**0.13**			**0.05**
Carduelis chloris				1.27	0.10			0.41	1.18	0.65		0.51			
Carduelis carduelis				0.42											
Serinus serinus				0.21	0.06								0.43		
Fringilla coelebs				1.06	0.06		2.11	1.43		1.30		1.40	1.01	2.54	0.16
Coccothraustes coccothraustes					0.03										
Fringillidae				**2.97**	**0.26**		**2.11**	**1.84**	**1.18**	**1.94**		**1.91**	**1.45**	**2.54**	**0.16**
Sturnus vulgaris				0.11		0.80		0.20							0.21
Sturnidae				**0.11**		**0.80**		**0.20**							**0.21**
Emberiza cirlus					0.03					0.22					0.05
Milaria calandra		2.83		0.11								0.51			
Emberizidae		**2.83**		**0.11**	**0.03**					**0.22**		**0.51**			**0.05**
Sylvia atricapilla	0.03			0.42											

Table 2.1 (continued)

	Crete	*Antikythera*	*Astypalaia*	*Kos*	*Corfu*	*Evoia*	*Avlona*	*Attica*	*Thessaly*	*Parthenio*	*Potidaia*	*P. Lagos*	*Lafres*	*Mitrikou*	*Evros Delta*
	n %	n %	n %	n %	n %	n %	n %	n %	n %	n %	n %	n %	n %	n %	n %
Sylvia borin				0.42											
Sylvidae	**0.03**			**0.85**											
Passer domesticus	0.16	3.77		16.35	0.29	1.60		6.13	2.76	1.73	1.01	2.17		7.63	0.83
Passer montanus															
Passeridae	**0.16**	**3.77**		**16.35**	**0.90**	**1.60**		**6.13**	**2.76**	**1.73**	**1.01**	**2.17**			**0.83**
Passeriformes	***0.22***				***1.91***	***4.00***	***3.16***	***9.00***	***3.95***	***4.10***	***1.35***	***4.71***	***2.46***	***12.29***	***1.35***
AVES	**0.22**	**16.04**		**21.23**	**1.97**	**4.00**	**3.16**	**9.00**	**3.95**	**4.10**	**1.35**	**4.71**	**2.46**	**12.29**	**1.45**
Hyla arborea				0.21	2.52								0.14		0.05
Bufo bufo					0.71										
Rana graeca				0.11						1.30	2.36		0.29		0.16
Anura				***0.32***	***3.23***					***1.30***	***2.36***		***0.43***		***0.21***
AMPHIBIA				**0.32**	**3.23**					**1.30**	**2.36**		**0.43**		**0.21**
Lacerta viridis					0.71	0.80									
Lacerta trilineata					0.39										
Lacertidae					**1.10**	**0.80**									
Tarentola mauritanica		3.77													
Cyrtopodion kotschyi		6.60													
Gekkonidae		**10.38**													
Squamata		***10.38***			***1.10***	***0.80***									
REPTILIA		**10.38**			**1.10**	**0.80**									
Curculionidae			7.03									0.51		0.85	
Carabidae															0.05
Scarabeidae										0.22					
Coleoptera			***7.03***							***0.22***		***0.51***		***0.85***	***0.05***
Forficulidae								0.41							
Dermaptera								***0.41***							
Mantidae			3.91			0.80									
Mantodea			***3.91***			***0.80***									
Acrididae			3.13			1.60			1.18			0.51			
Gryllotalpidae								0.82		0.43			0.43		
Tettigoniidae								1.43				0.13	0.58		0.10
Orthoptera			***3.13***			***1.60***		***2.25***	***1.18***	***0.43***		***0.64***	***1.01***		***0.10***
INSECTA			**14.06**			**2.40**		**2.66**	**1.18**	**0.65**		**1.15**	**1.01**	**0.85**	**0.16**
CHILOPODA															**0.10**
Total Prey Items (N)	**3180**	**106**	**128**	**942**	**3097**	**125**	**95**	**394**	**1013**	**463**	**296**	**785**	**692**	**236**	**1931**

were present in only three diets forming less than 1% of preyed items, except the island of Crete where they reached almost 5% (Tab. 2.1). Carnivore and lagomorph species were also minorly represented in just three diets as well, not exceeding 1% in total. Rodents and Insectivorous species were the two mammalian orders heavily preyed from Barn owl in Greece. From the captured insectivorous species, European mole (*Talpa europaea*) was minorly preyed (0.65%) and only in the region of Parthenio in northern Greece, whereas similarly, Eurasian water shrew (*Neomys anomalus*) was also captured scarcely (2.54%) in Evros Delta in the north-eastern borders between Greece and Turkey (Figs. 2.1 & 2.2). Lesser white-toothed shrew (*Crocidura suaveolens*) and Bi-colored white-toothed shrew (*Crocidura leucodon*) were the two most preyed insectivorous species (Tab. 2.1). Rodents were the most preyed order in terms of frequency, which included a total of 18 species and 3 families. From these three families, Gliridae was the least preyed and it had only two representatives in the owl's diet, Hazel dormouse (*Muscardinus avellanarius*) and Fat dormouse (*Glis glis*), which were captured only 124 times in a total of 13483 preyed items (Tab. 2.1). In all the studied localities, members of Muridae family were more preyed. From voles which formed the Cricetidae family, and the genera Apodemus, Mus and Rattus were highly captured and more specific the species Long-tailed field mouse (*Apodemus sylvaticus*), House mouse (*Mus (Mus) musculus [domesticus]*) and Brown rat (*Rattus norvegicus*). From the six different voles which were present in Barn owl's diet in Greece, the most common was East European vole (*Microtus levis*), formerly treated under the scientific name of *Microtus rossiaemeridionalis.*

In respect to non mammalian prey, birds, reptiles, amphibia and insects were also present in the owl's diet with minor frequencies though. Reptiles were present with 4 different species of lizards which were captured in only three regions with very low

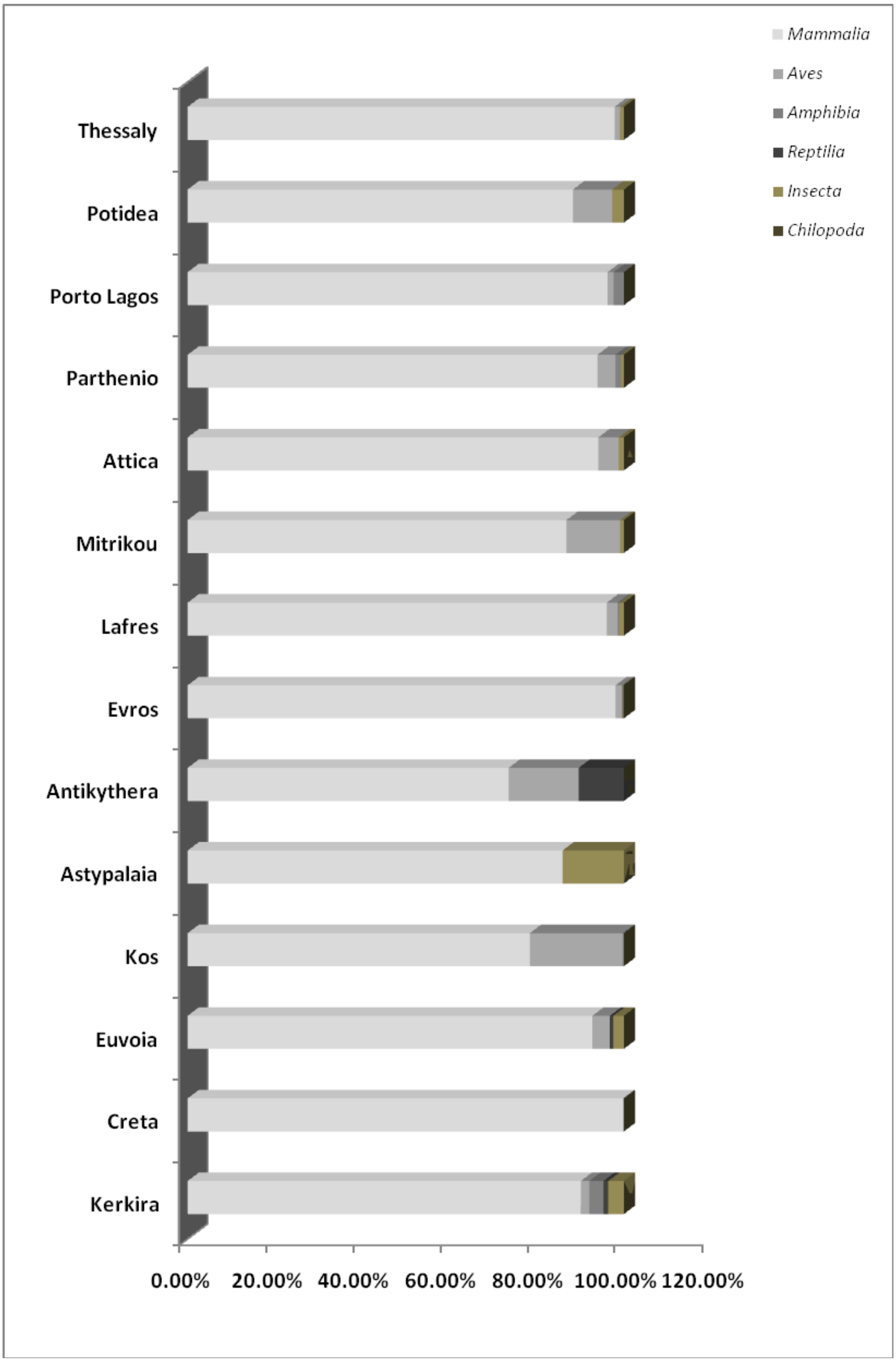


Figure 2.14 Percentages of frequency (n%) of all prey classes which were present in studied Barn owl diets in Greece up to date.

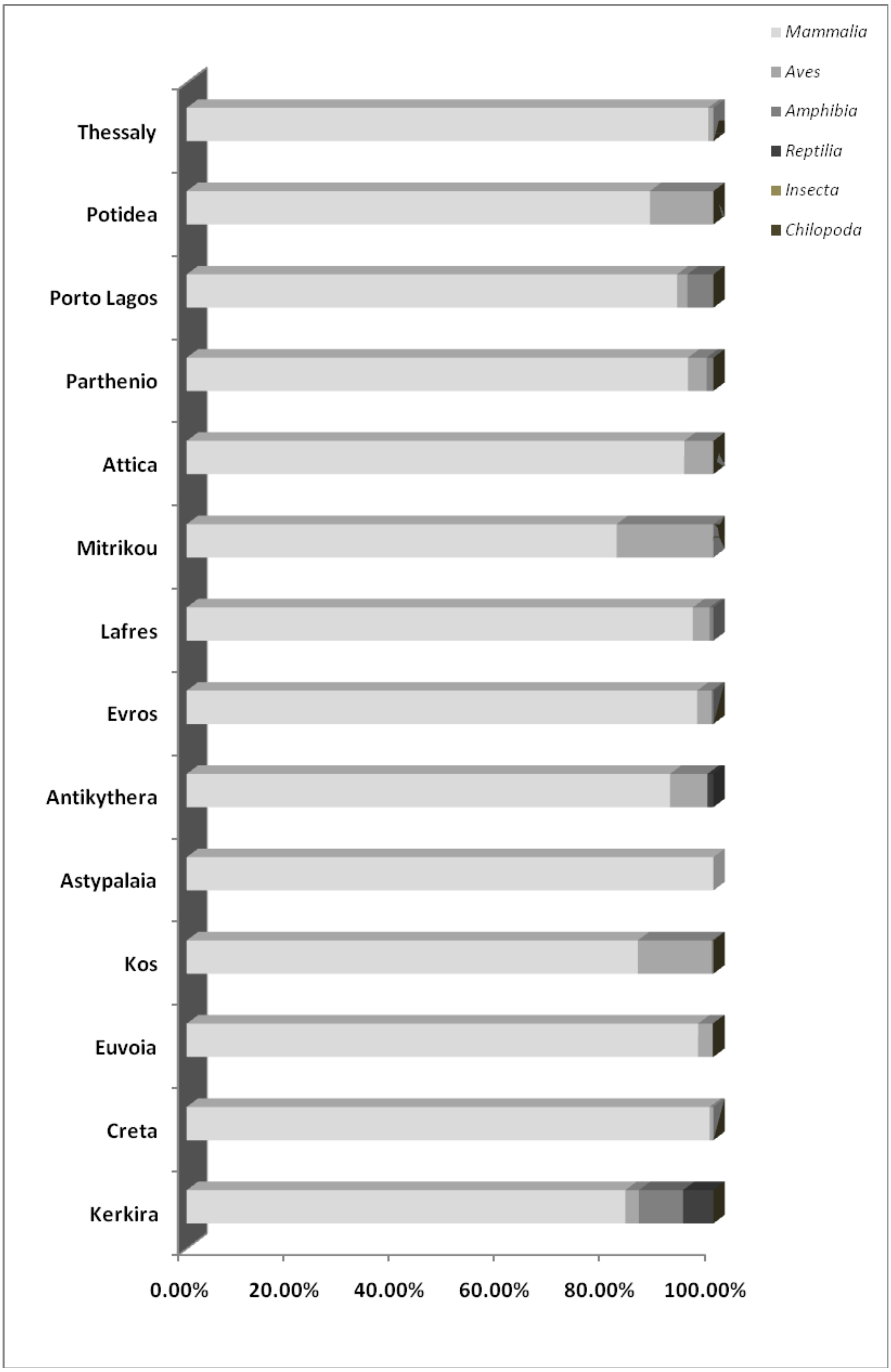


Figure 2.15 Percentages of contributed biomass (gr%) of all prey classes which were present in studied Barn owl diets in Greece up to date.

numbers, 3 different species of frogs were preyed in various regions not exceeding 3% though in any case, and various insect species were also present in most studied diets, which belonged to 8 different families and 4 different orders, forming nonetheless minimum percentages of frequency as well, which in addition also contributed minor biomass to the Barn owl's energetic needs (Tab. 2.1, Figs. 2.14 & 2.15). As far as avian prey is concerned, Barn owls captured a quite high number of different species in various geographical locations (Tab. 2.1). A total of 40 different species which belong to 19 families and 7 orders comprise the owls' avian preyed items in the country. Nevertheless, although avian species richness is very high, birds only formed relatively high percentages in no more than three locations, and specifically in the islands of Antikythera and Kos, and in the wetlands of northern Greece near the lake Mitrikou (Tab. 4.1). Except that fact, when observed the preyed items according to their energetic contribution, although avian intake presented a very high species richness, birds offered 18.37%, 14.07% and 12.05% of the consumed biomass only in lake Mitrikou, Kos island and Potidea region where they were highly preyed as well, while in the rest locations their contributed biomass just ranged from 0.70% in Crete island to 7.10% in Antikythera island (Tab. 2.1, Figs. 2.14 & 2.15). Therefore, since mammalian intake is dominating Barn owl's diet in Greece and specifically a small number of species comprise the main core of the raptor's prey use, both in frequency and energetic terms, the six mainly preyed mammalian genera's presence and contributed biomass are demonstrated analytically in all geographical regions where diet studies have been realized (Figs. 2.16. & 2.17). *Suncus* is the only one single-species genus including the Pygmy white-toothed shrew (*Suncus etruscus*), *Crocidura* genus includes three species, Lesser white-toothed shrew, Bi-colored white-toothed shrew and Cretan shrew (*Crocidura zimmermanni*),

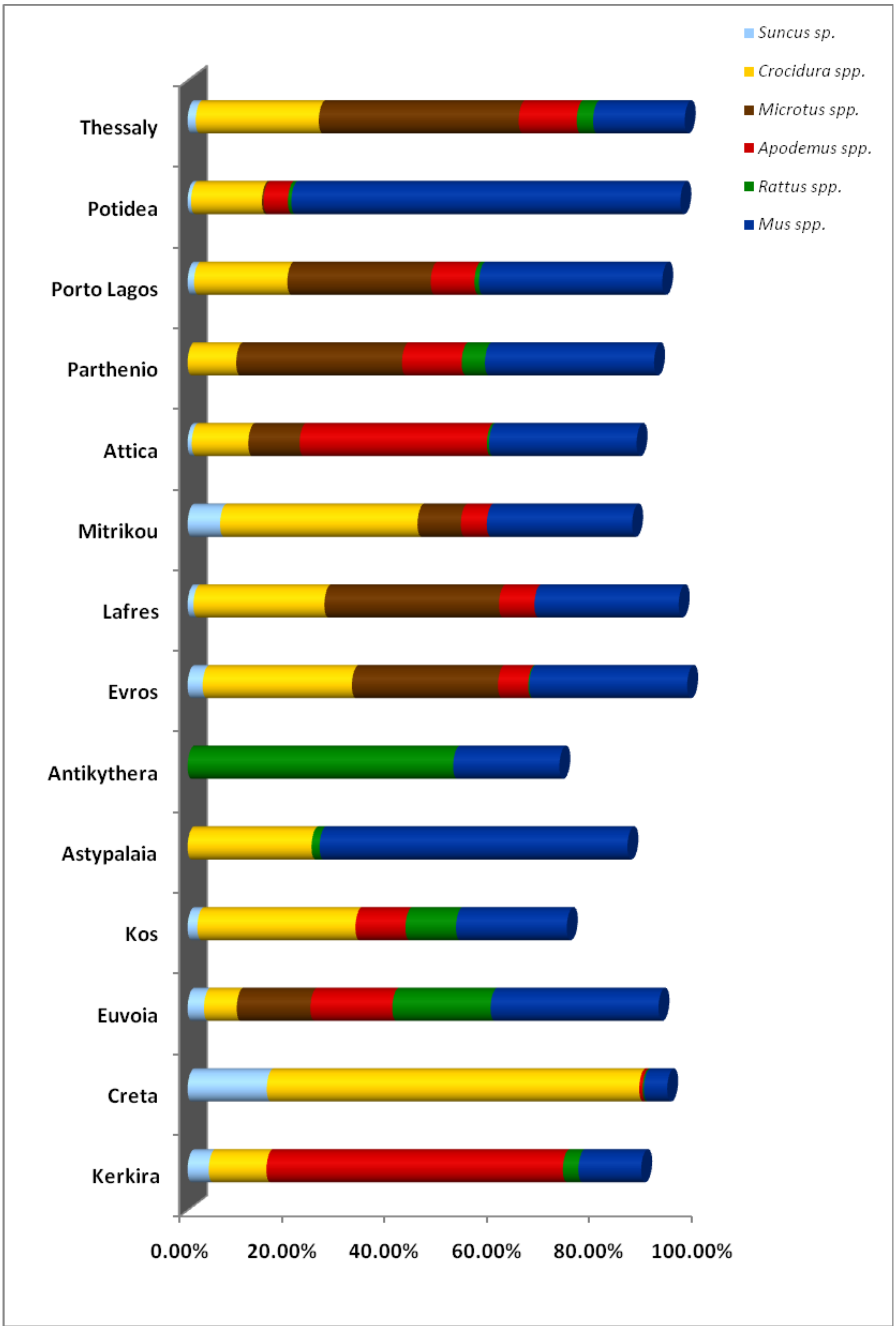


Figure 2.16 Percentages of frequency (n%) of the mainly preyed mammalian genera in all the geographical localities in Greece, where Barn owl diets have been studied up to date.

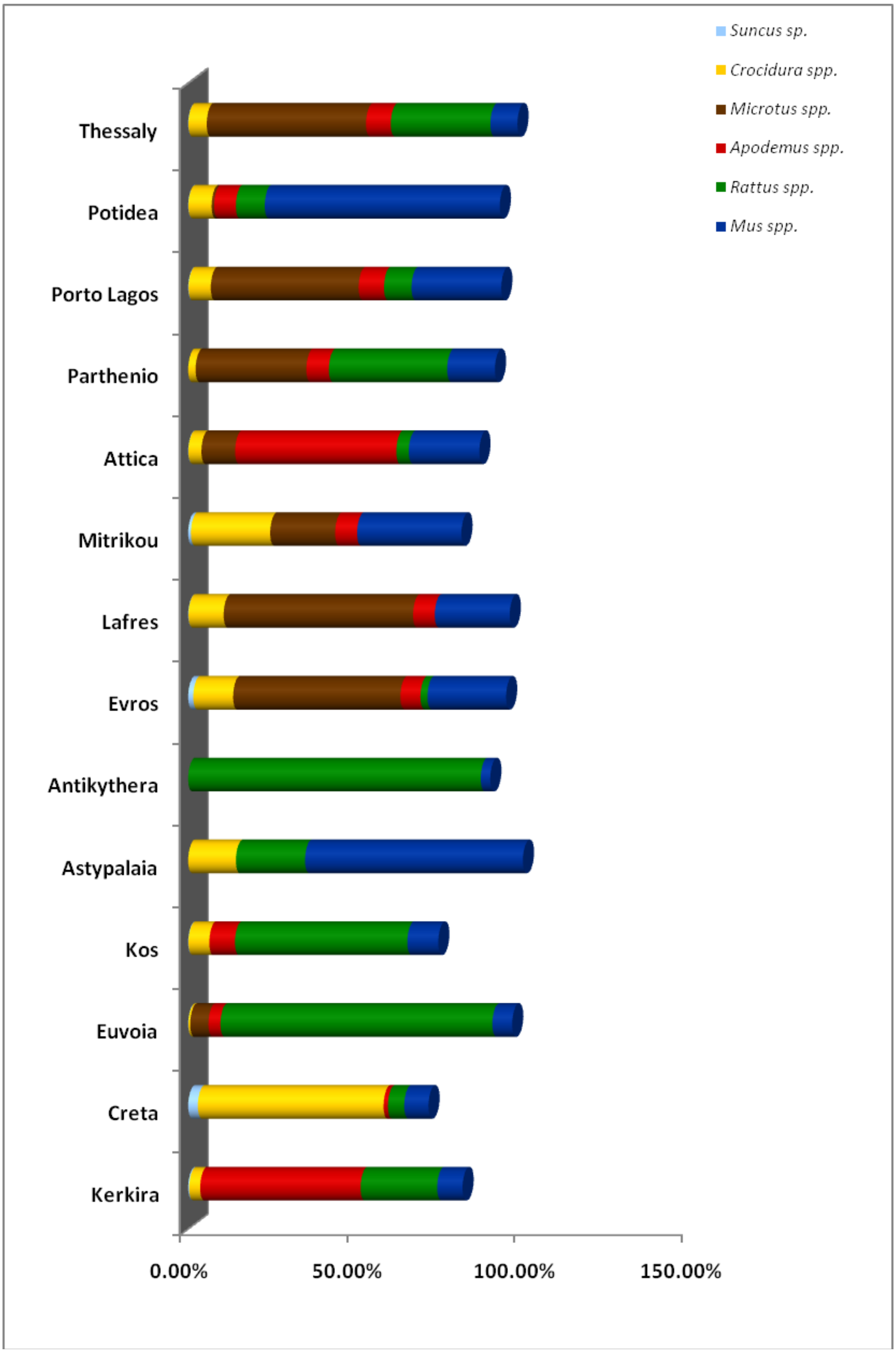


Figure 2.17 Percentages of contributed biomass (gr%) of the mainly preyed mammalian genera in all the geographical localities in Greece, where Barn owl diets have been studied up to date.

Microtus genus includes 4 species, East European vole, Guenther's vole (*Microtus guentheri*), Balkan pine vole (*Microtus felteni*) and Thomas's pine vole (*Microtus thomasi*), *Apodemus* genus is comprised of three species, Long-tailed field mouse, Yellow necked field mouse (*Apodemus flavicollis*) and Western broad-toothed mouse (*Apodemus epimelas*), *Rattus* genus includes two species, Black rat (*Rattus rattus*) and Brown rat, and finally *Mus* genus includes House mouse and Macedonian mouse (*Mus macedonicus*). Nonetheless, although in each genera group only one specie is mainly preyed as mentioned before, and some co-generic species also have different ecological niches, presenting and comparing mammalian genera as groups is meaningful for various reasons. Firstly, those species from each genera group which are mainly preyed are not captured in all regions, and comparisons among them would be more complicated in that case if treated as single species. Secondly, although some co-generic species demonstrate strict niche segregation, in terms of biomass they are almost similar, and therefore grouping them and making comparisons in genera level for energetic terms can produce meaningful conclusions. Finally, the single-species treatment is more meaningful in local-seasonal studies, whereas in broad spatial scale reviews like the one realized in this chapter, genera level comparisons are more practical, better handled, and provide a more thorough and meaningful image as well, like the one demonstrated in Figures 2.16 and 2.17.

2.4.2 Mainland Barn owl diets

The summed amount of captured prey in Evros Delta (Fig. 2.2) formed a total of 1931 identified prey items (Tab. 2.1). From these prey items, Soricomorpha, Muridae and Cricetidae orders comprised respectively 32.11%, 36.98% and 28.95% in frequency terms, with mostly preyed species the Lesser white-toothed shrew (25.32%), Macedonian mouse (22.68%) and East European vole (28.07%). Thus, in Evros Delta mammalian intake dominated heavily the owl's diet forming in total the 98.08% of captured prey. Eight different species of birds were also captured which formed though only 1.45% in frequency terms and 2.72% in contributed biomass (Tab. 2.1, Figs. 2.2 & 2.3), whereas reptiles and insects participated with extremely low percentages in both frequency and biomass terms (Tab. 2.1, Figs. 2.2 & 2.3). In the wetlands of northern Greece, in Porto Lagos the percentage of insectivorous species was the lowest (19.49%), and in Lake Mitrikou it was quite high reaching 44.92%. In all three major wetlands mammals also dominated the diet, with the exception of Lake Mitrikou where a significant part of the diet was also comprised by bird species (12.29%), whereas in Porto Lagos voles comprised almost half of the mammalian intake (46.24%). Lesser white-toothed shrew was the most preyed shrew in all three wetlands, while in all three diets, House mouse dominated from the Muridae family, and East European vole was actually the unique vole captured in the wetland complex, with high percentages as well (Tab. 2.1). In Potidaia, Lesser white-toothed shrew was like in all studied sites the most preyed insectivore, while in contradiction to the wetland Barn owl diets, the most preyed representative from Muridae family was Macedonian mouse, which also dominated heavily the diet (76.01%), and not the House mouse. Voles were almost absent from the owl's diet in Potidaia, forming actually the lowest percentage among all mainland diets (0.34%). Parthenio on the other hand, was the only site among mainland Barn owl diets where insectivore species where very low represented, forming just 10.15%, whereas the diet in this location is actually formed from Long-tailed field mouse and Macedonian mouse which comprised respectively 11.66% and 32.61%, and finally East European vole which formed 32.40%. In Thessaly plain, Lesser white-toothed shrew and House mouse formed half of the preyed items it terms of frequency (50.74%), while voles weren't often captured. Attica presented more or less the same Barn owl diet trends, with the usual 3 to 4 mammal species dominating the mammalian intake, with an important difference though. The Western broad-toothed field mouse which was scarcely preyed in any other mainland or insular diet was highly preyed (16.56%) in that location. A similar rare pattern was also present in Avlona diet, where Thomas's pine vole was highly captured forming 36.84% unlike any other Barn owl diet in the country.

2.4.3 Insular Barn owl diets

The Barn owl diets which were studied in island locations were also dominated from mammals, with lower percentages though than those observed in mainland results (Tab. 4.1). An exception to that was the island of Crete, but as mentioned in previous part this is probably an overestimation. Rats and mice dominated heavily Barn owl's diet in the islands in frequency terms, and they ranged from 45.65% (Kos) to 73.23% (Corfu), excluding Crete which presented a very low percentage of Muridae family, probably due to insufficient provided data. Lesser white-toothed shrew was highly captured in all studied insular diets, along with House mouse which dominated heavily the owl's prey (Tab. 4.1). In contradiction to mainland Barn owl diets though, birds were much more preyed in island locations. A total of 30 different avian species were captured in certain occasions, whereas the total percentages of preyed birds ranged from 4% (Evoia) to 21.23% (Kos). The other prey groups, similarly to the mainland diets were minimally represented in Barn owls' diets (Tab. 4.1), both in frequency and biomass terms (Figs. 2.16 & 2.17).

2.4.4 Niche Breadth, Geographical Trends and Comparisons

Three diversity indices were calculated in order to assess the niche breadth of Barn owl trophic guild in Greece. As stated before, diversity and species richness were both calculated after the results were rarefied, to the level of the diet which included the minimum preyed items. In this case it was in Antikythera island with 106 preyed items (Tab. 2.1). Barn owl diet from Thessaly (Tab. 2.1) was pooled with the results of this thesis presented analytically in Chapter 2 from Thessaly plain, in order to provide a thorough and better comparison between other locations and central Greece, where Barn owl diet hasn't been studied before.

Diversity was quite higher in Thessaly plain while it presented its lower mean values in the Greek islands where the owl's diet was studied (Fig. 2.18), a difference that was also statistically significant according to Kruskal-Wallis non-parametric test ($H_{0,05(df=2,n=44)} = 9.168$, $p = 0.0102$). Similarly, species richness was quite higher in Thessaly Barn owl diets, as it is also demonstrated in the box plots of Figure 2.19. That difference was also statistically significant according to one-way ANOVA tests ($F_{0,05(2,41)} = 19.103$, $p = 0.000001$), nonetheless in contradiction to diversity box plots, species richness is somewhat higher in insular diets in comparison to the mainland ones, although that difference is not statistically significant according to post-hoc Tukey HSD tests. When the evenness of prey included in Barn owl diets was compared between the grouped regions, a very similar pattern to the diversity box plots was observed. Prey was more evenly distributed in Thessaly plain, mainland diets presented lower mean values, whereas insular diets demonstrated the lower evenness (Fig. 2.20). These differences were though statistically non significant (Kruskal-Wallis, $H_{0,05(df=2,n=44)} = 2.635$, $p = 0.2678$). A different pattern was observed when the mean weight of mammal prey was compared between the grouped regions.

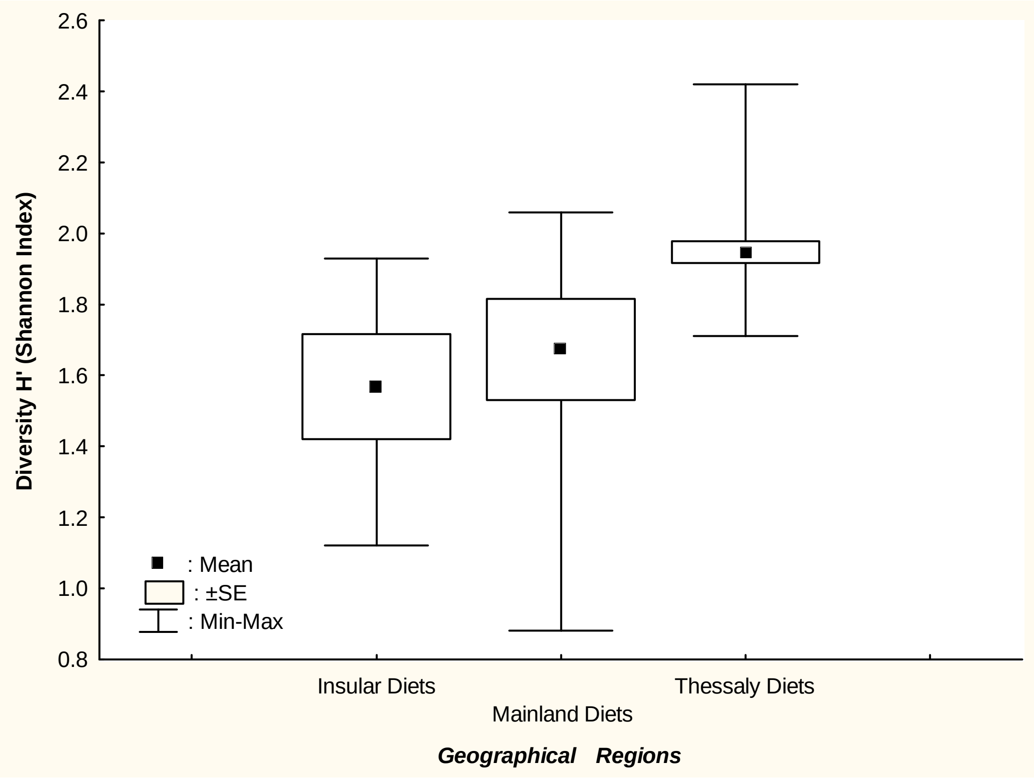


Figure 2.18 Comparison of mean values of diversity index H' (according to Shannon-Wiener), between insular, mainland and Thessaly Barn owl diets.

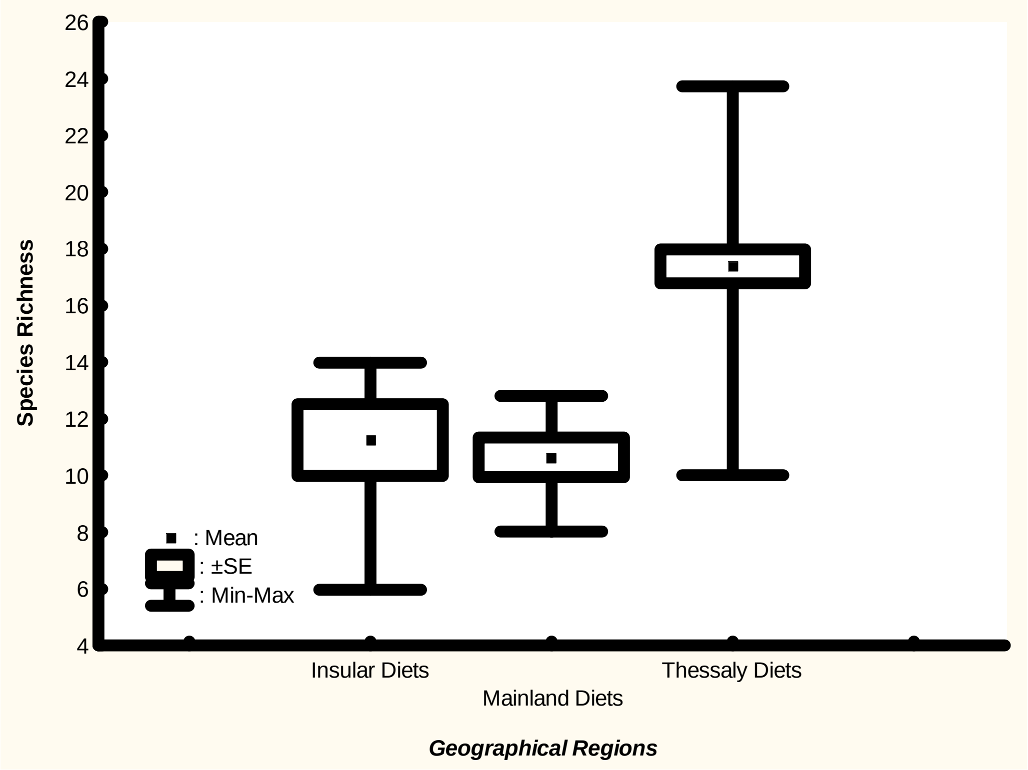


Figure 2.19 Comparison of mean values of species richness, between insular, mainland and Thessaly Barn owl diets.

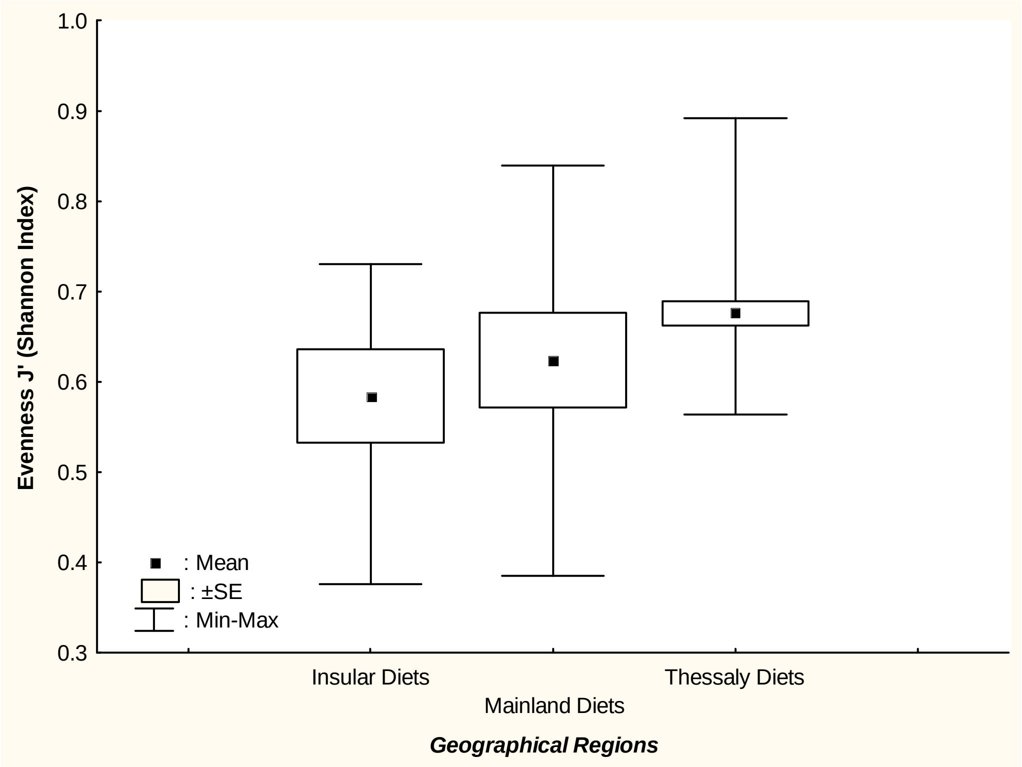


Figure 2.20 Comparison of mean values of evenness index J' (according to Shannon-Wiener), between insular, mainland and Thessaly Barn owl diets.

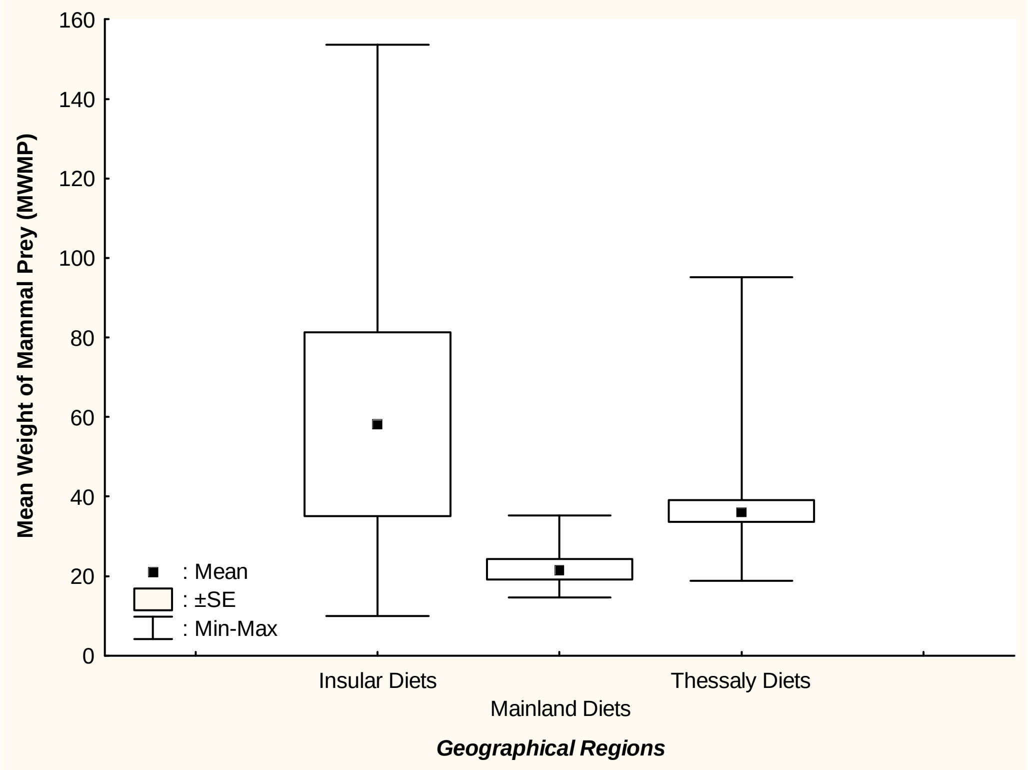


Figure 2.21 Comparison of mean values mean weight of mammal prey (MWMP), between insular, mainland and Thessaly Barn owl diets.

Insular Barn owl diets presented higher mean values in mean weight of captured mammal prey, mainland diets presented the lowest values slightly exceeding 20gr. whereas the mean weight of mammalian intake in Thessaly was between them (Fig. 2.21). These differences were also statistically significant (one-way ANOVA, $F_{0,05(2,41)} = 3.873$, $p = 0.0287$). Finally, the fraction Rodentia/Insectivora was calculated in all sites where Barn owl diet was studied. The comparison among grouped localities indicated that mainland and Thessaly diets presented very low and identical values, whereas unlike the patterns in the diversity box plots (Figs. 2.18 – 2.20), insular diets demonstrated the higher values (Fig. 2.22). These differences were also statistically significant according to one-way ANOVA tests ($F_{0,05(2,41)} = 7.459$, $p = 0.0017$).

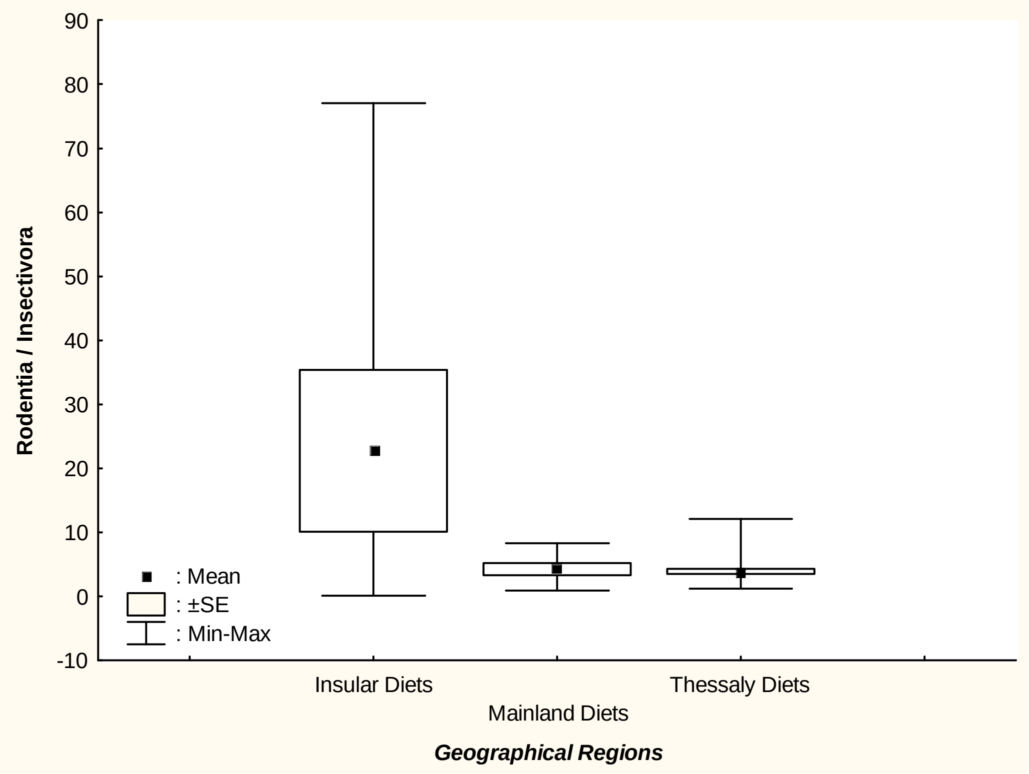


Figure 2.22 Comparison of mean values of the fraction Rodentia / Insectivora, between insular, mainland and Thessaly Barn owl diets.

2.5 DISCUSSION

The trophic guild of Barn owl in Greece has been poorly studied up to date in no more than just 13 geographical regions. It is nonetheless similar to the great majority of European (Herrera, 1974; Herrera & Hiraldo, 1976; Barbosa et al., 1992; Taylor, 1994; Shawyer, 1998) but also Nearctic and Neotropic Barn owl diets (Herrera & Jaksic, 1980; Jaksic et al., 1982; Bellocq, 2000). If observed principally from a general point of view, in respect to the prey classes which form it, it is also heavily depending in small mammal intake (Tab. 2.1). On the other hand, other groups of prey such as insects, reptiles, amphibian and invertebrate prey are actually alternative and negligible prey classes. In a minimum of two occasions in Greece, reptiles and insects formed more than 10% of the consumed prey in percentages of frequency (islands of Antikythera & Astypalaia respectively). Nonetheless, except the fact that this only occurred in two localities, when these prey groups are observed from the biomass spectrum (Fig. 2.15), it is clear that there is a minimum energetic compensation for the Barn owl when preying on these classes. Thus, small mammals in Greece form the main bulk of Barn owl's feeding habits, ranging from 73.58% (Antikythera) to 99.30% (Crete) which correspond respectively to 91.78% and 96.5% in consumed biomass (Figs. 2.14 & 2.15).

It is a fact that some of the studies included in this review chapter are outdated, dating some decades ago (Bohr, 1962; Cheylan, 1976; Pieper, 1977; Akriotis, 1981). Moreover, some other studies, although they reached the light of publication in the beginnings of 21st century are analyzing field data collected in the early 90's (Alivizatos et al., 2005), or in the 80's (Goutner & Alivizatos, 2003). During these years it is quite probable that trophic guilds have almost certainly changed, or available prey assemblages and habitats have been altered. Nonetheless, presentation and analysis of outdated studies, and even pooling of data in geographical regions where Barn owl diets have been studied in adjacent localities, even from different year publications (Crete: Cheylan, 1976; Pieper, 1977; Attica: Cheylan, 1976; Tsounis & Dimitropoulos; 1992; Evros: Gounter & Alivizatos, 2003; Alivizatos et al., 2005; Corfu: Bohr, 1962; Niethammer, 1962a), is a very common method used by many other authors, in some of the most referenced papers concerning Barn owl and other nocturnal raptor's diet reviews (Herrera, 1974a; Herrera & Hiraldo, 1976; Herrera & Jaksic, 1980; Jaksic & Marti, 1981, 1984; Jaksic et al., 1982; Donazar et al., 1989; Barbosa et al., 1992; Korpimaki, 1992; Bellocq, 2000). As a result, using different years' data, and pooling Barn owl diets from adjacent localities in one region which originated from different years, are necessary steps in a review synthesis. Moreover, detailed and accurate methodological approaches with seasonal samples during a concrete study period, are mainly demanded in local level field research. On the other hand, broad spatial scale analyses like the present one, function equally good, even when including the mentioned seasonal, time and geographical bias. The review and synthesis presented hereafter in this chapter, has been partially presented in the World Owl congress in Groningen (Bontzorlos et al., 2007a), and will also be soon published (Bontzorlos et al., 2009a).

In respect to the different habitat types between the studied regions, unfortunately most of the authors from older publications didn't present a clear status of the habitats surrounding the studied areas, or on the other hand they conducted field research with multiple samples from various localities without presenting a clear habitat type status from each one. For example, in the island of Crete, Barn owl diet was studied in 16 different localities scattered in all four prefectures which comprise the island (Fig. 2.13), occupying a great variety of habitats which weren't clearly indicated from the authors (Cheylan, 1976; Pieper, 1976). Similarly, in the island of Corfu, Barn owl diet was studied in a total of 9 different localities extending all over the island's surface (Fig. 2.8), without any specific indication of different habitats in each one of them (Bohr, 1962; Niethammer, 1962a). Finally, an important number of recent Barn owl diet studies were realized in northern Greece in some of the most important wetlands of the country. They were published by the same group of authors (Alivizatos & Goutner, 1999; Goutner & Alivizatos, 2003; Alivizatos et al., 2005; Alivizatos et al., 2006). Nonetheless, although these works were methodologically among the most complete, they included multiple samples, as well as a very rich habitat mosaic which was not quantified around each sampled area in detail (Figs. 2.2 & 2.3). Therefore, an unclear status of habitat types is present in Barn owl diets in Greece in various occasions, lacking a detailed description between each studied area. That fact goes along with a limited number of published studies and small prey samples in certain localities. As a result, a general habitat segregation couldn't be applied with certainty, and thus nor the application of correspondence analysis as followed by Donazar et al. (1989) was applicable for Greek Barn owl diets. Consequently, detailed information concerning habitat and prey use among sites couldn't be revealed. Nevertheless, from the existing data useful information can be deduced even under the circumstances.

For instance, in most of the studied islands the main habitat type is usually comprised of low mountains, rock debris, phrygana and maquis vegetation, and to a much lesser extent cultivated areas and other land uses. In respect to mainland diets, the region of Thessaly is the only studied area which is strictly agricultural as also explained in Chapter 3 in detail. In northern mainland areas, Barn owl diet studies were all conducted in major wetlands of Greece (Figs. 2.2 & 2.3), mainly comprised by a rich mosaic of extensive salt marshes, sand dunes and sandy islands, mudflats, lagoons, reed beds, tamarisk, riverine and riparian forests, permanent and temporary freshwater marshes and to a much lesser extent agricultural cultivations. Finally, the remaining mainland diets were conducted in Parthenio, Potidaia, Avlona & Attica (Figs. 2.4, 2.5 & 2.7) which are mainly agricultural areas, but also include some maquis vegetation, and some forest fragments adjacent to the studied areas along with vineyards.

It can be deduced that Barn owl diets which were realized in the wetlands of Greece in the north, are among those which depend heavily on mammalian intake (Tab. 2.1), ranging from 94.14% (Porto Lagos) to 98.08% (Evros Delta). The only exception to that rule is lake Mitrikou where mammalian prey formed 86.86% in frequency and 81.63% in biomass terms (Figs. 2.14 & 2.15). More specific, in the other three wetland diets (Evros Delta, Porto Lagos & Lafres), three species were actually mainly preyed, the House mouse, Lesser white-toothed shrew and East European vole (Tab. 2.1). As a matter of fact, from the total mammalian intake in these three wetlands, percentages of frequency are equally shared between Mus, Crocidura and Microtus species (Fig. 2.16), while in energetic terms voles and mice offered equally most of the consumed biomass (Fig. 2.17). In Lake Mitrikou on the other hand, voles participated with a minimum percentage not exceeding 10% (Tab. 2.1), Lesser white-toothed shrew, Bicolored shrew and House mouse were highly captured, to a smaller extent participated in the diet Long-tailed field mouse and East European vole, whereas birds formed a total of 12.29% in frequency and 18.37% in biomass terms (Figs. 2.14 & 2.15).

In a great number of diet studies it has been demonstrated that voles are the optimum specie for Barn owl (Herrera, 1974; Herrera & Hiraldo, 1976; Barbosa et al., 1992; Taylor, 1994; Torre et al., 1997; Shawyer, 1998; Torre, 2001). According to the optimum foraging theory as well, when there is high mammalian diversity in the foraging habitat and voles are present in the prey assemblage, a concentration of predation will be observed in this group, while preying on other energetically less profitable species will be avoided (Krebs & Davies, 1993; Taylor, 1994). There are of course three supplementary factors which create a strong problem in the quantification of this acceptance. These are the interregional differences in the size distribution of small mammal species and the configuration of the community of coexisting owl species which form the guild in each studied area. Along with the mammalian diversity in each area, these three factors operate simultaneously and generate interregional dietary differences. At the moment, quantification of the owl guild and the way that it interacts as a total in the studied areas of Greece cannot be achieved. On the other hand, mammal prey groups and species are the same among regions, and habitat complexity structure can be simply assessed, although not in detail.

Thus, from the first results discussed above concerning Barn owl diets in wetlands of northern Greece, it can be argued that the poor representation of voles in the prey assemblage of Lake Mitrikou, was reflected in the owl’s diet which was comprised equally from more mammal species in comparison to the other three sites, and also to the high percentage of avian intake (Tab. 2.1). Moreover, as a result, prey diversity according to Shannon-Wiener after the rarefaction was higher in Lake Mitrikou diet (1.9), whereas lower in all the other wetland diets (Evros Delta: 1.76, Lafres: 1.62, Porto Lagos: 1.74). In respect to the remaining mainland diets, in all four regions of Avlona, Parthenio, Attica, and Potidaia insectivorous species were represented in Barn owl prey with lower numbers than in wetland diets, ranging from 9.5% (Parthenio) to 14.53% (Potidaia). Exception was Thessaly with 25.27% of insectivore species, but still being lower than wetland Barn owl diets (Tab. 2.1). As far as other mammalian species are concerned, 3 to 4 species shared the main bulk in frequency and biomass terms, with differences from site to site. These differences in the diversity of small mammal community are attributed as proved by many authors, primarily to the complexity of habitat structure in each region, which is also affected by biotic and abiotic factors (Pianka, 1982; Barbosa et al., 1992; Krebs & Davies, 1993; Taylor, 1994; Blondel & Aronson, 1999). As a result, these differences will be reflected to the Barn owl's diet which is an opportunistic predator (Taylor, 1994; Shawyer, 1998), and according to this general acceptance, differences were also eminent in the remaining mainland diets. Voles were highly preyed only in Parthenio (32.40%) and Avlona (36.84%), with different species though (East European vole & Thomas's pine vole respectively), whereas in other mainland regions they presented very low percentages (Tab. 2.1). Mice were quite highly captured in Attica and Thessaly and mainly represented by Apodemus and Mus species (Tab. 2.1), while in Potidaia the Barn owl's diet was dominated by Macedonian mouse which reached the 76.01%. The high intake of a single specie in Potidaia appointed the region with the lowest diet diversity among all (H'=0.88), whereas in the other regions varied according the available prey assemblage and captured prey.

As far as insular diets are concerned on the other hand, a quite different pattern is demonstrated. It can be observed, that from all the islands in which the Barn owl diet was studied in Greece, voles are completely absent. The only exception to this rule is the island of Evoia (Fig. 2.11). Nonetheless, the reason to that exception is that as it was already stated in paragraph 2.2.2.4, Evoia is adjacent to Sterea Hellas and is communicating to the mainland with a bridge which is lifted whenever boats have to traverse. Consequently, immigration from voles to the island was very easy through the bridge construction. On the other hand, there are of course various types of immigration that could have been realized in the other islands as well (Macarthur & Willson, 1967). Nevertheless, apparently except Evoia, the other insular ecosystem's fauna has never included voles, or they were present but finally extinct at a certain time from predation. No previous recordings or studies though exist to shed light to these processes which formed the mammalian fauna in the studied Greek islands. Being voles absent from the insular mammalian fauna, has produced a broader Barn owl diet in the studied islands. 30 avian species were captured in total from Barn owls in insular ecosystems in Greece (Tab. 2.1), whereas in the mainland no more than 13 species participate in the owl's captured prey. Mammalian intake in island Barn owl diets was also among the lowest in Greece, ranging from 73.58% (Antikythera) to 92.80% (Evoia) which in biomass terms corresponds respectively to 91.78% and 97.1% (Figs. 2.14 & 2.15). In addition, except the higher species richness in insular diets there was also great fluctuation in the percentages and types of captured prey among sites, as expected. Insectivore species ranged from 9.60% (Evoia) to 32.80% (Kos), rats were highly captured in Astypalaia forming the 87.39% in biomass terms, House mouse formed 60.16% of the diet in frequency and 65.10% in biomass terms in Astypalaia, Long-tailed field mouse formed the main prey in Corfu (50.66%), and Muridae species formed in general the main bulk of Barn owl's mammalian prey in Greek islands (Tab. 2.1, Figs. 2.16 & 2.17), which was quite higher than most mainland diets. Moreover, in Antikythera and Kos birds were highly captured (16.04% and 21.23% respectively), reptiles were also highly captured in Antikythera (10.38%) and insects in Astypalaia (14.06%).

In respect to the island of Crete, apart from being the largest island of Greece located in the furthest southern location of the country (Fig. 2.13), it also presents some particularities in the studied Barn owl diet. As mentioned in the beginning of the chapter, although a total of 12842 prey items have been identified from Barn owl diets in Crete, only results about 3180 of them were published by Pieper (1976) and the collective works of Niethammer & Krapp (1977, 1982, 1990). Therefore, Crete should be treated separately because the results which are presented and reviewed in this chapter according to the official published data, are certainly biased, overestimating certain species and underestimating others. Nonetheless, according to the information in hand, the Barn owl diet in Crete was dominated from insectivorous species which reached the 88.24% in frequency terms, and especially the Lesser white-toothed shrew, whereas a small amount of the endemic Cretan shrew was captured (Tab. 2.1, Figs. 2.14 – 2.17). Moreover, a total of 11 different species of bats were included in its diet, which formed though minimum percentages in frequency and energetic terms (Tab. 2.1).

The total of these different geographical trends between mainland and insular Barn owl diets, are also reflected in the niche segregation among regions and the calculated diversity indices. In the case of niche breadth calculations as stated in methodology, Thessaly results from Table. 2.1 which were published by Bontzorlos et al. (2005), were pooled with the results of the present thesis presented analytically in Chapter 3. As a result, a total of 31 different Barn owl diets from various areas in the agricultural plain of Thessaly region were included in the indices calculations, and a total of 29.061 identified prey items, in order to explore if there is actually a strong niche segregation between Thessaly, and the rest mainland and insular Barn owl diets.

As far as species richness is concerned, Barn owl diets in Thessaly presented the higher values in comparison to mainland and insular species richness, a difference which was also statistically significant. Although Barn owls in islands captured also many other species and different prey types as mentioned, except mammalian prey, and although voles were absent from insular diets, nonetheless Thessaly diets presented the higher species richness (Fig. 2.19). That could partially be due to the fact that mammalian diversity in Thessaly is actually low, which is reflected in Barn owl diet with the intake of a larger number of different captured species. On the other hand, it has to be taken into account, that Barn owl diet in Thessaly was studied in a total of three years with seasonal samplings as well (see Chapter 3 for details), and also in a large study area. On the contrary, all the other studies in mainland and insular Greece, had small samples, or those which used large samples collected them in a unique period except in a minimum of occasions (Goutner & Alivizatos, 2003; Alivizatos et al., 2006). Thus, it is quite possible that all species present in the available assemblages, weren't reflected in the owl diets due to seasonal effect and smaller samples, attributing Thessaly with the highest species richness among Barn owl diets in Greece.

Diet diversity followed the same pattern with species richness. Thessaly presented the higher diversity among Barn owl diets, mainland diets followed and insular diets demonstrated the lower values (Fig. 2.18). Those differences were also highly significant. Barn owls in insular Greece, although they preyed on various prey groups and included more species from mainland diets (except Thessaly, Fig. 2.19), in each island though they also preyed heavily on one mammal specie as explained before (Tab. 2.1), and thus diversity values were the lowest. On the other hand, the high diversity demonstrated from Thessaly Barn owl diets, fortifies the argument that mammalian diversity is probably low in Thessaly plain, and thus species richness and diversity as reflected in the owl's diet is quite high. As demonstrated in review papers by Herrera (1974), Herrera & Hiraldo (1976), Jaksic et al. (1982) and Bellocq (2000), lower mammalian diversities in available prey assemblages are reflected with broader

Barn owl diets which demonstrate higher diversity and species richness. These conclusions were made comparing continental and Mediterranean Barn owl diets in Europe, as well as diets from Mediterranean habitats in Palearctic, Nearctic and Neotropic regions. Nonetheless, they can be as well in effect even in smaller spatial scale, for example in the country of Greece. Preying on one small mammal specie heavily in the island assemblages, is also the reason why insular prey demonstrated the lower evenness values in Barn owl diets (Fig. 2.20), whereas Thessaly, along with species richness and diversity also presented the higher evenness values.

In contradiction, mean weight of mammal prey and the fraction of Rodentia/Insectivora presented different interregional patterns to the ones mentioned earlier. Since Barn owl diets in island ecosystems preyed more on rats than in other regions, as well as more on species of Muridae family which dominated the diet, and to a much lesser extent insectivore species, that fact produced higher mean values of mean weight of mammal prey in insular diets (Fig. 2.21), and extreme minimum and maximum values as well. On the other hand, Thessaly diets which energetically were comprised 50% by voles, 20% by rats and 30% of other species (see Chapter 3 for details), presented a mean value of about 36 gr. Finally, mainland diets which also included wetland diets where insectivore species are present with the higher percentages of frequency, as expected demonstrated the lower mean values of mean weight of mammal prey. All these differences were also statistically significant. Moreover, since insectivore species were much less preyed in islands, and mammal species of the Muridae family dominated insular Barn owl diets, the mean values of the fraction Rodentia/Insectivora presented its higher values in island geographical regions (Fig. 2.22), whereas Thessaly and the other mainland diets demonstrated equal but quite lower mean fraction values.

Summarizing, the following points can be deduced. Firstly, Barn owl diets in Greece like in most parts of the world, depend heavily on small mammal prey. Moreover, although Barn owl in Greece demonstrated an opportunistic predation pattern among regions, according to the existing prey assemblages and habitat structures sustaining them, it also presented a clear optimum foraging technique, when the existing assemblages supported higher mammalian diversity and especially abundant vole species. In northern Greece specifically, Barn owl is preying significantly more on insectivore species than in other regions. This fact is due to the structure of available prey assemblages which are supported by the wetland habitats in these regions, where diets have been studied. Therefore, wetland diets also demonstrated very low Rodentia/Insectivora fraction values and also presented the lower mean values of mean weight of mammal prey. The other mainland Barn owl diets (except Thessaly region), which were primarily agricultural areas, presented a variety of preyed mammal species among regions, due the interregional differences in habitat structure and of course biotic and abiotic factors affecting the prey assemblages. Nonetheless, the mainly preyed mammal groups were primarily mice, rats and voles, with very few species from each group being mainly captured. Thessaly was an exception to the other mainland diets. It was the most intensive agricultural region in Greece where Barn owl diets were studied (see Chapter 3 for details) up to date. Voles formed half of its diet in biomass term, but nonetheless, it presented the higher diversity and species richness values among all diets. That is probably due to the fact that a low mammalian diversity is present in Thessaly region, in combination to the fact that 31 Barn owl diets were included in the analysis, from various Thessaly areas, in a total of three years with seasonal samples, possibly amplifying the niche breadth. Finally, insular diets demonstrated a different pattern. An important factor in island ecosystems was the total absence of voles from their mammal faunas, creating thus the absence of optimum prey. Owls in islands preyed less on insectivore mammals than other mainland regions, and heavily on mice and rats. Thus, they presented the higher Rodentia/Insectivora mean fraction values. Their mammalian intake was also among the lowest in Greece, including many other non mammalian prey groups, like birds, reptiles and insects. Nonetheless, they preyed heavily on rats in certain occasions, presenting therefore the higher mean values of mean weight of mammal prey among all studied regions. In addition, although they included various mammal species and non mammal prey in their diets as mentioned, Barn owls in Greek islands preyed in each separate region focusing mainly on one mammal specie, always according to the abundance of the available assemblages. Thus, they also presented the lower evenness, diversity and species richness values among all regions.

2.5 RESUMEN

2.5.1 Introducción

En Grecia un total de 9 especies de rapaces nocturnas forman parte de su avifauna, y ningún tipo de estudio se realizo sobre ningún de sus aspectos ecológicos en cuatro de ellas: el Búho campestre (*Asio flammeus*), el Mochuelo alpino (*Glaucidium passerinum*), el Mochuelo boreal (*Aegolius funereus*) y el Cárabo común (*Strix aluco*). Por otra parte, para las restantes 5 especies se ha estudiado solamente sus hábitos alimentarios en varias regiones. Así, para el Autillo europeo (*Otus scops*) se han identificado 52 presas capturadas, para el Búho real (*Bubo bubo*) un total de 783, otras 1382 han sido identificados para el Búho chico (*Asio otus*) y hasta 7737 para el Mochuelo europeo (*Athene noctua*). La especie más estudiada que todas, como también ocurre a nivel global, ha sido la Lechuza común (*Tyto alba*). Un total de 13 publicaciones realizadas en otras tantas 13 diferentes regiones de Grecia trataron de analizar su dieta a través de 13483 presas identificadas, a lo largo de los últimos 40 años. En nuestro caso, esta es la primera vez que se ha intentado una síntesis de los estudios realizados en Grecia para la dieta de la Lechuza común. Los objetivos principales de este capitulo son los siguientes: 1) Colectar todos los trabajos publicados para la dieta de la Lechuza común hasta hoy en día, introducir los datos de nuevo en softwares ecológicos y estadísticos, explorar los nichos ecológicos y realizar comparaciones. 2) Explorar las diferentes tendencias geográficas, y buscar posibles efectos longitudinales y latitudinales, y comparar dietas insulares y continentales. 3) Definir los patrones de la riqueza de las especies y la diversidad entre dietas diferentes, explorar diferentes usos de presa, y combinarlos con el uso de hábitat, cuando sea posible. 4) Comparar los resultados de este capitulo con aquellos de la presente tesis presentados analíticamente en el Capitulo 3.

2.5.2 Materiales y métodos

Las regiones donde la dieta de la Lechuza común ha sido estudiada en Grecia son 13 en total. Algunas de ellas incluyen más que una localidad donde se realizaron muestras, como se demuestra en los mapas analíticos. La dieta se estudio en 7 lugares del continente, y en 6 islas diferentes. Las egagrópilas y las presas identificadas que fueron muestreadas en varias localidades de la misma región, han sido agrupadas y tratadas como un conjunto. Los nichos ecológicos han sido calculados a través de tres índices de diversidad. La riqueza de las especies, que es el índice más sencillo se calculo como el número de las especies presentes en la dieta de cada región estudiada. El índice de la diversidad H´ se calculo según Shannon y Wiener, con base logarítmica e. Sin embargo, las diferentes muestras se diferencian en tamaño, y por lo tanto, ambos índices de la riqueza de las especies y de la diversidad se calcularon con la aplicación de la rarefacción, al nivel de la muestra con el tamaño menor. El índice de equitabilidad J´ se calculo también con respecto al índice de Shannon y Wiener, pero sin la aplicación de la rarefacción. por no tener ningún software disponible para realizar el algoritmo. También se han calculado comparaciones en el uso de presas entre regiones diferentes, entre la fracción Insectivora/Rodentia. La biomasa consumida en cada región también se calcula como porcentaje, multiplicando el numero de individuos de cada especie en la dieta por su biomasa respectiva, y luego el conjunto se dividió con la biomasa total consumida en cada dieta. El Peso Medio de Presas Micromamíferos (MPMP) se calculo multiplicando cada individuo por su peso medio, añadiendo los productos, y dividiendo el total con el número de presas de micromamíferos en la dieta. Las comparaciones entre regiones geográficas para los índices de diversidad y equitabilidád se realizaron con pruebas no paramétricas de Kruskal Wallis, y para la riqueza de especies y MPMP con ANOVAs.

2.5.3 Resultados y discusión

Las dietas estudiadas en las 13 regiones de Grecia dependen fuertemente de la captura de micromamíferos. La Lechuza común ha demostrado un patrón de depredación muy oportuno, siempre según los ensamblajes existentes y las estructuras de hábitat que les sostienen. Por otra parte, al mismo tiempo ha demostrado una técnica óptima para forrajear y capturar sus presas cuando la diversidad de micromamíferos es alta, y especialmente cuando son abundantes en campo, las distintas especies de topillos.

En el norte de Grecia, la Lechuza común se nutre principalmente de especies insectívoras asociadas con los hábitats acuáticos, y por lo tanto los valores de la fracción Rodentia/Insectivora han sido bajos, y también estas dietas presentaron bajos valores de MPMP. En las demás regiones de Grecia continental, excepto Tesalia, donde más que 50% del hábitat es área agrícola, la dieta esta constituida por una variedad de especies de micromamíferos de acuerdo a los ensamblajes existentes en cada región. Sin embargo, hay un patrón general y los grupos mas capturados han sido ratones, ratas y topillos. Tesalia ha sido una excepción a las demás dietas del continente porque ha sido el ecosistema agrícola mas grande y más intensivamente explotado. Los topillos en Tesalia constituyeron la mitad de las presas capturadas en términos de frecuencia relativa y biomasa consumida, pero en contraste también presento los valores más altos en los índices de diversidad entre todas las regiones estudiadas. Este hecho ocurrió posiblemente a pesar de la baja diversidad en los existentes ensamblajes de micromamíferos en campo.

Las dietas insulares presentan un patrón diferente. Un factor importante que afectó al patrón es el hecho de que la fauna de las islas estudiadas no incluye ninguna especie de topillo. La Lechuza común en las islas griegas cazo menos especies insectívoras que en Grecia continental, y capturo más ratones y ratas. Consiguientemente la fracción Rodentia/Insectivora presenta valores altos. El total de los micromamíferos capturados también forma los porcentajes más bajos entre todas las regiones estudiadas, y la Lechuza insular también captura otros grupos de presas, como aves, reptiles e insectos. Sin embargo, las ratas fueron cazadas fuertemente en las islas, hecho que produjo los valores más altos de MPMP. Adicionalmente, aunque las dietas insulares incluyeron otros grupos de presas también y menos porcentajes de micromamíferos que en otras regiones, la Lechuza captura en cada isla una especie diferente de micromamíferos y que domina en su dieta. Por lo tanto, al final las dietas insulares presentaron los valores más bajos en índices de diversidad, equitabilidad, y de riqueza de especies, entre todas las regiones estudiadas.

CHAPTER 3

The Feeding Ecology of Barn owl (*Tyto alba, Scopoli 1769*) in Thessaly, central Greece.

Geographical Tendencies and Seasonal Comparisons

3.1 INTRODUCTION

Ecologists and researchers across the world admit that food supply can affect the size of raptor populations and cause population explosions or even breakdowns (Newton, 1979; Taylor, 1994; Shawyer, 1998). In order to take measures to conserve a raptor population, information concerning predator - prey relationships should be studied in first place and then necessarily be supplemented by studies concerning nesting ecology, breeding ecology, habitat structure and the extent to which human activity affects these factors (Bakaloudis, 2000).

Barn owl diet has been studied in more detail and more extensively than that of any other bird or prey, due to the species' wide distribution and the ease with which pellets containing the regurgitated, indigestible remains of prey items can be found almost intact, and then be analyzed (Taylor, 1994; Shawyer, 1998).

The food habit studies of Barn owl that have been previously carried out in numerous occasions and in many parts of the world, comprise a list that is too big to be cited here complete, but some characteristic and important works should be mentioned: Northern Europe (Lange, 1948; Zelenka & Pricam, 1964; Glue, 1974; Brown, 1981; Smal, 1987; Korpimaki, 1998; Roulin, 2004), Central Europe (Straeten & Asselberg, 1973; De Bruijn, 1979; Bethge & Hayo, 1979; Baudvin, 1983; De Bruijn, 1994), Eastern Europe (Ruprecht, 1964; Ruprecht, 1979; Pikula et al., 1984; Vohralik & Lazárova, 2002), Mediterranean Europe (Herrera, 1974; Lovari et al., 1976; Brunet-Lecompte & Delibes, 1984; Catalisano & Massa, 1987; Alegre et al., 1989; Luiselli & Capizzi, 1996; Torre, 2001; Alivizatos et al., 2005; Bontzorlos et al., 2005), Australia (Morton & Martin, 1979; Dickman et al., 1991), North America (Marti, 1973; Marti, 1974; Marks & Marti, 1984; Colvin & McLean, 1986; Marti, 1988), South America (Jaksic, 1979; Herrera & Jaksic, 1980; Travaini et al., 1997; Bellocq, 1998; Bonvicino

& Bezerra, 2003; Carmona & Rivadeneira, 2006), Africa (Vernon, 1972; Perrins, 1982; Avery et al., 2005), Middle East (Yom Tov & Wool, 1997; Rifai et al., 1998; Obuch, 2001; Shehab, 2005; Shehab & Al Charabi, 2006).

In the 20 year period 1960-1980, the majority of publications concerning Barn owl feeding habits were concentrated in northern America, central and northern Europe. After the 80s' Spain and Italy have also contributed highly to the knowledge of the specie's trophic ecology in Mediterranean ecosystems, and each one of these countries participates nowadays in the global bibliography with more than 100 published papers (Zoological Records Database, National Museum of Natural Sciences of Madrid).

On the other hand, although Barn owl is nesting and reproducing in many parts of continental and insular Greece (Handrinos & Akriotis, 1997), limited research has been realized for the specie's ecology in the country. Up to day, only exist 13 published studies, and all of them focus on the Barn owl's feeding habits in various parts of Greece (see Chapter 2 for details).

The majority of published papers in Greece are dating before the 80s', whereas some of the recent ones have based their analyses on small samples or on specimens (pellets, prey remains) which were opportunistically collected without a proper sampling method. Additionally, Thessaly is the largest agricultural area of Greece and probably holds the highest Barn owl population in the country. Nonetheless, no study has been realized in the area except a publication of preliminary results for the present thesis (Bontzorlos et al., 2005).

Therefore, the aims of this chapter are:

1) Present detailed data and record the existence of Barn owl population in central Greece.

2) Study the trophic ecology of the specie, define niche dimensions and explore any existing patterns within the niche breadth (seasonal – spatial differences).

3) Investigate prey – predator – habitat possible relationships.

3.2 METHODS AND MATERIAL

3.2.1 Field methodology

In order to realize any kind of study concerning raptor ecology, it is essential to locate nesting and roosting sites. Certain nocturnal species reply to the broadcast of their conspecific calls, and this behavioral response helps locating their territories, nesting and roosting sites. Such species are the Long-eared owl (*Asio otus*) (Martínez et al., 2002), Eurasian scops owl (*Otus scops*) (Galeotti et al., 1997), Eagle owl (*Bubo bubo*) (Martínez & Zuberogoitia, 2002), Tawny owl (*Strix aluco*) (Redpath, 1994) and some other species which aren't present in Greece.

Barn owls though, unlike other nocturnal raptors have some special attributes that makes location of their nests more difficult. Firstly they do not have any specific pattern in responding to broadcasts of conspecific calls (Taylor, 1994). Additionally, the rest owl species are in their majority tree nesters. Therefore it is easier to locate their nests by observation, or by locating prey remains and pellets below trees, whereas Barn owl is a cavity and roof nester preferring the inside of human constructions (Shawyer, 1998). Combining these characteristics with the nocturnal activity of the specie, no easy or alternative method for finding nesting pairs is discovered until now. The only way to locate Barn owl nesting and roosting sites is the exhaustive search of all possible breeding places (Taylor, 1994; Shawyer, 1998).

Such was the case in Thessaly as well. From December 2002 to March 2003, daily exhaustive searches were realized in all four prefectures in Thessaly. All possible breeding and roosting sites were checked except the inaccessible ones (due to private property) and some of them were checked repeatedly. Until April 2003, 300 villages were visited and checked thoroughly. A total of 42 breeding pairs were located, and another eleven nesting sites were occupied by one adult (7 females and 4 males). From the 42 breeding sites, seven were not included in the study due to their proximity in other breeding pairs (less than 3 km), 2 breeding pairs abandoned the site in the first year and three pairs were found dead. From 11 sites occupied only by one adult, four abandoned the site, 3 were found dead, 3 didn't mate until the end of the present study and one mated the second year.

As a result, 31 breeding sites were included in the present study. Coordinates of each site were recorded in the Greek Geodetical Reference System (GGRS87) with the use of GPS, and they were transformed in the World Geodetical Reference System (WGS84, UTM zone34: range 18E – 24E) with the software Franson Coordinates Transformation, version 2.2. Table 3.1 presents analytically names of the sites, codenames, altitude and coordinates in both Geodetical Reference Systems, and the geographical distribution of breeding (and at the same time sampling) sites in Thessaly, is demonstrated in Figure 3.1.

During the month of April in 2003, all 31 breeding and roosting sites were carefully and thoroughly cleaned from old prey remains and pellets. April coincides with the beginning of courtship and breeding season. That way, any pellets regurgitated from that day and on would reflect the diet habits of a well defined period depending on the dates of next samplings.

From April 2003 to March 2005, 4 samplings were realized in all 31 breeding sites. The first took place in September 2003, the second in March 2004, the third in September 2004 and the 4rth and last one in March 2005. That way, the collected

Table 3.1 Breeding (sampling) sites in Thessaly, codenames, altitude and coordinates in both Geodetical Reference Systems: Greek Geodetical Reference System (GGRS87) and World Geodetical Reference System (WGS84).

Site	**Codename**	**Greek Geodetical Reference System GGRS87**		**World Geodetical System WGS84**		**Altitude (m)**
		Easting	*Northing*	*Easting & Northing*	*Longitude & Latitude*	
Agios Vissarios	AGVIS	0338342	4351362	597177.29 4350582.23	22° 07’ 37’’ 39° 17’ 57’’	108
Agios Georgios L.	AGGEL	0338342	4368313	615296.16 4368142.17	22° 20’24’’ 39° 27’ 18’’	186
Ampelonas K.	AMPEK	0342063	4364500	600459.35 4363833.88	22° 10’ 01’’ 39° 25’ 05’’	97
Amigdalaia	AMIGD	0352008	4390157	609542.32 4389803.96	22° 16’ 36’’ 39° 39’ 03’’	92
Ano Bounaina	ANBUN	0350715	4371720	608865.01 4371336.52	22° 15’ 57’’ 39° 29’ 05’’	203
Armenio	ARMEN	0387910	4371408	646049.18 4372263.01	22° 41’ 53’’ 39° 29’ 15’’	57
Asprogeia	ASPRO	0381123	4350829	639949.24 4351468.15	22° 37’ 23’’ 39° 18’ 04’’	306
Astritsa	ASTRI	0340295	4367690	598586.61 4366962.72	22° 08’ 44’’ 39° 26’ 47’’	99
Aura	AURA	0355660	4360938	614165.23 4360726.19	22° 19’ 32’’ 39° 23’ 18’’	137
Girtoni	GIRTO	0365821	4401360	622971.77 4401461.69	22° 26’ 07’’ 39° 45’ 15’’	86
Dasoxori K.	DASOK	0330589	4348295	589532.02 4347260.67	22° 02’ 16’’ 39° 16’ 12’’	138
Deleria	DELER	0358040	4406555	615021.64 4406392.8	22° 20’ 36’’ 39° 47’ 59’’	80
Doxaras	DOXAR	0351369	4368541	609624.35 4368181.46	22° 16’ 27’’ 39° 27’ 22’’	165
Eleftherio	ELEFT	0378213	4392248	635661.64 4392769.36	22° 34’ 54’’ 39° 40’ 26’’	65
Zoodoxos Pigi	ZOODP	0362228	4358468	620811.12 4358475.9	22° 24’ 08’’ 39° 22’ 02’’	207
Kalamaki	KALAM	0392271	4380553	650103.49 4381549.32	22° 44’ 51’’ 39° 34’ 13’’	82
Kileler	KILER	0383258	4373543	641328.25 4374242.08	22° 38’ 37’’ 39° 30’ 22’’	76
Krannonas	KRANN	0355489	4375363	613514.48 4375136.04	22° 19’ 14’’ 39° 31’ 06’’	116
Kiparissos	KIPAR	0358482	4366725	616793.06 4366603.26	22° 21’ 25’’ 39° 26’ 27’’	249

Table 3.1 (continued)

Site	Codename	Greek Geodetical Reference System GGRS87		World Geodetical System WGS84		Altitude (m)
		Easting	*Northing*	*Easting & Northing*	*Longitude & Latitude*	
Loutro	LOUTR	0346104	4378428	604033.82 4377886.21	22° 12’ 38’’ 39° 32’ 39’’	135
Magoula El.	MAGEL	0335691	4408491	592623.94 4407578.42	22° 04’ 55’’ 39° 48’ 47’’	182
Melissa	MELIS	0323850	4355347	582564.83 4354083.38	22° 57’ 28’’ 39° 19’ 56’’	120
Mirina	MYRIN	0324720	4363149	583175.05 4361907.61	21° 57’ 57’’ 39° 24’ 09’’	104
Niamata	NIAMA	0381902	4386416	639543.6 4387063.56	22° 37’ 32’’ 39° 37’ 19’’	58
Nees Karyes	NEKAR	0367974	4374420	626023.16 4374609.51	22° 27’ 57’’ 39° 30’ 42’’	158
Orfana	ORFAN	0346176	4362647	604630.94 4362118.92	22° 12’ 54’’ 39° 24’ 08’’	109
Palaio Grammatiko	PAGRA	0343600	4345443	602627.51 4344841.86	22° 11’ 21’’ 39° 14’ 48’’	117
Pedino	PEDIN	0323836	4376010	581863.98 4374728.2	21° 57’ 08’’ 39° 31’ 05’’	140
Stavros	STAVR	0347577	4353396	606338.08 4352920.99	22° 14’ 00’’ 39° 19’ 08’’	110
Stefanovikeio	STEFN	0391833	4368990	650050.96 4369976.67	22° 44’ 39’’ 39° 27’ 58’’	55
Xaidemeni	XAIDE	0308067	4387072	565740.55 4385254.39	21° 45’ 57’’ 39° 36’ 52’’	160

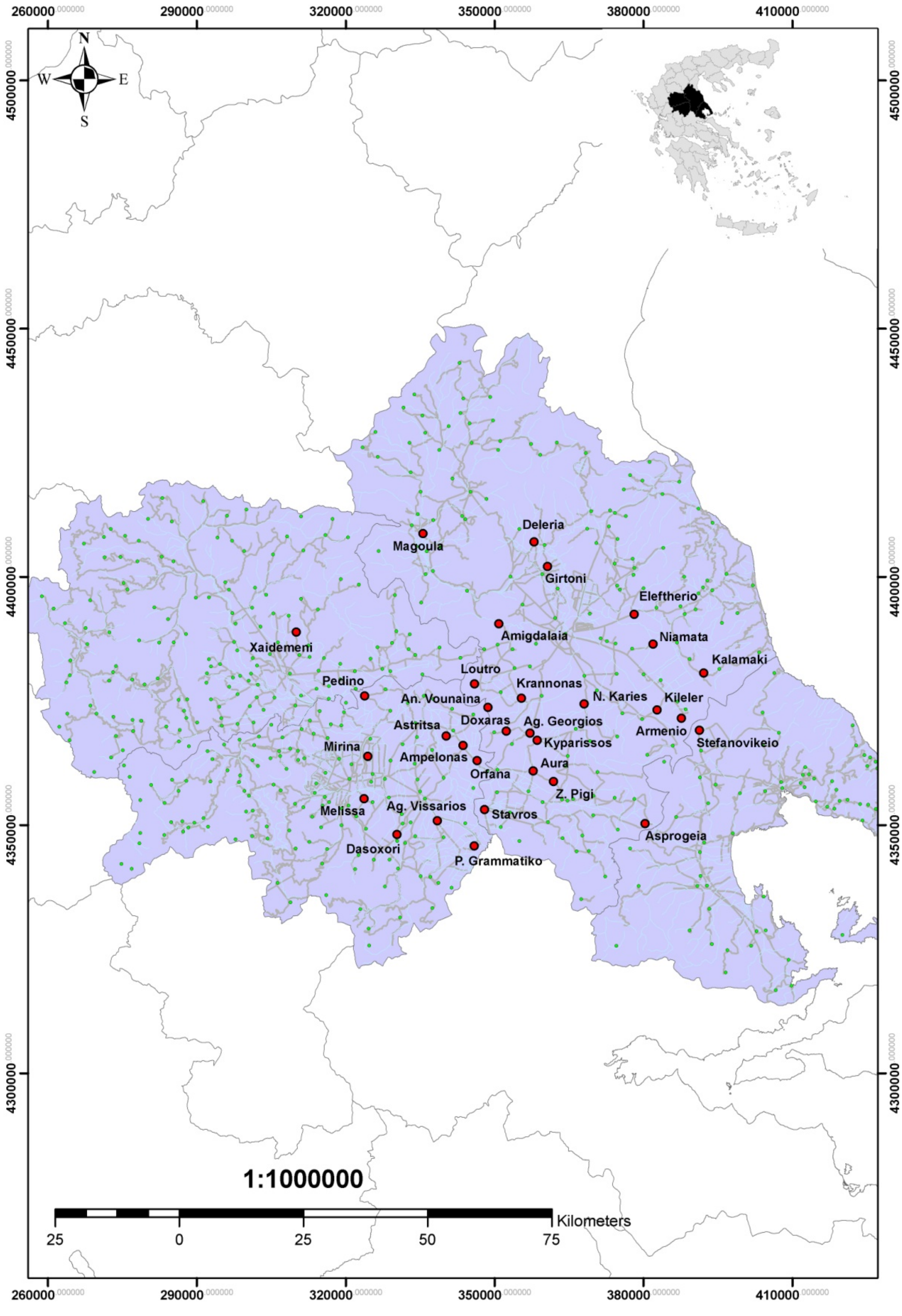


Figure 3.1 Map of Thessaly region. Villages are indicated with green dots and sampling sites with red. Reference map of Thessaly region in respect to Greece is located in upper right corner.

pellets reflect 2 breeding periods “April – September” and 2 non breeding periods “October – March”. Although in some studies the diet periods are divided in 3 month seasons (Webster, 1973; Dawe et al., 1978; Campbell et al., 1987) or even less, such was not a possibility in Thessaly. In 22 of 31 breeding sites, Barn owl pairs nested in roofs of abandoned houses, and samples of pellets collected from the ground didn’t form adequate samples to divide the study in 3 month seasons. In order to get larger samples for smaller periods, entering the roofs from existing enter points would be necessary, but that would cause great disturbance to the nesting pairs, especially during breeding and incubation period. Therefore such a decision wasn’t taken, and the “breeding - non breeding” period was applied to the data.

After the realization of each sampling, pellets were placed separately in small plastic bags, in order not to lose prey remains during transportation or until the analysis would take place. Pellets from each site after each sampling were also placed in larger plastic bags along with anti moth tablets. In every plastic bag a label was placed with the codename of the breeding site, number of pellets collected, the date of the sampling and some comments.

3.2.2 Laboratory methodology

In laboratory the first step of pellet analysis, is to separate mammal hair from mammal and avian bones, and then locate insect remains. Two methods are proposed for this kind of analysis: The “water” method where pellets are soaked in water before separation and the “dry” method where the separation is realized without anterior use of water. In this study the “dry” method was used according to Marti (1987) and Yalden (2003). Bone and insect remains produced from each pellet analysis were placed in separate small cylinder boxes of hard plastic, in order to protect the fragile bone remains from breaking due to massive storage of a large number of data. In each box a label was placed with the codename of each breeding site where the sampling was realized, date of the sampling, and a serial box number, each time according to the current sampling. The serial number was placed for two reasons: Firstly to allow easy handling of the data during identification and secondly to permit easy access as a reference collection, in order to make comparisons anytime that it was necessary or to solve later on any doubts that may rise during the identification.

The tools used for pellet analysis were a strong light source, a pair of pincers and a lancet. Analysis is done with caution during the separation of mammal hair from bone and insect remains in order not to destroy them. After the analysis of each pellet, mammal hair was thrown away and all avian and mammalian bones were kept, as well as insect remains. From mammal remains, skulls, mandibles, scapula, humerus, radius and ulna, tibia and fibula, femur, pelvis girdle, sacrum and sternum were all (when present) kept. In respect to avian remains, skull, nasal bones, mandibles, radius and ulna, humerus, tibiotarsus and fibula, femur and tarsometatarsus were also kept after the separation (when present). Insects on the other hand, were present in Barn owl pellets with parts such as their head, mandibles, maxilla, wings, femur, tibia and tarsus.

Although identification of mammals was based mainly in skulls' and mandible's morphology and measurements, all the rest bone parts were kept for two reasons: First, because it is very useful in the moment of defining the number of prey items in each pellet. In case that a skull is missing, the prey item's presence in the pellet can be indicated by the existence of other bone parts. Second, because no detailed and thorough reference bone collection exists in Greece about small mammals of

Thessaly. The most complete reference bone collection about small mammals of Greece in general, is situated in the University of Bonn, Germany.

For the identification of mammals, reference books were used (Toschi & Lanza, 1959; Toschi, 1965; Chaline et al., 1974; Lawrence & Brown, 1974; Niethammer & Krapp, 1977, 1982, 1990; Krystufek & Vohralik, 2005). Additionally, reference collections which were quite incomplete though were used from the Aristotle's University, from Biology and Forestry departments. Avian remains were identified according to Chaline et al. (1974), Moreno (1985, 1986, 1987) and Collado et al. (2004), and insects were identified according to Chinery (1993), along with the use of reference collections from the department of Biology, in Aristotle's University. Mammals, birds and insects were all identified to specie level, and when that wasn't possible, they were assessed to genus level.

3.2.3 Qualitative and Quantitative Methodology

3.2.3.1 Biomass

The species' biomass contribution to the Barn owl diet was also calculated. Since no systematic trap sessions were realized in the study area nor for this study neither from other researchers in the past, no previous data exist about small mammals' weight in Thessaly. Therefore small mammal species' biomass was based to bibliographical references (Niethammer & Krapp, 1977, 1982, 1990; Macdonald & Barrett, 1993; Alcantara, 1998; Moreno & Balbontin, 1998; Krystufek & Vohralik, 2005), and avian species' weight was calculated according to Hume (2002). The biomass contribution to the owl's diet was calculated as the percentage biomass, multiplying the number of each species' individuals in each sample by the estimated body mass of each species respectively and then divided by the total sum of biomass in the sample. The average weight of mammalian prey (MWMP) in each sample and in totals was obtained by multiplying each prey item by its average weight, summing the products, and dividing the sum by the total number of mammalian prey in the sample (Marks, 1984). Insects' biomass wasn't calculated due to their minor contribution in the Barn owl diet, and therefore they were considered as non significant, as in other authors' methodology (Goutner & Alivizatos, 2003; Alivizatos et al., 2005).

The distinction between male and female mammal specimens according to the shape of the obturator foramen is quite problematic since age and sex variation interact. In Thessaly moreover, where a reference bone collection produced from snap-trap sessions doesn't exist, distinction becomes more complex. Therefore the biomass was attributed to each of the mammal species as the mean between male and female weights. Additionally, only when cranial measurements clearly suggested that a specimen is sub adult was it attributed with the respective sub adult biomass and when uncertainty existed, specimens' biomass was considered as the mean of adult and sub adult biomass. A similar technique was followed with the avian specimens as well.

3.2.3.2 Niche Indices

The dietary habits of Barn owl were assessed and analyzed as a total in a wide geographical scale (whole Thessaly region), and they were also compared as well between seasons. In the former case and in order to reach conclusions about a raptor's diet in a large spatial scale, including all sites where samplings were realized, the seasonality effect had to be eliminated (Shawyer, 1998). Therefore, in order to analyze the geographical tendencies of Barn owl diet in Thessaly, data were pooled in each site for all 4 consequent samplings, and the sums where considered as the owl's "total" diet in each breeding site.

The sampling methods were all similar, realized at the same period and all sampling sites were mainly agricultural areas. Nonetheless, before pooling the data as well as afterwards (in order to produce the "total" diet), sample sizes varied in each season, in respect to their prey item numbers. In the first sample prey items ranged from 129 to 484, in the second from 117 to 431, in the third from 121 to 484, in the fourth from 135 to 425 and in respect with the pooled sum, prey items ranged from 572 to 1431. In Appendix C are demonstrated analytically the results of Barn owl diet in Thessaly. Therefore, in order to calculate niche indices for comparisons between sampling sites and between seasons, the rarefaction method was applied according to Sanders (1968), Hurlbert (1971), Simberloff (1972) and Krebs (1999).

Although the rarefaction method assumes that individuals have a random spatial distribution in respect with others of their own or different species, rarely that assumption is real in nature. Such bias though can be eliminated in practice with the use of large samples throughout the total community analyzed. Rarefaction calculations were realized with the software packages Past (Hammer et al., 2001), Biodiversity Pro (McAleece et al., 1997) and Ecosim version 7.0 (Gotelli & Entsminger, 2001).

The following 2 indices were calculated with rarefaction method:

1) Species richness, which is the oldest and simplest concept of species diversity, and is the number of species in a community or in a sample.

2) The Shannon-Wiener diversity index which was calculated as:

$$H' = -\sum_{i=1}^{n} pi \ln pi$$

pi = proportion of species i in each sample (seasonal or total)

ln = natural logarithm (base e)

H' was calculated both for species' numbers and their biomass contribution. That way the species' contribution in the owl's diet can be examined through two dimensions. H' will also allow comparison of the index between the studied communities based on equal sample sizes (rarefied results). Although Hurlbert (1971) and Washington (1984) criticized heavily the use of Shannon-Wiener function, it has been repeatedly used in similar studies, and it can also be employed in both species' counts and biomass, an important attribute that other indices usually don't have. Shannon-Wiener function for diversity theoretically ranges from 0 to ∞, but in practical experiments for biological communities in doesn't exceed 5.0 (Washington, 1984). In numerous ecological papers, the calculation of "diversity" is synonym to the calculation of "niche breadth", "niche width" or "niche size" (Krebs, 1999).

Finally, an equitability index that could be calculated in order to allow comparisons between equal size samples (rarefaction analysis), and is also unbiased by sample size and easily interpreted as a probability, is Hurlbert's evenness index (1971). Nonetheless, it is an oversimplified equitability index (Krebs, 1999), and is rarely used in raptor diet literature. Therefore, in the present study evenness was calculated with Shannon-Wiener function J' (Krebs, 1999) both for the species' numbers and their biomass contribution (without prior rarefaction), with the software Biodiversity Pro (McAleece et al., 1997) according to the equation:

$$J' = \frac{Observed\ Shannon\ Measure\ of\ Niche\ Breadth\ H'}{Maximum\ Possible\ Shannon\ Measure}$$

Although the evenness index J' cannot be calculated after rarefying the results, so there may be bias in some sites, it is the most common index of evenness in raptor diet literature (Krebs, 1999), and allows various comparisons with other studies, and also between frequency and biomass terms.

Many different measures of evenness have been proposed through the years and literature is most confusing about which measure is best. Another general problem of evenness indices is that they all assume that you know the total number of species in the whole community (Pielou, 1969). Since this number is usually impossible to determine and observed species' numbers are less than true species' numbers in a community, evenness ratios are always overestimated (Sheldon, 1969). Some authors like Peet (1974, 1975) and Routledge (1983) even argue in a very strict and purist sense that evenness measures should not be used in ecological work unless the number of species in the whole community is known.

Indices' values calculated for the species' biomasses were the same both before and after the rarefaction analysis. In each sampling site there were also some species which were equally used in the owl diet in terms of frequency and others in terms of biomass contribution. These species were also calculated in numerical terms in order to allow some comparisons in that dimension too. These calculations were realized with the software Ecological Methodology, version 5.2 (Krebs, 2002).

3.2.4 Statistical Analysis

Data groups were tested for normal distribution with the application of two tests: Kolmogorov-Smirnov's D statistic and Shapiro-Wilk's W-test. During the late years, compared to a wide range of alternative tests, these two are the preferred tests of normality because of their good power properties (Shapiro et al., 1968; Royston, 1982). Homogeneity of variances (or else homoscedasticity) was tested with Levene's test and Brown & Forsythe test. Those tests are considered to be more robust for testing homoscedasticity (Brown & Forsythe, 1974; Glass & Hopkins, 1996), among others. If any of the mentioned tests were statistically significant, then the hypothesis of normality or homogeneous variances had to be rejected, and data transformations took place according to each case's particularities.

Since there were many samples to be analyzed in the present study (31 sampling sites, 4 samplings in each site), similarity of both independent and dependent variables could not be assessed with simple measurements of similarity (binary coefficients, Euclidean distance, Bray-Curtis Measure, Canberra Metric, Morisita's or Horn's Index). Some authors have used clustering methods when their objective was to group species with similar habitat requirements and define guilds, (Ward, 1963; Short & Burnham, 1982; Raphael & White, 1984). Nonetheless, although Cluster analysis frequently involves the assessment of species-habitat relationships, it is a less common technique in wildlife literature (Krebs, 1999). Moreover, the chosen procedure within each cluster analysis is heavily dependent on each writer's choice and preference, and the interpretation of the results is usually more generalist than actually giving concrete answers (Krebs, 1999; Farias & Jaksic, 2007).

Although the variation in biotic communities can be summarized using a wide range of statistical methods, when the objective is to study the continuity change in community composition, along various environmental gradients, ordination methods are the tools of trade (Ter Braak & Smilauer, 2002). Ordination methods became widespread in most studies of vegetation ecological communities, emphasizing species' composition and their relationship with underlying gradients (Leps & Smilauer, 2003). Nonetheless, advanced applications of ordination analyses are nowadays found outside vegetation sciences as well, for instance in zoology (Birks et al., 1996; Birks et al., 1998). Therefore, in order to study the composition and continuity change of Barn owl diet in Thessaly, along various environmental gradients, ordination analysis was applied using the software Canoco, version 4.5 for Windows (Ter Braak & Smilauer, 2002; Leps & Smilauer, 2003).

Before deciding on the appropriate kind of ordination analysis, the underlying environmental gradients whose effect on the diet composition would be tested, had to be defined. Since many independent environmental variables of different nature were recorded (see Chapter 1, pp: 43-46 & 50-52), a data reduction method had to be applied. Additionally, many independent variables were highly correlated between them. Therefore Factor analysis was applied in order to reduce the number of independent variables, detect the structure and the relationships between variables, and produce new non-correlated factors, combining the original independent variables (Lindeman et al., 1980; Hurley et al., 1997; Stevens, 2001; Costello & Osborne, 2005). Factor analysis was applied twice in two homogeneous sets of data, once in the data-set of "Agricultural Crops & Land Uses" and once in the data-set "Soil Types & Soil Texture". The reason that two separate Factor analyses were realized is that it is best to produce new factors combining independent variables of same nature (Costello & Osborne, 2005). For the same reason three predictor variables (River length, Road length and Altitude) were not included in Factor analysis, but were used in the next steps of statistical procedure as they were.

The first group of independent variables which was processed through Factor analysis (Agricultural Crops & Land Uses), included the following general categories: 1) Cereals, 2) Industrial cultivations, 3) Arable cultivated land, 4) Non arable cultivated land, 5) Non Irrigated cultivated land, 6) Irrigated cultivated land, 7) Other land uses, and 8) Total cultivated land. The categories "Cereals" and "Industrial cultivations" include all their respective subcategories as described in Chapter 1 (p: 50), "Arable cultivated land" includes the general categories of pasture, cereals, mpostanika, and industrial cultivations. “Non arable cultivated land” includes the subcategories vegetables, tree cultivations & vineyards, whereas the categories “Irrigated” and “Non – irrigated cultivated land” include respectively the total crop extensions in the study area which were and weren’t irrigated. Finally, the category “Other land uses” includes fallow land, set-aside fields, hills, natural grassland and urban areas.

The second group of predictor variables where Factor analysis was applied (Soil Types & Soil Texture), included the following categories: 1) Alfisol soil type, 2) Entisol soil type, 3) Inceptisol soil type, 4) Mollisol soil type, 5) Vertisol soil type, 6) Sandy – Clay soil texture, and 7) Argillaceous - Clay soil texture (for details see Chapter 1, pp: 43-46).

Firstly, one matrix was constructed for each group of predictor variables, demonstrating the percentages of each variable, in each sampling site and for each sampling season. That way Factor analysis could calculate the total variability taking into account the seasonal variation in each sampling site, and each season. Then the percentages were transformed with the arcsine method, and Factor analysis was applied once for each group. Afterwards, in order to decide which factor loadings will actually define each one of the new factors, a correlation matrix was constructed between the transformed independent variables and the produced factor scores. Then the Bonferroni correction was applied to each one of the produced correlations separately, and the remaining significant correlations were those factor loadings (original variables) which actually explained the new factors.

Once all predictor variables were processed through Factor analysis and new non-correlated factors (combined environmental variables) were produced, the problem of multicollinearity in the forthcoming statistical analysis was consequently avoided. Since the next step was to detect geographical tendencies in Barn owl diet, the composition and gradual change of the owl's prey items had to be studied in a large spatial scale, along various different environmental gradients. Therefore ordination techniques were the tool to be used. In order to decide which ordination technique explains best the nature of the data, the newly produced factors along with the remaining three independent variables were introduced in a new matrix, with their respective factor scores and values for each sampling site and for each season.

Since the tendencies of Barn owl diet were to be explored in this chapter, the prey items' matrix included five main small mammal prey groups (at genus level) and the classes of Aves and Insecta. Then, in order to decide which ordination technique fits best the nature of the data, both matrices were introduced in software Canoco, version 4.5 for Windows. In order to decide if linear or unimodal methods should be used, and therefore to search for the best explanatory variables within the framework of ordination analysis, a Detrended Correspondence Analysis (DCA) was firstly applied on the matrix of response variables (Barn owl prey groups – genera level). This indirect gradient analysis' results are actually measurements of beta diversity in community composition (the extent of species turnover along various communities), which is finally expressed in gradient lengths. If the value of the largest gradient length is larger than 4 then unimodal methods are appropriate for the next steps of ordination analysis, whereas if the value is less than 3 then linear methods should be used.

When linear methods should be used (which is the case of Thessaly), a direct gradient analysis is applied, named Redundancy Analysis (RDA). Redundancy Analysis is actually a constrained ordination technique, which creates from the multidimensional space of predictor variables (environmental gradients) new axes in two dimensions.

These new axes correspond to the directions of greatest data set variability of response variables that can be best explained by the environmental variables.

Before the Redundancy Analysis results are produced, Canoco realizes a forward stepwise selection on the predictor variables, using Monte Carlo permutation tests in order to generate the "null hypothesis". Null hypothesis is stating the independence of response variables on the values of explanatory variables. What Monte Carlo permutation tests actually do is to reshuffle (permute) the samples (rows) within the environmental data set matrix, while keeping the corresponding response (prey groups) data set matrix intact, and the value of the test statistics is calculated in each case exploring for the "best fit" model.

As a result, the predictor variables can be evaluated at the end of Monte Carlo permutations both for their conditional and marginal effects. Conditional effect is the effect that each explanatory (environmental) variable has on the response variables, beginning from the most important and adding each time in the model the next more important, whereas marginal effect is the effect of each predictor variable on the response variables, if it is used as the only explanatory variable.

Finally, two-sample means were tested with Student's T test, and seasonal comparisons of Barn owl prey items were realized with one-way ANOVA tests. Similarly were tested the diversity indices and species richness between seasons.

3.3 RESULTS

3.3.1 The Barn owl feeding habits in Thessaly. General overview

A total of 31 breeding sites were sampled four times during the period 2003 – 2005 (Fig. 3.1). From those samplings a total of 10.065 pellets were collected which provided after the laboratory analysis a total 29.061 prey items. For the total diet results, data from every sampling site and for each sampling season were used, all four sampling seasons were pooled together and the general sum is demonstrated in Table 3.2.

Table 3.2 presents the absolute frequency, relative frequency (%) and biomass percentages of all the species found in the analyzed pellets, which belong in three main classes: Aves, Insecta and Mammalia respectively. The main bulk of Barn owl's diet consisted from mammalian species (rel.freq. 97.97%, biomass 99.06%). Although birds participate in the diet with 13 different species they form a minor frequency percentage (1.14%) and insects are even less (0.88%). The families Passeridae and Fringillidae concentrate most of the avian species found in the pellets whereas in respect to insects, Acrididae is the best represented family. The order Insectivora contains three species with Lesser white-toothed shrew (*Crocidura suaveolens*) dominating between them (rel.freq. 21.43%), whereas from the order Rodentia in terms of frequency, Microtus spp., Mus spp., and Apodemus spp. form the higher percentages in that specific descending order (39.94%, 17.61% and 11.09% respectively). On the other hand, Rattus spp. although poorly represented in numbers (rel.freq. 2.93%) come second in energetic contribution (biomass 27.37%) with Microtus spp. being the major source of biomass (49.84%). The order Rodentia contains 12 species, and those with higher abundance are Guenther's Vole (*Microtus guentheri*) with 28.60%, House mouse (*Mus musculus*) with 12.54%, East European vole (*Microtus levis*) with 7.09%, and Long-tailed field mouse (*Apodemus sylvaticus*) with 6.96%. Finally, the order Chiroptera is the least represented in the owl's diet with a percentage of frequency 0.03%, and only three species present. The average prey items per pellet were 2.93 ± 0.47 (1.96-3.84) and the average mammalian prey items per pellet were 2.87 ± 0.46 (1.96-3.76). Mean weight of mammalian prey in

Table 3.2 Total results of Barn owl diet in Thessaly. Absolute frequency (n), relative frequency (n%) and species' biomass contribution (gr%). un = unidentified.

	Absolute frequency n	**Relative frequency n%**	**Biomass gr%**
Crocidura leucodon	708	2.44%	0.72%
Crocidura suaveolens	6229	21.43%	4.80%
Crocidura un.	37	0.13%	0.03%
Suncus etruscus	478	1.64%	0.09%
Soricidae	*7452*	*25.64%*	*5.64%*
INSECTIVORA	7452	25.64%	5.64%
Microtus guentheri	8313	28.60%	40.05%
Microtus levis	2060	7.09%	7.05%
Microtus thomasi	1233	4.24%	2.73%
Microtus un.	2	0.01%	0.01%
Cricetulus migratorius	162	0.56%	0.55%
Cricetidae	*11770*	*40.50%*	*50.39%*
Apodemus flavicollis	973	3.35%	2.63%
Apodemus epimelas	201	0.69%	0.81%
Apodemus sylvaticus	2024	6.96%	3.90%
Apodemus un.	26	0.09%	0.08%
Rattus norvegicus	500	1.72%	19.15%
Rattus rattus	223	0.77%	4.46%
Rattus un.	129	0.44%	3.76%
Mus musculus	3644	12.54%	5.97%
Mus macedonicus	1375	4.73%	1.99%
Mus un.	99	0.34%	0.15%
Muridae	*9194*	*31.63%*	*42.90%*
Muscardinus avellanarius	50	0.17%	0.11%
Myoxidae	*50*	*0.17%*	*0.11%*
RODENTIA	21014	72.30%	93.40%
Pipistrellus pipistrellus	2	0.01%	0.01%
Vespertilionidae	*2*	*0.01%*	*0.01%*
Tadarida teniotis	2	0.01%	0.01%
Molossidae	*2*	*0.01%*	*0.01%*
Rhinolophus ferrumequinum	5	0.02%	0.01%
Rhinolophidae	*5*	*0.02%*	*0.01%*
CHIROPTERA	9	0.03%	0.03%
MAMMALIA	**28475**	**97.97%**	**99.06%**
Passer domesticus	100	0.34%	0.24%
Passer montanus	25	0.09%	0.05%
Passeridae	*125*	*0.43%*	*0.29%*
Carduelis chloris	31	0.11%	0.08%
Serinus serinus	39	0.13%	0.05%
Fringilla coelebs	44	0.15%	0.09%
Fringillidae	*114*	*0.39%*	*0.22%*
Milaria calandra	16	0.06%	0.07%
Emberizidae	*16*	*0.06%*	*0.07%*

Table 3.2 (continued)

	Absolute frequency n	**Relative frequency n%**	**Biomass %**
Turdus merula	14	0.05%	0.13%
Erithacus rubecula	26	0.09%	0.05%
Turdidae	*40*	*0.14%*	*0.18%*
Parus major	10	0.03%	0.02%
Parus caeruleus	15	0.05%	0.02%
Paridae	*25*	*0.09%*	*0.03%*
Sturnus vulgaris	6	0.02%	0.05%
Sturnidae	*6*	*0.02%*	*0.05%*
Pica pica	2	0.01%	0.04%
Corvidae	*2*	*0.01%*	*0.04%*
PASSERIFORMES	328	1.13%	0.89%
Streptopelia decaocto	3	0.01%	0.05%
Columbidae	*3*	*0.01%*	*0.05%*
COLUMBIFORMES	3	0.01%	0.05%
AVES	**331**	**1.14%**	**0.94%**
Chorthippus parallelus	115	0.40%	
Locusta migratoria	60	0.21%	
Acrididae	*175*	*0.60%*	
Gryllotalpa gryllotalpa	9	0.03%	
Gryllotalpidae	*9*	*0.03%*	
Tettigonia veridissima	9	0.03%	
Tettigonidae	*9*	*0.03%*	
ORTHOPTERA	193	0.66%	
Pterostichus nigrita	21	0.07%	
Carabus nemoralis	11	0.04%	
Carabidae	*32*	*0.11%*	
Copris lunaris	20	0.07%	
Melolontha melolontha	10	0.03%	
Scarabaeidae	*30*	*0.10%*	
COLEOPTERA	62	0.21%	
INSECTA	**255**	**0.88%**	
Total Prey Items	**29061**		

Thessaly is 36.37 ± 14.93 (18.87-95.08), and mammal prey sizes vary from 2gr (Etruscan shrew) to 397.5gr (adult Brown rat), whereas the bird prey sizes vary from 13gr (Serin) to 215gr (adult Magpie).

3.3.1.1 Niche breadth

Once data were pooled in each site for all 4 consequent samplings, they were rarefied on the basis of the smallest sample (MAGEL: 572 prey items), with first calculation point the number 2 and a gap of 10 between iterations. Iterations were repeated until they reached the number of individuals in the largest sample (ZOODP: 1431), and species richness for each site was considered the one calculated after consequent iterations at the level of 572 prey items. As a result, species' richness in the sampling sites was calculated before the rarefaction method (18.9 ± 4.08, range: 10-26) as well as afterwards (17.39 ± 3.38, range: 10-23.78). Species richness was higher before the rarefaction, and comparisons between the two groups of species richness measurements (before-after rarefaction) were tested with a two tailed t-test for dependent samples and differences resulted significant ($t = 8.40$, $p < 0.001$). Box-Whisker plots for species richness before and after the data were rarefied are demonstrated in Figure 3.2. Equally common shared species in Barn owl diet were also calculated in terms of frequency (7.19 ± 1.33, range: 5.57-11.4) and biomass contribution (5.54 ± 1.58, range: 3.52-9.48) and the respective Box-Whisker plots are demonstrated in Figure 3.3. The total prey items (n) consumed in each sampling site along with their respective biomass, and the diversity indices values for both frequency and biomass terms (before and after rarefaction) are demonstrated in Tables 3.3 & 3.4. Shannon-Wiener index H' which was calculated in frequency terms, didn't present any statistical differences before and after rarefaction ($t=0.15$, $p=0.88$).

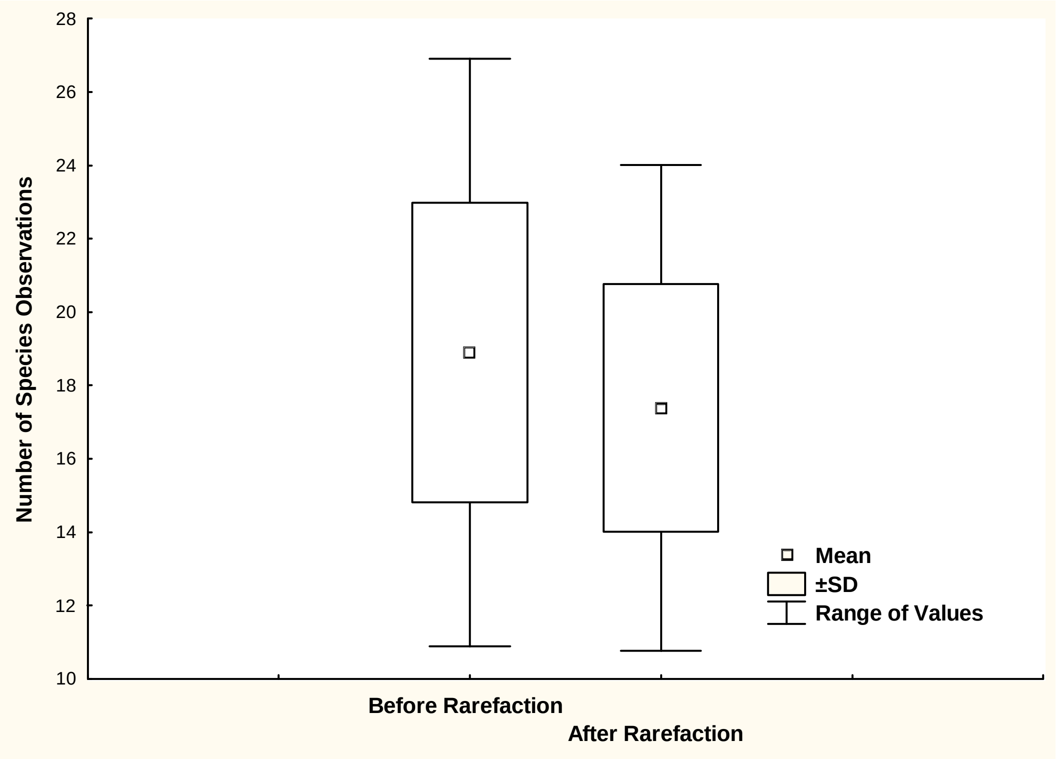


Figure 3.2 Comparison of species richness in the Barn owl diet before and after the rarefaction method, calculated for each one of the 31 sampling sites.

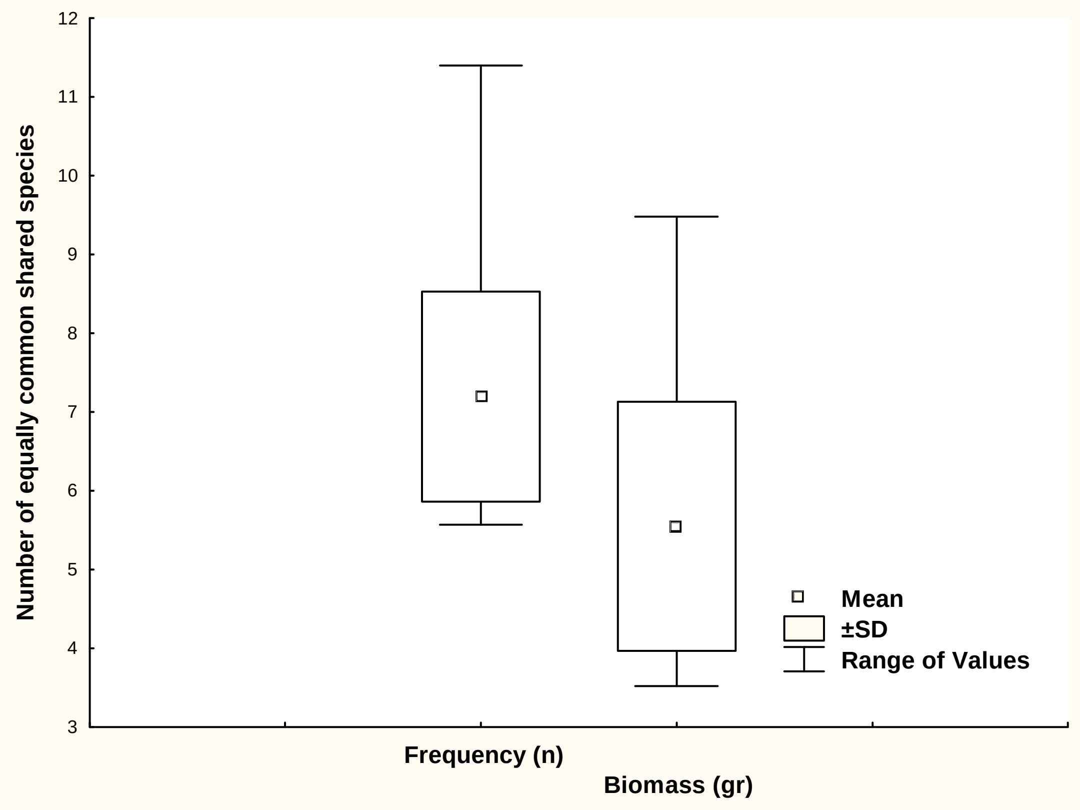


Figure 3.3 Comparison of equally common shared species in Barn owl diet in terms of frequency (n) and biomass (gr) for all 31 sampling sites.

3.3.3 Geographical tendencies

In order to analyze the geographical trends of Barn owl diet in Thessaly, independent variables which were to be included in the statistical analysis were firstly tested for correlations, as mentioned in the methodology part. Since many of them were highly correlated, the effect of multicollinearity was conspicuous in the forthcoming analysis and had to be eliminated. Therefore, the predictor variables were firstly reduced and combined through Factor analysis and Principal Components extraction. The analysis was applied twice in two separate groups of predictor variables, “Agricultural Crops & Land Uses” and “Soil Types & Soil Texture”, whereas River length, Road length and Altitude were used as they were, and weren’t included at all in the Factor analysis procedure. Three main factors were produced from Factor analysis on the group of “Agricultural Crops & Land Uses”, explaining the 92% of the variance, and three main factors were produced from “Soil Types & Soil Texture” group which explained 80% of the variance, according to Kaiser criterion in both cases. The results are demonstrated in Figures 3.4 & 3.5 and Tables 3.5 & 3.6. A total of 124 factor scores were produced for each new factor (4 samplings, 31 sites). Once the Bonferroni corrections were also applied, and the new factors were produced and defined through their respective significant factor loadings, they were renamed accordingly to their new attributes. Therefore from the 1st group of “Agricultural Crops & Land Uses”, Factor 1, 2 and 3 were renamed respectively Intensive cultivations, Land uses and Arable land, whereas from the 2nd group of “Soil Types & Soil Texture”, Factor 1, 2 and 3 were renamed respectively Soil texture, Soil type E, M & V and Soil type I & V (Tab. 3.7). Once Factor analysis was completed, both the new matrices of predictor variables in total, including factor scores and values of independent variables, along with the response variables’ matrix were introduced in Canoco.

Table 3.3 Sites' codenames and prey items (n) found in Barn owl diet in each site. Diversity index calculated with Shannon-Wiener function (H') in absolute frequency terms, both before and after rarefaction analysis. Equitability index J' calculated without prior rarefaction.

Sites Codenames	**Absolute frequency**	**Frequency (n)**		
	n	Diversity – Shannon Wiener Index H'		Evenness – Shannon Wiener function J'
		Before Rarefaction	*After Rarefaction*	*No Rarefaction*
AGVIS	1393	2.03	2.02	0.680
AGGEL	1010	2.27	2.26	0.697
AMPEK	1104	2.03	2.02	0.670
AMIGD	740	2.05	2.05	0.892
ANBUN	859	1.71	1.71	0.583
ARMEN	816	1.92	1.92	0.777
ASPRO	848	1.88	1.87	0.618
ASTRI	672	1.84	1.84	0.617
AURA	880	1.81	1.81	0.688
GIRTO	879	1.86	1.85	0.657
DASOK	894	2.23	2.22	0.722
DELER	965	1.83	1.82	0.603
DOXAR	849	1.97	1.97	0.640
ELEFT	928	1.83	1.82	0.601
ZOODP	1431	1.87	1.86	0.626
KALAM	968	1.85	1.84	0.591
KILER	1333	1.92	1.90	0.605
KRANN	990	1.84	1.83	0.650
KIPAR	875	2.14	2.14	0.717
LOUTR	603	1.73	1.73	0.613
MAGEL	572	2.05	2.05	0.726
MELIS	1293	2.15	2.14	0.662
MYRIN	853	2.43	2.42	0.787
NIAMA	737	1.79	1.78	0.747
NEKAR	896	1.90	1.90	0.722
ORFAN	1196	2.02	2.01	0.665
PAGRA	926	2.02	2.01	0.687
PEDIN	863	1.74	1.73	0.604
STAVR	691	1.97	1.97	0.748
STEFN	1164	1.74	1.73	0.564
XAIDE	833	2.13	2.13	0.790
	29061			

Table 3.4 Sites' codenames and prey biomass contribution (gr) in Barn owl diet in each site. Diversity index calculated with Shannon-Wiener function (H') in biomass terms, both before and after rarefaction analysis. Equitability index J' calculated without prior rarefaction.

Sites Codenames	**Biomass**	**Biomass (gr.)**	
	gr.	Diversity – Shannon Wiener Index H' *Before & After Rarefaction*	Evenness – Shannon Wiener function J' *No Rarefaction*
AGVIS	41541	1.89	0.702
AGGEL	31481.75	2.10	0.702
AMPEK	25666.5	1.74	0.629
AMIGD	70365.75	1.30	0.569
ANBUN	38105.5	1.29	0.466
ARMEN	28664.5	1.61	0.651
ASPRO	20593	1.47	0.546
ASTRI	24830.5	1.49	0.517
AURA	23073	1.45	0.553
GIRTO	30134.75	1.43	0.507
DASOK	23749.25	2.24	0.751
DELER	56551.5	1.47	0.501
DOXAR	26688	1.79	0.599
ELEFT	48241.5	1.53	0.531
ZOODP	48415.5	1.76	0.610
KALAM	39227.75	1.58	0.505
KILER	42195.75	1.60	0.544
KRANN	32200.5	1.53	0.565
KIPAR	35428.5	2.02	0.702
LOUTR	21756.75	1.33	0.470
MAGEL	17928.5	1.45	0.567
MELIS	48126.5	2.07	0.682
MYRIN	36873.75	2.04	0.708
NIAMA	32466	1.51	0.634
NEKAR	24208	1.71	0.652
ORFAN	30691	1.89	0.700
PAGRA	19588.5	2.01	0.713
PEDIN	16195	1.59	0.604
STAVR	16484	1.65	0.668
STEFN	67464.75	1.25	0.435
XAIDE	18815	2.00	0.783
	1037752.25		

Indirect gradient analysis (DCA), which was primarily applied on the response variables' matrix (Barn owl prey genera groups), indicated that linear methods should be applied for the forthcoming ordination analysis (Tab. 3.8), since the value of the largest gradient length was 1.310. Therefore a Redundancy Analysis (RDA) was applied afterwards on both the predictor and response variables' matrices. The application of direct gradient analysis (RDA) on both matrices produced new axes, from which the first two explained a total 89% of the variability within the response variables' data set (Tab. 3.8).

At the same time, when independent variables where tested for their marginal and conditional effects, Monte Carlo permutations in the case of Thessaly indicated that the ones that actually do not offer additional information and value to the produced models are "Road Length", "River Length" and the factor "Soil Type I & V" (Tab. 3.9). Nonetheless, they were all included in the following ordination analysis, because each one of them was also tested separately for the effect that it has on the response variables, and also because their inclusion in the ordination analysis takes into account their "less" power and the results are not misled in any kind of way.

In the case of Barn owl prey items in specific, five main prey groups were used as response variables at genus level (Crocidura spp., Mus spp., Microtus spp., Apodemus spp. and Rattus spp). The groups of birds and insects were used in Class level (Aves & Insecta) because they were scarcely preyed. Although some co-generic species may have different behaviour and habitat preferences, small mammal prey items were used in the model as response variables at genus level, for three reasons. Firstly because the aim of this chapter is to explore the geographical tendencies of Barn owl diet in a large spatial scale, and handling data in genus level is more practical, better visualized and has also been used by other authors in Greece and other countries.

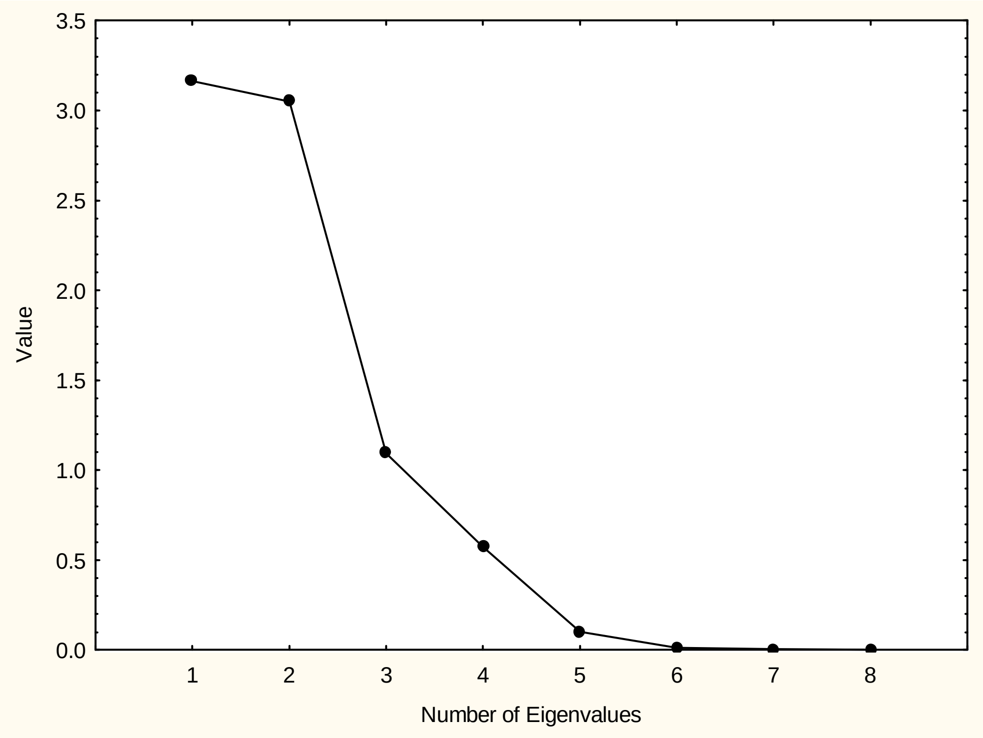


Figure 3.4 Plot of total number of eigenvalues vs. their values, produced from Factor analysis on the group "Agricultural Crops & Land Uses". Value equal to 1 is considered the minimum eigenvalue according to Kaiser criterion.

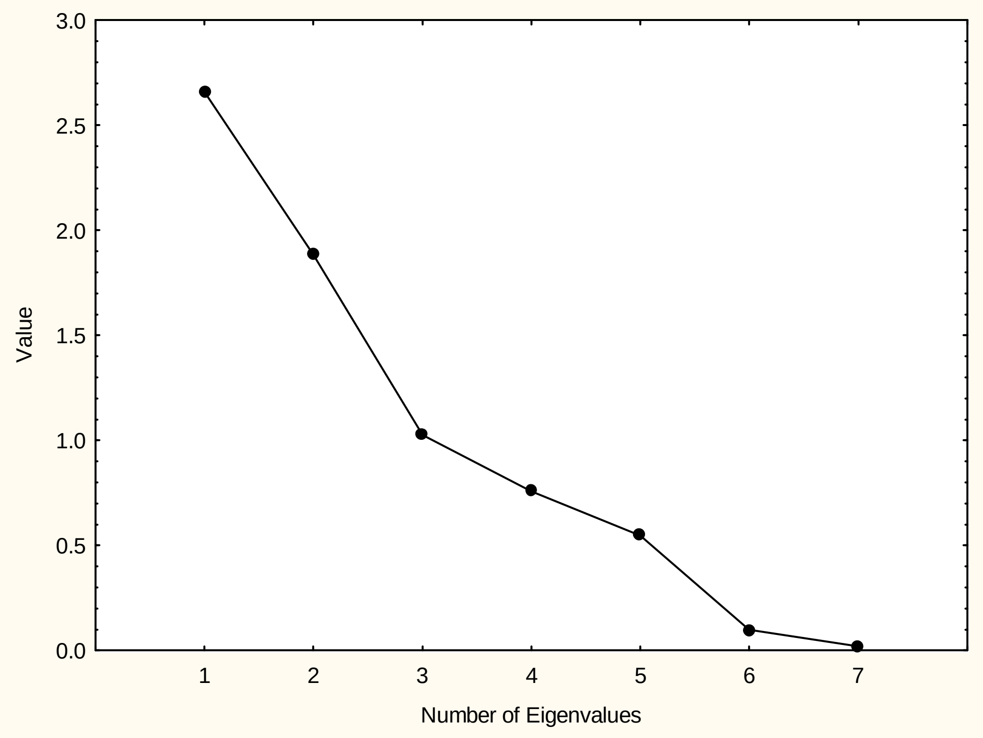


Figure 3.5 Plot of total number of eigenvalues vs. their values, produced from Factor analysis on the group "Soil Types & Soil Texture". Value equal to 1 is considered the minimum eigenvalue according to Kaiser criterion.

Table 3.5 Eigenvalues produced from Factor analysis on the group "Agricultural Crops & Land Uses". Principal components extraction was followed, and rotation was realized with the "varimax" normalized method.

Value	**Eigenvalues**	**Total Variance (%)**	**Cumulative Eigenvalue**	**Cumulative Variance (%)**
1	3.16308	39.53852	3.16308	39.53852
2	3.05025	38.12821	6.21333	77.66673
3	1.09463	13.68290	7.30797	91.34963

Table 3.6 Eigenvalues produced from Factor analysis on the group "Soil Types & Soil Texture". Principal components extraction was followed, and rotation was realized with the "varimax" normalized method.

Value	**Eigenvalues**	**Total Variance (%)**	**Cumulative Eigenvalue**	**Cumulative Variance (%)**
1	2.66113	38.01623	2.66113	38.01623
2	1.88713	26.95910	4.54827	64.97533
3	1.02679	14.66848	5.57506	79.64381

Table 3.7 Correlations between independent variables and factor scores which were produced through Factor analysis for each group of predictor variables. Significant p_s(*) are presented after the level of significance was corrected with Bonferroni correction (a = 0.05 / (number of variables) x (number of factors)). Significant p_s suggest which factor loadings (original variables) actually "define" the new factors, and are noted as: p < 0.01 = *, p < 0.001 = **, p < 0.0001 = ***, p < 0.00001 = ****, p < 0.000001 = *****.

1st Group	Factor 1 Intensive Cultivations	Factor 2 Land Uses	Factor 3 Arable Land	***2nd Group***	Factor 1 Soil texture	Factor 2 Soil type E, M & V	Factor 3 Soil type I & V
Cereals	**- 0.7336** **			Alfisol soil type	**- 0.7208** **		
Industrial Cultivations	**0.9380** *****			Entisol soil type		**0.8441** **	
Arable Cultivated land		**0.9054** **	**0.4128** ***	Inceptisol soil type			**- 0.9503** **
Non Arable Cultivated land			**- 0.9776** **	Mollisol soil type		**0.6666** *****	
Irrigated Cultivated land	**0.9282** *****			Vertisol soil type		**- 0.6750** *****	**0.4700** *****
Non Irrigated Cultivated land	**- 0.9119** *****			Sandy-clay texture	**- 0.9345** *****		
Other land uses		**- 0.9989** **		Argillaceous-clay texture	**0.9463** *****		
Total Cultivated land		**0.9989** **					

Secondly, because ordination analysis (as will be demonstrated hereafter in this chapter), reveals clear trends concerning the interactions between response and predictor variables. And finally, because small mammals' distribution and habitat associations are analyzed with detail in Chapter 4, focusing on specie level. Thus, that kind of information is also displayed afterwards.

Additionally there are some species which are not included in this analysis such as the Hazel dormouse (*Muscardinus avellanarius*), the Gray dwarf hamster (*Cricetulus migratorius*), and the Etruscan shrew (*Suncus etruscus*), because they were minimally preyed, and in few sampling points.

Hence, once the stepwise forward selection was completed, interactions and correlations between response and predictor variables were visualized using Canodraw, a utility which is included in Canoco software (version 4.5). In Figure 3.6 the two dimension axes used in the graphic are the fist two Axes produced from Redundancy analysis (RDA). These axes actually combine the largest variability of the data set of predictor (environmental) variables, which also explain the 89% (Tab. 3.8) of the variability within the data set of response variables (Barn owl prey groups). Length of vectors indicates increase of abundance and strength of the variable that each vector represents in the model. Their direction indicates positive or negative correlations, associations between response and explanatory variables separately, as well as between them.

Table 3.8 Indirect gradient analysis (DCA) taking into account only the variability of the response variables, and direct gradient analysis (RDA) taking into account the variability of both response and predictor variables.

Detrended Correspondence Analysis (DCA)				
Axes	**1**	**2**	**3**	**4**
Eigenvalues	0.091	0.052	0.040	0.023
Lengths of gradients	1.310	1.335	1.050	0.879
Cumulative percentage variance of species data	34.9	54.9	70.4	79.0
Redundancy Analysis (RDA)				
Axes	**1**	**2**	**3**	**4**
Eigenvalues	0.177	0.091	0.017	0.010
Species & Environmental variables correlations	0.574	0.671	0.518	0.447
Cumulative percentage variance of species data	17.7	26.8	28.5	29.6
Cumulative percentage of species & environmental variables relation	58.8	89.0	94.7	98.1

Table 3.9 Results of forward selection on predictor variables. Marginal effects are the effects of each predictor variable when used as the only explanatory variable in the model, and variables are ranked according to their variance. Conditional effects are the effects of each predictor variable in the model adding each time the next more important, and variables are ranked according to their added significance of their inclusion in the model.

Marginal effects		***Conditional effects***			
Variable	Lambda 1	*Variable*	Lambda A	F	P
Intensive Cultivations	0.10	Intensive Cultivations	0.10	13.62	0.002
Soil type E, M & V	0.06	Soil type E, M & V	0.06	8.09	0.002
Altitude	0.05	Altitude	0.03	4.97	0.004
Soil texture	0.04	Land Uses	0.02	4.02	0.012
Arable Land	0.04	Arable Land	0.03	3.77	0.014
Land Uses	0.03	Soil texture	0.03	4.33	0.018
Road Length	0.02	Road Length	0.01	2.50	0.058
Soil Type I & V	0.01	Soil Type I & V	0.01	1.76	0.154
River Length	0.01	River Length	0.01	1.14	0.312

Table 3.10 "Best fit" model selection based on Akaike (AIC) criterion and results of Generalized Linear Model analysis (GLM) applied on each one of the response variables. The first two axes produced from Redundancy Analysis (RDA) were used as predictor variables. Level of significance is set at a = 0.05. Significant p_s are noted: < 0.01 = *, < 0.001 = **, < 0.0001 = ***, < 0.00001 = ****, < 0.000001 = *****.

		Model Selection		**Generalized Linear Model**	
Response Variable	AIC	b_0+b_1X	$b_0+b_1X+b_2X^2$	F	P
Crocidura spp.	218.085		√	20.58	*****
Apodemus spp.	272.377	√		7.92	**
Microtus spp.	335.982	√		31.76	*****
Mus spp.	356.287	√		15.32	*****
Rattus spp.	1022.616	√		18.44	*****
Aves	593.086		√	4.88	**
Insecta	764.949		√	5.00	**

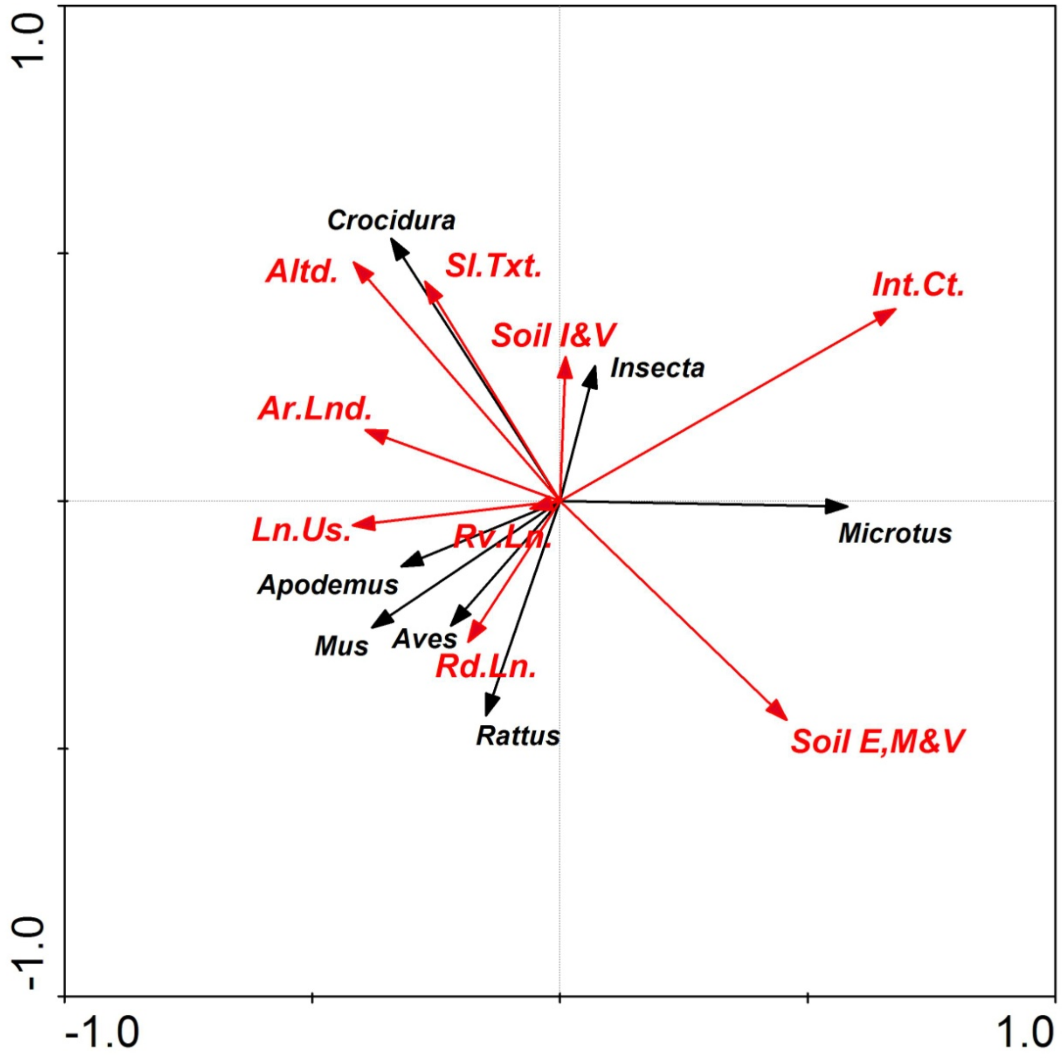


Figure 3.6 Biplot ordination diagram of response (small mammal genera, insect and bird orders) and predictor (environmental) variables on Axis 1 and Axis 2 of Redundancy Analysis (RDA), with scaling based on inter-species distances. Response variables are demonstrated with black arrows whereas predictor with red. Length and direction of vectors indicate respectively strength and associations between them. Length of response variables indicates the amount of their relative frequency in the Barn owl diet, and direction indicates the positive and negative correlations between them. Length of predictor variables indicates which environmental variables explain best the variability of the response variables, whereas the direction of predictor variables indicates associations between them, and also negative and positive correlations between environmental variables and Barn owl prey groups. Acronyms of predictor variables stand for: ***Altd***: Altitude, ***Sl.Txt***: Soil Texture, ***Soil I & V***: Soil Type Inseptisol and Vertisol, ***Int.Ct***: Intensive Cultivations, ***Soil E, M & V***: Soil Type Entisol, Mollisol and Vertisol, ***Rd.ln***: Road Length, ***Rv.Ln***: River Length, ***Ln.Us***: Land Uses, ***Ar.Lnd***: Arable Land.

The first two axes produced from Redundancy analysis (Tab. 3.8 & Fig. 3.6), summarize as mentioned the maximum variance within the data set of all independent variables (environmental gradients). Therefore they were used as predictor variables to test the total effect of all environmental gradients on each dependent variable, in order to explore what kind of model fits best each response (1st, 2nd or 3rd order Polynomial model). The analysis was realized with Canoco software and application of Generalized Linear Models. The choice of "best fit" model for each response variable was realized with the criterion of Akaike (AIC), and the regression models which fitted best in each case were all significant for all seven response variables (Tab. 3.10). Visualization of the results is demonstrated in Figures 3.7 to 3.13. In the produced figures, increase in the values of contour isolines indicates increase in the response variables' relative frequency. The direction to which that increase is observed, indicates positive correlation with those explanatory variables whose vectors increase and point in the same direction too.

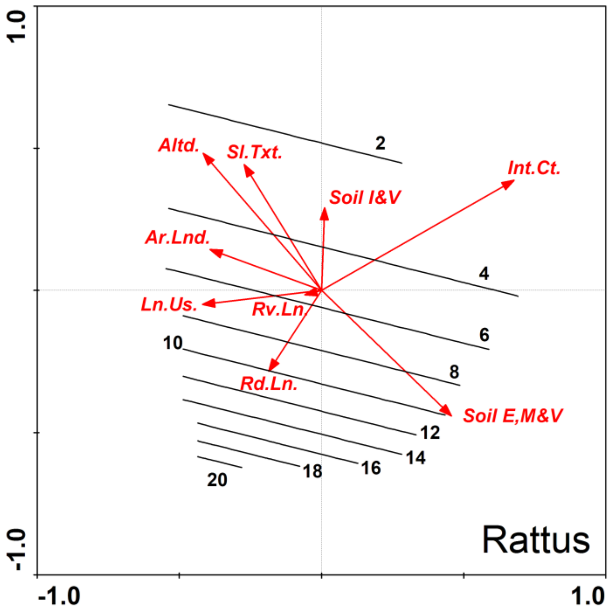


Figure 3.7 Contour isolines of response variable "Rattus spp." summarizing the fitted regression model. Increase in values indicates increase in the variable's relative frequency.

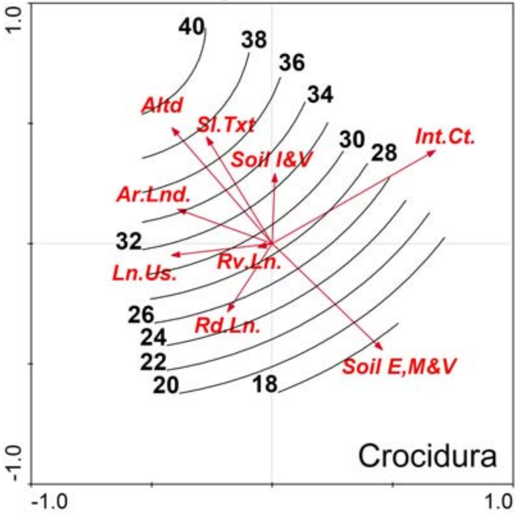


Figure 3.8 Contour isolines of response variable "Crocidura spp." summarizing the fitted regression model. Increase in values indicates increase in the variable's relative frequency.

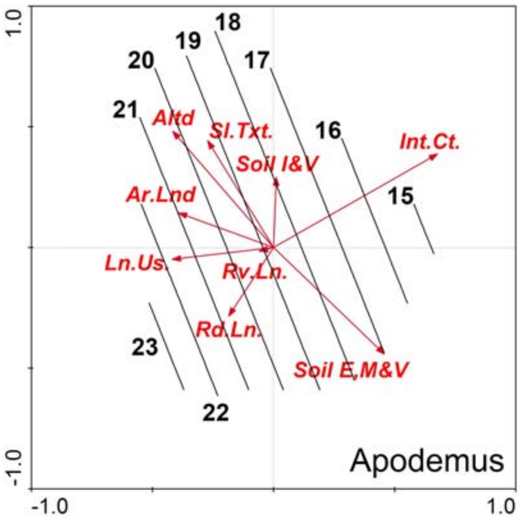


Figure 3.9 Contour isolines of response variable "Apodemus spp." summarizing the fitted regression model. Increase in values indicates increase in the variable's relative frequency.

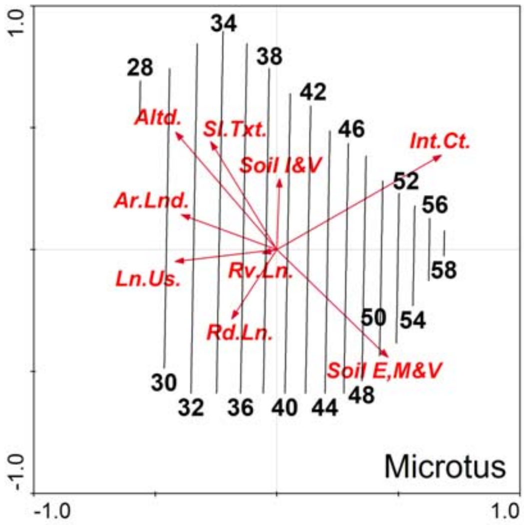


Figure 3.10 Contour isolines of response variable "Microtus spp." summarizing the fitted regression model. Increase in values indicates increase in the variable's relative frequency.

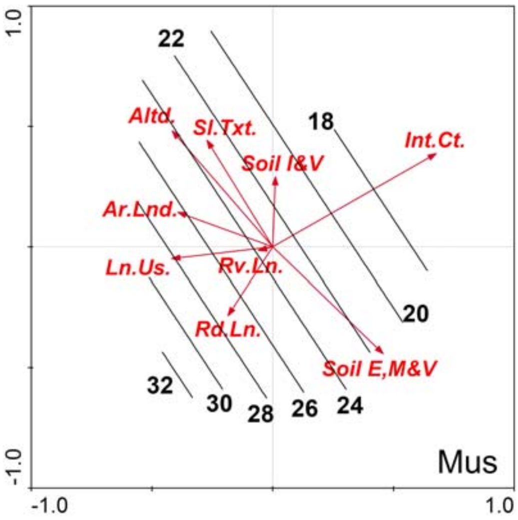


Figure 3.11 Contour isolines of response variable "Mus spp." summarizing the fitted regression model. Increase in values indicates increase in the variable's relative frequency.

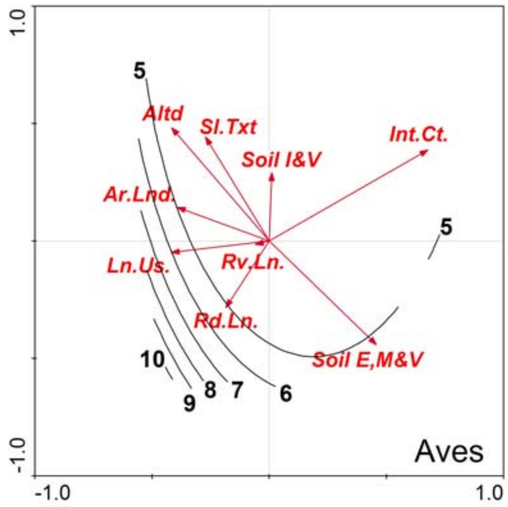


Figure 3.12 Contour isolines of response variable "Aves" summarizing the fitted regression model. Increase in values indicates increase in the variable's relative frequency.

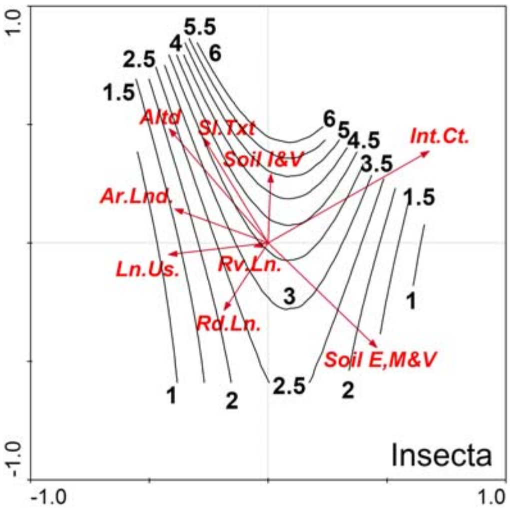


Figure 3.13 Contour isolines of response variable "Insecta" summarizing the fitted regression model. Increase in values indicates increase in the variable's relative frequency.

From the models that "best" fitted in each response variable (Tab. 3.10) and their respective produced graphics (Figs. 3.7 to 3.13), it is observed that Rattus spp., Apodemus spp., Microtus spp., Mus spp. and Crocidura spp. respond with simple 1st order polynomial models, whereas the orders of Aves and Insecta fitted best polynomial models of 2nd order. It is also clear that different patterns occur in the direction to which the contour isolines of each dependent variable increase. Apodemus spp., Rattus spp. and Mus spp. present a somewhat similar response, increasing towards the same direction. The same pattern can also be observed in the class Aves, although birds have a more complicated response due to the 2nd order polynomial model which they fitted best. On the other hand, Crocidura spp. and Microtus spp. present quite different patterns of increase, and Insects finally have the most complicated response pattern.

In order to comprehend further the interactions between environmental variables and Barn owl prey groups, the response of each dependent variable was also tested separately on each independent variable. The analysis was realized again with Canoco software and Genereralized Linear Models. The choice of "best fit" model for each response variable was realized with the criterion of Akaike (AIC). Some response variables didn't fit any model (Null model selection) and therefore they were rejected from that part of the analysis. That was expected because the behaviour of the whole model including all the variables is different from testing each variable separately. The regression models which fitted best in each case are demonstrated in Table 3.11, along with the results of GLMs, whereas the rejected response models are not included in the table. The results are visualized and demonstrated in Figures 3.14 to 3.21.

Table 3.11 Response of each one of dependent variables to each one of the predictor variables. “Best fit” model selection according to Akaike criterion (AIC), and Generalized Linear Model analysis. Response variables which didn’t fit any model (Null model selection) are not included in the table. Significant p_s are noted: $p < 0.01$ = *, $p < 0.001$ = **, $p < 0.0001$ = ***, $p < 0.00001$ = ****, $p < 0.000001$ =*****.

		Model Selection		**Generalized Linear Model results**	
	AIC	$b_0 + b_1X$	$b_0 + b_1X + b_2X^2$	F	P
ALTITUDE					
Crocidura spp.	301.628	√		19.03	***
Microtus spp.	469.052	√		9.12	*
Mus spp.	398.642		√	6.99	**
Insecta	805.326	√		6.96	*
SOIL TEXTURE					
Crocidura spp.	297.494	√		20.71	****
Aves	623.502	√		4.99	*
INTENSIVE CULTIVATIONS					
Apodemus spp.	252.314		√	13.92	*****
Microtus spp.	403.074		√	16.40	*****
Mus spp.	357.818		√	14.95	****
Rattus spp.	1234.379	√		6.22	*
Aves	568.667	√		20.52	****
Insecta	728.653	√		19.56	****
LAND USES					
Microtus spp.	475.692	√		7.33	*
Mus spp.	399.205		√	6.84	**
ARABLE LAND					
Crocidura spp.	322.755	√		9.30	*
Microtus spp.	479.748		√	4.15	*
Mus spp.	418.671		√	3.45	*
Aves	624.620		√	3.34	*
ROAD LENGTH					
Crocidura spp.	332.772		√	3.68	*
Mus spp.	400.756		√	6.55	**
Rattus spp.	1233.423		√	4.12	*
Aves	620.194		√	3.93	*
Insecta	819.657	√		4.73	*
RIVER LENGTH					
Crocidura spp.	333.253		√	3.58	*
SOIL TYPE E, M & V					
Crocidura spp.	283.596		√	14.88	****
Microtus spp.	460.853		√	6.79	**
Rattus spp.	1239.045		√	3.89	*
SOIL TYPE I & V	-	-	-	-	-

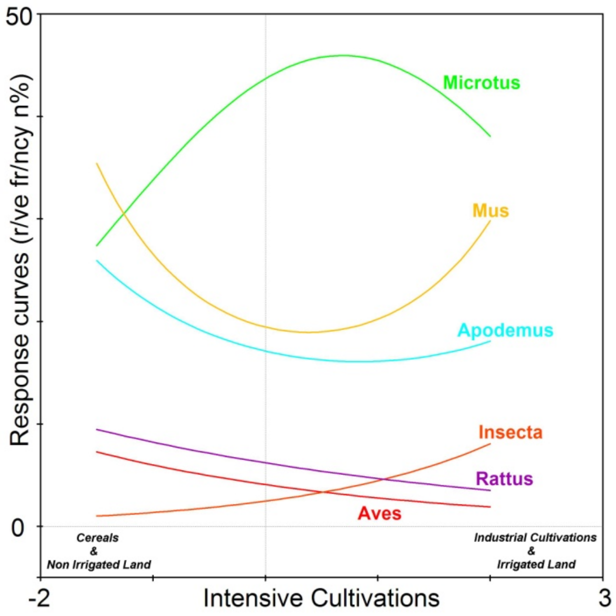


Figure 3.14 Response of Barn owl prey groups to the Factor: "Intensive Cultivations". Only significant response curves are demonstrated in the figure. Dependent variables which were rejected through "null model selection" are not included.

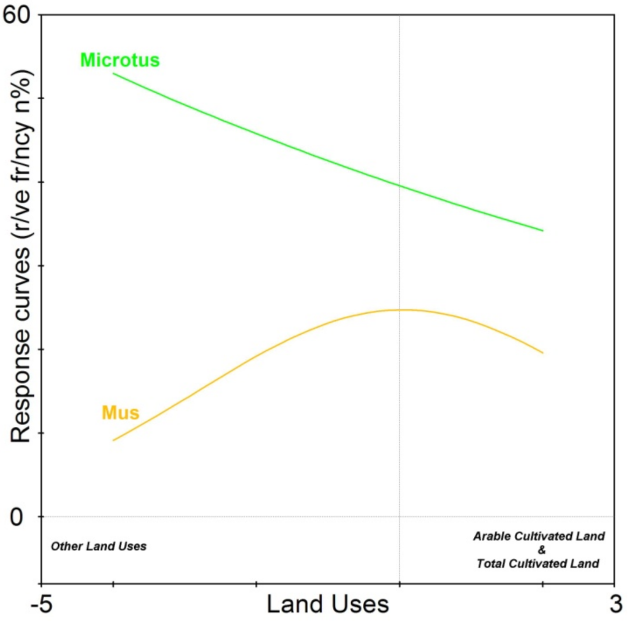


Figure 3.15 Response of Barn owl prey groups to the Factor: "Land Uses". Only significant response curves are demonstrated in the figure. Dependent variables which were rejected through "null model selection" are not included.

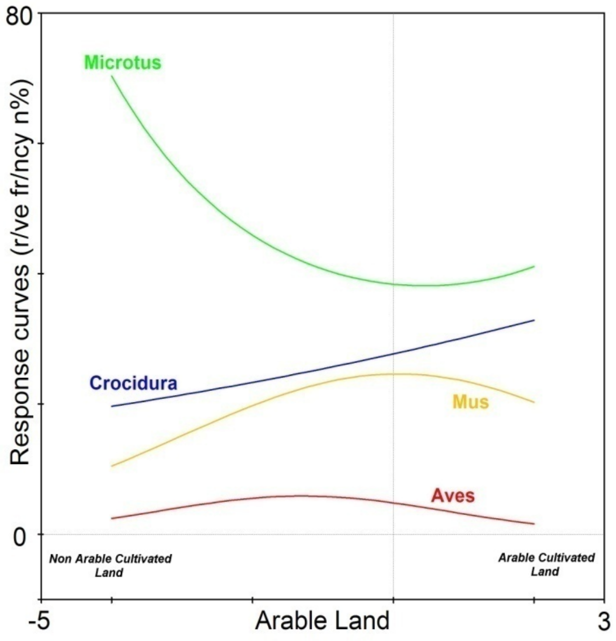


Figure 3.16 Response of Barn owl prey groups to the Factor: "Arable Land". Only significant response curves are demonstrated in the figure. Dependent variables which were rejected through "null model selection" are not included.

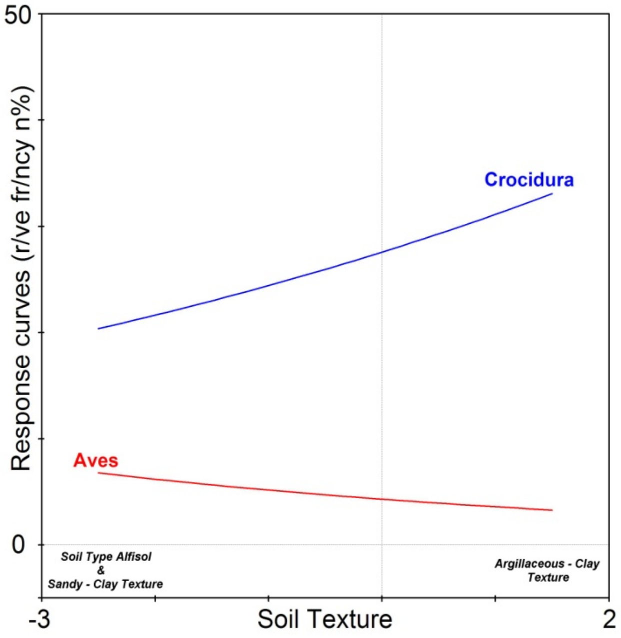


Figure 3.17 Response of Barn owl prey groups to the Factor: "Soil Texture". Only significant response curves are demonstrated in the figure. Dependent variables which were rejected through "null model selection" are not included.

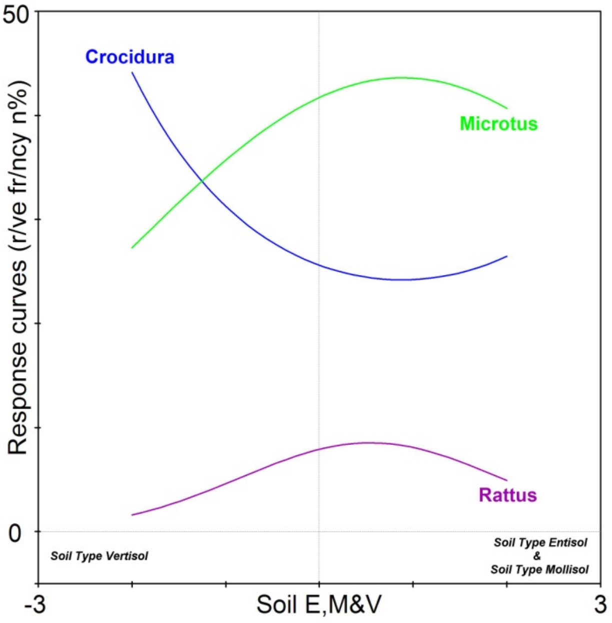


Figure 3.18 Response of Barn owl prey groups to the Factor: "Soil E,M&V". Only significant response curves are demonstrated in the figure. Dependent variables which were rejected through "null model selection" are not included.

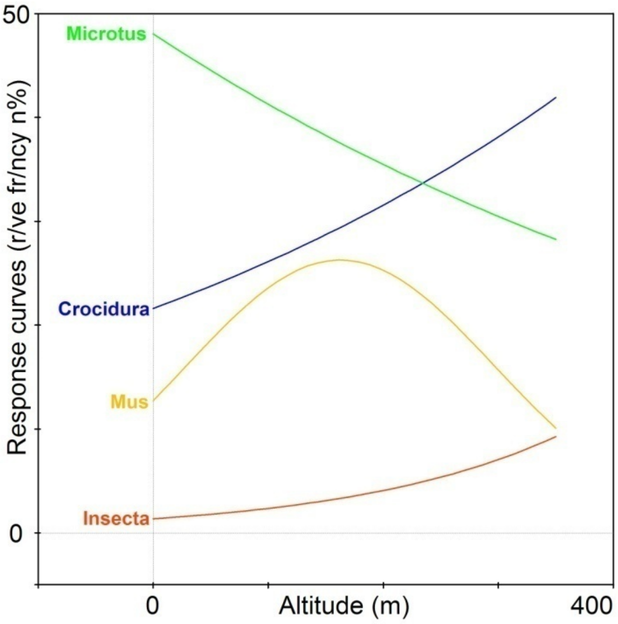


Figure 3.19 Response of Barn owl prey groups to the independent variable "Altitude". Only significant response curves are demonstrated in the figure. Dependent variables which were rejected through "null model selection" are not included.

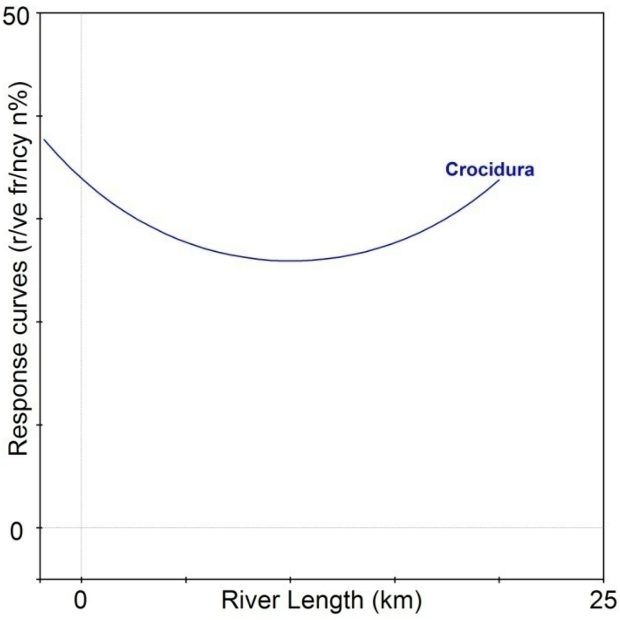


Figure 3.20 Response of Barn owl prey groups to the independent variable "River Length". Only significant response curves are demonstrated in the figure. Dependent variables which were rejected through "null model selection" are not included.

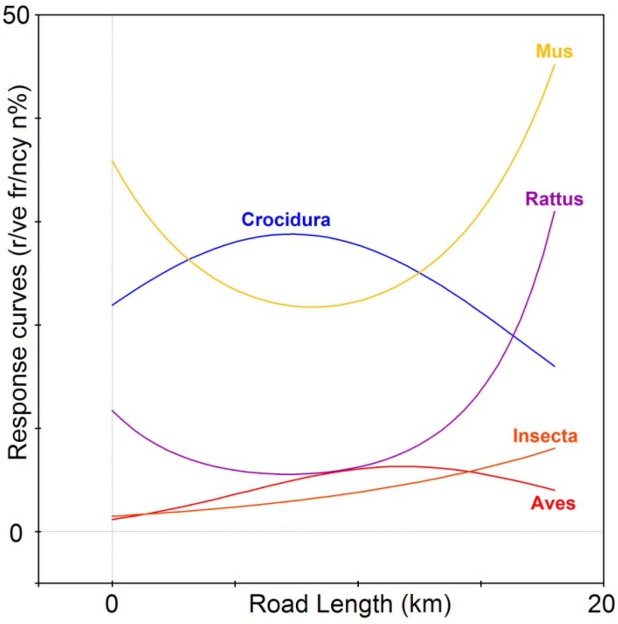


Figure 3.21 Response of Barn owl prey groups to the independent variable "Road Length". Only significant response curves are demonstrated in the figure. Dependent variables which were rejected through "null model selection" are not included.

Species richness in Barn owl diet, along with the diversity and evenness of its main prey groups, were also treated as depended variables in order to explore the effect that the total of environmental gradients have on them. Canoco allows the calculation of Shannon-Wiener diversity index, and tests its change along the two axes as derived from Redundancy Analysis (RDA). The diversity index fitted a 1st order polynomial model according to the criterion of Akaike (AIC: 5.41), and Generalized Linear Models demonstrated that the model was also significant (F = 9.39, $p < 0.0001$). Visualization of the response model is demonstrated in Figure 3.22. Similarly, Canoco performs the same procedure for Shannon evenness index (J'), and species richness (n = number of species). Evenness index fitted a 2nd order polynomial model according to criterion of Akaike (AIC: 0.07), and Generalized Linear models proved the model to be significant (F = 4.99, $p < 0.001$), and finally species richness fitted a 1st order polynomial model (AIC: 192.09), an also significant model according to Generalized Linear Models (F = 5.21, $p < 0.01$). Figures 3.23 and 3.24 summarize the fitted regression models for evenness and species richness respectively.

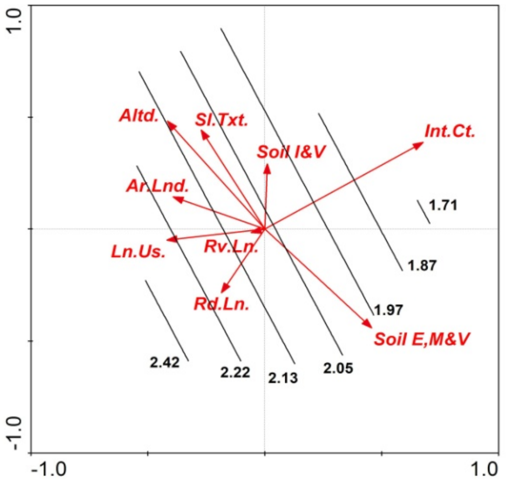


Figure 3.22 Contour isolines of Shannon diversity index (H') summarize the fitted regression model. Increase in values indicates increase of the index.

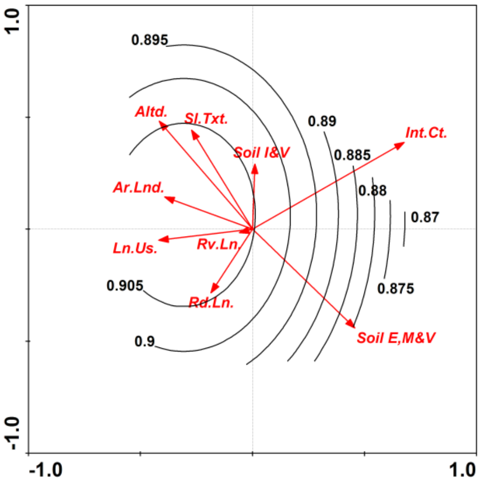


Figure 3.23 Contour isolines of Shannon evenness index (H') summarize the fitted regression model. Increase in values indicates increase of the index.

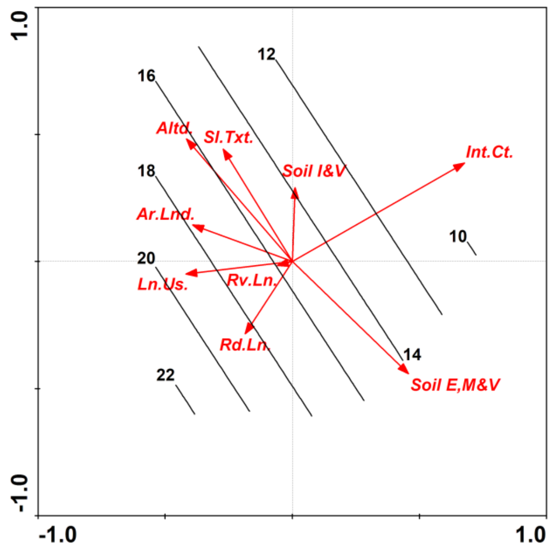


Figure 3.24 Contour isolines of species richness summarizing the fitted regression model. Increase in values indicates increase in the number of species.

3.3.4 Seasonal comparisons

The seasonal trends of Barn owl diet were also assessed in Thessaly. Prior to the analysis some species in the Barn owl diet were excluded because they were scarcely preyed. Such species were: The Hazel dormouse which was present in Barn owl diet only in 4 breeding sites (Appendix C), it was minimally preyed (n=50, 0.17%), and no significant differences existed between seasons ($x^2_{Yates\ correction}$ = 3.30, df = 1, p = 0.0694). The Gray dwarf hamster which was preyed in 10 of 31 sampling sites (Appendix C), which was also rarely captured (n=162, 0.56%) and no significant differences occurred between sampling periods ($x^2_{Yates\ correction}$ = 4.85, df = 1, p = 0.1347). The Etruscan shrew (*Suncus etruscus*) which wasn't highly preyed neither (n=478, 1.64%), appeared in Barn owl diet with minimal percentages in most sites (Appendix C) and no significant differences existed between seasons neither ($x^2_{Yates\ correction}$ = 0.19, df = 1, p = 0.6666).

Five main mammal groups were highly preyed during all 4 sampling periods (Microtus spp., Crocidura spp., Apodemus spp., Rattus spp. & Mus spp.). They were present in all 31 sampling sites and they all presented significant differences between seasons, both in frequency and biomass terms. Birds and insects were not highly preyed, but they presented certain significant differences between seasons. One-way ANOVA tests were applied in each prey group for seasonal comparisons and in all cases tests were proved significant (Tab. 3.12). The Tukey HSD post-hoc test was also applied in each prey group in order to specify which seasonal samples produced the significant results in one-way ANOVAs. These results are also demonstrated in Table 3.12. Visualization of analysis of variance and seasonal patterns existing in the Barn owl diet are demonstrated in Figures 3.25 to 3.32.

During breeding seasons, the prey groups which were more preyed compared to the respective non-breeding seasons were shrews, voles and insects (Figs. 3.28 to 3.30). Nonetheless, within this pattern of increased abundance during breeding seasons, the Barn owl has preyed on these three groups with different trends during the years of the study.

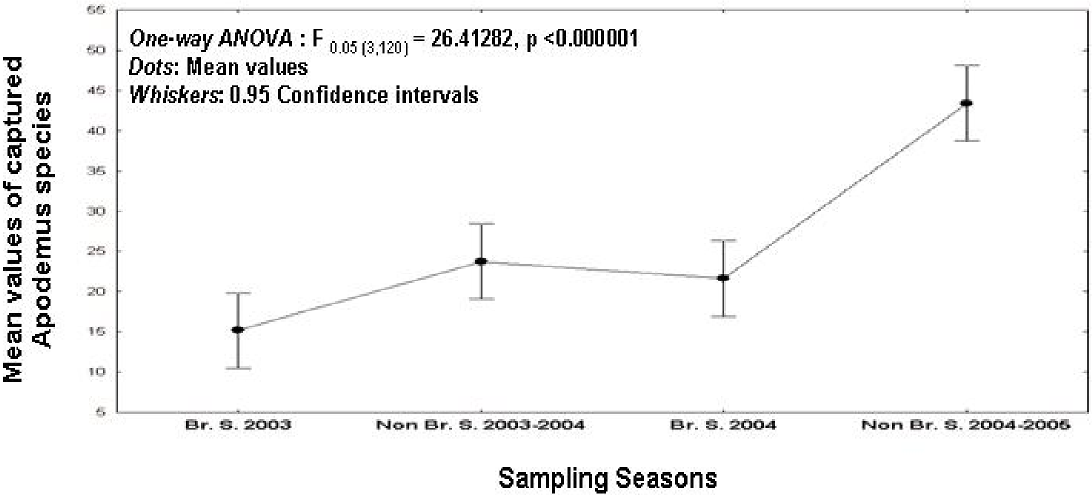


Figure 3.25 Mean values of Apodemus species in Barn owl diet. Seasonal comparisons and one-way ANOVA results. Acronyms stand for: ***Br.S.:*** Breeding season, ***Non Br.S.:*** Non Breeding season.

Table 3.12 Results of one-way ANOVA tests for seasonal comparisons, on the seven main prey groups which comprise the Barn owl diet in Thessaly. Level of significance is set at a = 0.05. Significant p_s for one-way ANOVA tests are noted: $p < 0.01$ = *, $p < 0.001$ = **, $p < 0.0001$ = ***, $p < 0.00001$ = ****, $p < 0.000001$ = *****. Significant differences between seasonal samples for Tukey HSD post-hoc tests are noted: *. Acronyms stand for: Br: Breeding season, N.Br: Non Breeding Season.

	One-Way ANOVA	Sum of squares	df	Mean square	F	p	*Tukey – HSD post hoc tests*	Br. 2003	N. Br. 2003-2004	Br. 2004	N. Br. 2004-2005
Crocidura spp.	***Between groups***	16937.71	3	5645.903	3.221796	*	***Br. 2003***				
	Within groups	210289	120	1752.409			***N.Br 2003-2004***			*	
	Total	227226.71	123				***Br. 2004***		*		
							N.Br. 2004-2005				
Microtus spp.	***Between groups***	72604.13	3	24201.38	9.695246	****	***Br. 2003***		*		*
	Within groups	299545.3	120	2496.211			***N.Br 2003-2004***	*			
	Total	372149.43	123				***Br. 2004***				*
							N.Br. 2004-2005	*		*	
Apodemus spp.	***Between groups***	13772.58	3	4590.860	26.41282	*****	***Br. 2003***				*
	Within groups	20857.42	120	173.8118			***N.Br 2003-2004***				*
	Total	34630	123				***Br. 2004***				*
							N.Br. 2004-2005	*	*	*	
Rattus spp.	***Between groups***	2110.129	3	703.3763	4.6592	*	***Br. 2003***		*		
	Within groups	18115.81	120	150.9651			***N.Br 2003-2004***	*		*	
	Total	20225.939	123				***Br. 2004***		*		
							N.Br. 2004-2005				
Mus spp.	***Between groups***	18292.68	3	6097.559	8.429611	***	***Br. 2003***				*
	Within groups	86802	120	723.3500			***N.Br 2003-2004***				*
	Total	105094.68	123				***Br. 2004***				*
							N.Br. 2004-2005	*	*	*	
Aves	***Between groups***	251.5081	3	83.83602	7.343647	***	***Br. 2003***				*
	Within groups	1369.935	120	11.41613			***N.Br 2003-2004***				
	Total	1621.4431	123				***Br. 2004***				*
							N.Br. 2004-2005	*		*	
Insecta	***Between groups***	389.5081	3	129.8360	12.95018	*****	***Br. 2003***			*	
	Within groups	1203.097	120	10.02581			***N.Br 2003-2004***			*	
	Total	1592.6051					***Br. 2004***	*	*		*
							N.Br. 2004-2005			*	

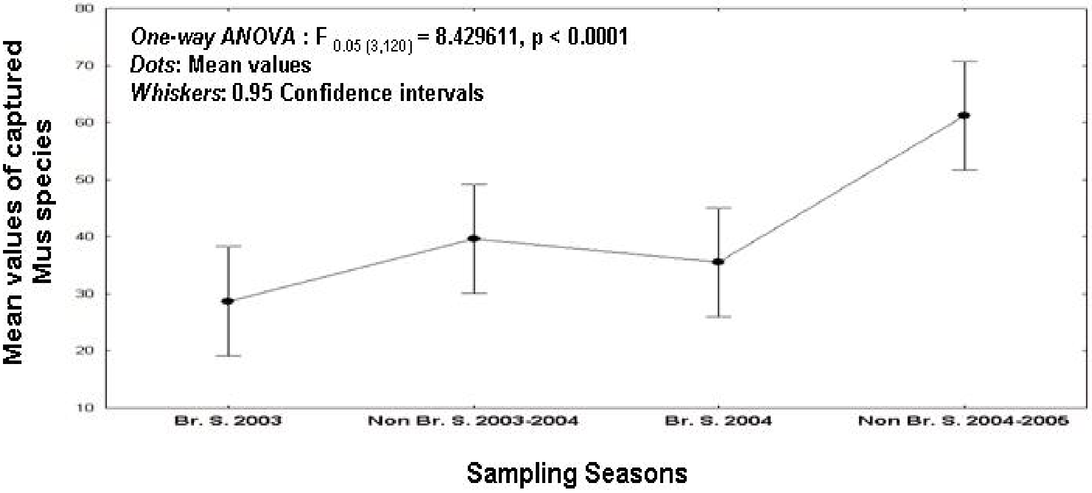


Figure 3.26 Mean values of Mus species in Barn owl diet. Seasonal comparisons and one-way ANOVA results. Acronyms stand for: ***Br.S.:*** Breeding season, ***Non Br.S:*** Non Breeding season.

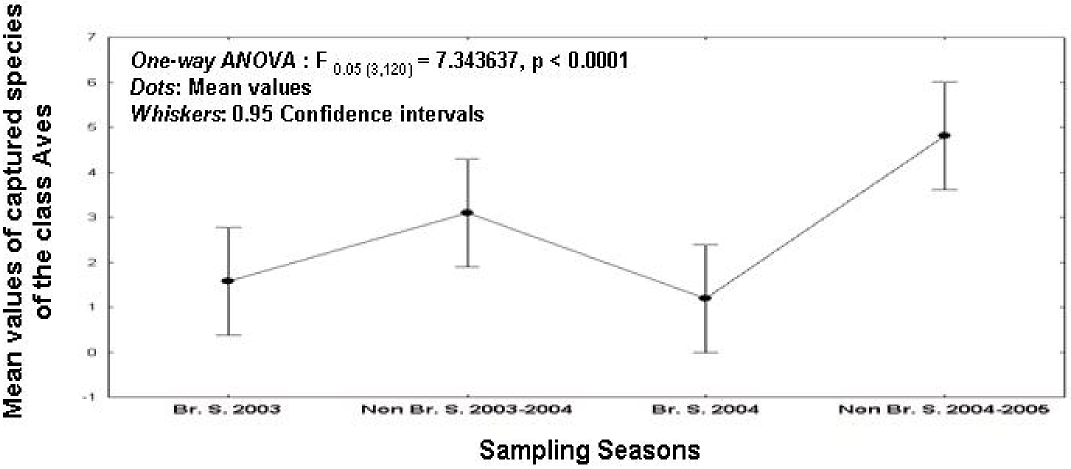


Figure 3.27 Mean values of bird species in Barn owl diet. Seasonal comparisons and one-way ANOVA results. Acronyms stand for: ***Br.S.:*** Breeding season, ***Non Br.S.:*** Non Breeding season.

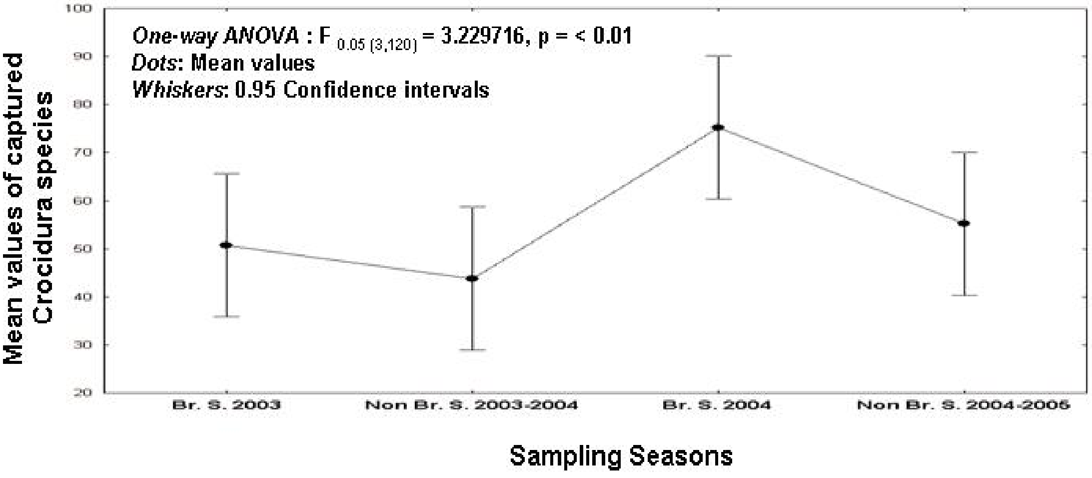


Figure 3.28 Mean values of Crocidura species in Barn owl diet. Seasonal comparisons and one-way ANOVA results. Acronyms stand for: ***Br.S.:*** Breeding season, ***Non Br.S.:*** Non Breeding season.

Although significant differences for Crocidura species were located only between non-breeding season 2003 – 2004 and breeding season 2004 (Tab. 3.12), the trend is clear (Fig. 3.28). Moreover, shrews were increasingly captured along the three year study. On the other hand, voles strongly decreased from 2003 to 2005 (Fig. 3.29) and various significant differences existed between seasonal samples (Tab. 3.12). Insects finally, although they were more preyed during breeding seasons they remained actually in the same levels of capture through the years (Fig. 3.30) with an exception of a strong increase during the breeding season of 2004, which is also the only statistically significant seasonal sample within the group (Tab. 3.12).

The remaining prey groups of Apodemus spp., Rattus spp., Mus spp. and Aves were more preyed during non-breeding seasons compared to the respective breeding seasons, and they were all increasingly captured through the three years of the study. Moreover, the groups of Apodemus spp., Mus spp. and Aves present a high increase in Barn owl diet during non-breeding season 2004 – 2005 (Figs. 3.25, 3.26 & 3.27), which is also the only statistically significant sample within each group (Tab. 3.12). On the other hand their relative frequencies in the owl's diet during the other sampling seasons are practically at the same levels and non significant. Finally, Rattus spp. participates in the owl's diet with the same trends as Apodemus spp., Mus spp. and Aves, but is also the only one among these four prey groups which presents statistical differences between most sampling seasons (Fig. 3.31 & Tab. 3.12).

The different trends of Barn owl diet in respect to its main prey groups are summarized in Figure 3.32, where the relative frequencies of each group are presented during each sampling season. Microtus and Crocidura species are the main prey groups in all seasons.

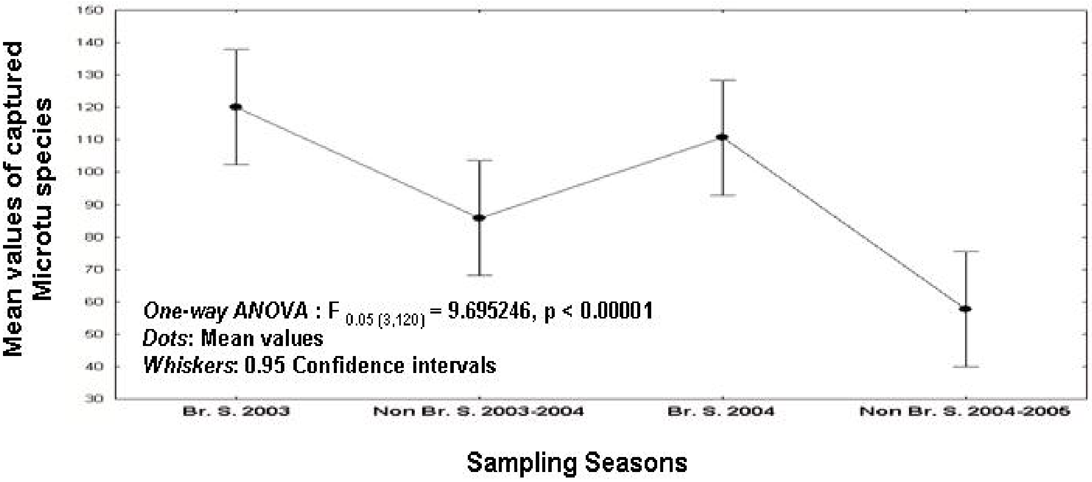


Figure 3.29 Mean values of Microtus species in Barn owl diet. Seasonal comparisons and one-way ANOVA results. Acronyms stand for: ***Br.S.:*** Breeding season, ***Non Br.S.:*** Non Breeding season.

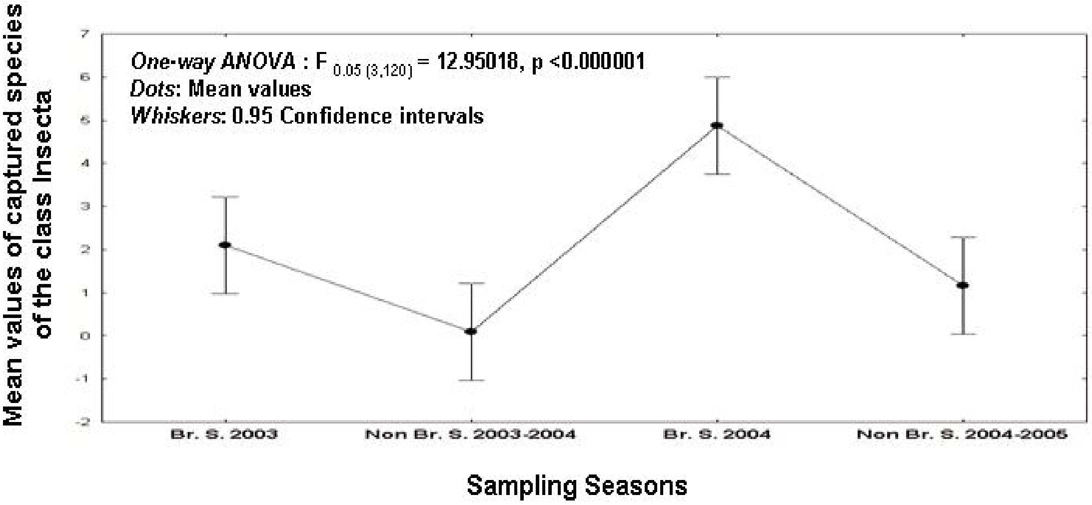


Figure 3.30 Mean values of Insect species in Barn owl diet. Seasonal comparisons and one-way ANOVA results. Acronyms stand for: ***Br.S.:*** Breeding season, ***Non Br.S.:*** Non Breeding season.

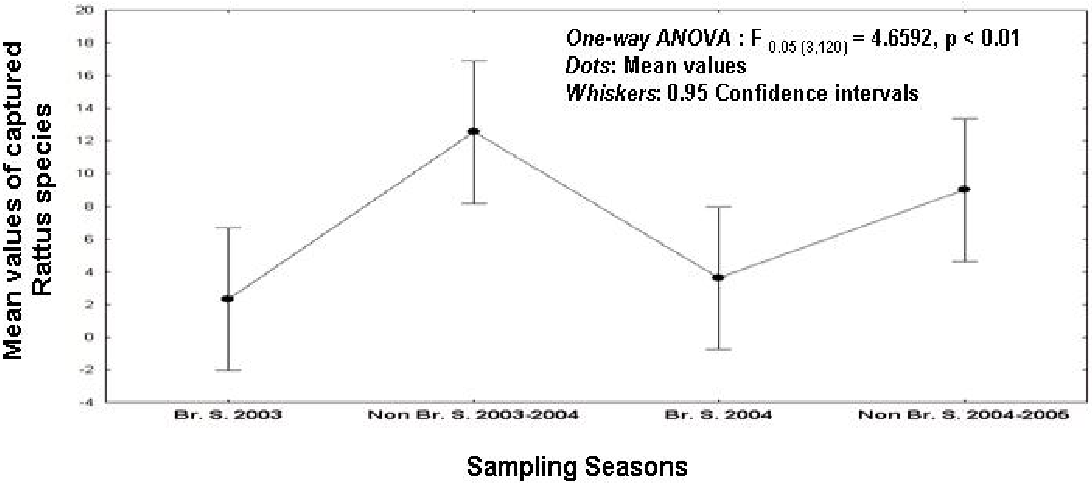


Figure 3.31 Mean values of Rattus species in Barn owl diet. Seasonal comparisons and one-way ANOVA results. Acronyms stand for: ***Br.S.:*** Breeding season, ***Non Br.S.:*** Non Breeding season.

Additionally, although voles and shrews are more preyed during breeding seasons and the remaining prey groups of mice, rats and bird species are more preyed during non breeding seasons, there is a general pattern through the three year study according to which only Microtus species decrease in the owl's diet and all the rest prey groups increase.

Moreover, if observed the Barn owl diet through the biomass spectrum of each prey group (Fig. 3.33), a quite different pattern is revealed from the one that the prey groups' relative frequency suggests. According to Figure 3.33, although rats belong to the less preyed groups in numbers along with insect and bird species, they are the main biomass contributors to the owl's diet along with voles, especially during non breeding seasons.

The niche breadth and niche indices which were shaped within the Barn owl diet also present distinct patterns between seasons. Diversity according to Shannon index and species richness, were calculated on specie level once the results were rarefied, whereas evenness was also calculated on specie level but without prior rarefaction.

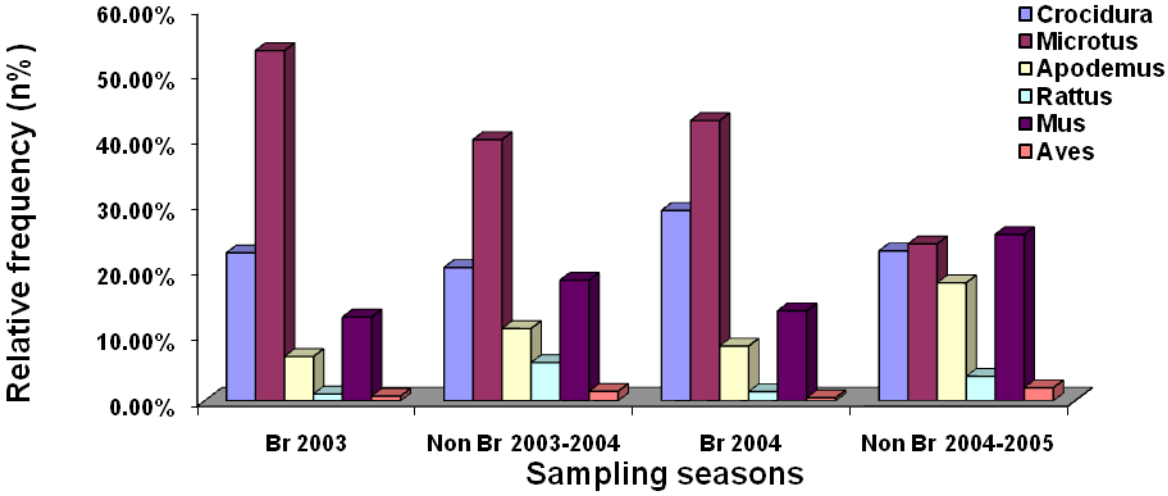


Figure 3.32 Percentages of frequency (n%) of main prey groups in Barn owl diet during the 4 sampling seasons. Acronyms stand for: ***Br***: Breeding season and ***Non Br***: Non breeding season.

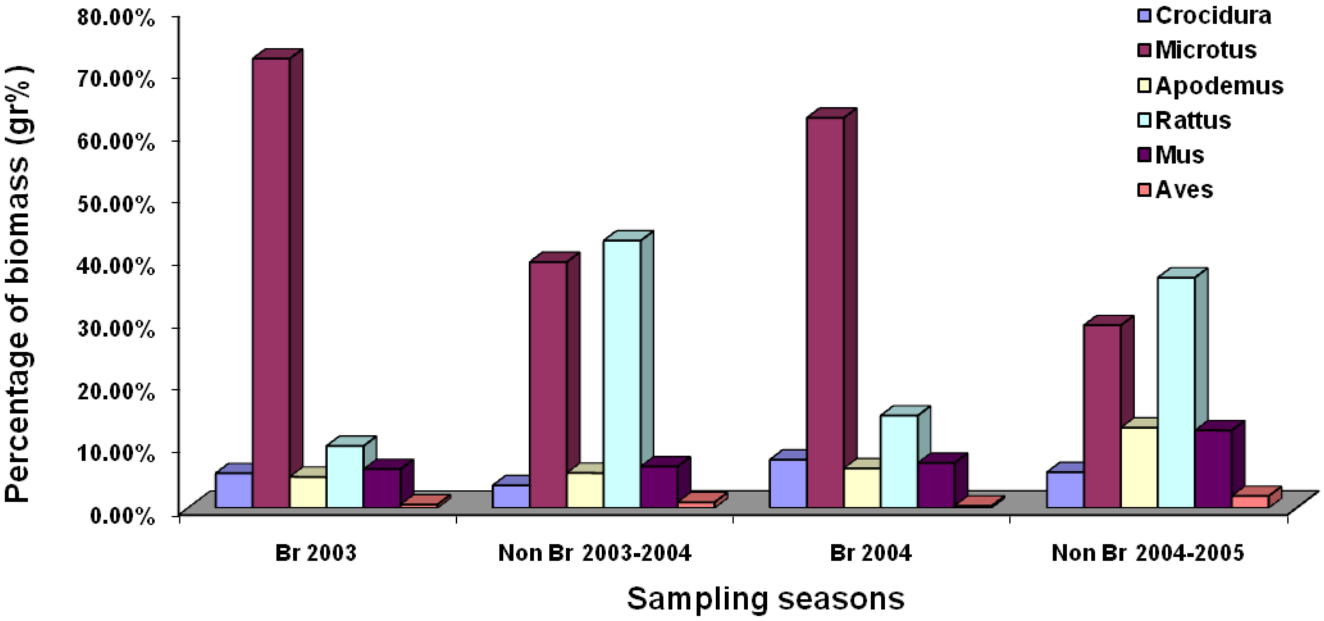


Figure 3.33 Percentages of consumed biomass (gr%) of main prey groups in Barn owl diet during the 4 sampling seasons. Acronyms stand for: ***Br***: Breeding season and ***Non Br***: Non breeding season.

Species richness is gradually increasing between seasons through the years, presenting its maximum value in the non breeding season of 2004 – 2005 (Fig. 3.34). Similarly, diversity index presents higher values during non breeding seasons and is also increasing through the years (Fig. 3.35). The differences between seasons in species richness are statistically significant (one-way ANOVA, $F_{0,05(3,120)} = 4.023$, $p = 0.009$) as well as in the diversity index (one-way ANOVA, $F_{0,05(3,120)} = 14.668$, $p < 0.000001$). Nonetheless, post-hoc Tukey HSD tests revealed that in the case of species richness only the seasonal sample of non-breeding season 2004-2005 is statistically different from the rest samples, whereas the Shannon diversity index presents statistical differences in both non-breeding seasons.

Prey items are more evenly distributed in Barn owl diet during non-breeding seasons and evenness is increasing through the years of the study (Fig. 3.36), presenting the same pattern with the diversity index. Differences between seasonal samples in evenness index are statistically significant (one-way ANOVA, F $_{0,05(3,120)}$ = 10.565, p < 0.00001) with post-hoc Tukey HSD tests indicating that non-breeding seasonal samples are the ones producing the statistical difference.

Mean weight of mammal prey (MWMP) was also calculated for all sampling sites and for each season (Figure 3.37). The seasonal comparison indicated just a slight increase in the mean weight of mammal prey during non-breeding season 2003-2004, but no statistical differences were present between any samples (one-way ANOVA, F $_{0,05(3,120)}$ = 2.365, p = 0.0743).

Finally, the prey items per pellet were calculated for each sampling site and for each sampling season and their mean values were compared and are demonstrated in Figure 3.38. A gradual increase is observed through the years of the study in the mean values or prey items per pellet, during all consequent sampling seasons.

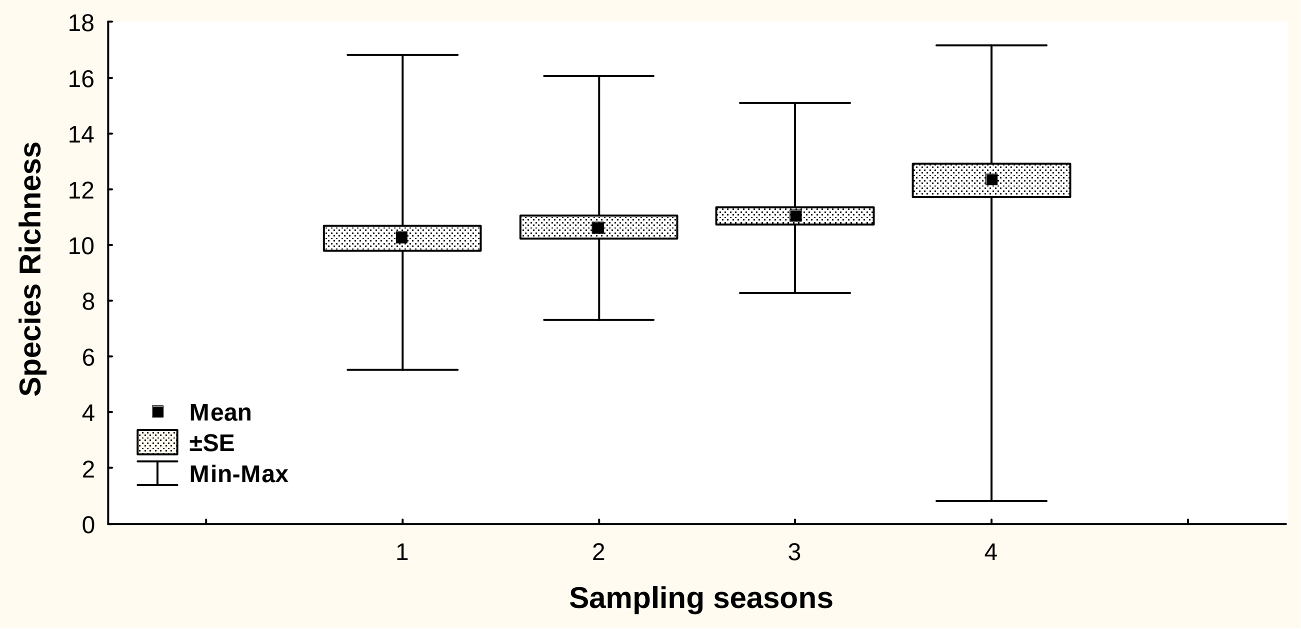


Figure 3.34 Mean values of species richness calculated with rarefaction analysis, for all 31 sampling sites and for each sampling season. Sampling season numbers stand for: ***1***: Breeding season 2003, ***2***: Non breeding season 2003-2004, ***3***: Breeding season 2004, ***4***: Non breeding season 2004-2005.

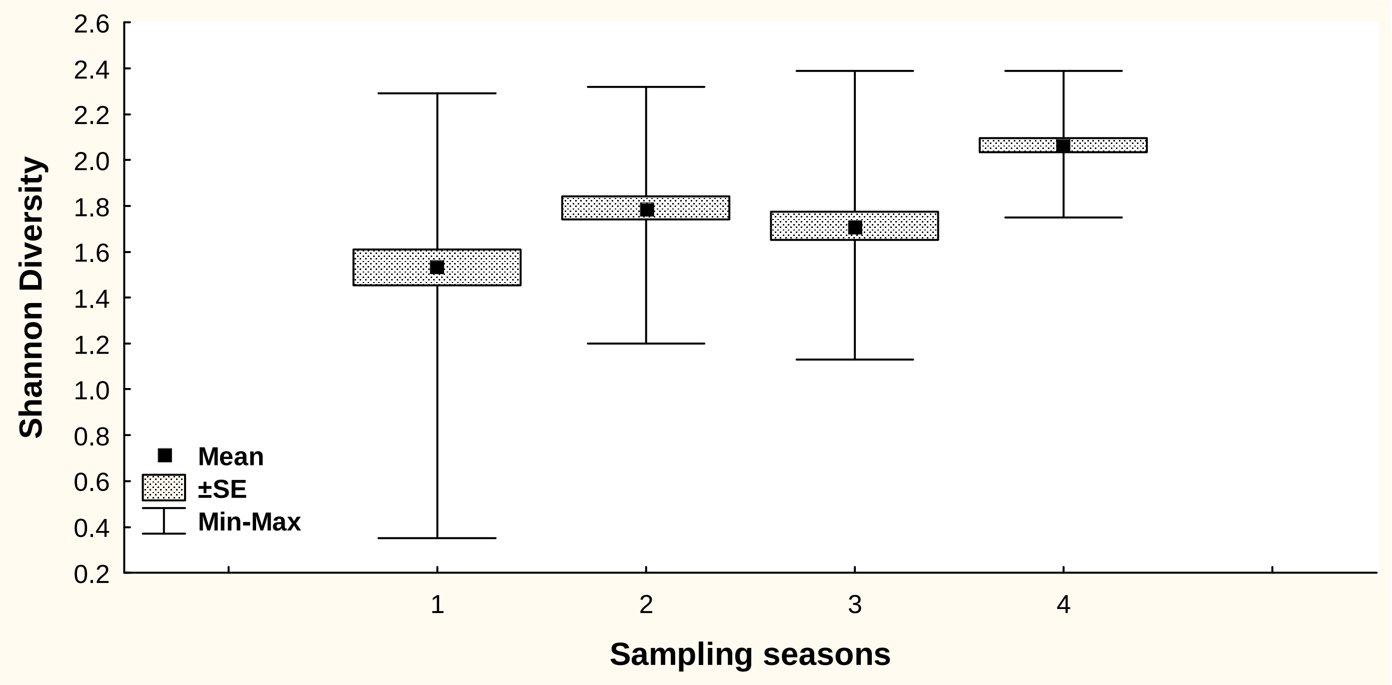


Figure 3.35 Mean values of Shannon diversity (H') calculated with rarefaction analysis and logarithm base e, for all 31 sampling sites and for each sampling season. Sampling season numbers stand for: ***1***: Breeding season 2003, ***2***: Non breeding season 2003-2004, ***3***: Breeding season 2004, ***4***: Non breeding season 2004-2005.

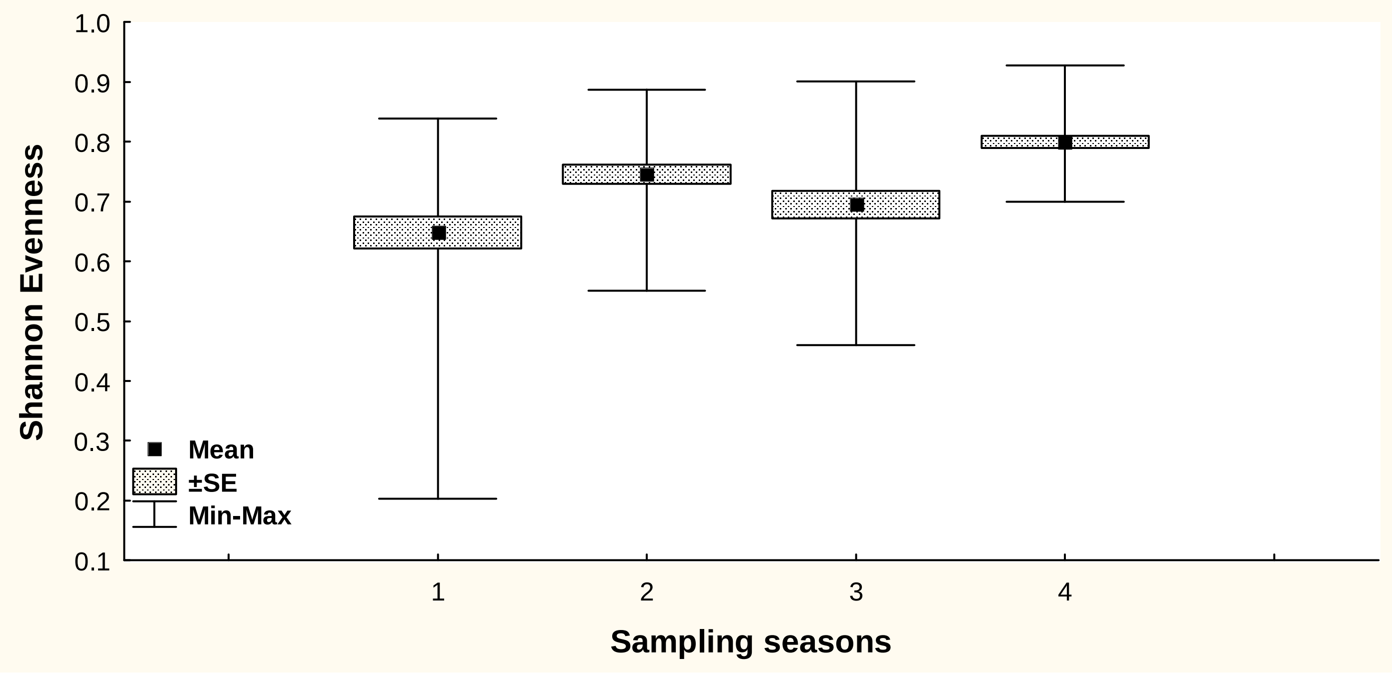


Figure 3.36 Mean values of Shannon evenness (J) calculated without prior rarefaction analysis, for all 31 sampling sites and for each sampling season. Sampling season numbers stand for: ***1***: Breeding season 2003, ***2***: Non breeding season 2003-2004, ***3***: Breeding season 2004, ***4***: Non breeding season 2004-2005.

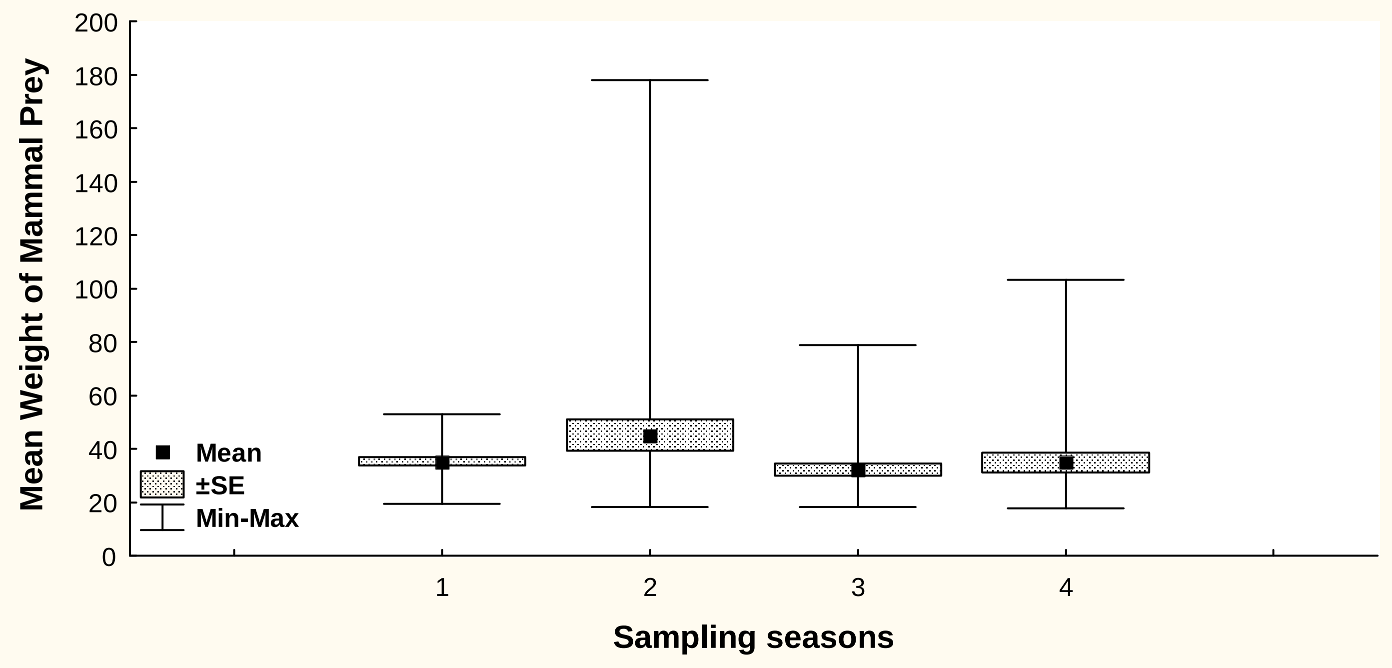


Figure 3.37 Mean values of mean weight of mammal prey (MWMP) calculated for all 31 sampling sites and for each sampling season. Sampling season numbers stand for: ***1***: Breeding season 2003, ***2***: Non breeding season 2003-2004, ***3***: Breeding season 2004, ***4***: Non breeding season 2004-2005.

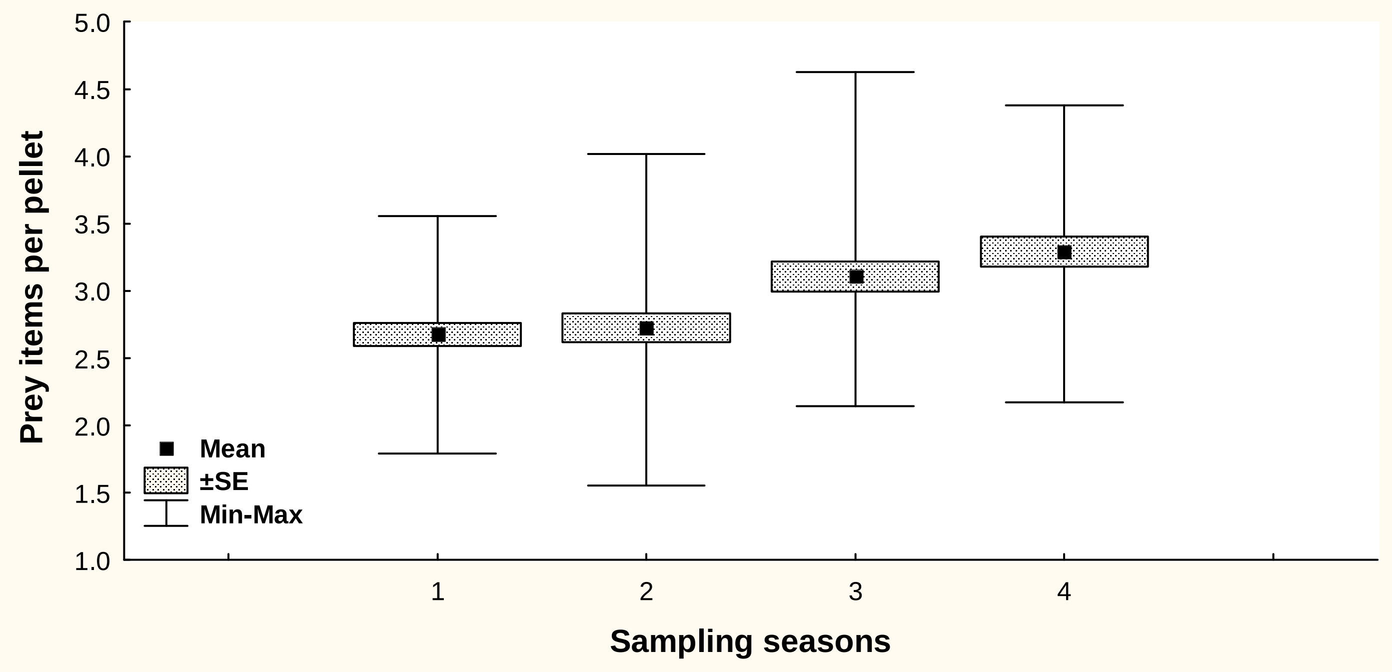


Figure 3.38 Mean values of prey items per pellet calculated for all 31 sampling sites and for each sampling season. Sampling season numbers stand for: ***1***: Breeding season 2003, ***2***: Non breeding season 2003-2004, ***3***: Breeding season 2004, ***4***: Non breeding season 2004-2005.

The differences are statistically significant (one-way ANOVA, $F_{0,05(3,120)} = 8.152$, $p < 0.0001$). Post-hoc Tukey HSD tests indicated that the statistical differences in MWMP values, derived from breeding season 2004 and non-breeding season 2004 – 2005.

3.4 DISCUSSION

The Barn owl in Thessaly preyed heavily on small mammals, which formed 98% of its diet if frequency terms, and comprised 99% of its consumed biomass (Tab. 3.2). This is one of the highest percentages of small mammals recorded in Barn owl diet from Greece up to date. In comparison with insular Barn owl diets from Greece, all of them also dependent highly on small mammals, but presented lower percentages than that of Thessaly (Bohr, 1962; Cheylan, 1976; Akriotis, 1981; Niethammer, 1989; Angelici & Riga, 1994; Alivizatos et al., 2005). In respect to mainland Barn owl diets, only in northern Greece did the small mammals present a similar high percentage forming 98% of the diet (Alivizatos et al., 2005; Alivizatos et al., 2006). In the rest continental geographic locations, the percentages of preyed small mammals were lower from Thessaly ranging from 75% to 90% (Cheylan, 1976; Tsounis & Dimitropoulos, 1992; Goutner & Alivizatos, 2003; Alivizatos et al., 2005).

Species richness in Thessaly was tested both before and after the rarefaction analysis, including the species counts from all 31 sampling sites (Figure 3.2). The significant two-tailed t-test between these groups ($t = 8.40$, $p < 0.001$) indicated that larger samples of Barn owl pellets eventually include some rare species that are scarcely preyed (Taylor, 1994; Krebs, 1999). Such rare mammalian species in Thessaly are the Gray dwarf hamster, the Western broad-toothed field mouse, the Hazel dormouse, the three bat species and of course many avian and insect species (Table 3.2). In comparison with other also rarefied Barn owl diets from Greece, their species richness ranged from 5.97 in the island of Astipalaia (Angelici & Riga, 1994) to 13.99 in the island of Evoia (Akriotis, 1981). Thessaly presented a value of 17.39 after rarefaction analysis, being the highest recorded in Greece. Similarly, diversity presented the higher values among all diets (see Chapter 2 for details). That is also due to the fact that southern Mediterranean climates sustain lower mammal diversities. According to optimal foraging theory, Barn owls are more euryphagous in the Mediterranean basin than in central Europe, where high mammalian diversity produces stenophagous owl diets (Herrera, 1974; Taylor, 1994). Therefore, the fact that Thessaly presented the higher diversity and species richness among all Greek Barn owl diets, suggests clearly that the available prey assemblages of central Greece present low mammalian diversity.

Nonetheless, although species richness was quite high, the number of species which were equally preyed among sites in terms of frequency was 7.19, whereas in terms of biomass, that number was reduced to 5.54 (Figure 3.3). The Box-Whisker plots of Figure 3.3 actually indicate that although many species were revealed from pellet analysis, the owl’s diet in Thessaly mainly depends on a small number of mammalian species, which is even smaller in energetic terms. That is a general pattern encountered in a great number of studies across the world concerning the Barn owl feeding habits (Glue, 1974; Lovari et al., 1976; Morton et al., 1977; Baudvin, 1983; Colvin, 1984; Taylor, 1994; Shawyer, 1998). Specifically in Thessaly, there are five mammalian species which are heavily preyed and actually form the main core of Barn owl diet in frequency terms. In descending order these species are: the Guenther’s vole (28.60%), the Lesser white-toothed shrew (21.43%), the House mouse (12.54%), the East European vole (7.09%) and the Long-tailed field mouse (6.96%).

The owl's diet in Thessaly was mainly consisted of voles which formed the 40% in frequency terms, and more importantly the 50% of consumed biomass (Table 3.2), attributing them as an optimum prey for this generalist predator (Taylor, 1994) in the region. In comparison with conspecific diets from Europe, it is more similar to those of England and Mediterranean France (Glue, 1974; Brown, 1981; Smal, 1987; Cuisin & Cuisin, 1979; Baudvin, 1983, Taylor, 1994; Shawyer, 1998) which are also mainly consisted of voles (40% - 50%). In contradiction the Spanish and Italian Barn owl diets, although they also belong to the Mediterranean basin, they are dominated from shrews and mice, and voles are secondly captured (Herrera, 1974; Lovari, 1976; Herrera & Jaksic, 1980; Contoli et al., 1983; Capizzi & Luiselli, 1995; Torre et al., 1997; Capizzi et al., 1998; Torre, 2001; Varuzza et al., 2001).

Voles' general response in the Barn owl's diet in Thessaly, fitted a highly significant 1st order polynomial model, when tested on the measured environmental gradients (Table 3.10). They appeared to increase strongly in the diet when correlated with irrigated cultivations, as revealed from the general response model (Figure 3.10). Nonetheless, that fact should be interpreted cautiously. Such a trend has of course also been strongly observed in similar highly referenced studies, where voles were more preyed in irrigated areas (Marti, 1988). Marti (1988) proposed that Microtus species are more attached to irrigated agricultural schemes, because they are productive systems and also offer cultivations with adequate vegetation cover. Nonetheless, most vole species in Thessaly are strictly fossorial with nest and nest chambers close to the surface, and they do not tolerate ploughing, and thus arable cultivation schemes (Krystufek & Vohralik, 2005). In addition, when observed the individual response models of Barn owl prey groups, a quite different trend is revealed. When the response of voles included in the owl's diet was tested separately on each environmental gradient, it was apparent that Barn owl didn't capture vole species neither on cereals, nor in industrial cultivations, since the species avoided strongly both arable cultivated schemes (Fig. 3.14, 3.15 & 3.16).

In conclusion, Barn owl captured voles mainly when it foraged over non arable cultivated land (Fig. 3.16), as well as over other land uses and land types, such as set-aside fields and natural grasslands (Fig. 3.15), avoiding any type of arable crop (Fig. 3.14). That result is consistent with those of other more recent studies, where Barn owls captured mainly voles by foraging over non arable cultivated areas (Alasdair, 2000; DEFRA, 2004; Bond et al., 2004; Kasprzykowski & Golawski, 2006). That is due to the fact that most vole species construct their nest chambers and corridors beneath the surface but close to it (<20cm), and therefore are not tolerant with arable land uses where the ploughing of the land destroys their subterranean habitat (Macdonald & Barret, 1993; Krystufek & Vohralik, 2005; Macdonald et al., 2007).

It is also widely accepted that Microtus species are the optimum prey for Barn owl across Europe (Taylor, 1994; Shawyer, 1998; Alasdair et al., 2000), when abundant in the available prey assemblages. Moreover, according to the optimum foraging theory, as prey abundance and mammalian diversity declines, the Barn owl diet becomes more diverse and less profitable prey is captured (Krebs & Davies, 1993; Taylor, 1994; Alasdair et al., 2000). According to the seasonal diet analyses of the present study, in the agroecosystems of central Greece, Barn owl preys on voles which appear to be its main and optimum prey (in frequency and biomass terms) when they are abundant in the studied areas.

On the other hand though, non-arable cultivated land in Thessaly, such as horticultural cultivations, orchards and tree cultivations, vineyards, and some other non arable land uses like set-aside fields and natural grasslands (see Appendix C for details), where voles are highly captured, occupy a total of 5% and 10% of the studied areas respectively. Therefore, since the owl is preying primarily on voles with a significant increase during breeding seasons (Tab. 3.12 & Fig. 3.29), and the habitat where it captures the main bulk of its diet comprises only 15% of the total studied areas, it is clearly suggested that in the agroecosystems of Thessaly, the Barn owl presents a strong habitat selection for its foraging activities. It could also be argued that during breeding seasons in Thessaly, the Barn owl is under more stress since it has to exploit minimum extensions of preferred hunting areas, especially during years with low vole abundances. Although lack of live-trapping sessions doesn't allow testing this hypothesis more rigorously, the multivariate statistical analysis reveals an undoubtedly clear trend. Of course, when voles have explosions in their populations they can disperse and thus be captured in a variety of less favourable habitats and cultivations, but still their main dispersal tank remains the non-arable cultivated land and other non-arable land uses (Krystufek & Vohralik, 2005). That is probably also the reason, why during breeding seasons when vole species were highly captured, and at the same time cereals along with industrial crops dominated the area, voles had dispersed in these habitats as well, and therefore presented higher abundances because until harvest such crops remain unploughed. And finally, that is probably the reason why the biased general response model (Fig. 3.10) was produced.

In most parts of Europe, Barn owl diets include shrews as the usual alternative prey to voles, which often come second in capturing frequency or even substitute voles in periods of low vole abundances (Taylor, 1994; Shawyer, 1998). Similarly in Thessaly, shrews were second in frequency terms forming 26% of the total Barn owl diet, but only 6% of the consumed biomass (Tab. 3.2). As demonstrated from the significant response model that shrews fitted (Tab. 3.10 & Fig. 3.8), they seem to be more attached to soil properties instead of cultivation types or land uses. Specifically, shrews were more abundant in the owl's diet when it hunted over areas which were comprised of Vertisol soil types with argillaceous soil texture (Tab. 3.11, Figs. 3.18 & 3.17). Unlike other parts of central and north Europe, in Mediterranean basin the Lesser white-toothed shrew which was also the main shrew prey in Thessaly, is more attached to humid environments with dense vegetation cover (Vlasak & Niethammer, 1990; Macdonald & Barret, 1993). Since Vertisol soil types with argillaceous soil texture have higher moisture percentages that other soil types (U.S. Department of Agriculture, 1975), it is one possible reason for shrews to be more abundant and more preyed on fields of such soil texture. Moreover, shrews were significantly higher in the owl's diet in arable cultivations (Tab. 3.11 & Fig. 3.16) probably because most arable crop types are also irrigated in Thessaly, and therefore provide additional humidity and dense vegetation cover as needed (cotton, wheat, barley, corn, alfalfa, vetch etc.).

Although in most European Barn owl diets shrews were more abundant during winter, as alternate prey to lower vole densities (Taylor, 1994), in Thessaly a different pattern appears. Shrews were preyed similarly to voles, presenting the same significant seasonal differences and being more abundant during spring and summer (Tab. 3.12 & Fig. 3.28). Moreover, in comparison with vole responses on certain environmental gradients, the shrews followed exactly the opposite pattern. In specific, shrews were significantly more preyed in arable cultivations whereas voles in non-arable crop types (Tab. 3.11 & Fig. 3.16), and voles were significantly more captured in fields with Entisol and Mollisol soil types which usually sustain non-arable land crops, whereas shrews were significantly more preyed in fields with Vertisol soils and argillaceous soil texture which sustain arable and irrigated cultivations (Tab. 3.11, Figs. 3.16, 3.17 & 3.18). Since both voles and shrews present similar seasonal predation patterns, being both more captured during spring and summer, it can be deduced that Barn owl also forages over unfavourable habitats during breeding seasons, in order to capture prey with less energetic compensation. The breeding attempts though, are highly demanding in hunting energy and consumed prey biomass (Taylor, 1994; Shawyer, 1998), so in periods of low vole abundances that fact could possibly have negative implications for the owl's breeding success (number of hatched eggs & fledged nestlings). Finally, shrews are significantly more captured in higher altitudes again oppositely to voles which are more abundant in the lowlands (Tab. 3.11 & Fig. 3.19). That is probably due to the fact that in Thessaly higher altitudes possibly sustain habitats favourable to shrews as described before, or because Guenther's vole which is the main vole specie in the diet, is mainly encountered in quite low altitudes in the Balkan Peninsula (Niethammer, 1982; Krystufek & Vohralik, 2005).

From the group of mice in the owl's diet, Mus and Apodemus species fitted similar significant response models, increasing along the negative values of factor "Intensive Cultivations" (Tab. 3.10, Figs. 3.9 & 3.11). A more detailed approach of the species' response on each independent variable separately, revealed that along the environmental gradient "Intensive Cultivations", Mus species presented opposite trends of abundance in comparison to voles. They were significantly more captured both in cereal and non-irrigated crops as well as in industrial cultivations with intensive irrigation schemes (Tab. 3.11 & Fig. 3.14). In addition, they were also significantly preyed with higher percentages in arable cultivated fields, oppositely to voles (Tab. 3.11, Figs 3.15 & 3.16). Mus species were captured in quite different habitats, due to the fact that both the House mouse and Macedonian mouse which are present in Thessaly, are highly opportunistic animals (Vohralik & Sofianidou, 1987; Auffray et al., 1990; Vohralik & Sofianidou, 1992; Macdonald & Barrett, 1993). Therefore they can exploit an extremely wide range of habitats, and although in central and north Europe are mainly commensal species attached to human and urban environments, in favourable Mediterranean climatic conditions they live independently (Berry, 1981; Macdonald & Barrett, 1993). Moreover, apart from being opportunistic species they also are very weak competitors, and therefore occupy habitats others than those of voles, which are less tolerant in arable land uses, and more specialized and territorial within their home ranges (Sage et al., 1993; Macdonald & Barrett, 1993). Finally, Mus species also responded with significant 2nd order polynomial models on the total length of roads included within the 2 km radius of each study area (Tab. 3.11 & Fig. 3.21). They were highly more captured in study areas with total road lengths of more than 15 km. In a homogeneous agroecosystem like that of Thessaly dominated from agricultural crops, it is quite probable that the construction of roads in order to facilitate machinery transport could create multiple edge habitat effects. Additionally, various telemetry studies have proved that Barn owl realizes most of its captures in edge habitats (Taylor, 1994; DEFRA, 2004). Along with the fact that Mus genera include individuals more agile in avoiding predators in agricultural environments (Taylor, 1994), it is possible that those specific habitats in the agroecosystems of Thessaly which are highly fragmented from road networks, could be more ideal in order to prey on Mus species.

On the other hand, Apodemus species in the Barn owl diet didn't present significant responses in most individual tests. Their general response model on the total of environmental gradients (Tab. 3.10 & Fig. 3.9) indicated that they were less frequent in the owl's diet when it foraged over intensive cultivations and irrigated land. That fact was confirmed from the species' unique significant response on the factor "Intensive Cultivations", where Apodemus species fitted a 1st order polynomial model, and were slightly but significantly more preyed in areas with cereal crops and absence of irrigation schemes (Tab. 3.11 & Fig. 3.14). Since the main Apodemus prey specie in Thessaly was the Long-tailed field mouse, which is also a generalist specie with high adaptability, it can also be encountered in various arable cultivations including cereal crops types (Macdonald & Barrett, 1993). In similar Mediterranean agroecosystems, other authors have also recorded the Long-tailed field mouse more abundant in cereal crops, but it was proved to be exploiting such habitats only occasionally (Alcantara & Telleria, 1991). Nonetheless, the Long-tailed field mouse is one of the most common and abundant small mammal species in the Mediterranean basin, with opportunistic behaviour, which could also be a possible reason for not responding significantly to more gradients, while also being present in heterogeneous habitats (Flowerdew et al., 1985).

Finally, the mammalian genus which was less captured by the Barn owl was the rat group, which included two species and formed only 3% of the total diet in frequency terms (Tab. 3.2). Although forward selection on independent variables for both their marginal and conditional effects, indicated that "River Length" and "Road Length" produced non significant models in both cases (Tab. 3.9), rats responded significantly along these specific gradients. They fitted a 1st order polynomial model on the total of environmental variables, according to which they were more preyed in areas with longer river and road networks (Tab. 3.10 & Fig. 3.7). Since Brown rat is often recorded as semi aquatic specie strongly attached to water habitats, irrigated crops and river banks (Becker, 1978; Glass et al., 1989; Macdonald & Barrett, 1993), it is thus expected to be more preyed when the owl hunted in such areas (Fig. 3.7).

Additionally, when rats' response was tested on each environmental gradient separately they responded significantly along the variable "Road Length", which indicated that they were highly preyed in study areas with road networks longer than 15 km, just like Mus species (Tab. 3.11 & Fig. 3.21). That is probably due to the fact that Brown rat which was more preyed than Black rat (Tab. 3.2), is also a strictly urban specie when not present in aquatic habitats (Taylor & Quy, 1978; Becker, 1978; Macdonald & Barrett, 1993). Therefore, it would be more abundant in study sites with larger urban areas, which eventually support longer road networks. Since rats were significantly more captured during non-breeding seasons (Tab. 3.12 & Fig. 3.31), the results also suggest that during winter the Barn owl forages more over agricultural habitats fragmented from longer river and road networks. That way, by optimizing the energy spent while foraging over preferred edge habitats (Taylor, 1994), the owl can capture a highly compensating prey especially during harsh winter months.

Barn owl predation on rats presented a significant seasonal pattern as mentioned; by capturing them more frequently during autumn and winter seasons (Tab. 3.12 & Fig. 3.31). Moreover, although rats only formed 3% of the diet in frequency terms, they contributed 27% of the consumed biomass (Tab. 3.2), and they were the main biomass source in autumn-winter periods, although minimally preyed (Figs. 3.32 & 3.33). Rat predation followed exactly the opposite seasonal pattern from voles and shrews, which were significantly more captured during spring and summer seasons (Tab. 3.12, Figs. 3.28 & 3.29). That fact suggests that probably during winter the vole abundances are lower, and the Barn owl preys alternatively on rats. Both rat species in Thessaly are a lot heavier than voles, even the subadults. Therefore, they can be highly more compensating in energetic terms, since the harsh winter conditions oblige the owl to limit the spent energy while hunting, and optimize the consumed biomass

(Taylor, 1994). Nevertheless, male Brown rats in low temperatures lack sperm and females do not breed (Becker, 1978; Macdonald & Barrett, 1993), whereas female Black rats usually have a defined breeding period from March to November (Becker 1978; Macdonald & Barret, 1993). That could apply in Thessaly as well since it is a region with harsh winters and low temperatures, and in that case, rats couldn't have higher populations during winter. That fact would indicate that Barn owl captures them selectively because they are a more compensating prey during winter (Bontzorlos et al., 2007b; 2007c; Bontzorlos et al., 2009b), and not because they are abundant. On the other hand, since Barn owl diet reflects changes occurring in the available mammal populations, it is quite more possible that rats presented higher abundances during autumn and winter seasons, while voles didn't. If both rat species are provided with adequate food sources they can breed all year long, and thus present actually higher abundances during winter (Becker 1978; Macdonald & Barret, 1993). Live trapping sessions have to be realized in order to test this hypothesis further, but independently of that, it is certain that during winter the Barn owl spends more time foraging over river banks, ditches, and urban areas with longer road networks, since it captures rats significantly more in such habitats. The percentage of rats recorded in Barn owl diet from Thessaly during its non-breeding seasons, is also one of the highest in the Mediterranean basin (Bontzorlos et al., 2005; Bontzorlos et al., 2007b).

In respect to bird and insect prey groups, although 13 avian species and 8 insect species were captured from the owl, they are considered as negligible prey since they formed 2% of the diet in frequency terms and 1% in biomass (Tab. 3.2). Nonetheless, birds were significantly more captured during winter (Tab. 3.12 & Fig. 3.27), because they are easier to catch at their communal winter roosts, a hunting technique used successfully by Barn owls (Sage, 1962; Fernandez & Garcia, 1971). Insects on the other hand were more captured during spring and summer seasons as expected (Tab. 3.12 & Fig. 3.30). Both insects and birds fitted significant 2nd order polynomial models on the total of environmental gradients (Tab. 3.10, Figs. 3.12 & 3.13). Nonetheless, since these groups were minorly preyed, they produced quite complex response models, and not too much credit should be given to their interpretation. When tested separately though on each environmental gradient, birds were significantly more captured in study areas with cereal crops (Tab. 3.11 & Fig. 3.14), and insects in study areas with higher altitudes (150-300m) and longer road networks (Tab. 3.12, Figs. 3.19 & 3.21).

In conclusion, Barn owl predation on different prey groups demonstrated strong seasonal patterns mainly when capturing voles, shrews and rats. Voles and shrews were significantly more preyed during breeding seasons whereas rats during autumn and winter periods (Tab. 3.12, Figs. 3.28, 3.29 & 3.31). Birds and insects, although considered as negligible prey due to very low frequency and biomass percentages, were also significantly more preyed during non-breeding and breeding seasons respectively (Tab. 3.12, Figs. 3.27 & 3.30). On the other hand, Mus and Apodemus species were taken in the same levels without significant differences, increasing in the Barn owl diet only during the last sampling season (Tab. 3.12, Figs. 3.25 & 3.26). Apart from these specific patterns though, which occur within each prey group, another general pattern can also be observed in the intake of prey. During the three year study, voles decreased gradually in the owl’s diet whereas all the other prey groups presented the opposite pattern, increasing from 2003 to 2005 (Fig. 3.32). That fact is proof that Barn owls in Thessaly select their prey according to the optimum foraging theory, like in many other parts of the world. More specific, in the year 2003 which was apparently a high vole year, the Barn owl preyed heavily on vole species.

As a result the diet was comprised on a smaller number of species, demonstrating that voles are its optimum prey, as also proved in numerous other studies (Fig. 3.34). As voles decreased through the years, the owl preyed gradually on a broader number of species. Thus, species richness in the owl's diet increased significantly in the last sampling season (Fig. 3.34). That change is also demonstrated in the significant increase of diversity and evenness indices (Figs. 3.35 & 3.36). Only the average weight of mammalian prey (MWMP) didn't differ significantly between seasons, but it only presented higher maximum values during non-breeding seasons due to higher rat predation (Fig. 3.37).

As species richness increased through the years and different prey other than voles was included in the owl's diet, species like shrews (Crocidura) and mice (Mus & Apodemus) which are less compensating though in energetic terms, were more captured (Figs. 3.32 & 3.33). That fact was also apparent in the mean values of prey items per pellet, which also increased significantly from 2003 to 2005 (Fig. 3.38). More prey items per pellet, actually indicate more hunting efforts and more energy spent while hunting, in order to capture more prey items which will finally meet its energetic needs (Taylor, 1994).

Summarizing, when voles are abundant in the agroecosystems of Thessaly, the Barn owl is hunting mainly on vole species which are its optimum prey worldwide, producing stenophagous diets with low diversity indices. On the other hand, a very small percentage of land uses favourable to voles are present in Thessaly. Although they can be captured in a variety of heterogeneous habitats when abundant, their main dispersal tank is non-arable land with irrigated cultivations. Therefore especially during breeding seasons when voles are more preyed, Barn owl demonstrates a strong habitat selection for its foraging activities. That fact is stressful for the owl during the highly demanding breeding seasons, and could also have negative implications in years of low vole abundance. Shrews are also highly preyed but they are captured in unfavourable foraging habitats for the Barn owl, and compensate minimally in biomass terms. Rats appear to be the alternative compensating prey during autumn and winter seasons which sustain lower vole numbers, and the owl captures them by foraging more over habitats with longer river and road networks. According to the optimum foraging theory, when mammal diversity decreases and optimum prey species like voles present lower numbers, the Barn owl preys on more species and captures less profitable prey. That was also the case of Thessaly, where the owl's diet changed gradually to be more euryphagic from 2003 to 2005. Moreover, its hunting efforts increased in order to capture more prey items, which energetically are less compensating, and that fact could also have negative implications in breeding success. Therefore, the Barn owl in Thessaly in periods of high vole abundance presents a specialist's behaviour and a strong microhabitat selection, but as vole numbers decrease, the owl is feeding in a highly opportunistic way foraging also over less favourable habitats.

3.5 RESUMEN

3.5.1 Introducción

La dieta de la Lechuza común ha sido más estudiada que cualquier otra rapaz a nivel mundial. Ello se debe a su distribución amplia, y a la facilidad con que sus egagrópilas se encuentran en el campo, y su análisis en laboratorio. Durante el periodo 1960-1980 la mayoría de las publicaciones sobre la dieta de la Lechuza común se concentran en Norte América y Europa central y norte. Después de los 80s, España e Italia también contribuyen en este aspecto científico para la Europa

Mediterránea; y hoy en día cada país participa en la bibliografía mundial con más que 100 artículos publicados.

Por otra parte, aunque la Lechuza común cría en varias regiones de Grecia continental y insular, la investigación realizada en el país sobre la especie es limitada. Hasta la fecha, solamente existen 13 publicaciones, y todas analizan la dieta de la especie en regiones diferentes. Adicionalmente, Tesalia, como el ecosistema agrícola de mayor superficie del país, y sosteniendo posiblemente la población más numerosa, no ha sido estudiada. Por tanto, los objetivos principales del presente capitulo son: 1) Presentar datos detallados y registrar la existencia de la población de Lechuza común en Grecia central. 2) Estudiar la ecología trófica de la especie, explorar las dimensiones de varios nichos ecológicos, e investigar los patrones existentes y diferencias geográficas y estacionales. 3) Explorar las relaciones e interacciones entre depredador, hábitat y presas.

3.5.2 Material y métodos

Para localizar los lugares de cría de la Lechuza común en zonas agrícolas de Tesalia, entre Diciembre de 2002 hasta el Marzo de 2003, se visitaron 300 pueblos, y todos los lugares de posible nidificación fueron revisados. Un total de 31 parejas en diferentes regiones han sido incluidas en el presente trabajo. En Abril 2003 todos los lugares de cría fueron limpiados de egagrópilas antiguas; de tal manera las próximas egagrópilas recopiladas reflejen las estaciones concretas de la dieta. Cuatro muestras han sido recogidas en cada una de las 31 localidades. La primera en Septiembre de 2003, la segunda en Marzo de 2004, la tercera en Septiembre de 2004 y la última en Marzo de 2005. De tal manera, las egagrópilas regurgitadas reflejan dos periodos reproductores y dos no reproductores. Un total de 10065 egagrópilas fueron recopiladas, con un total de 29061 presas identificadas. Las egagrópilas fueron analizadas en el laboratorio en seco, y la identificación de las presas se realiza con el uso de un microscopio estereoscópico y la ayuda de claves especiales. La biomasa consumida se ha calculado como porcentaje, multiplicando el número de individuos de cada especie en cada dieta por su biomasa respectiva, y luego el conjunto se dividió con la biomasa total consumida en cada dieta. El Peso Medio de Presas Micromamíferos (PMPM)- MPMP en el texto en inglés- se calculo multiplicando cada individuo por su peso medio, añadiendo los productos, y dividiendo el total por el número de presas micromamíferos en la dieta. Los nichos ecológicos han sido calculados a través de tres índices de diversidad. La riqueza de las especies, que es el índice más sencillo, se calcula como el número de las especies presentes en la dieta de cada región estudiada. El índice de la diversidad H´ se calcula según Shannon y Wiener, con base logarítmica e. Sin embargo, las diferentes muestras se diferencian en tamaño y por lo tanto ambos índices de riqueza de las especies y de diversidad se calculan con la aplicación de rarefacción, al nivel de la muestra con el tamaño menor. El índice de equitabilidad J´ se calculo también en respecto a Shannon y Wiener, sin la aplicación de rarefacción.

3.5.3 Análisis estadístico

La existencia de varias muestras, específicamente un total de 124 (cuatro muestras estacionales por 31 localidades diferentes), exigen un análisis estadístico multivariante, para explorar correlaciones e interacciones entre variables dependientes e independientes. Otros métodos como los índices de similitud sencillos (Bray Curtis, Canberra, Índice de Horn y más) y métodos Clúster no son adecuados en este caso. Por lo tanto, para analizar el cambio de la composición en las comunidades de los micromamíferos incluidos en la dieta, en varios gradientes ecológicos, los análisis de ordinación son las herramientas para trabajar, con el uso del software CANOCO.

En primer lugar, se aplica un Análisis Factorial en las variables independientes, para reducir su número, detectar la estructura y las relaciones entre ellas, y producir nuevos factores no correlacionados, combinando las variables independientes originales. El Análisis Factorial ha sido aplicado a dos grupos de variables ambientales homogéneos, en "Cultivos Agrícolas & Usos de Tierra", y "Tipos & Estructura del Suelo". Tres variables ambientales de naturaleza diferente (Longitud de ríos y carreteras, y Altitud) no han sido incluidas en el Análisis Factorial, aunque fueron utilizadas después sin este análisis.

Una vez que son producidos los nuevos factores, se construyen dos matrices. Una incluye los "scores"- parámetros- factoriales y las tres variables ambientales no analizadas, con sus valores por cada muestra y cada estación. La otra matriz, tiene las frecuencias relativas de los grupos de presas incluidas en la dieta, transformadas con el método de arcosino a nivel de género. Ambas matrices fueron introducidas en el CANOCO. En primer lugar, un Análisis de Correspondencias (DCA) ha sido aplicado en la matriz de las variables dependientes (grupos de presas), y demostró un valor menor de 3, indicando que métodos lineares deben de ser utilizadas posteriormente. Después, un Análisis de Redundancias (RDA) ha sido aplicado entre ambas matrices, y el espacio multifactorial de las variables independientes, produciendo nuevos "axis"- ejes canónicos en dos dimensiones, los cuales reflejan la varianza máxima de los valores de las variables dependientes que puede ser explicada por las variables independientes. Estos ejes funcionan en las próximas pruebas como variables independientes para explorar su efecto en las variables dependientes, y producen modelos polynomiales de 1era, 2nda y 3ra orden, según los Modelos Lineares Generalizables y el criterio del Akaike (AIC).

3.5.4 Resultados y Discusión

La Lechuza común en Tesalia demostró varios patrones de depredación estacional. Topillos y musarañas son significativamente mas capturados durante la época reproductora, mientras tanto las ratas solo durante otoño e invierno. Las aves también fueron más capturadas durante otoño y invierno, e insectos fueron más cazados durante primavera y verano respectivamente, pero con diferencias no significativas entre estaciones. Por otra parte, las especies del género Mus y Apodemus han sido consumidos sin diferencias entre estaciones, pero aumentaron significativamente más en la dieta de la última muestra. Paralelamente a este patrón, se ha observado que a lo largo de los tres años del estudio, los topillos decrecieron fuertemente, mientras todos los otros grupos de presa aumentaron. Este hecho, en combinación con el aumento de todos los índices de diversidad estacionales a lo largo de los tres años, sugiere que según la teoría del forrajeo óptima, los topillos forman la presa optima para la Lechuza en la región.

En general, cuando los topillos son abundantes en los ecosistemas agrícolas de Tesalia, aparentemente la Lechuza se nutre principalmente de ellos, una dieta estenofága. Sin embargo, el tipo de hábitat donde la Lechuza captura los topillos es la definida como los usos de tierra no arada. La tierra no arada ocupa una extensión mínima en las áreas estudiadas, produciendo posiblemente un caso de búsqueda intensiva en ellas, especialmente durante la época reproductora cuando se consumen significativamente más topillos.

Las musarañas también han sido capturadas con altos porcentajes, pero en hábitats no favorecidos por la Lechuza común, y además energéticamente le compensaron mínimamente. Las ratas parece de ser la presa alternativa durante otoño e invierno, cuando las poblaciones de topillos presentan bajas valores de diversidad en el campo y parecen decrecer. La Lechuza captura las ratas en hábitats que incluyen redes de largos ríos y carreteras. La depredación sobre ellas ha sido mínima en respecto a la frecuencia relativa, pero compensaría enérgicamente.

Finalmente, el cambio de la dieta de ser estenofága en 2003 cuando los topillos eran aparentemente abundantes, a ser eurífaga a finales de 2005, año en que los topillos decrecieron en la dieta y supuestamente en campo también, indica fuertemente que la Lechuza es un depredador generalista que puede explotar varios recursos tróficos, pero en Tesalia como en otras regiones del mundo, se nutre principalmente de topillos cuando son abundantes en el campo, demostrando una técnica de forrajeo optima.

CHAPTER 4

Distribution and Structure of Small Mammal Populations in the Agricultural Ecosystems of Thessaly, central Greece. Associations with Habitat, Soil Types and Land Uses

4.1 INTRODUCTION

Small mammals represent a heterogeneous group from a taxonomic point of view as they include among others, species from the orders Insectivora and Rodentia. However, species within this group share biological and ecological features related to their small size. They have high metabolic rates, short life spans, fast metabolism, high reproductive rates and they respond quickly to environmental changes (Krebs, 2006). Their demographic plasticity, along with their high turnover rate and adaptability (Promislow & Harvey, 1990), have made small mammals an interesting group for studying demography and population dynamics both from theoretical and empirical approaches (Stenseth, 1985; Montgomery, 1989a,b). Small mammals are also considered as the ideal taxonomic group to be used as models for addressing questions at different spatial scales and in time (Barrett & Peles, 1999; Manning & Edge, 2004).

Trapping is the most common method used to sample small mammal communities (Gurnell & Flowerdew, 1990). However, trapping always exhibits biases according to traps and baits used (O'Farrell et al., 1994) and is sensitive to sampling effort (Yu, 1994). Indirect approaches have also been used in studies of small mammal communities' composition and distribution, such as the study of gut contents of specialized small mammal predators, like reptiles and amphibians (Bury, 1972; Capula & Luiselli, 1990; Parmley & Parmley, 2001), the analysis of fox and genet scats (Agnelli & Marinis, 1993; Torre et al., 2004), and the analysis of prey items in owl pellets (Taylor, 1994; Krebs, 1994; Alasdair et al., 2000, Baleiauskiene et al., 2006; Gryz et al., 2008).

From the total of indirect approaches that have been applied up to day in order to study various aspects of small mammal populations, the most effective and extensively used is the analysis of Barn owl pellets (Taylor, 1994; Shawyer, 1998; Torre et al., 2004). Barn owl pellets provide a true picture of the proportions of vertebrate prey that owls consume (Taylor, 1994), due to the generalized feeding habits of this predator (Korpimaki, 1992; Díaz et al., 1996). Furthermore, changes in diet as seen in pellets reflect real changes in availability of small mammal species (Clark and Bunck, 1991; Torre et al., 2004). This method has been successfully used to study patterns of small mammal distribution at a geographical scale, on both gradients of elevation and latitude (Alegre et al., 1989; Clark and Bunck, 1991; Moreno & Barbosa, 1992; Torre et al., 1996; Torre, 2001), as well as at landscape and habitat scales (Cooke et al., 1996; Torre et al., 1997).

Additionally, Torre et al. (2004) have proved that when the study area is open agricultural land with no woodland nearby, the study of richness, composition and abundance of non-volant small mammal communities in various environmental gradients, is better estimated through Barn owl pellet analysis. The same deduction stands when studying non-volant small mammal assemblages, in study areas with altitude from 0 to 300m (Torre et al., 1997; Torre et al., 2004).

The region of Thessaly in central Greece presents both these characteristics, forming a study area of low altitude (0 – 300m), which is also dominated from agricultural crops. Therefore, the non-volant small mammal assemblages of Thessaly were studied through the indirect and non-invasive method of Barn owl pellet analysis. Moreover, Greece is a geographical region with a huge lack of information concerning small mammal populations, concerning both the species' distribution as well as the dynamics of their populations. Since the realization of the collective works that Niethammer and Krapp published (1977, 1982, 1990), very few new information has been published on small mammal fauna from Greece. Some recent but few papers come from northern Greece (for details see: Krystufek & Vohralik, 2005) and some investigators have worked recently with small mammal genetics (Papa et al., 2001; Tea et al., 2004; Tryfonopoulos et al., 2005). Additionally, in the recent Atlas of European Mammals (Mitchell-Jones et al., 1999), some species are mal represented in Greece due to lack of information. Especially in the region of Thessaly, some species are noted as absent from the area, a fact which in various cases is not consistent with the results of this work. Hence, the aims of this chapter are:

Use the analysis of Barn owl pellets in the area of Thessaly as an indirect, non-invasive and appropriate method, for the study of non-volant small mammal populations in order to:

1). Present maps with new data on the distribution of small mammal species in the region of Thessaly.

2). Explore the relationships and interactions between small mammal species, habitat, soil types, agricultural crops and land uses.

3). Define the patterns of species richness and diversity in small mammal populations in various different environmental gradients.

4.2 METHODS AND MATERIAL

The most adequate method up to day for locating Barn owl nesting and roosting sites, is the exhaustive search of all possible breeding places (Taylor, 1994; Shawyer, 1998). As mentioned analytically in Chapter 3 (see p: 127) such was the case of Thessaly as well. From December 2002 to March 2003, daily exhaustive searches were realized in all four prefectures of Thessaly. The total of 31 sampling sites which were finally included in the study are demonstrated in Figure 3.1, and their coordinates are presented in Table 3.1 (Chapter 3). From April 2003 to March 2005, 4 samplings were realized in each one of the 31 breeding sites. The first took place in September 2003, the second in March 2004, the third in September 2004 and the 4th and last one in March 2005. A total of 10.065 pellets were collected which were afterwards analyzed in the laboratory according to the "dry" method (Marti, 1987; Yalden; 2003), and small mammal prey items were identified with reference books (Toschi & Lanza, 1959; Toschi, 1965; Chaline et al., 1974; Lawrence & Brown, 1974; Niethammer & Krapp, 1977, 1982, 1990; Krystufek & Vohralik, 2005).

Species richness which is the oldest and simplest concept of species diversity was calculated as the number of species in a community or in a sample. Small mammal diversity was calculated according to the Shannon-Wiener diversity index (Pianka, 1980):

$$H' = -\sum_{i=1}^{n} pi \ln pi$$

where *pi* = proportion of species i in each sample (seasonal or total) and ln = natural logarithm (base e). In order to avoid bias in the data, both diversity and species richness were calculated using the rarefaction method due to differences in the sampling effort between seasons, with the softwares: Ecosim (Gotelli & Entsminger, 2001) and Past (Hammer et al., 2001). Evenness was calculated with the Shannon-Wiener function J' (Krebs, 1999) using the softwares Biodiversity Pro (McAleece et al., 1997) and Ecological Methodology (Krebs, 2002), according to the equation:

$$J' = \frac{Observed Shannon Measure of\ Niche Breadth H'}{Maximum Possible Shannon Measure}$$

The equitability index (J') was calculated without prior rarefaction of the data, since no available software could perform the task. Hence, there is possibility of some bias in certain cases, although it would possibly be insignificant due to the large size of each sample (Krebs, 1999).

4.2.1 Statistical analysis

In this chapter the analysis focuses on small mammals' communities' composition and their changes along various environmental gradients. The main difference from 3rd Chapter is that in this case the procedure is realized on a specie level, analyzing each one of the 15 small mammal species present in the study area, as they were recovered from pellet analysis. As mentioned in Chapter 3, in order to test which environmental gradients have a significant effect on small mammal species' abundance and distribution, the first step is to define which independent variables will be included in the analysis (Ter Braak & Smilauer, 2002).

Since many predictor variables were recorded, and some of them were highly correlated between them, Factor analysis was applied in order to reduce the variables (see Chapter 3 for details), explore the structure and relationships between them, and produce new non-correlated factors (Lindeman et al., 1980; Hurley et al., 1997; Stevens, 2001; Costello & Osborne, 2005).

Once explanatory variables were properly processed and defined through factor analysis, an appropriate method had to be applied in order to explore the gradual change in community composition of dependent variables (small mammal species), and how is it affected by different environmental gradients (new factors & variables). The gradual change in community composition is often dependent upon certain environmental variables, which cannot be identified in nature as visible spatial gradients, neither as uniquely measurable environmental factors (Leps & Smilauer, 2003). Therefore, the tools for analyzing this continuity of change are the ordination methods (Ter Braak & Smilauer, 2002). Although the evolution of ordination methods since the early 1950's has radiated into a confusing mixture of techniques (Ter Braak, 1988; Ter Braak, 1994), those methods which are widely used and accepted nowadays are summarized and included in the software Canoco, version 4.5 for Windows (Ter Braak & Smilauer, 2002; Leps & Smilauer, 2003).

In order to introduce the data in Canoco, a matrix was firstly constructed including the relative frequencies (n%) of each one of the 15 small mammal species which were recorded in Thessaly, for each season and each site. Then, the "species" matrix (Ter Braak & Smilauer, 2002), was introduced in the software in order to realize an indirect gradient analysis, which is the first step of ordination analysis. Indirect gradient approach actually performs a Detrended Correspondence Analysis (DCA) on the "species" matrix, which measures the beta diversity in community composition (the extent of species turnover) as it is formed within the "species" matrix alone (Leps & Smilauer, 2003). The results are expressed in gradient lengths, and when the largest gradient's value is more than 4, unimodal methods should be used in the next steps of ordination analysis. If the value is less than 3, then linear methods should be used (Ter Braak & Smilauer, 2002), which is the case of Thessaly.

A similar matrix was constructed secondly which included the factor scores of each one of the new factors, and the values of any independent variables which weren't included in the factor analysis procedure. A total of 124 factor scores and values were included for each factor and each independent variable respectively (31 sampling sites, 4 sampling seasons). That second matrix, which is called "environmental" matrix in Canoco terminology, was introduced along with the "species" matrix in the software, and a direct gradient analysis was realized on both (Ter Braak & Smilauer, 2002). The direct gradient analysis, or else constrained analysis, is creating from the multidimensional space of independent variables ("environmental" matrix) new axes in two dimensions. These newly produced axes actually resume the greatest data set variability of response variables ("species" matrix) that can be best explained by the predictor variables ("environmental" matrix). Detrended Correspondence Analysis (DCA) in the case of Thessaly, suggested that direct gradient analysis should be applied using linear methods (gradient length < 3), an ordination technique known as Redundancy Analysis (RDA).

The first part of Redundancy Analysis (RDA) is a forward stepwise selection on the predictor variables using Monte Carlo permutation tests. Monte Carlo permutation tests actually generate the "null hypothesis", according to which the response variables are independent of any of the predictor variables. Monte Carlo permutation tests reshuffle (permute) the samples (which are the "rows" or else "cases") in the "environmental" data set matrix, while keeping the corresponding values in the "species" data set matrix intact. That way in each case, the value of test statistics is calculated by exploring for the "best fit" model.

Hence, Monte Carlo permutations finally evaluate each and every one of the independent variables included in the "environmental" data set matrix, both for their conditional and marginal effects. A conditional effect is the effect that each explanatory (environmental) variable has on the response variables, beginning from the most important, and adding each time in the model the next more important. On the other hand, a marginal effect is the effect of each predictor variable on the response variables, if it is used as the only explanatory variable in the model.

The second part of Redundancy Analysis (RDA), is the construction of new axes in two dimensions, which concentrate the greatest data set variability from response variables ("species" matrix) that can be best explained by predictor variables ("environmental" matrix). For that reason it is also called a "constrained" ordination technique because the new gradients, or else the new axes that this methods explores and defines are further restricted. In contradiction, Detrendend Correspondence

Analysis (DCA) which is an unconstrained ordination technique, only explores the variability within the "species" matrix alone. The number of newly produced axes from Redundancy Analysis (RDA) varies and depends on the total variability of each data set (Ter Braak & Smilauer, 2002). Nonetheless, the decision about how many interpretable axes will be used in the next steps of the analysis is an easy task, because the significance of each new canonical (constrained) axe is tested, and measured in percentages of explained variance. For practical reasons usually, only the first two axes are used when visualizing the results in order to perform more statistical tests. When the first two axes also explain a high percentage of the total variability, then the results are even more solid (Ter Braak & Smilauer, 2002). If not, incorporating more in the analysis could be a tedious task, and not easily interpreted (Leps & Smilauer, 2003).

Once the new axes are produced through Redundancy Analysis (RDA), the next step is to test the effect that the "environmental" matrix has upon the change of composition in the "species" matrix, or else the effect that independent variables have on the dependent ones. The newly produced axes from RDA, summarize the maximum variance within the independent variables' data set ("environment" matrix) which actually is the maximum variance of environmental gradients recorded in the study area. Canoco then realizes a test on the effect that these axes have (summarizing the total "environmental" matrix variability) on each one of the dependent variables (small mammal species) separately. That way Canoco explores which kind of model (1^{st}, 2^{nd} or 3^{rd} order polynomial model) fits best the response of each dependent variable on the total of independent ones. The choice of "best fit" model is realized with the criterion of Akaike (AIC), and the regression models which finally fit best the response of each dependent variable, are tested for their significance with the use of Generalized Linear Models, an application also included in Canoco.

In order to test further and realize better the effect and interactions between various environmental gradients and the change of species composition, Canoco also tests the response of each dependent (small mammal species) variable on each one of the independent (environmental) variables, but separately this time. The choice of "best fit" model on the response of each dependent variable in that case is also realized with the criterion of Akaike (AIC). The statistical significance of each model is realized again with the use of Generalized Linear Models.

Therefore two groups of statistical tests are realized: Firstly the effect of the total of environmental gradients (independent variables) which is summarized in two dimension axes produced from Redundancy Analysis (RDA), on each dependent variable (small mammal species), and secondly the effect that each independent variable has separately on each dependent. Results of both tests are also visualized with the utility Canodraw, included in Canoco software version 4.5.

4.3 RESULTS

Since many independent variables were correlated between them, Factor analysis was applied in order to reduce the variables, explore the structure and relationships between them, and produce new non-correlated factors. The steps followed are the same as explained in Chapter 3 (p: 149) and are demonstrated in Figures 3.4 and 3.5 (number of eigenvalues vs their values), and in Tables 3.5 to 3.7 (Chapter 3, pp: 153-154). Six new factors were produced from Factor analysis on the two groups of predictor variables, "Agricultural Crops & Land Uses" and "Soil Types & Soil

Texture", and the original variables which define them are demonstrated in Table 3.7 (Chapter 3, p: 154).

The six new factors were renamed according to their attributes (Table 3.7), as Intensive Cultivations, Land Uses, Arable Land, Soil Texture, Soil Type E,M & V and Soil Type I&V. Additionally, three variables (River length, Road length & Altitude) were not included in Factor analysis due to their different nature from the analyzed groups. Therefore, a total of 9 new non-correlated factors-variables formed the data set of independent variables, which were included in the "environmental" matrix.

A similar matrix was constructed with the percentages of small mammal species transformed with the arcsine method, which formed the "species" matrix, and it was introduced in Canoco for an indirect gradient analysis. The Detrended Correspondence Analysis (DCA) that was realized on the "species" matrix produced gradient lengths which are demonstrated in Table 4.1, and since the largest gradient's value is less than three (2.205), therefore linear methods should be used in the next step of direct (constrained) gradient analysis.

The "environmental" matrix was then also introduced in Canoco, and before the constrained ordination a forward stepwise selection was realized on the independent variables. The marginal effects of independent variables indicated that the factors Soil texture, Intensive Cultivations and Land Uses are the three more important affecting small mammal species' composition (Table 4.1). When the predictor variables were tested for their conditional effects, four factors (Soil texture, Intensive Cultivations, Land Uses & Soil E,M&V) maintained the same high level of significance when introduced in the model ($p=0.002$). Finally only the factor "Soil type I&V" and independent variable “River Length” do not produce a significant statistical model when added with the rest environmental variables (Table 4.1).

After forward stepwise selection, Redundancy Analysis (constrained ordination) was realized on both “species” and “environmental” matrices. The first two axes explained the 73.4% of the variability, whereas the third and fourth axes only added the 14.5% and 6% respectively to the total variance (Table 4.2). Therefore, since the first two axes explained almost 75% of the variance, as well as for practical reasons, these two axes will be the only ones included in the next steps of constrained ordination. Visualization of the results along with the realization of further tests will be realized on a canonical axes system constructed by these first two axes, as indicated in Table 4.2.

The response of each dependent variable (small mammal species) on these two axes was further tested with Redundancy Analysis and the use of Generalized Linear Models (Table 4.3). The criterion of Akaike (AIC) explored which kind of model fits best the response of each dependent variable. Some dependent variables had a linear response and fitted to a 1st order polynomial model, some fitted to 2nd order polynomial models, and some didn’t’ present any significant response and were rejected through the “null model” selection. According to the summarized results demonstrated in Table 4.3, the species Bicoloured shrew (*Crocidura leucodon*), East European vole (*Microtus levis*), Yellow-necked field mouse (*Apodemus flavicollis*) and Brown rat (*Rattus norvegicus*) didn’t fit any response model and were rejected (null model selection), whereas Western broad-toothed field mouse (*Apodemus epimelas*) although it fitted a 2nd order polynomial response model, its response wasn’t significant (p=0.059). Therefore, a total of 10 small mammal species fitted statistically significant models, and will be included in the next parts of analysis.

Table 4.1 Indirect gradient analysis (DCA) taking into account only the variability of "species" matrix (dependent variables), and direct gradient analysis (RDA) taking into account the variability of both "species" and "environmental" (independent variables) matrix.

Detrended correspondence analysis (DCA)				
Axes	**1**	**2**	**3**	**4**
Eigenvalues	0.172	0.081	0.056	0.035
Lengths of gradients	2.205	1.609	1.757	1.032
Cumulative percentage variance of species data	30.0	44.1	54.0	60.1
Redundancy analysis (RDA)				
Axes	**1**	**2**	**3**	**4**
Eigenvalues	0.112	0.095	0.041	0.017
Species & Environmental variables correlations	0.554	0.665	0.627	0.550
Cumulative percentage variance of species data	11.2	20.7	24.7	26.4
Cumulative percentage of species & environmental variables relation	39.8	73.4	87.9	93.9

Table 4.2 Results of forward stepwise selection on the predictor variables. Marginal effects are the effects of each predictor variable when used as the only explanatory variable in the model, and variables are ranked according to their variance. Conditional effects are the effects of each predictor variable in the model adding each time the next more important, and variables are ranked according to their added significance of their inclusion in the model.

Marginal effects		***Conditional effects***			
Variable	Lambda 1	*Variable*	Lambda A	F	P
Soil texture	0.10	Soil texture	0.07	9.41	0.002
Intensive Cultivations	0.06	Intensive Cultivations	0.05	7.08	0.002
Land Uses	0.05	Land Uses	0.05	6.24	0.002
Soil E, M & V	0.04	Soil E, M & V	0.03	4.68	0.002
Altitude	0.04	Arable Land	0.03	3.76	0.006
Arable Land	0.03	Altitude	0.02	3.87	0.008
Road Length	0.02	Road Length	0.01	2.59	0.030
River Length	0.01	Soil Type I & V	0.01	1.65	0.126
Soil I & V	0.01	River Length	0.01	1.11	0.348

Table 4.3 Response of each dependent variable (small mammal species) to the first two axes produced from RDA. The two axes summarize the total variability within the "environmental" matrix. Selection of "best fit" regression model was realized with Generalized Linear Models and the criterion of Akaike (AIC). The significance of each model was also tested with Generalized Linear Models (GLM), applied on each one of the response variables. Level of significance was set at a = 0.05, and significant p_s are noted: $p < 0.01$ = *, $p < 0.001$ = **, $p < 0.0001$ = ***, $p < 0.00001$ = ****, $p < 0.000001$ = *****.

		Model Selection			**Generalized Linear Model**	
Response Variable	AIC	b_0+b_1X	$b_0+b_1X+b_2X^2$	Null model	F	P
Crocidura leucodon	-			√	-	-
Crocidura suaveolens	253.06		√		17.67	*****
Suncus etruscus	584.53	√			14.58	****
Microtus guentheri	707.16	√			21.54	*****
Microtus levis	-			√	-	-
Microtus thomasi	1091.45		√		21.82	*****
Cricetulus migratorius	545.285		√		7.59	***
Apodemus flavicollis	-			√	-	-
Apodemus epimelas	743.93		√		2.34	0.059
Apodemus sylvaticus	316.41	√			7.95	**
Rattus norvegicus	-			√	-	-
Rattus rattus	690.52		√		9.00	****
Mus musculus	321.28	√			17.31	*****
Mus macedonicus	358.53		√		7.29	****
Muscardinus avellanarius	247.61	√			24.63	*****

Nonetheless, maps of distribution will also be presented for the 5 species which didn't fit any response model (null model selection).

In indirect gradient analysis (unconstrained ordination) small mammal species are represented as points (triangles) in a two dimensions graphic (Figure 4.1) whereas in direct gradient analysis (constrained ordination) both small mammal species and environmental variables are presented as vectors commencing all from the centre of the graph (Figure 4.2). Unconstrained ordination (Detrendend Correspondence Analysis), presents the species composition in two dimension axes measuring only the variability occurring within the "species" matrix, based on inter-species correlations. With this analysis part of the variability that is related to the measured environmental variables is missing, but information on the small mammal species' variability and interactions between them are demonstrated (Figure 4.1).

Constrained ordination (Redundancy Analysis), demonstrates the biological variability of small mammal assemblages ("species" matrix) in Thessaly, which is explained by the predictor variables ("environmental" matrix).

In Figure 4.1 it is observed that the species Yellow-necked field mouse, Long-tailed field mouse (*Apodemus sylvaticus*), House-mouse (*Mus musculus*) and Macedonian mouse (*Mus macedonicus*) are highly correlated. To the same direction with that group are also positively correlated the species East European vole, Lesser white-toothed shrew (*Crocidura suaveolens*) and Western broad-toothed field mouse, forming though a group a little more adjacent to the axes center. The Etruscan shrew (*Suncus etruscus*) and Guenther's vole (*Microtus guentheri*) are more adjacent to the vertical axe and located higher up than the two previous groups. On the other hand, Bicoloured shrew and Thomas's pine vole (*Microtus thomasi*), are positively correlated between them, to the same direction with the first two groups but in quite a distance from them, located further up in the 2nd quadrant of the graph. The Gray dwarf hamster (*Cricetulus migratorius*) is negatively correlated with all the previously mentioned groups figuring oppositely in the 4th quadrant of the graph, and finally the species Brown Rat, Black rat (*Rattus rattus*) and Common dormouse (*Muscardinus avellanarius*) are positively correlated between them, forming a group which figures separately in the lower part of the 3rd quadrant of the graph.

On the other hand, the graph of constrained ordination realized on both "species" and "environment" matrix (Figure 4.2), presents a different pattern since the variability of small mammal species' composition is now explained by the variability occurring in the environmental gradients. Small mammal species are demonstrated with black arrows whereas environmental variables with red.

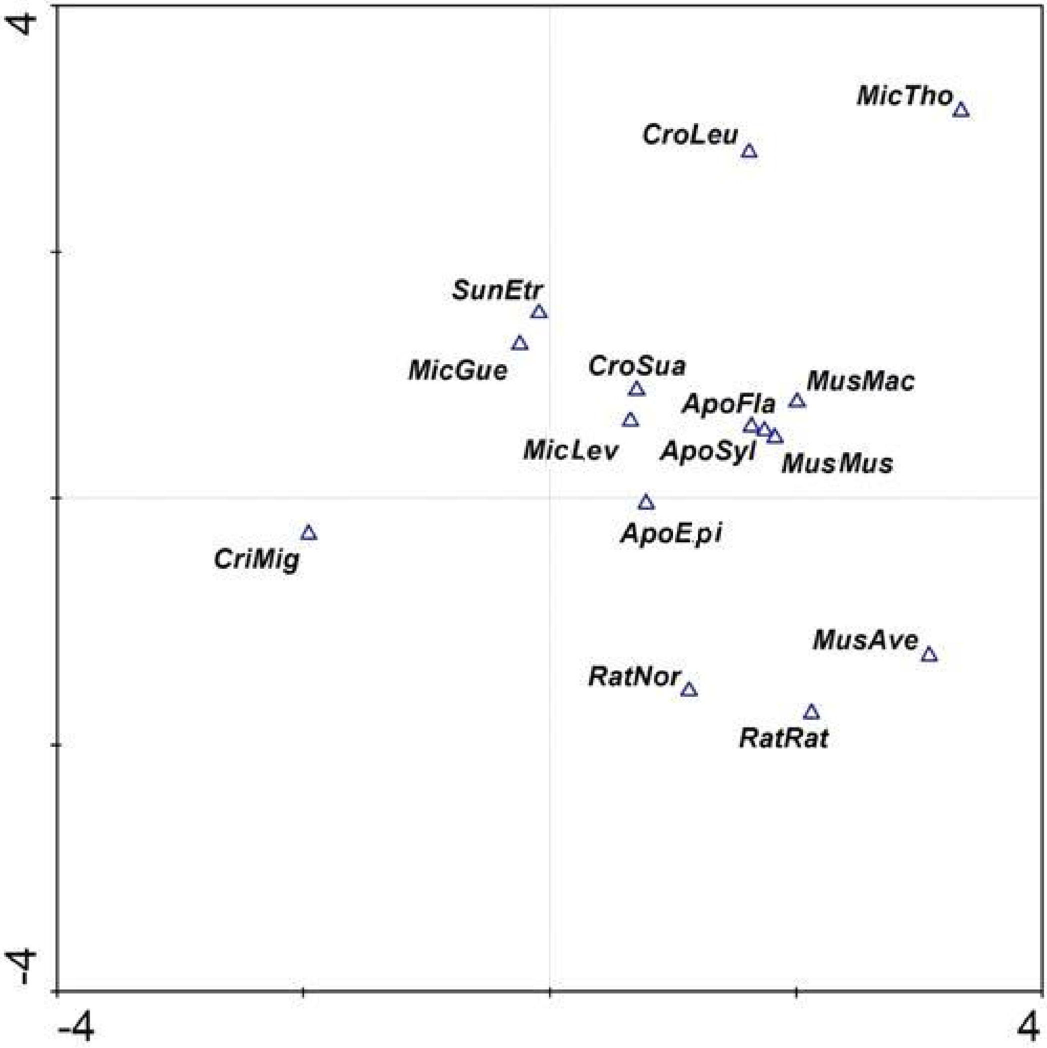


Figure 4.1 Unconstrained ordination of dependent variables (small mammal species) as recorded in Thessaly and included in the “species” matrix. Canonical axes indicate the variability occurred within the species’ composition, based on inter-species correlations. The variability measured doesn’t include that part of the variance which is explained by the environmental gradients. Acronyms stand for: ***CroLeu***: Crocidura leucodon, ***CroSua***: Crocidura suaveolens, ***SunEtr***: Suncus etruscus, ***MicGue***: Microtus guentheri, ***MicLev***: Microtus levis, ***MicTho***: Microtus thomasi, ***CriMig***: Cricetulus migratorius, ***ApoSyl***: Apodemus sylvaticus, ***ApoEpi***: Apodemus epimelas, ***ApoFla***: Apodemus flavicollis, ***MusMus***: Mus musculus, ***MusMac***: Mus macedonicus, ***RatRat***: Rattus rattus, ***RatNor***: Rattus norvegicus, ***MusAve***: Muscardinus avellanarius.

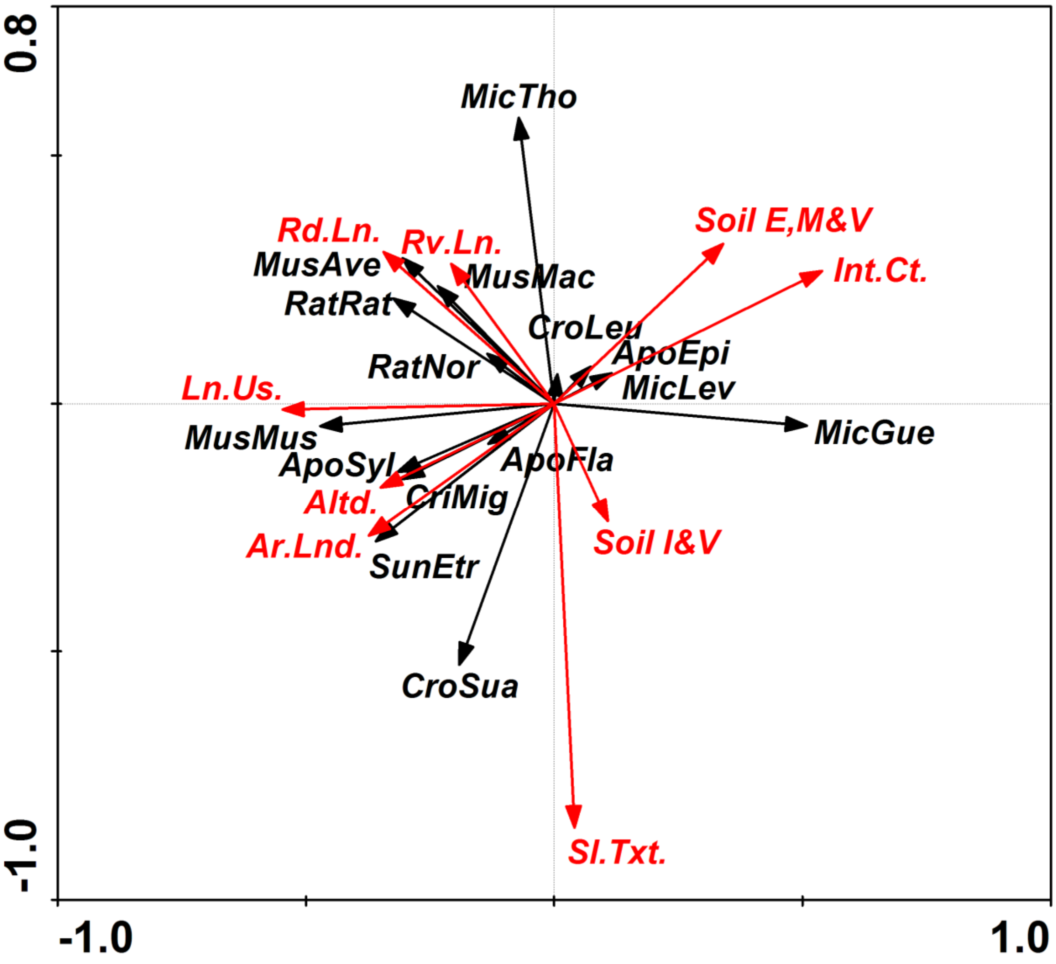


Figure 4.2 Biplot of constrained ordination on small mammal species and environmental variables, on Axis 1 and 2 of Redundancy Analysis (RDA). Small mammal species are demonstrated with black arrows whereas environmental variables with red. Length of response variables indicates the amount of their relative frequency, and direction indicates the positive and negative correlations between them. Length of predictor variables indicates which environmental variable explains best the variability of response variables, whereas direction of predictor variables indicates associations between them, and also negative and positive correlations between environmental variables and small mammal species. Acronyms stand for: ***Altd***: Altitude, ***Sl.Txt***: Soil Texture, ***Soil I & V***: Soil Type Inseptisol and Vertisol, ***Int.Ct***: Intensive Cultivations, ***Soil E, M & V***: Soil Type Entisol, Mollisol and Vertisol, ***Rd.ln***: Road Length, ***Rv.Ln***: River Length, ***Ln.Us***: Land Uses, ***Ar.Lnd***: Arable Land, ***CroLeu***: Crocidura leucodon, ***CroSua***: Crocidura suaveolens, ***SunEtr***: Suncus etruscus, ***MicGue***: Microtus guentheri, ***MicLev***: Microtus levis, ***MicTho***: Microtus thomasi, ***CriMig***: Cricetulus migratorius, ***ApoSyl***: Apodemus sylvaticus, ***ApoEpi***: Apodemus epimelas, ***ApoFla***: Apodemus flavicollis, ***MusMus***: Mus musculus, ***MusMac***: Mus macedonicus, ***RatRat***: Rattus rattus, ***RatNor***: Rattus norvegicus, ***MusAve***: Muscardinus avellanarius.

Length of response variables' vectors (small mammal species) indicates the relative frequency of each species, and direction indicates the positive and negative correlations between them. Length of predictor variables indicates which environmental variable explains best the variability of response variables, whereas direction of predictor variables indicates associations between them, and also negative and positive correlations between environmental variables and small mammal species. As it can be deduced from Figure 4.2, the environmental gradient "Soil texture" (Sl.Txt) coincides with the lower part of the vertical axe and is actually the gradient which defines this axe. Similarly, the environmental variable Land uses (Ln.Us.) coincides with the left part of the horizontal axe and is the gradient which defines that axe. In respect with small mammal species, the House-mouse is highly correlated with the gradient Land uses, whereas Long-tailed field mouse and Gray dwarf hamster are highly correlated with the environmental gradient Altitude (Altd.). Etruscan shrew is positively correlated with the environmental variable Arable land (Al.lnd.), and the species Brown rat, Black rat, Hazel dormouse and Macedonian mouse are positively correlated with the environmental gradients River length (Rv.Ln.) and Road length (Rd.Ln.). Other species such as Western broad-toothed field mouse, Yellow-necked field mouse, Bicolored shrew and East European vole, are represented in the study area with low abundances, and their respective vectors in the graph are therefore small, very near to the centre of the canonical axes. These latter species also present more generalist habits in the study area, resulting therefore to their rejection through Generalized Linear Models process and Akaike criterion (Table 4.3). The response models of each mammal species to the total of environmental gradients, as well as their response to each environmental variable, are presented in the next parts.

4.3.1 Effect of environmental gradients on small mammal assemblages. Distribution and gradual composition changes

In the plains of Thessaly a total of 28.475 small mammals were recorded during the three years of the study (2003-2005). A total of 15 species constituted the sample. Insectivora were represented with a total of three species, two of them belonging in the genus Crocidura. Lesser white-toothed shrew (21.87%) was the dominant among the class Insectivora, and Bicolored shrew was second with 2.48%. The third insectivorous specie was the Etruscan shrew (1.67%). The other 12 small mammal species all belonged in the order Rodentia. Genus Microtus was represented with 3 species: Guenther's vole (29.19%) which was the dominant of Microtus species and also among all small mammals in the study area, East European vole (7.23%) and Thomas's pine vole (4.33%). Three Apodemus species were also present in Thessaly: the Western broad-toothed field mouse (0.7%), the Long-tailed field mouse (7.1%) and the Yellow-necked field mouse (3.41%). Each one of Rattus and Mus genera had also had two representative species in the study area: Brown rat (1.75%), Black rat (0.78%), House-mouse (12.79%) and Macedonian mouse (4.82%) respectively. Cricetidae family, included except the three Microtus species, the specie Gray dwarf hamster which was also recorded in the area (0.56%). Finally there was also a unique representative of Myoxidae family, the Hazel dormouse (0.17%).

4.3.1.1 Bicolored shrew (*Crocidura leucodon*)

Bicolored shrew was present in 28 of 31 sampling sites in the study area (Figure 4.3), and was recorded with a range of frequency between 0.56% (n=5, site: Nees Karyes) and 7.32% (n=61, site: Xaidemeni). In total it formed the 2.48% (n=708) of small mammals recorded in Thessaly plains.

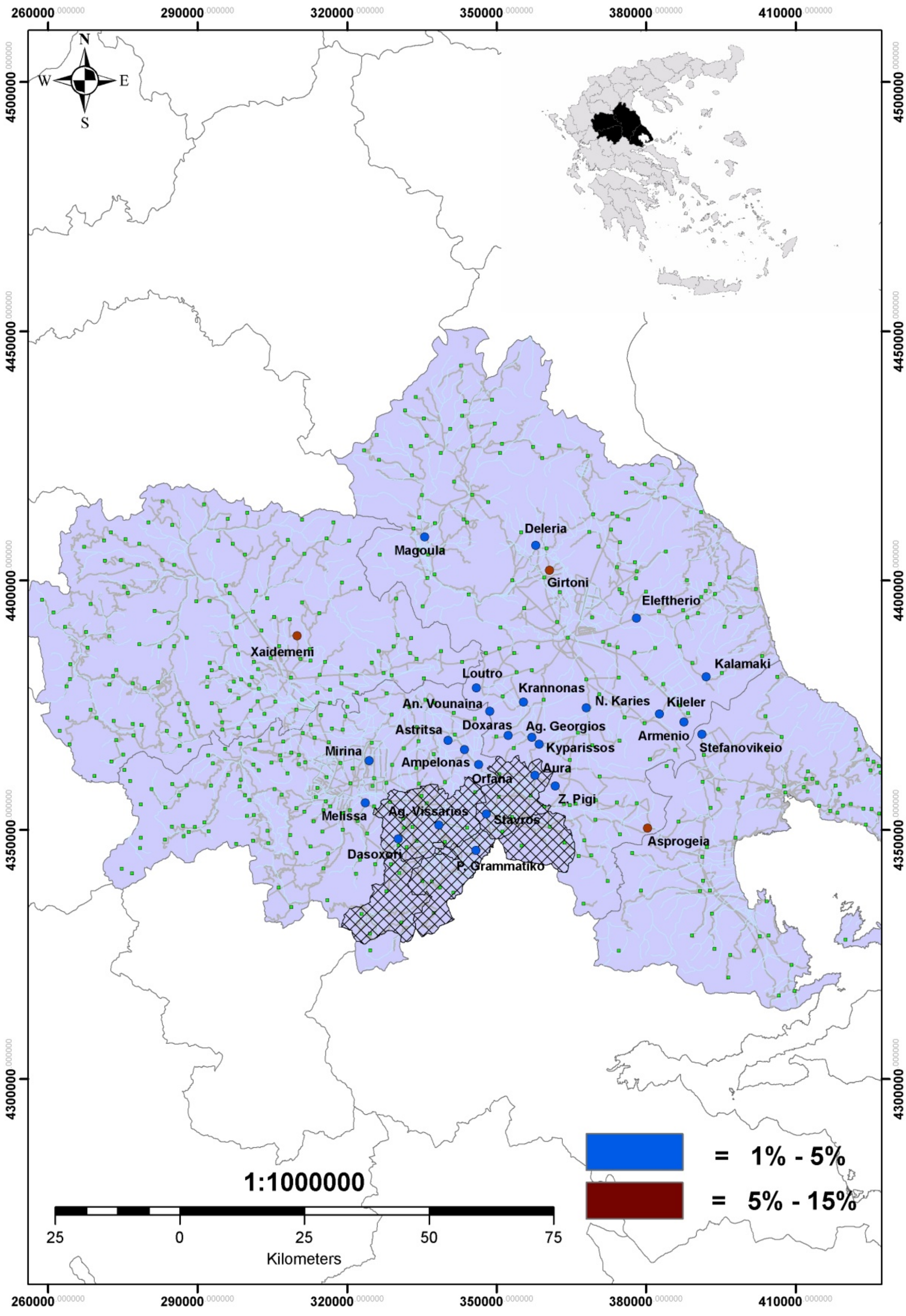


Figure 4.3 Distribution of Bicolored shrew (*Crocidura leucodon*) in the sampling sites of Thessaly region. Colored circles indicate the specie's presence and green squares indicate villages of the area. In the upper right corner, reference map of Thessaly in respect to Greece. Previously known distribution of the specie in the region, indicated in cross-lined area. Color index in lower right corner.

According to the criterion of Akaike (AIC) it didn't fit any response model and it was rejected through the "null model" generated hypothesis (Table 4.3). Although the previously known distribution of the specie according to Krapp (1990, 1999) and Wilson & Reeder (2005) was restricted in a small part in southern Thessaly (Figure 4.3), data presented in this thesis indicate a much broader distribution. Nonetheless, the specie's low percentages of frequency (0.56% - 7.32%) didn't fit any response model (Table 4.3) and therefore its distribution and abundance variation couldn't be explained by any of the measured environmental gradients.

4.3.1.2 Lesser white-toothed shrew (*Crocidura suaveolens*)

In contradiction to its co-generic Bicolored shrew, the Lesser white-toothed shrew was present in all sampling sites of the study area (Figure 4.4), with high percentages of frequency ranging from 6.32% (n=61, site: Deleria) to 41.16% (n=589, site: Zoodoxos Pigi). Moreover it was the second most abundant specie (n= 6229) forming 21.87% of the total recorded small mammal specimens. Up to day, the previously known distribution of the specie was located in a southern part of Thessaly and in western and south-western mountainous parts of the region (Vlasak & Niethammer, 1990; Libois et al., 1999; Wilson & Reeder, 2005). Nonetheless, data of this study indicate that the specie is abundant in the agricultural lowlands of Thessaly and also present in all sampling sites (Figure 4.4), holding the second highest percentage of frequency among all species.

Generalized Linear Models proved that the specie responded significantly ($p < 0.00001$) to the measured environmental gradients, fitting a 2nd order polynomial model according to the criterion of Akaike (Table 4.3). Its response model is demonstrated in Figure 4.5, where the change of its abundance is summarized in the

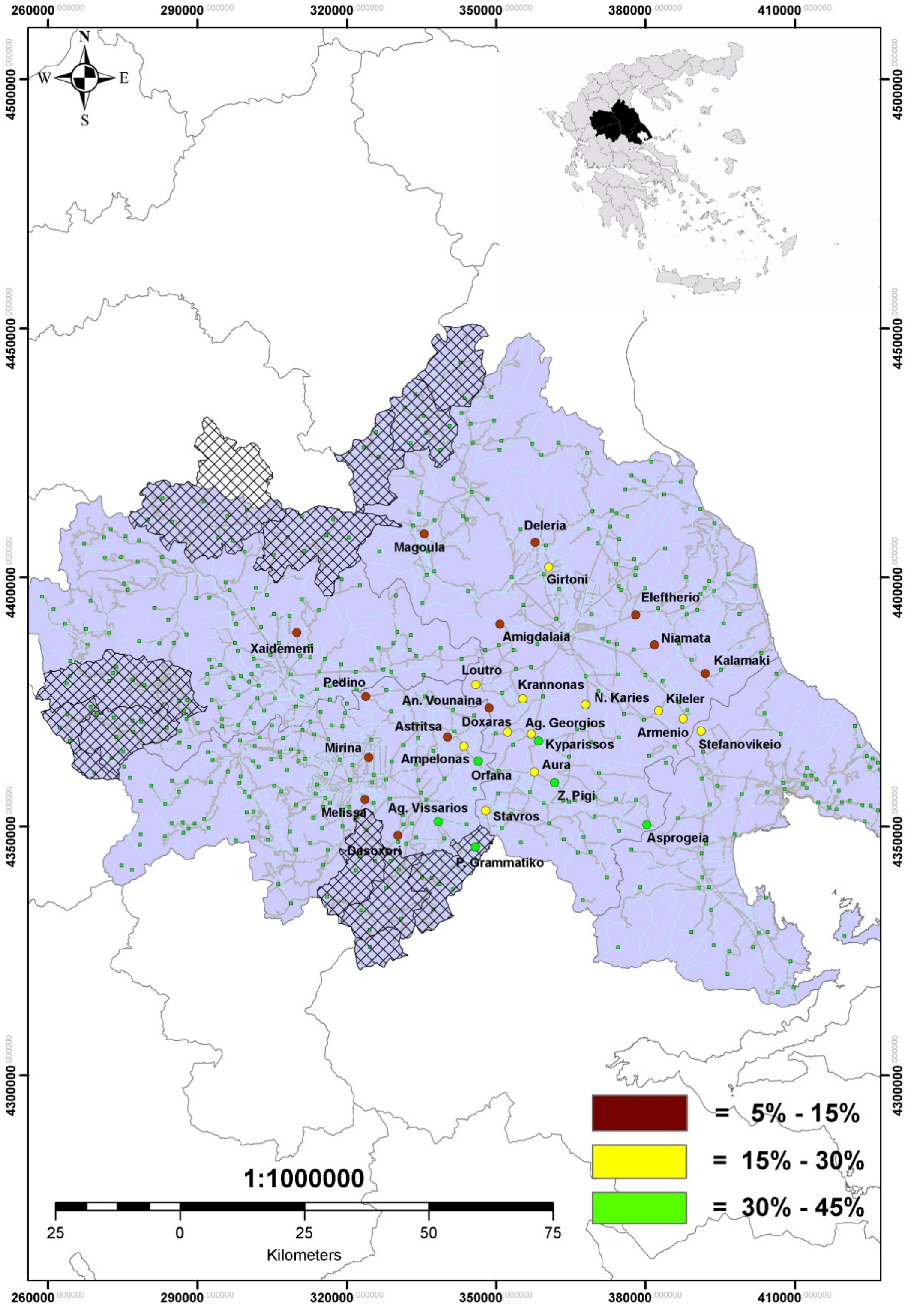


Figure 4.4 Distribution of Lesser white-toothed shrew (*Crocidura suaveolens*) in the sampling sites of Thessaly region. Colored circles indicate the specie's presence and green squares indicate villages of the area. In the upper right corner, reference map of Thessaly in respect to Greece. Previously known distribution of the specie in the region, indicated in cross-lined area. Color index in lower right corner.

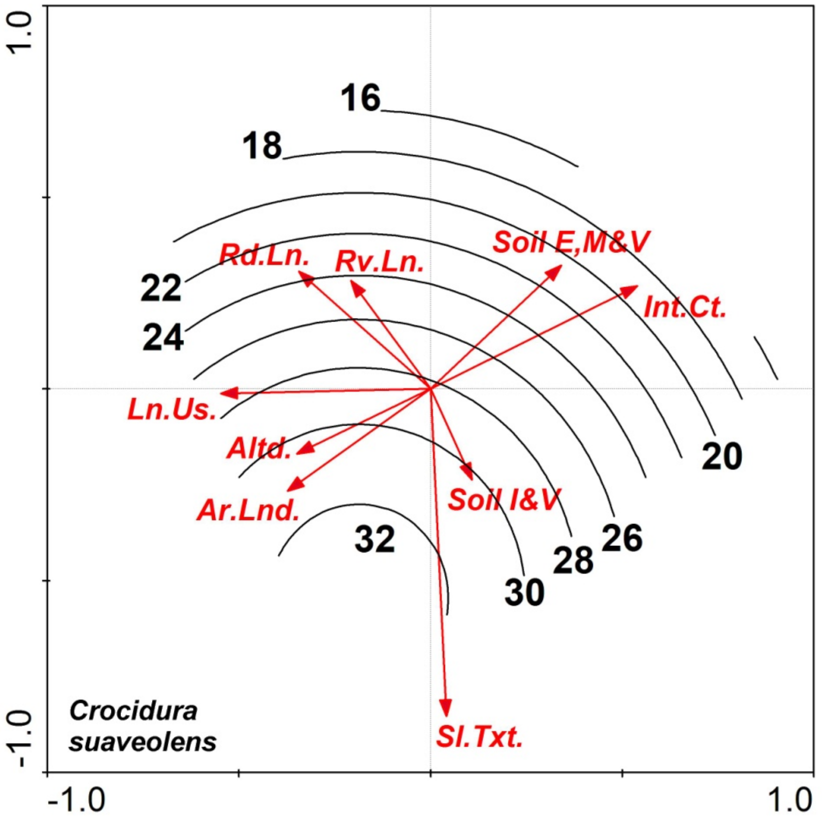


Figure 4.5 Response of Lesser white-toothed shrew to the environmental gradients. Contour isolines indicate increase in the specie's relative frequency.

increase of contour isolines' values, which actually reflect the increase of its relative frequency. According to Figure 4.5, the Lesser white-toothed shrew is increasing when correlated with factors Soil texture (Sl.Txt.), Arable land (Ar.Lnd.) and the variable Altitude (Altd.), whereas it presents lower abundances and is negatively correlated with the positive values of factors Intensive cultivations (Int.Ct.) and Soil types E, M, and V (Soil E,M&V).

4.3.1.3 Etruscan shrew (*Suncus etruscus*)

The third representative of the class Insectivora in Thessaly plains is the Etruscan shrew. It was recorded with the lower percentages of frequency among all insectivorous species, and also among most small mammal species, ranging from

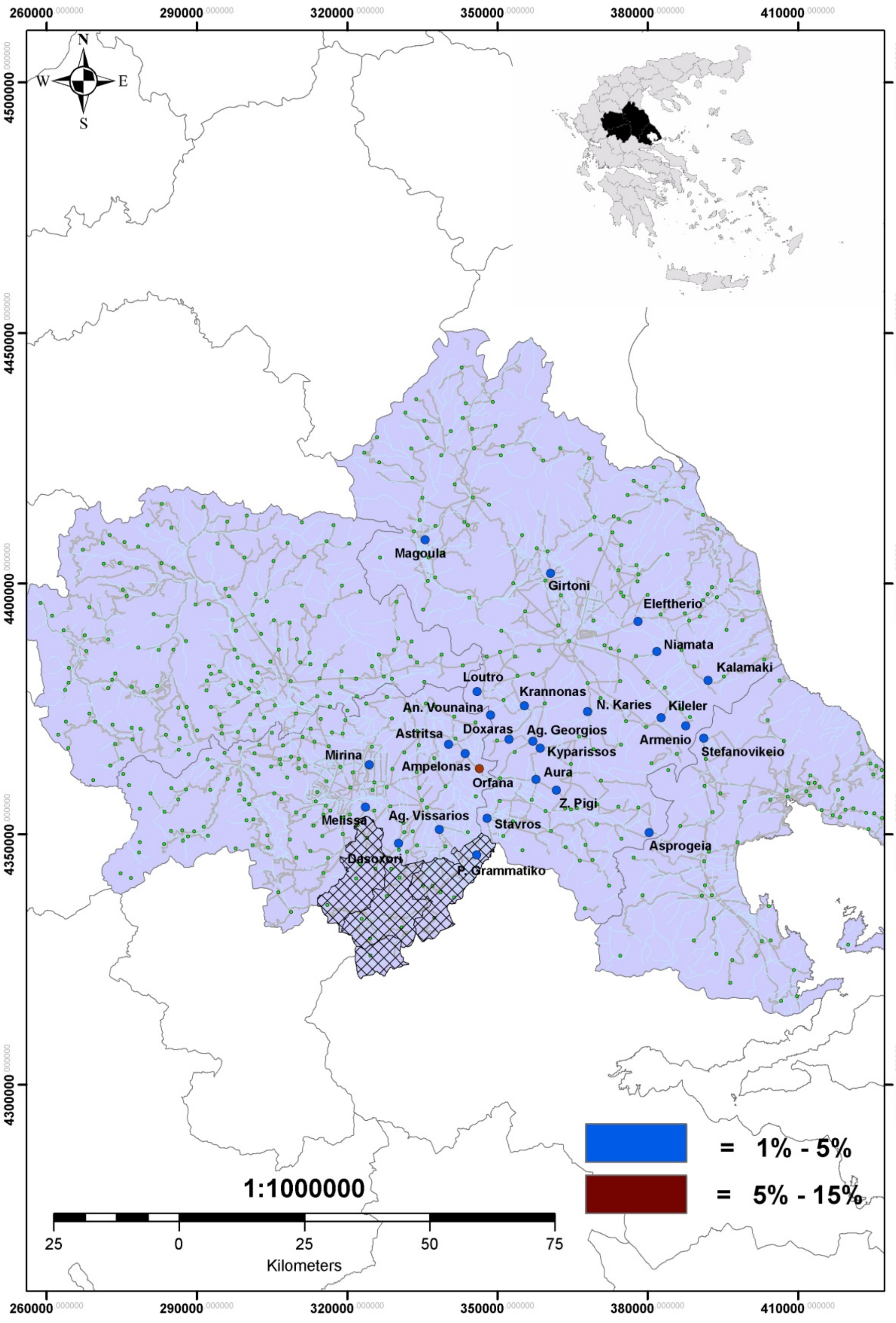


Figure 4.6 Distribution of Etruscan shrew (*Suncus etruscus*) in the sampling sites of Thessaly region. Colored circles indicate the specie's presence and green squares indicate villages of the area. In the upper right corner, reference map of Thessaly in respect to Greece. Previously known distribution of the specie in the region, indicated in cross-lined area. Color index in lower right corner.

0.15% (n=2, site: Melisa) to 5.85% (n=70, site: Orfana), and thus constituting the 1.67% (n=478) of the total recorded specimens. Its previously known distribution according to Spitzenberger (1990c), Libois & Fons (1999) and Wilson & Reeder (2005) was restricted to a small part in southern Thessaly, whereas data of this study indicate a much broader distribution towards central, eastern and some northern parts of the area (Figure 4.6).

Although the Etruscan shrew was recorded with low percentages in the study area, nonetheless its gradual frequency change had a significant response to the measured environmental gradients ($p<0.00001$), fitting a 1st order polynomial model (Table 4.3). According to the model (Figure 4.7), the abundance of the specie in Thessaly plains was negatively correlated with the positive values of factor Soil types E, M & V (Soil E,M&V) and was also correlated with factor Intensive cultivations (Int.Ct).

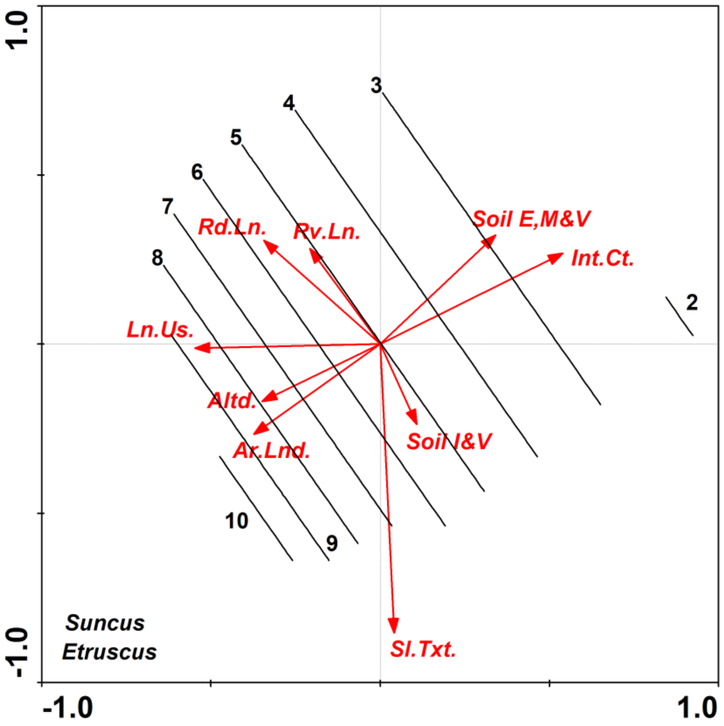


Figure 4.7 Response of Etruscan shrew to the environmental gradients. Contour isolines indicate increase in the specie's relative frequency.

4.3.1.4 Guenther's vole (*Microtus guentheri*)

In the agricultural plains of Thessaly, voles were present with three representative species, Guenther's vole being the most abundant among them. It was also the most abundant among all recorded small mammals in the area, forming a total of 21.19% (n=8313). Guenther's vole presence was within a wide range of percentages of frequency in the sampling sites, with a minimum of 4.22% (n=36, site: Myrina) and a maximum of 48.55% (n=470, site: Kalamaki). Moreover, it was present with a percentage of frequency of more than 45% in 5 sampling sites (Figure 4.8). Niethammer (1982c), Krystufek (1999j) and Wilson & Reeder (2005) presented a distribution map of the specie restricted in southern Thessaly and in a central part of the region. Results of this study though demonstrate (Figure 4.8) that Guenther's vole has a broader range of distribution in the area, apart its high abundance.

According to the criterion of Akaike (AIC), the response of Guenther's vole frequency along the measured environmental gradients fitted a 1st order polynomial model (Table 4.3). The formulation of "null model" hypothesis and the results of Generalized Linear Models indicated that this response was also highly significant ($p<0.000001$). Visualization of the results was realized with Canodraw, and the response model is demonstrated in Figure 4.9. According to the model the specie's abundance is increasing strictly along the positive values of horizontal Axis in Figure 4.9. Thus, its increase is positively correlated with the positive values of factor Intensive Cultivations (Int.Ct) and negatively correlated with the negative values of factor Land Uses (Ln.Us), which are the two factors that mainly define the horizontal axis, according to Redundancy Analysis results.

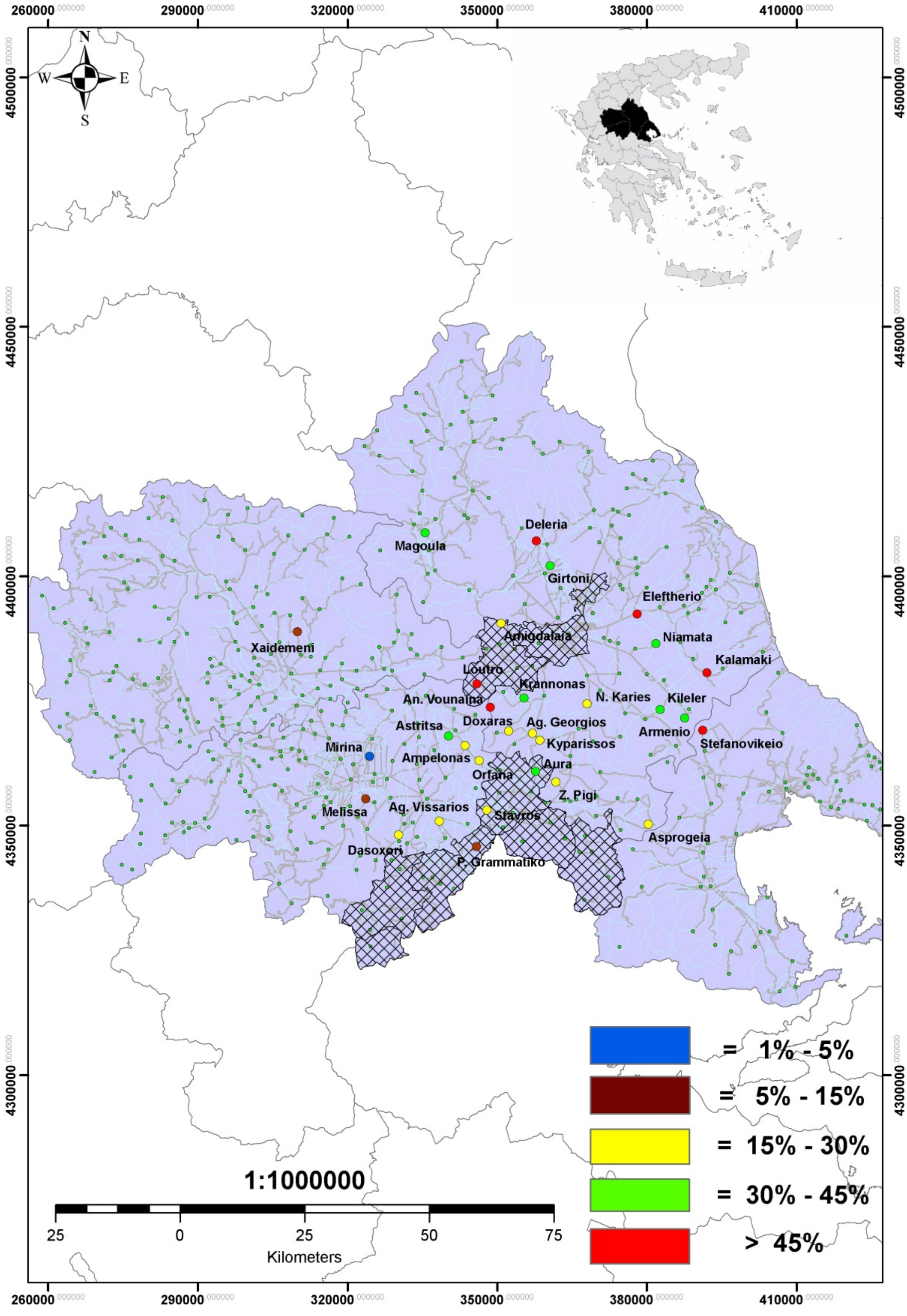


Figure 4.8 Distribution of Guenther's vole (*Microtus guentheri*) in the sampling sites of Thessaly region. Colored circles indicate the specie's presence and green squares indicate villages of the area. In the upper right corner, reference map of Thessaly in respect to Greece. Previously known distribution of the specie in the region, indicated in cross-lined area. Color index in lower right corner.

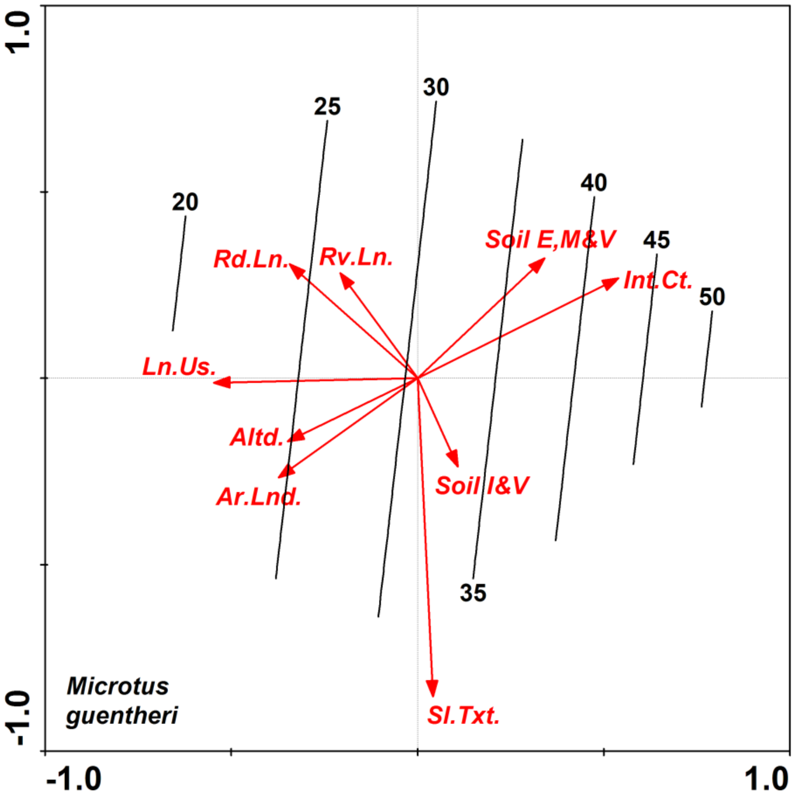


Figure 4.9 Response of Guenther's vole to the environmental gradients. Contour isolines indicate increase in the specie's relative frequency.

4.3.1.5 East European vole (*Microtus levis*)

In terms of abundance, the second member of voles' group in the study area is the East European vole, which formed the 7.23% (n=2060) of the total recorded individuals. It was present in 30 of 31 sampling sites and its respective percentages of frequency in these sites ranged from 2.78% (n=36, site: Melisa) to 13.97% (n=114, site: Armenio). The specie's frequency gradually varied from site to site, but yet that change didn't fit any response model according to the criterion of Akaike (AIC) and Generalized Linear Model analysis (Table 4.3). Nonetheless, as it is demonstrated in Figure 4.10 the specie's percentages of frequency increase from southern and south-western parts towards central and northern locations of the sampling sites. Moreover, the specie's last known distribution in the region according to Petrov & Ruzic (1982), Zima (1999c) and Wilson & Reeder (2005) was located in a central area of Thessaly.

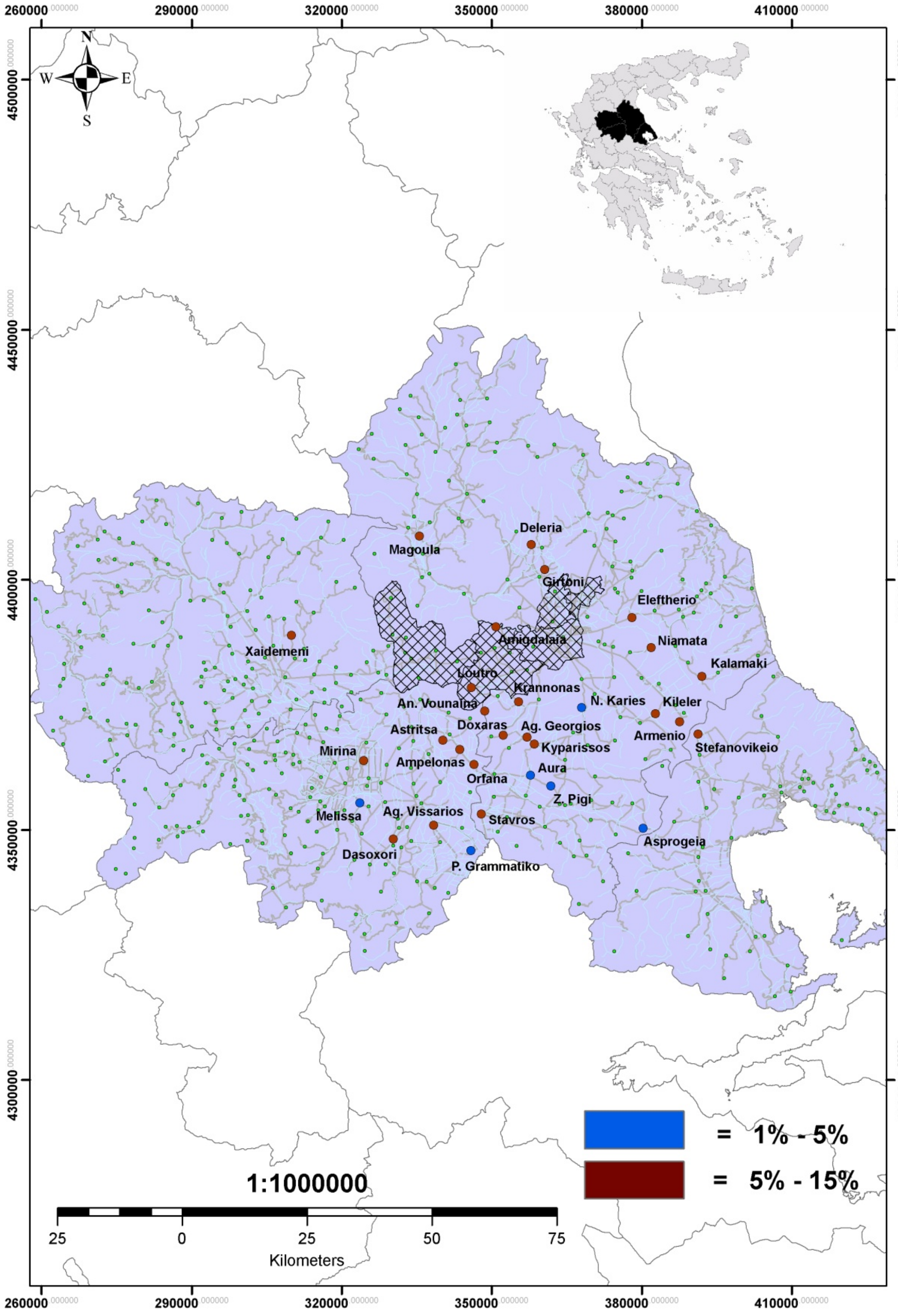


Figure 4.10 Distribution of East European vole (*Microtus levis*) in the sampling sites of Thessaly region. Colored circles indicate the specie's presence and green squares indicate villages of the area. In the upper right corner, reference map of Thessaly in respect to Greece. Previously known distribution of the specie in the region, indicated in cross-lined area. Color index in lower right corner.

Still, the results of this study indicate a much broader area of distribution expanding mainly in the southern and south-western parts.

4.3.1.6 Thomas's pine vole (*Microtus thomasi*)

The third representative of Microtus species in the agricultural ecosystems of Thessaly is the Thomas's pine vole. It was recorded in only 12 of 31 sampling sites, but still presented a wide range of percentages of frequency, starting from 0.23% (n=2, site: Ano Vounaina) and reaching a maximum of 39.86% (n=344, site: Pedino), and thus forming in total the 4.33% (n=1233) of all recorded small mammals. The sampling sites where it was recorded are located in central, western and north-western parts of the study area. In addition, the previously known distribution of the specie was located in the mountainous regions of western and south-eastern Thessaly according to Niethammer (1982e), Krystufek (1999l) and Wilson &Reeder (2005), whereas data of the present study demonstrate a broader distribution also in the agricultural lowlands of the area (Figure 4.11).

Although the specie was only present in 12 sampling sites, its high variation in percentages of frequency fitted a response polynomial model of 2nd order according to the criterion of Akaike (AIC). The model was also highly significant ($p<0.000001$) according to Generalized Linear Model results (Table 4.3). As the response model demonstrates in Figure 4.12, the increase of the specie's abundance has a strong correlation with factor Soil Texture (Sl.Txt.), and an also strong but not that straightforward correlation with factors Soil Types E, M and V (Soil E,M&V) and Intensive Cultivations (Int.Ct.).

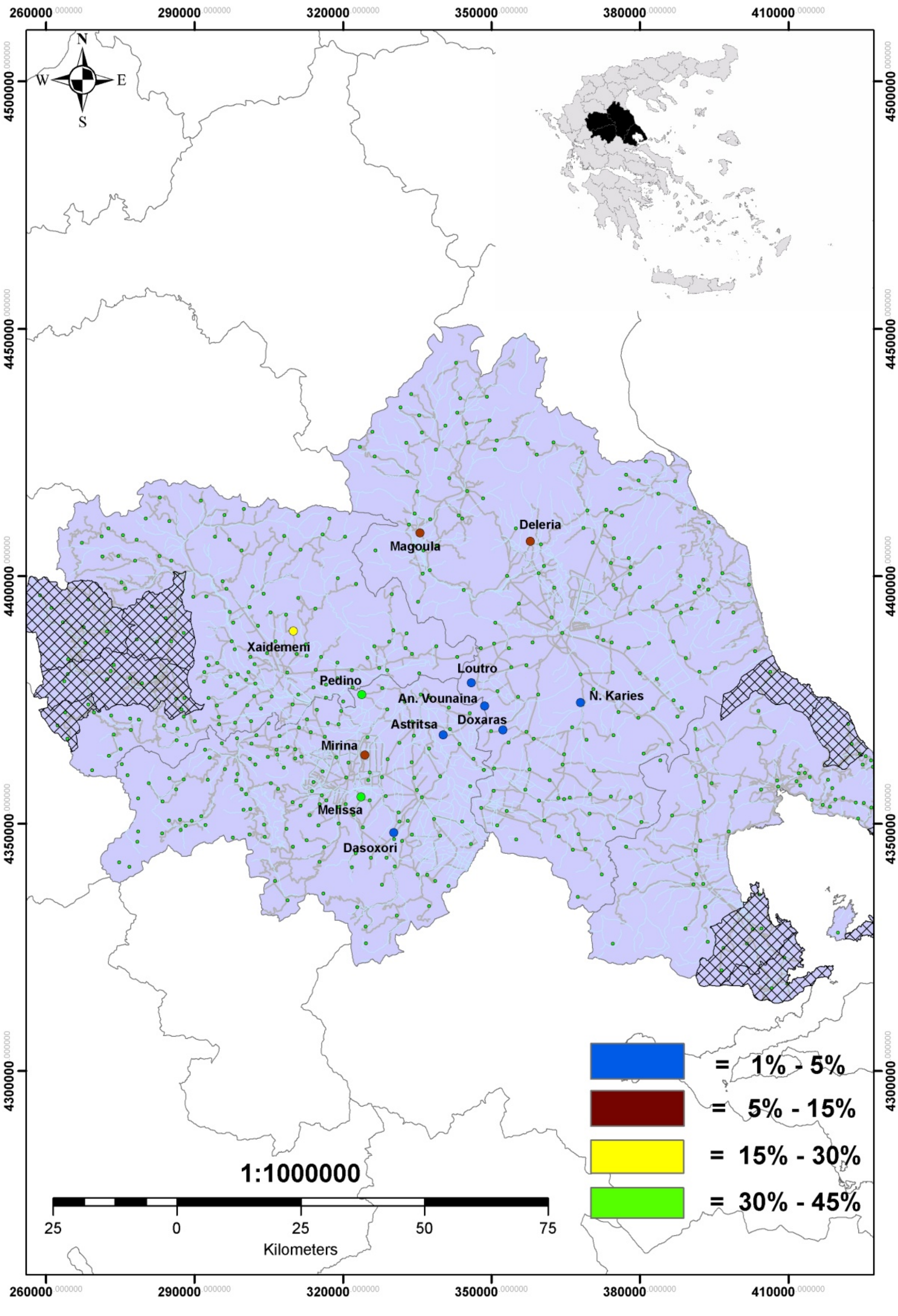


Figure 4.11 Distribution of Thomas's pine vole (*Microtus thomasi*) in the sampling sites of Thessaly region. Colored circles indicate the specie's presence and green squares indicate villages of the area. In the upper right corner, reference map of Thessaly in respect to Greece. Previously known distribution of the specie in the region, indicated in cross-lined area. Color index in lower right corner.

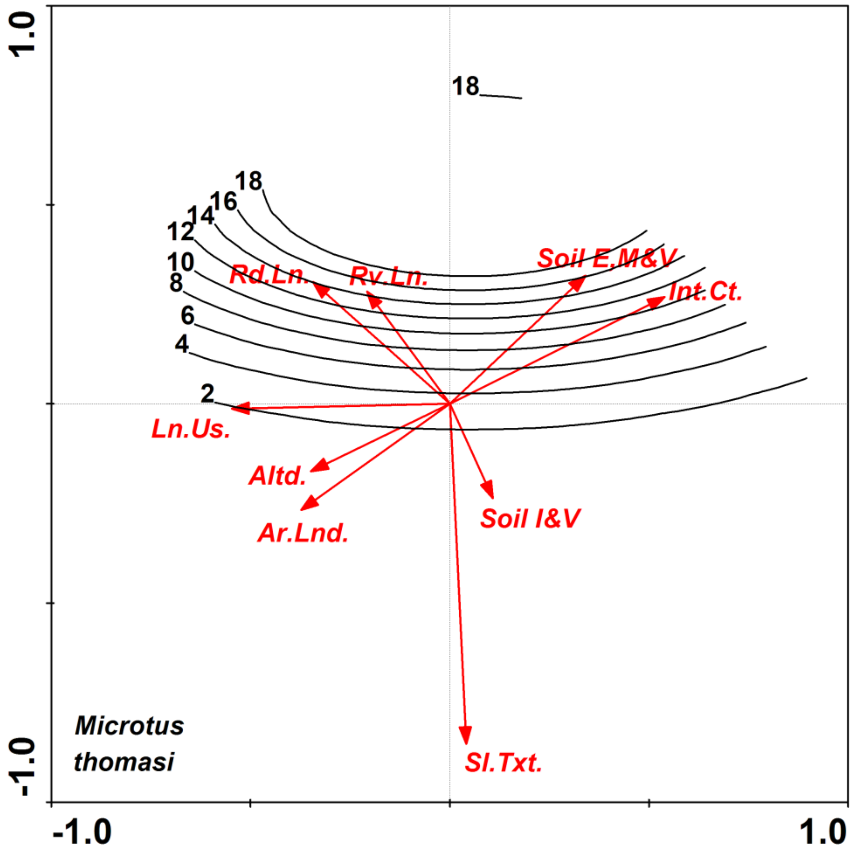


Figure 4.12 Response of Thomas's pine vole to the environmental gradients. Contour isolines indicate increase in the specie's relative frequency.

4.3.1.7 Gray dwarf hamster (*Cricetulus migratorius*)

Finally, except the three co-generic Microtus species which actually dominate the area in terms of abundance, there is another member from Cricetidae family which inhabits part of the region. That specie is the Gray dwarf hamster, present in 10 of 31 sampling sites, with quite low percentages of frequency ranging from 0.11% (n=1, site: Girtoni) to 6.73% (n=68, site: Agios Georgios) and forming the 0.56% in respect to the total of small mammal specimens recorded in Thessaly. The specie was recorded in central and eastern locations of sampling sites in Thessaly, in contradiction to Niethammer (1982a) and Vohralik (1999) who recorded a restricted distribution of the specie only in the southern parts of the region (Figure 4.13). Although the specie was recorded in few sites and with low percentages, nonetheless it had a significant response model.

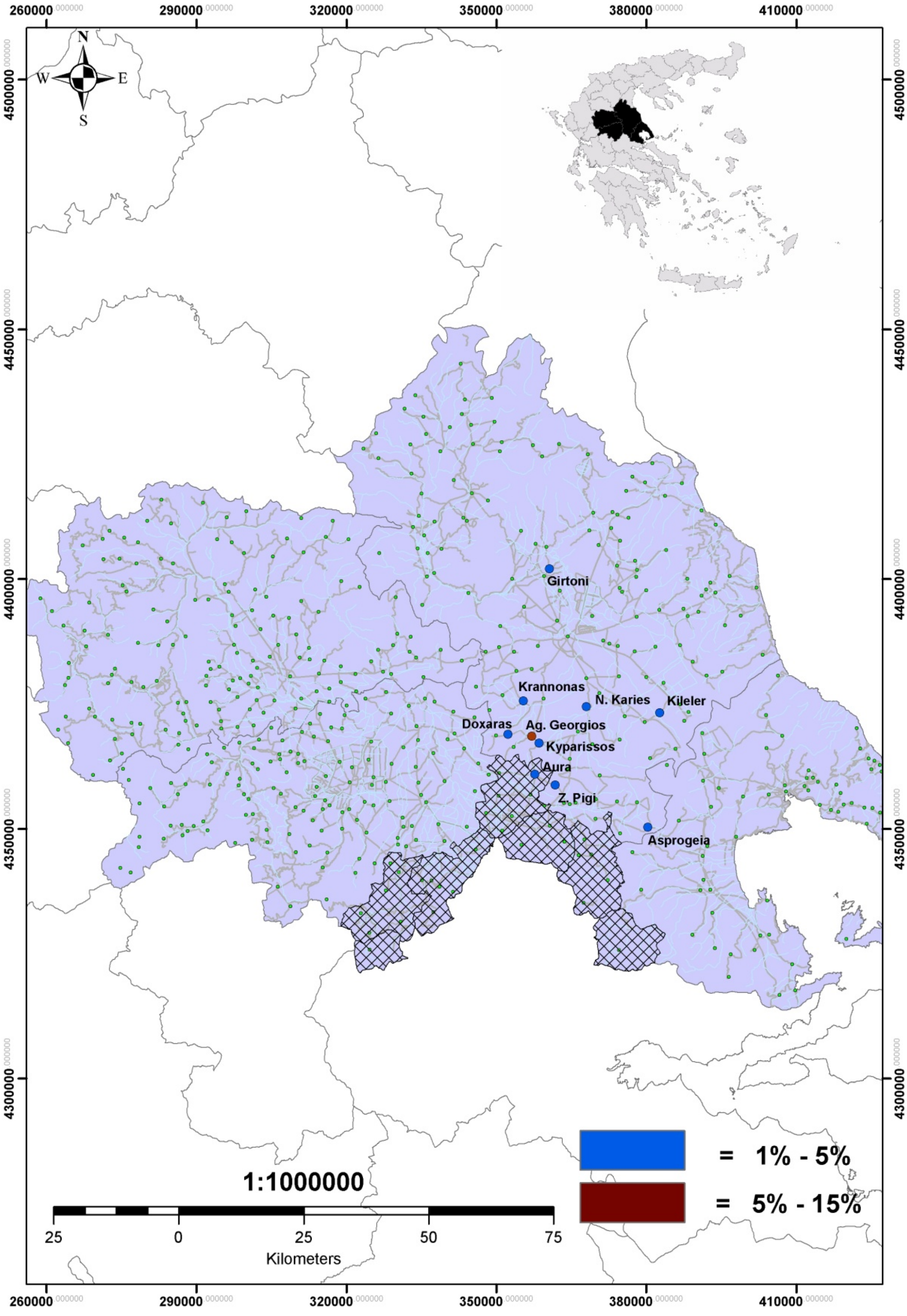


Figure 4.13 Distribution of Gray dwarf hamster (*Cricetulus migratorius*) in the sampling sites of Thessaly region. Colored circles indicate the specie's presence and green squares indicate villages of the area. In the upper right corner, reference map of Thessaly in respect to Greece. Previously known distribution of the specie in the region, indicated in cross-lined area. Color index in lower right corner.

Its frequency of appearance varied along the environmental gradients and fitted a polynomial model of 2nd order according to Akaike (AIC) criterion (Table 4.3). The Gray dwarf hamster's response model was also significant ($p<0.0001$) according to Generalized Linear Model analysis. Polynomial models of 2nd order are more complex and difficult to interpret, because the interactions between the specie's response and underlying ecological gradients are not actually straightforward. Nonetheless, Figure 4.14 which demonstrates Gray dwarf hamster's response model, clearly indicates that increase of the specie's abundance is positively correlated with the variable Altitude (Altd.) and factors Land Uses (Ln.Us.) and Arable Land (Ar.Lnd.). Additionally, it can be observed that factor Soil Types E, M & V (Soil E,M&V) has a certain effect on the specie's presence in the studied areas.

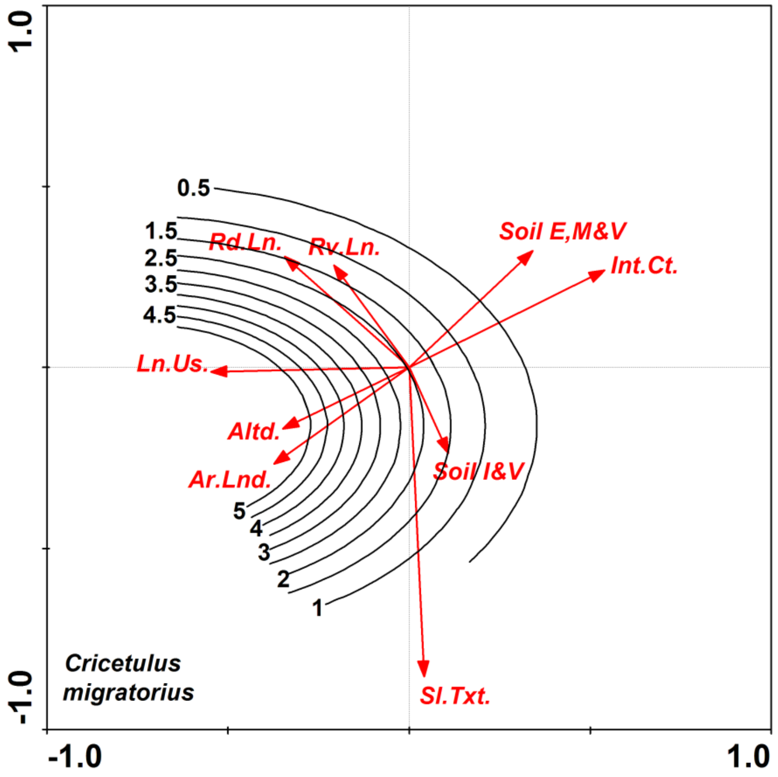


Figure 4.14 Response of Gray dwarf hamster to the environmental gradients. Contour isolines indicate increase in the specie's relative frequency.

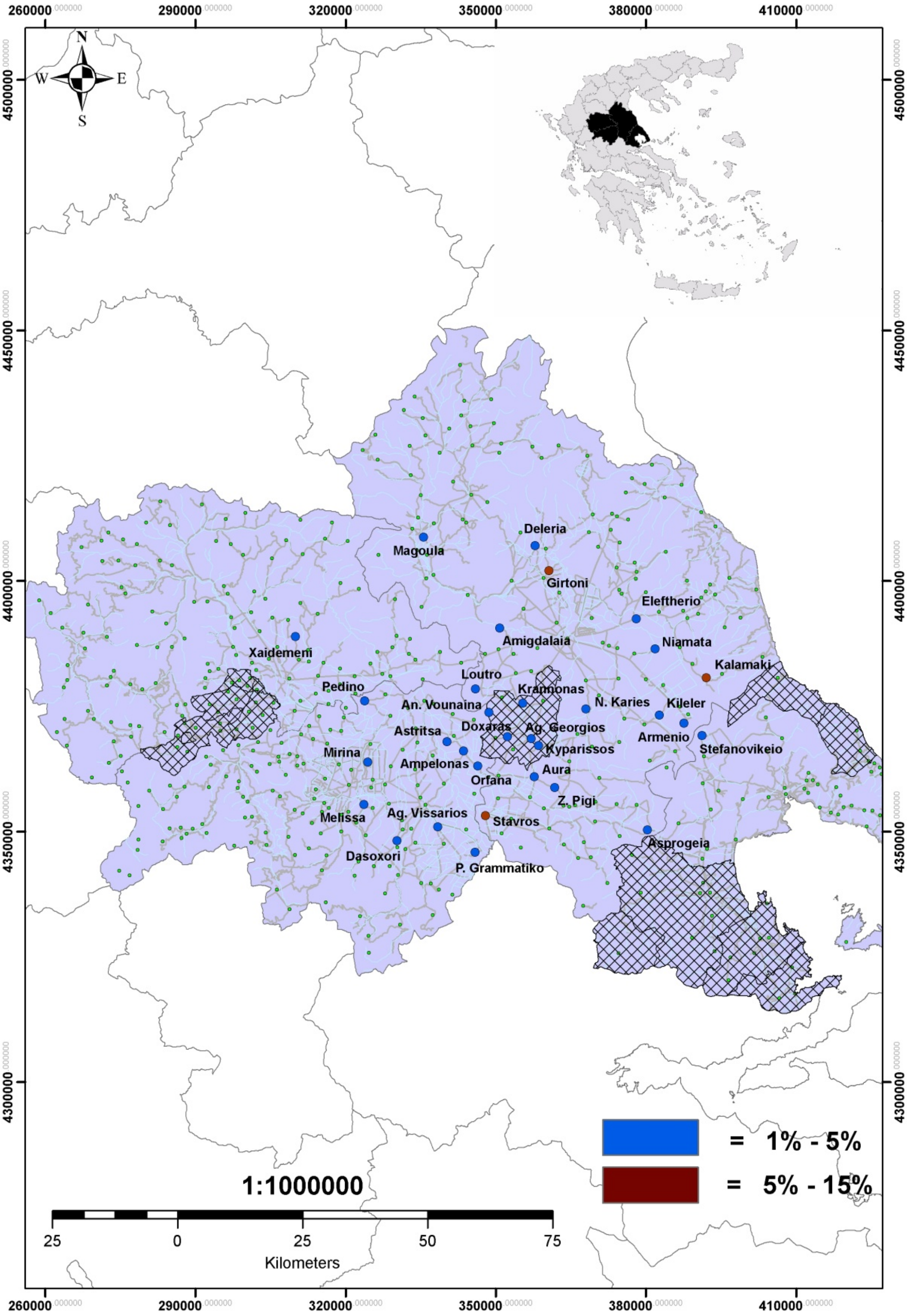


Figure 4.15 Distribution of Yellow-necked field mouse (*Apodemus flavicollis*) in the sampling sites of Thessaly region. Colored circles indicate the specie's presence and green squares indicate villages of the area. In the upper right corner, reference map of Thessaly in respect to Greece. Previously known distribution of the specie in the region, indicated in cross-lined area. Color index in lower right corner.

4.3.1.8 Yellow-necked field mouse (*Apodemus flavicollis*)

The Yellow-necked field mouse was the only one of three Apodemus species which were present in Thessaly, that didn't fit any response model according to Generalized Linear Model analysis and Akaike (AIC) criterion (Table 4.3). Nonetheless, it was present in all sampling sites of the study area, although with low percentages of frequency ranging from 1.29% (n=15, site: Stefanovikeio) to 5.68% (n=55, site: Kalamaki), and thus forming the 3.41% of the total small mammals recorded in the area. The specie had low percentages in all sampling sites exceeding the 5% only in three sites. Moreover, data of the present work have broadened the distribution of Yellow-necked field mouse in the whole study area, which was previously restricted according to Niethammer (1978a), Montgomery (1999a) and Wilson & Reeder (2005) in fragmented parts of central, eastern and south-western Thessaly (Figure 4.15).

4.3.1.9 Western broad-toothed field mouse (*Apodemus epimelas*)

In contradiction to Yellow-necked field mouse and according to the criterion of Akaike (AIC), Western broad-toothed field mouse fitted a response polynomial model of 2nd order (Table 4.3). On the other hand, that response model wasn't significant (p=0.059), and therefore it will not be demonstrated hereafter. Still, the Western broad-toothed field mouse had a broad distribution in Thessaly, and was present in 22 of 31 sampling sites, mainly in central, southern and south-eastern parts of the study area (Figure 4.16). Oppositely, the previously recorded distribution of the specie according to Niethammer (1978b), Storch (1999) and Wilson & Reeder (2005), was confined in two small areas located in the western and eastern extremes of the region (Figure 4.16), a fact which is inconsistent with the results of this work. Western broad-toothed field mouse's abundance was very low in all sites when it was present,

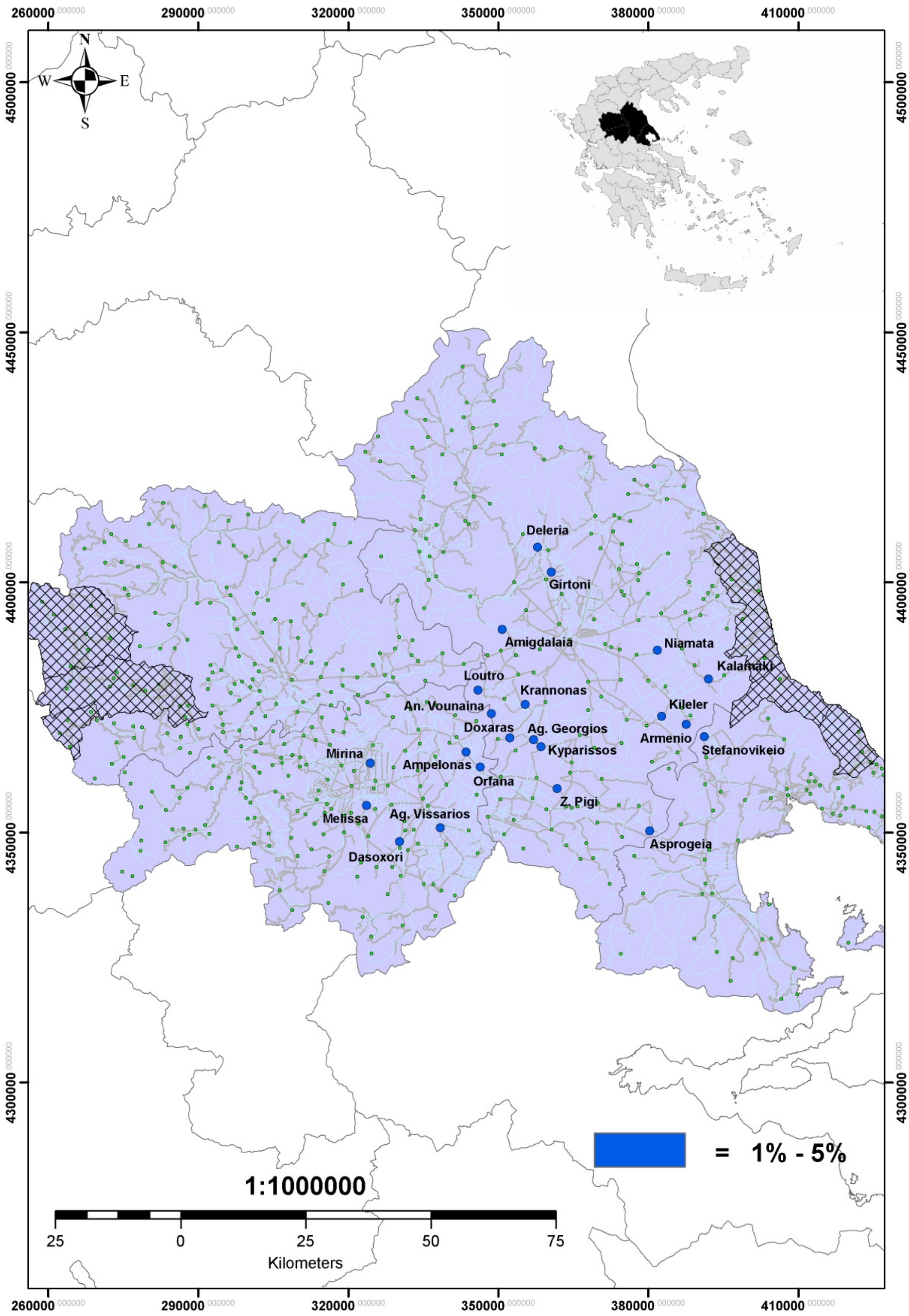


Figure 4.16 Distribution of Western broad-toothed field mouse (*Apodemus epimelas*) in the sampling sites of Thessaly region. Colored circles indicate the specie's presence and green squares indicate villages of the area. In the upper right corner, reference map of Thessaly in respect to Greece. Previously known distribution of the specie in the region, indicated in cross-lined area. Color index in lower right corner.

never exceeding 5%. More specifically it ranged from 0.09% (n=1, site: Stefanovikeio) to 3.93% (n=38, site: Kalamaki), forming in total the 0.7% of all small mammal specimens recorded in Thessaly.

4.3.1.10 Long-tailed field mouse (*Apodemus sylvaticus*)

The third and last representative of Apodemus species in Thessaly is the Long-tailed field mouse. It was the most abundant in comparison with its co-generic species, forming 7.1% of the total small mammals recorded in the area. It was present in all 31 sampling sites, with lower abundances in northern parts, which increased towards southern and eastern locations (Figure 4.17). More specific, its percentages of frequency ranged from 4.15% (n=25, site: Loutro) to 12.88% (n=89, site: Stavros). The previously known distribution of the specie was restricted in mountainous areas on the extremes of eastern and western Thessaly according to Niethammer (1978c), Montgomery (1999b) and Wilson & Reeder (2005), and in two more southern areas (Figure 4.17). Data of this study though, indicate a much broader distribution of the specie occupying the total of the study area.

The variation of Long-tailed field mouse's frequency among sites was tested on the measured environmental gradients with Generalized Linear Model analysis. The criterion of Akaike (AIC) indicated that the specie's response fitted a polynomial model of 1st order (Table 4.3), and the model was also significant ($p<0.001$). The specie's frequency increased when correlated with the variable Altitude (Altd.) and the negative values of factor Arable Land (Ar.Lnd.), whereas it was negatively correlated with the positive values of factor Intensive Cultivations (Int.Ct.).

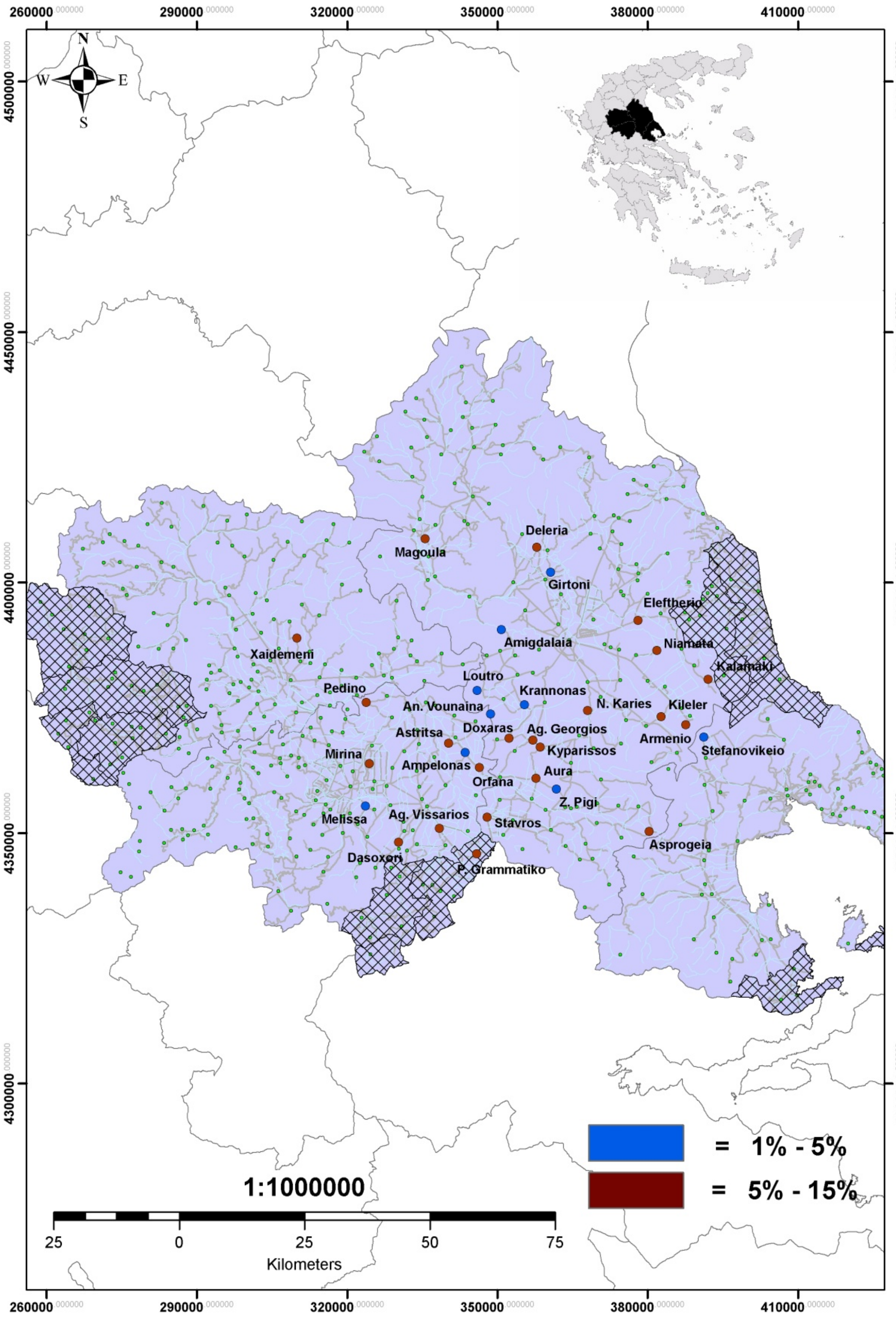


Figure 4.17 Distribution of Long-tailed field mouse (*Apodemus sylvaticus*) in the sampling sites of Thessaly region. Colored circles indicate the specie's presence and green squares indicate villages of the area. In the upper right corner, reference map of Thessaly in respect to Greece. Previously known distribution of the specie in the region, indicated in cross-lined area. Color index in lower right corner.

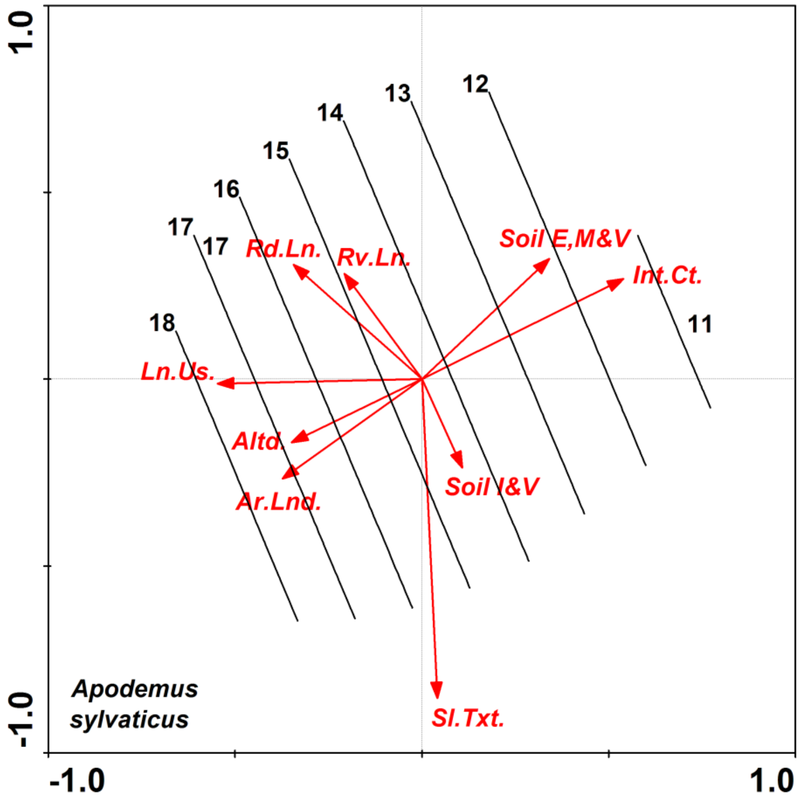


Figure 4.18 Response of Long-tailed field mouse to the environmental gradients. Contour isolines indicate increase in the specie's relative frequency.

4.3.1.11 Brown rat (*Rattus norvegicus*)

Rats were the heavier and larger small mammals recorded in Thessaly plains. They were represented with two co-generic species, and both of them were present in the study area with low percentages of frequency. Brown rat specifically had a little more than the double percentage in comparison with Black rat, forming 1.78% (n=500) of the total small mammal specimens recorded in the region. The Brown rat was present in 24 of 31 sampling sites (Figure 4.19), and its abundance among sites varied from 0.17% (n=1, site: Loutro) to 13.38% (n=99, site: Amigdalaia). According to Becker (1978a), Amori & Cristaldi (1999a) and Wilson & Reeder (2005) its distribution was restricted in southern Thessaly (Figure 4.19). Data of this study though demonstrate a much broader distribution of the specie, expanding mainly in central and south-eastern locations of the study area. The response of Brown rat to the measured

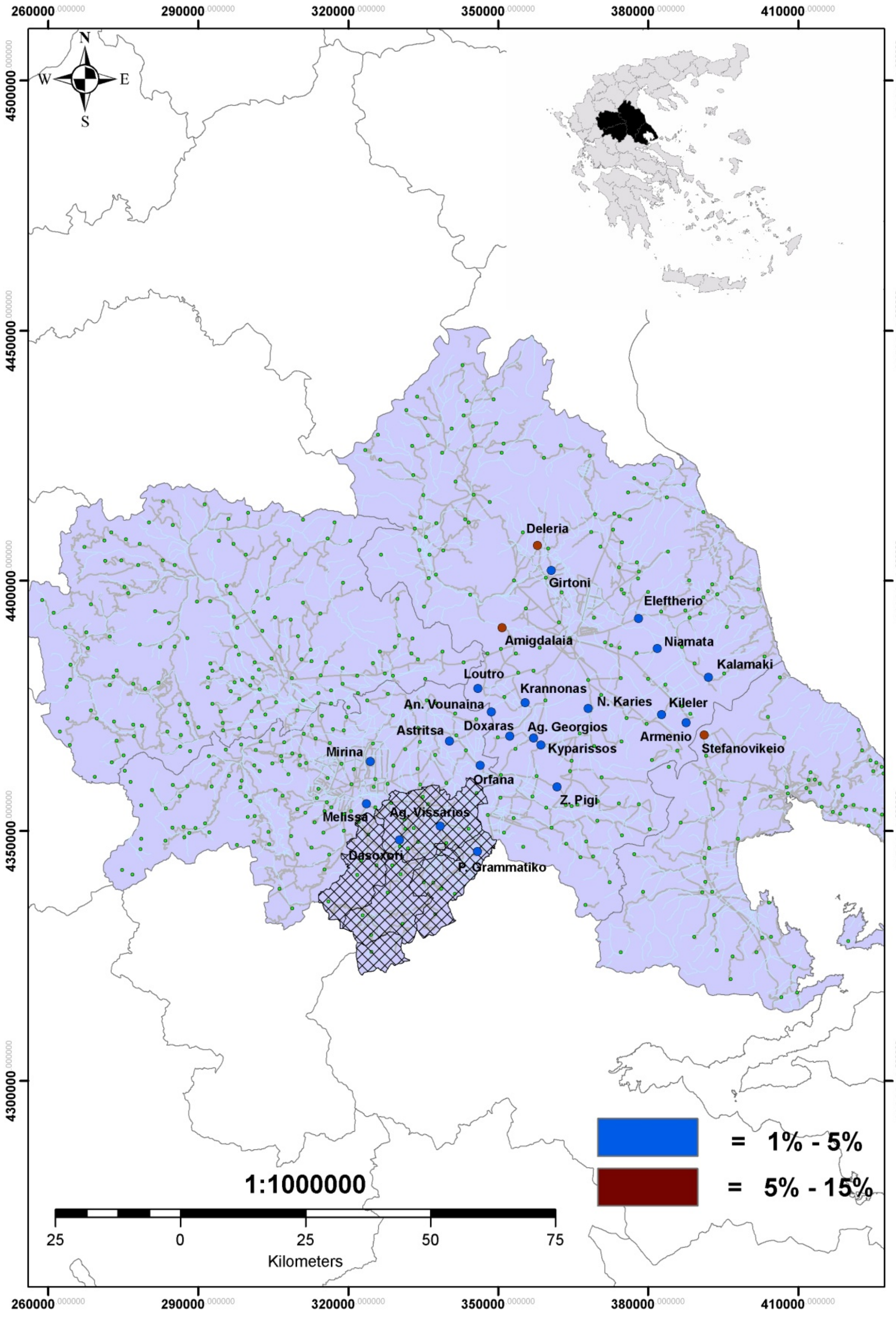


Figure 4.19 Distribution of Brown rat (*Rattus norvegicus*) in the sampling sites of Thessaly region. Colored circles indicate the specie's presence and green squares indicate villages of the area. In the upper right corner, reference map of Thessaly in respect to Greece. Previously known distribution of the specie in the region, indicated in cross-lined area. Color index in lower right corner.

environmental gradients was tested with the use of Generalized Linear Model analysis. Nonetheless, the gradual change of its frequency among sites and among the environmental gradients didn't fit any response model, and was rejected through "null model" hypothesis and Akaike (AIC) criterion (Table 4.3).

4.3.1.12 Black rat (*Rattus rattus*)

Black rat was present in Thessaly in 22 of 31 sampling sites, also with low percentages as its co-generic Brown rat which was mentioned previously, forming 0.78% of the total small mammals recorded for this study. The specie's frequency varied among sites from 0.10% (n=1, site: Krannonas) to 7.15% (n=61, site: Mirina). The Black rat was considered until recently to be completely absent from the region of Thessaly according to Becker (1978a), Amori & Cristaldi (1999b) and Wilson & Reeder (2005). On the other hand, results of the present study demonstrate a broad distribution of the specie in the agricultural ecosystems of the study area, occupying areas in central and south-eastern locations, similarly to Brown rat (Figure 4.20).

The gradual change of Black rat's frequency among the measured environmental gradients was tested with the use of Generalized Linear Models. According to the criterion of Akaike (AIC), the specie's response fitted a 2nd order polynomial model (Table 4.3), which was significant ($p<0.00001$). The response model is demonstrated in Figure 4.21. As it can be observed, the Black rat increases when correlated with the variables River and Road Length (Rv.Ln. & Rd.Ln.), and moreover, although the relationship is not straightforward and will be tested later on for each environmental gradient separately, it appears that the specie's response is also affected by the factors Soil Texture (Sl.Txt) and Soil Types E, M & V (Soil E,M&V).

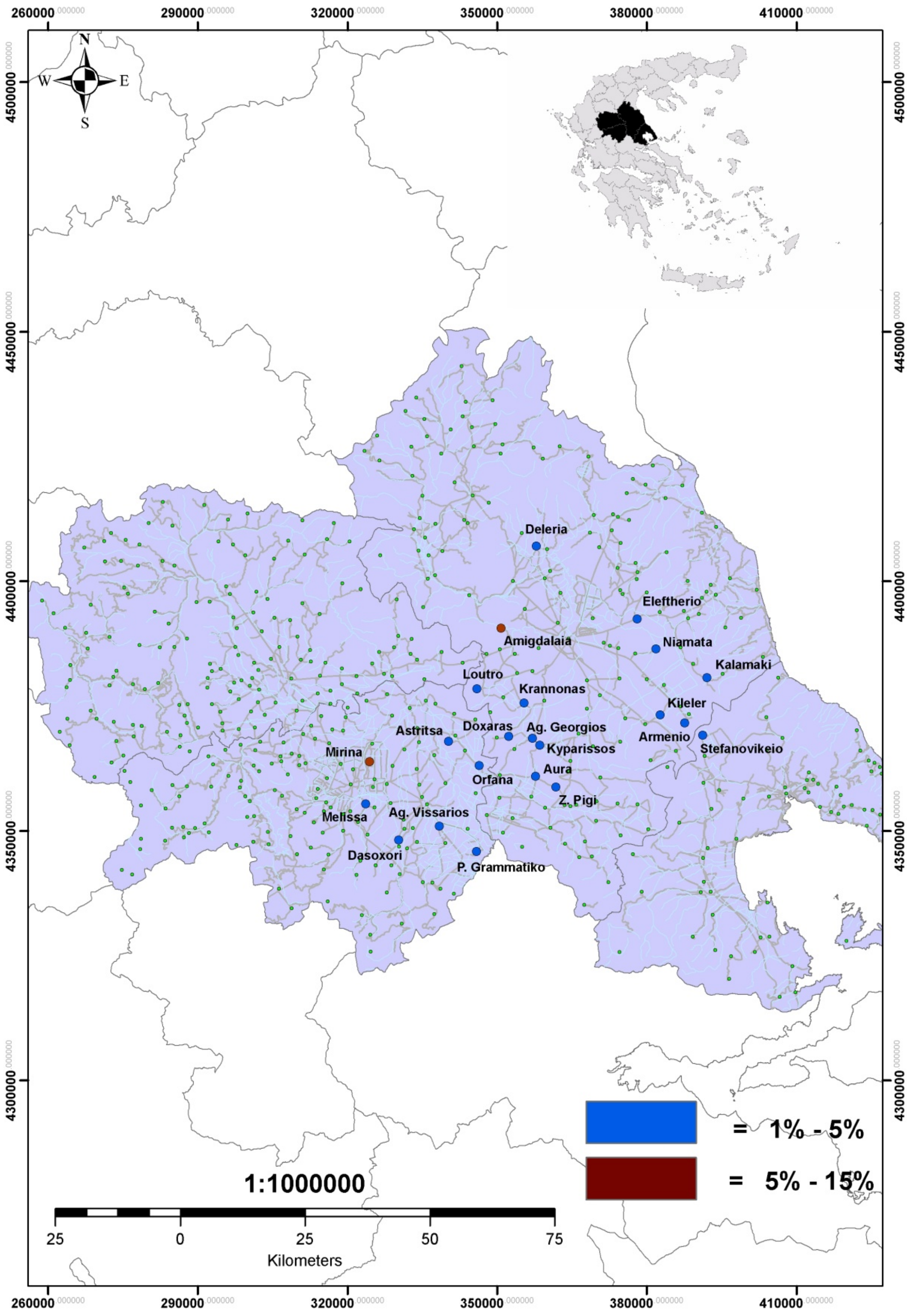


Figure 4.20 Distribution of Black rat (*Rattus ratttus*) in the sampling sites of Thessaly region. Colored circles indicate the specie's presence and green squares indicate villages of the area. In the upper right corner, reference map of Thessaly in respect to Greece. Color index in lower right corner.

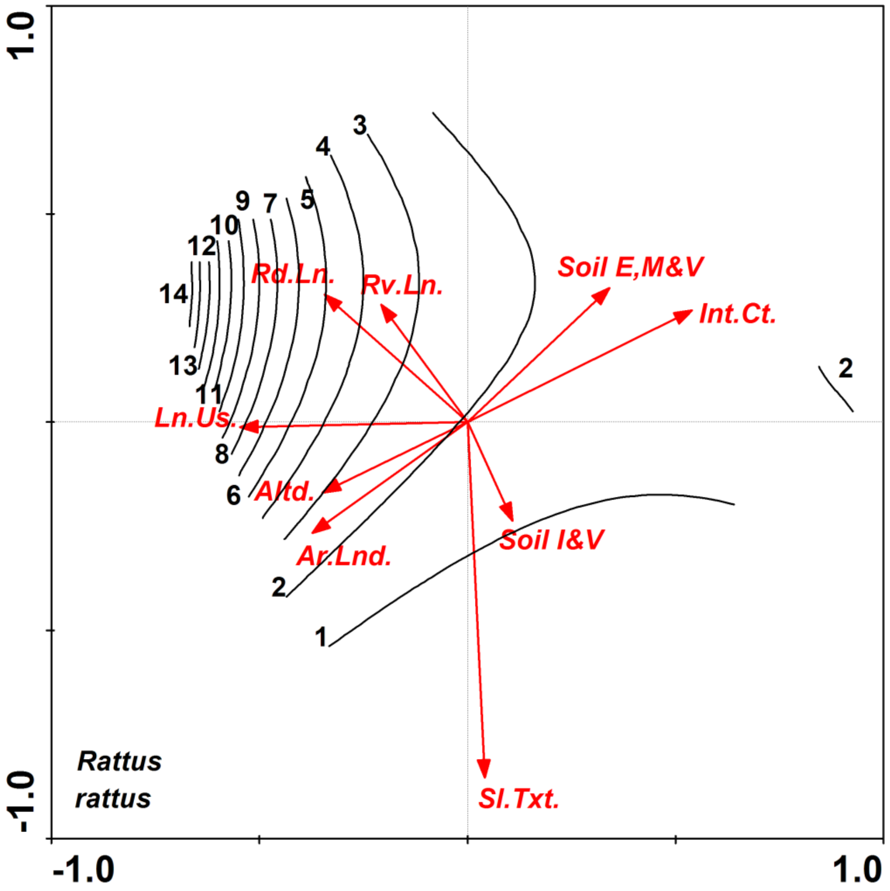


Figure 4.21 Response of Black rat to the environmental gradients. Contour isolines indicate increase in the specie's relative frequency.

4.3.1.13 House mouse (*Mus (Mus) musculus [domesticus]*)

Among small mammal species recorded in Thessaly plains, the House mouse was the third more abundant forming the 12.79% (n=3644) in total. It was present in all 31 sampling sites, with percentages of frequency which ranged from 4.64% (n=28, site: Loutro) to 25.39% (n=227, site: Dasoxori), and its abundance increased from eastern to western locations of the study area (Figure 4.22). According to Reichstein (1978), Macholan (1999a) and Wilson & Reeder (2005) the previously known distribution of the specie was restricted in three separate mountainous regions of Thessaly, in northern, western and south-eastern parts. Data presented in this study though demonstrate that the House mouse has a broad distribution in the lowlands of Thessaly as well (Figure 4.22).

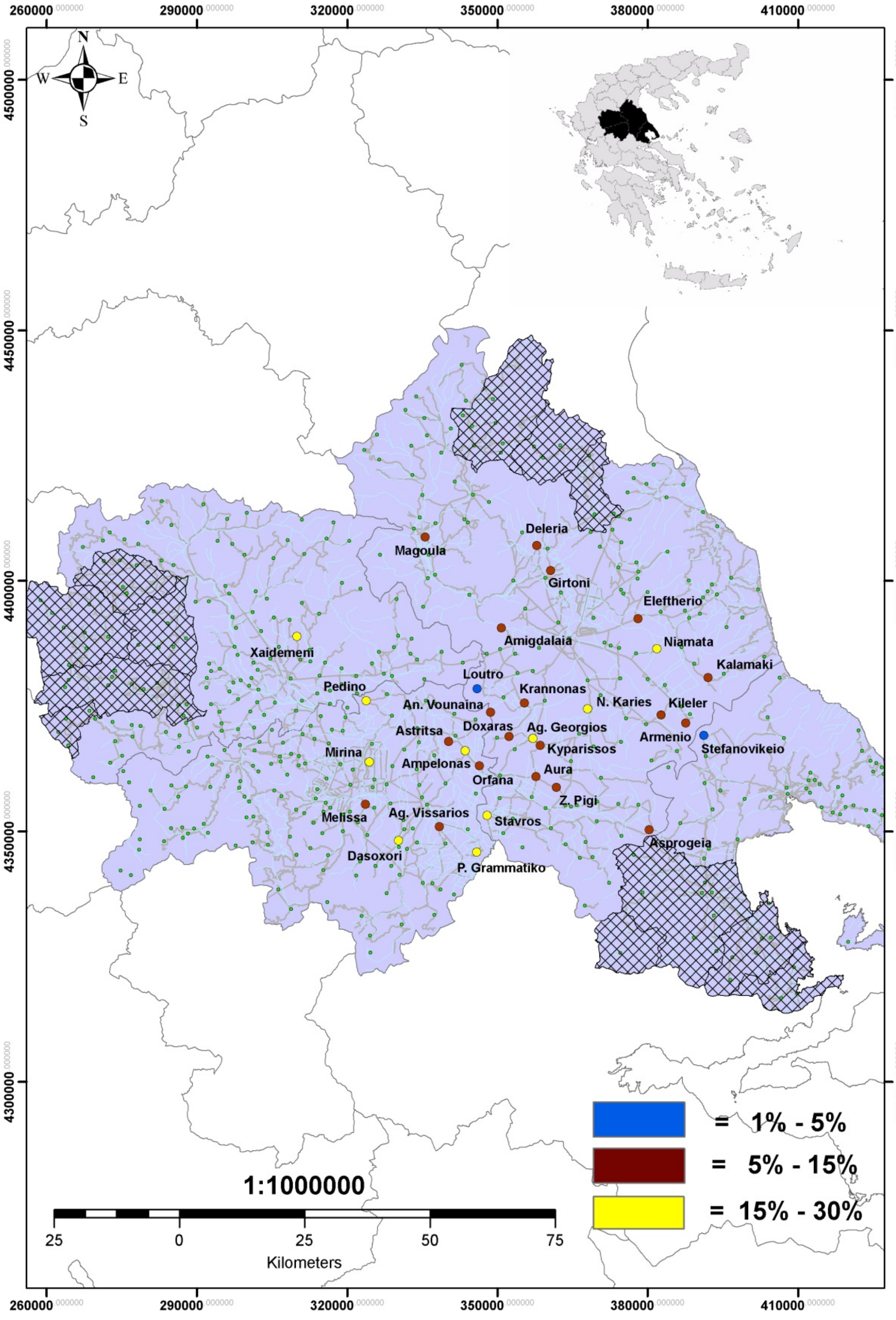


Figure 4.22 Distribution of House mouse (*Mus (Mus) musculus [domesticus]*) in the sampling sites of Thessaly region. Colored circles indicate the specie's presence and green squares indicate villages of the area. In the upper right corner, reference map of Thessaly in respect to Greece. Previously known distribution of the specie in the region, indicated in cross-lined area. Color index in lower right corner.

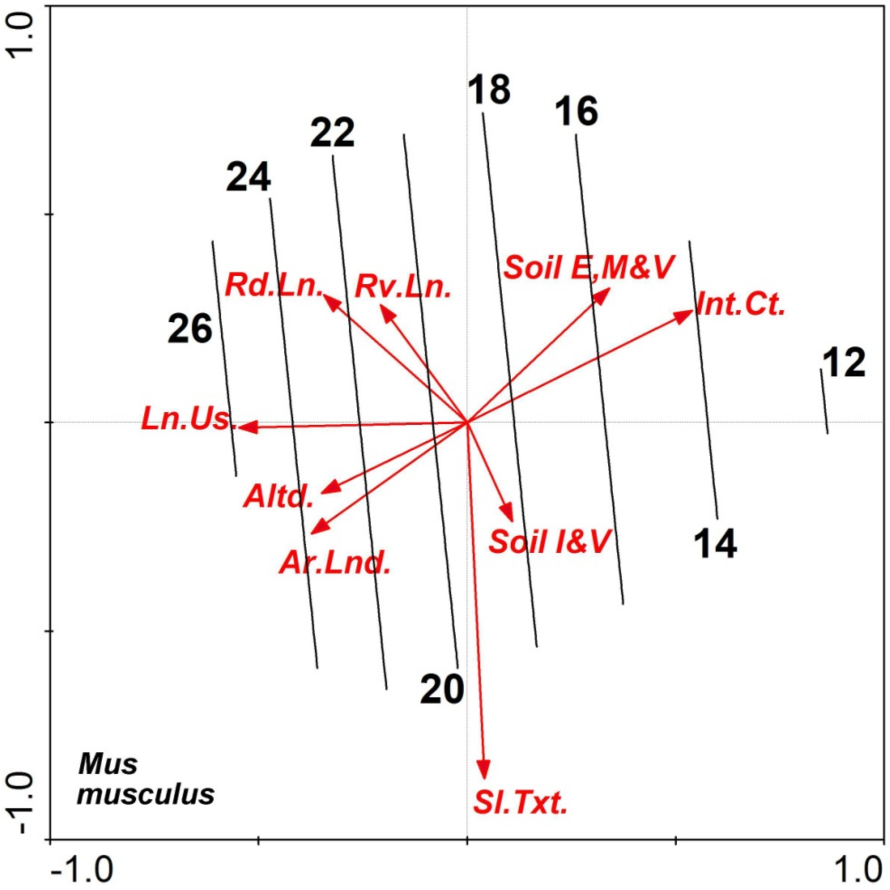


Figure 4.23 Response of House mouse to the environmental gradients. Contour isolines indicate increase in the specie's relative frequency.

According to the criterion of Akaike (AIC), the specie's response to the measured environmental gradients fitted a 1st order polynomial model (Table 4.3), which was also highly significant ($p<0.000001$). The House mouse followed the exactly opposite pattern that Guenther's vole demonstrated, increasing towards the negative values of Axis 1. The horizontal Axis is mainly defined by the factor Land Uses (Ln.Us), which is positively correlated with the increase of the specie's abundance, and factor Intensive Cultivations (Int.Ct.) which also seems to affect strongly the specie's frequency in the studied areas (Figure 4.23).

4.3.1.14 Macedonian mouse (*Mus macedonicus*)

The second member of Mus species in the region of Thessaly is the Macedonian mouse. It was recorded with quite lower percentages than its co-generic House mouse, forming a 4.82% (n=1375) from the total of small mammal specimens recorded in the area. Its frequency among sampling sites varied from 0.83% (n=8, site: Kalamaki) to 12.30% (n=110, site: Dasoxori), and its increase presented a clear trend from eastern to western locations in the study area (Figure 4.23), which is very similar to the trend of House mouse as well. Moreover, although the distribution maps according to Macholan (1999b) and Wilson & Reeder (2005) presented its distribution constrained in the mountainous region of northern Thessaly, data of this study demonstrate that the Macedonian mouse has a broad distribution in the lowlands as well (Figure 4.24).

Generalized Linear Models were applied, and according to the criterion of Akaike (AIC) the specie’s response fitted a 2nd order polynomial model (Table 4.3) which was also significant ($p<0.00001$). The response model is summarized in Figure 4.25, and although its increase pattern isn’t very easy to interpret due to the 2nd order polynomial model, a clear trend can be observed. The Macedonian mouse is increasing when positively correlated with the variables Road Length (Rd.Ln.) and River Length (Rv.Ln.). It is also possible that the negative values of the factors Land Uses (Ln.Us.) and Arable Land (Ar.Lnd) have an effect on the specie’s increase, along with factors Soil Texture (Sl.Txt.), Soil Types I and V (Soil I&V), and Intensive Cultivations (Int.Ct). Nonetheless, since the interactions of the latter four factors and the specie’s gradual change of frequency are not straightforward, the response model (Figure 4.25) should be interpreted cautiously, and supplemented afterwards by testing the response of the specie on each environmental gradient separately.

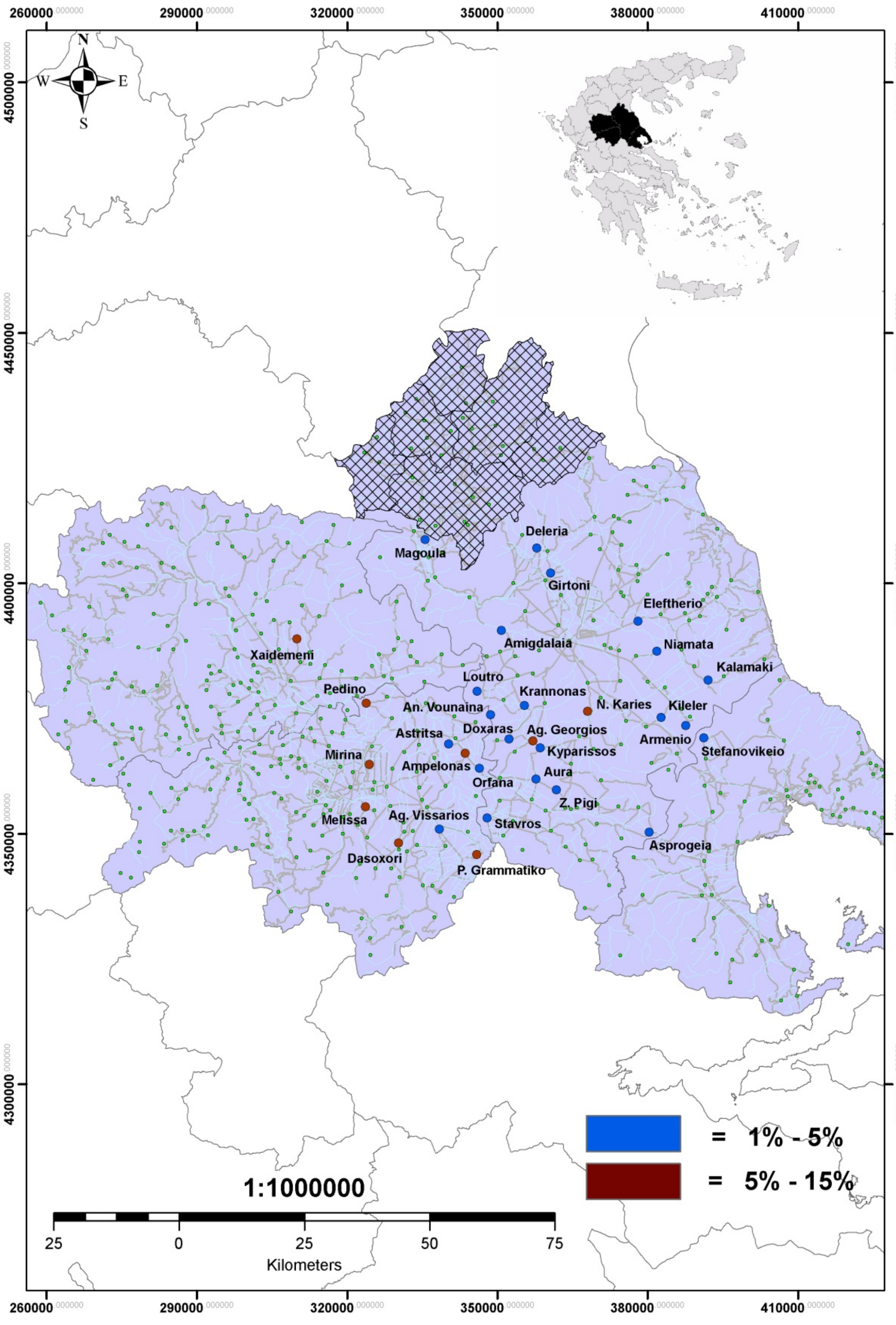


Figure 4.24 Distribution of Macedonian mouse (*Mus macedonicus*) in the sampling sites of Thessaly region. Colored circles indicate the specie's presence and green squares indicate villages of the area. In the upper right corner, reference map of Thessaly in respect to Greece. Previously known distribution of the specie in the region, indicated in cross-lined area. Color index in lower right corner.

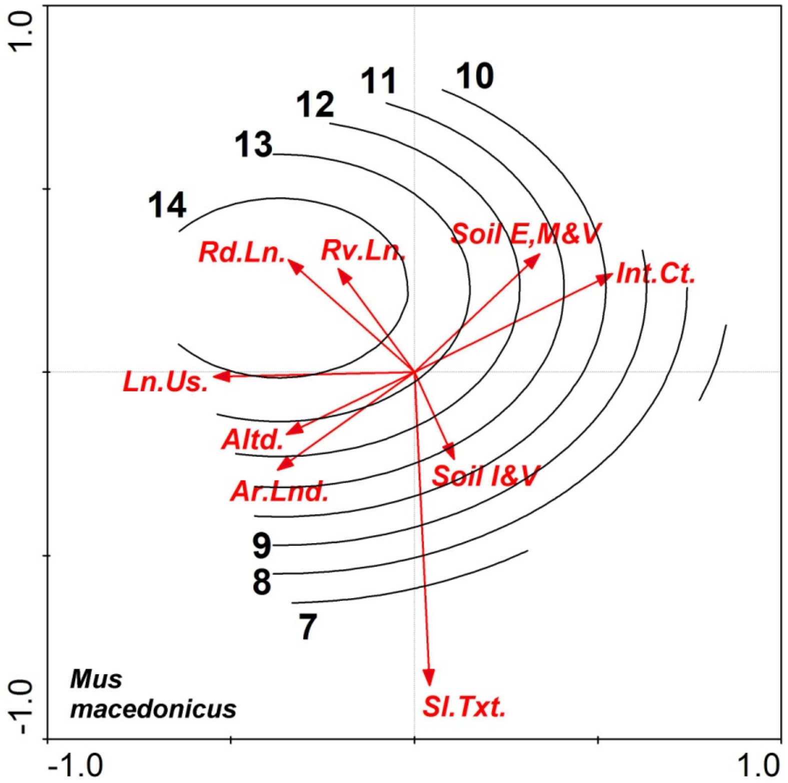


Figure 4.25 Response of Macedonian mouse to the environmental gradients. Contour isolines indicate increase in the specie's relative frequency.

4.3.1.15 Hazel Dormouse (*Muscardinus avellanarius*)

The last of small mammal species which were recorded in the agricultural ecosystems of Thessaly, is the Hazel Dormouse. Since its habits are more of a forest dweller specie, therefore it was minimally represented in the agricultural ecosystems of Thessaly, occupying only 4 out of 31 sampling sites (Figure 4.26), and forming only a 0.17% of the total small mammals recorded in the region. Its percentages of frequency were very low ranging from 0.11% (n=1, site: Palaio Grammatiko) to 2.93% (n=25, site: Myrina).

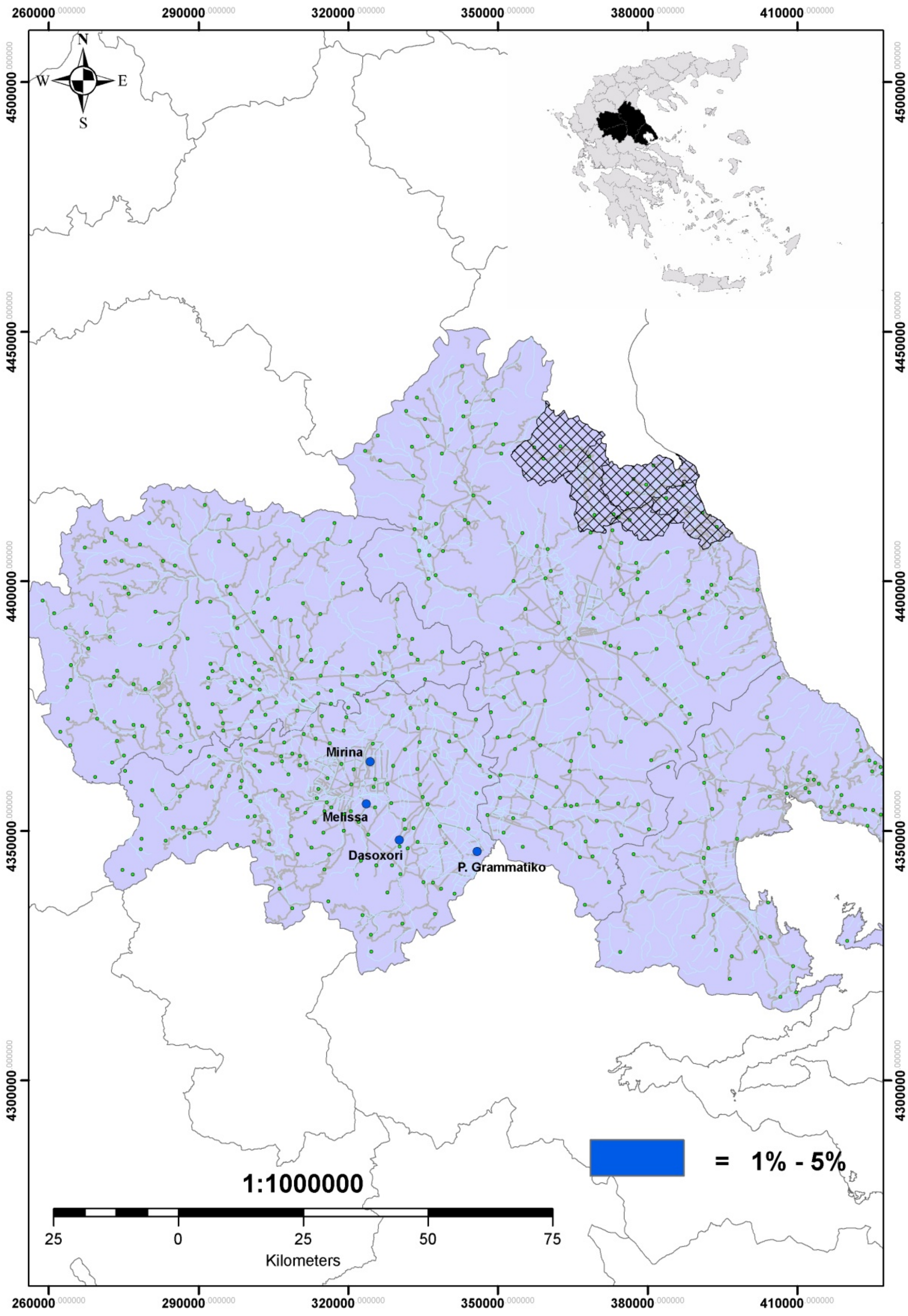


Figure 4.26 Distribution of Hazel dormouse (*Muscardinus avellanarius*) in the sampling sites of Thessaly region. Colored circles indicate the specie's presence and green squares indicate villages of the area. In the upper right corner, reference map of Thessaly in respect to Greece. Previously known distribution of the specie in the region, indicated in cross-lined area. Color index in lower right corner.

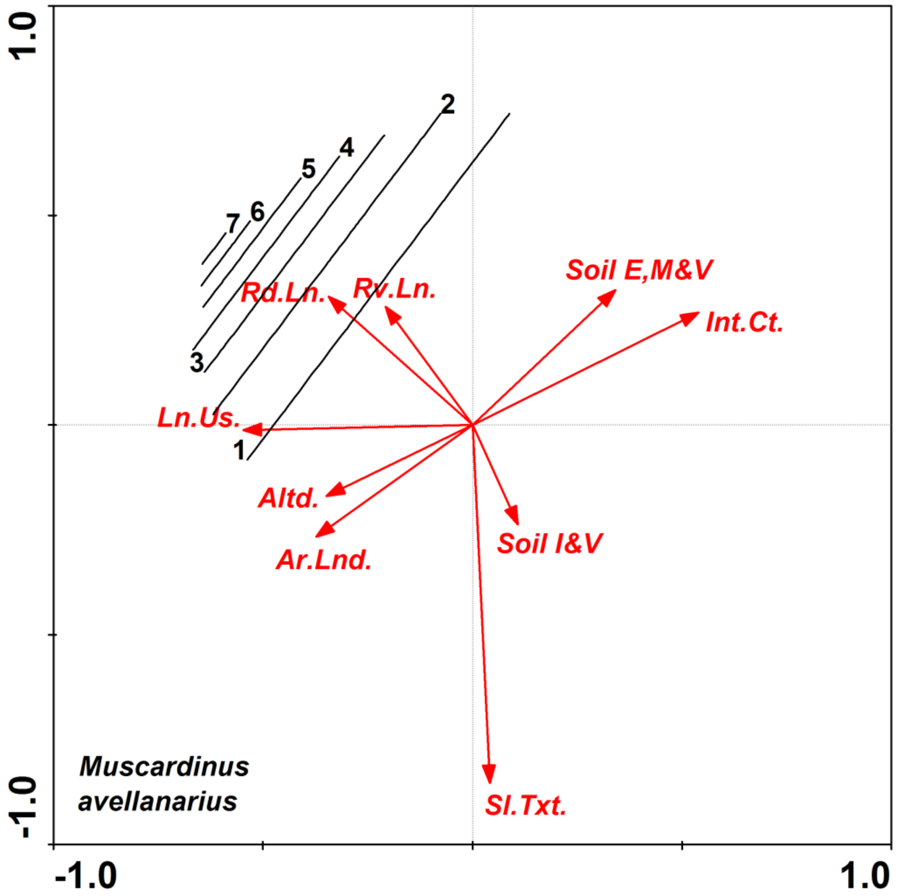


Figure 4.27 Response of Hazel dormouse to the environmental gradients. Contour isolines indicate increase in the specie's relative frequency.

According to the Atlas of European Mammals and the publications of Storch (1978b), Morris (1999) and Wilson & Reeder (2005), the previous distribution of the specie in Thessaly occupied only a part of the northern mountainous region. Nonetheless, data of this study demonstrate that it also occupies another area in the south (Figure 4.26). Although the Hazel dormouse was only present in 4 sites with low percentages of frequency, it fitted nonetheless according to the criterion of Akaike (AIC) a 1st order polynomial model (Table 4.3). The response model was highly significant ($p<0.000001$) and indicated that the specie's abundance increased when correlated with the variables River Length and Road Length (Rv.Ln. & Rd.Ln.).

4.3.2 Individual response of small mammal species on each environmental gradient

The general response models of each recorded species in Thessaly were presented in the previous part, demonstrating concentrative information both for their space use and habitat selection. Large spatial scale studies of dynamic Mediterranean agroecosystems like that of Thessaly include numerous underlying gradients. Such environmental gradients like "Land Uses" and "Intensive Cultivations" for example, interact with small mammals' intrinsic demographic processes, and define their population structure in the landscape of Thessaly lowlands. Nonetheless, although this concentrative information gives a quite clear image, it cannot outline in detail all the interactions between species and certain gradients, with which they don't have a straightforward correlation. Moreover, since most underlying gradients are factors produced from Factor analysis, which combine original variables along their negative and positive values, model interpretation is more complex and needs to be deconstructed and simplified if possible.

Therefore, in order to gain further perspective on interactions between measured environmental gradients, and small mammal space use, population structure and distribution, one more statistical step was applied. With the use of Canoco, the response of every recorded species was tested against each environmental gradient separately. Canoco tests the significance of response models using Generalized Linear Model Analysis. The choice of "best fit" model is realized once more with the criterion of Akaike (AIC), as demonstrated in Table 4.4, and statistical significance is set at alpha level equal to 0.05. Visualization of each model was realized with the utility Canodraw also included in Canoco (version 4.5 for Windows) and is demonstrated in Figures 4.28 to 4.36.

Table 4.4 Response of small mammal species' on each environmental gradient separately. "Best fit" model selection according to the criterion of Akaike (AIC) through Generalized Linear Model analysis. Response variables which didn't fit any model and were rejected through "null model" hypothesis are not included in the table. Significant p_s are noted: p < 0.01 = *, p < 0.001 = **, p < 0.0001 = ***, p < 0.00001 = ****, p < 0.000001 = *****.

		Model Selection		**Generalized Linear Model results**	
	AIC	$b_0 + b_1X$	$b_0 + b_1X + b_2X^2$	F	p
ALTITUDE					
Cricetulus migratorius	509.887		√	15.69	*****
Crocidura suaveolens	339.898	√		15.24	***
Microtus guentheri	839.373		√	6.39	*
Microtus thomasi	1494.893		√	20.35	*****
Mus musculus	379.776		√	4.64	*
Mus macedonicus	377.475		√	8.15	**
Muscardinus avellanarius	315.148		√	15.93	*****
SOIL TEXTURE					
Cricetulus migratorius	510.662		√	22.95	*****
Crocidura suaveolens	315.082	√		25.58	****
Microtus thomasi	1400.404		√	20.99	*****
Mus macedonicus	394.196		√	4.43	*
Muscardinus avellanarius	278.222		√	24.36	*****
Rattus rattus	828.029		√	4.19	*
INTENSIVE CULTIVATIONS					
Apodemus sylvaticus	301.322		√	12.25	***
Microtus guentheri	778.679		√	12.38	***
Microtus thomasi	1949.367	√		6.34	*
Mus musculus	298.536		√	23.61	*****
Mus macedonicus	398.985		√	3.38	*
Suncus etruscus	630.404		√	8.08	**
LAND USES					
Cricetulus migratorius	628.855	√		12.59	**
Microtus guentheri	846.075	√		9.55	*
Mus musculus	365.356		√	7.41	**
Mus macedonicus	391.935		√	4.82	*
Muscardinus avellanarius	298.719		√	18.55	*****
ARABLE LAND					
Cricetulus migratorius	684.847	√		3.98	*
Crocidura suaveolens	336.623	√		16.15	**
Microtus guentheri	872.843		√	3.49	*
Mus musculus	387.938		√	3.12	*
Mus macedonicus	395.878	√		5.96	*
Muscardinus avellanarius	324.252		√	13.52	****
Rattus rattus	837.398	√		5.05	*

Table 4.4 (continued)

		Model Selection		**Generalized Linear Model results**	
	AIC	$b_0 + b_1X$	$b_0 + b_1X + b_2X^2$	F	p
RIVER LENGTH					
Cricetulus migratorius	494.333	√		32.76	*****
Crocidura suaveolens	367.222		√	3.23	*
Microtus thomasi	1784.929		√	9.63	**
Muscardinus avellanarius	287.839		√	21.87	*****
Suncus etruscus	653.615		√	4.96	*
ROAD LENGTH					
Cricetulus migratorius	661.715	√		7.44	*
Crocidura suaveolens	363.784		√	3.87	*
Microtus guentheri	863.323		√	4.31	*
Mus musculus	372.938		√	5.91	*
Mus macedonicus	389.701		√	5.30	*
Muscardinus avellanarius	305.670	√		18.54	***
Rattus rattus	756.640		√	8.94	**
Suncus etruscus	664.907	√		5.07	*
SOIL E,M&V					
Cricetulus migratorius	682.624	√		4.30	*
Crocidura suaveolens	311.201		√	14.82	****
Microtus thomasi	1921.316		√	4.99	*
Muscardinus avellanarius	261.291		√	11.23	***
Suncus etruscus	632.931		√	7.87	**
SOIL I&V					
Microtus thomasi	1624.949		√	14.91	****
Mus macedonicus	400.967	√		4.02	*
Muscardinus avellanarius	395.268		√	4.29	*
Rattus rattus	846.362	√		3.93	*

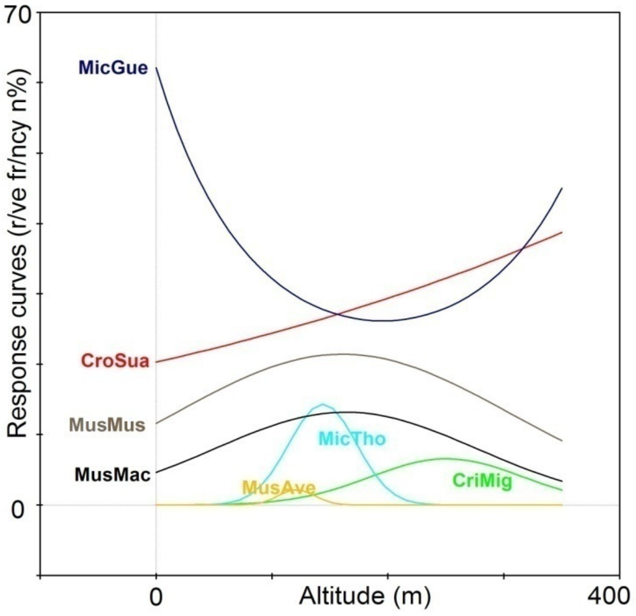


Figure 4.28 Response curves of small mammal species on the environmental gradient "Altitude". Only significant curves are demonstrated in the figure. Acronyms stand for: ***MicGue:*** Microtus guentheri, ***CroSua:*** Crocidura suaveolens, ***MusMus:*** Mus musculus, ***MusMac:*** Mus macedonicus, ***MicTho:*** Microtus thomasi, ***MusAve:*** Muscardinus avellanarius, ***CriMig:*** Cricetulus migratorius.

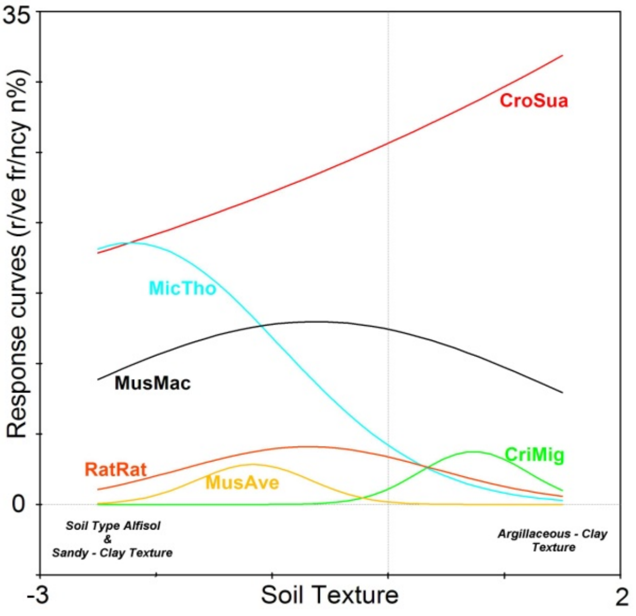


Figure 4.29 Response curves of small mammal species on the environmental gradient "Soil Texture". Only significant curves are demonstrated in the figure. Acronyms stand for: ***CroSua:*** Crocidura suaveolens, ***MicTho:*** Microtus thomasi, ***MusMac:*** Mus macedonicus, ***RatRat:*** Rattus rattus, ***MusAve:*** Muscardinus avellanarius, ***CriMig:*** Cricetulus migratorius.

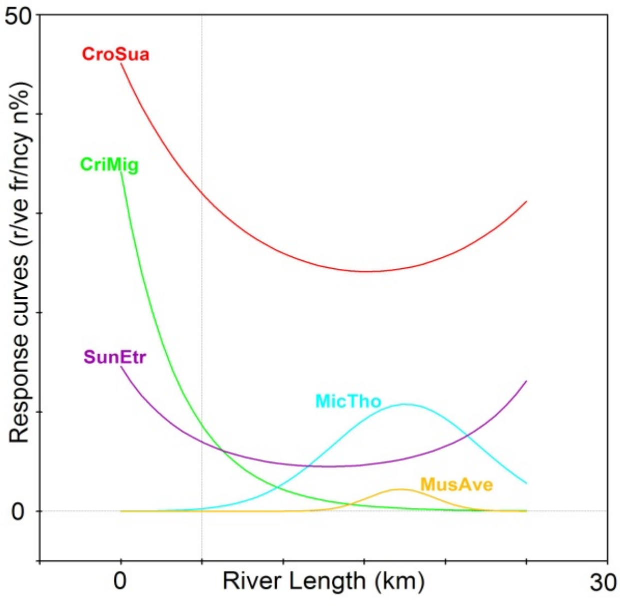


Figure 4.30 Response curves of small mammal species on the environmental gradient "River Length". Only significant curves are demonstrated in the figure. Acronyms stand for: ***CroSua:*** Crocidura suaveolens, ***CriMig:*** Cricetulus migratorius, ***SunEtr:*** Suncus etruscus, ***MicTho:*** Microtus thomasi, ***MusAve:*** Muscardinus avellanarius.

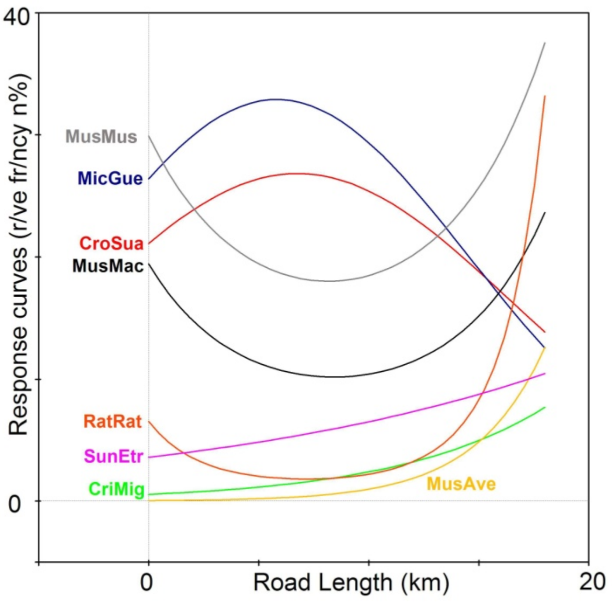


Figure 4.31 Response curves of small mammal species on the environmental gradient "Road Length". Only significant curves are demonstrated in the figure. Acronyms stand for: ***MusMus:*** Mus musculus, ***MicGue:*** Microtus guentheri, ***CroSua:*** Crocidura suaveolens, ***MusMac:*** Mus macedonicus, ***RatRat:*** Rattus rattus, ***SunEtr:*** Suncus etruscus, ***CriMig:*** Cricetulus migratorius, ***MusAve:*** Muscardinus avellanarius.

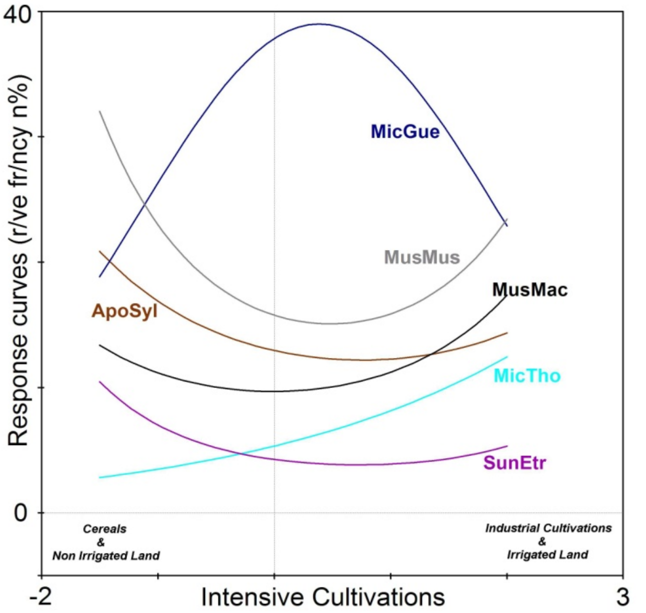


Figure 4.32 Response curves of small mammal species on the environmental gradient "Intensive Cultivations". Only significant curves are demonstrated in the figure. Acronyms stand for: ***MicGue:*** Microtus guentheri, ***MusMus:*** Mus musculus, ***MusMac:*** Mus macedonicus, ***ApoSyl:*** Apodemus sylvaticus, ***MicTho:*** Microtus thomasi, ***SunEtr:*** Suncus etruscus.

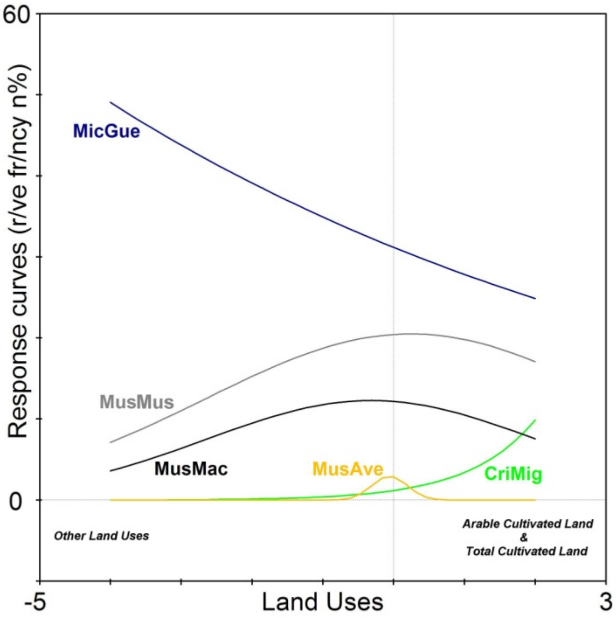


Figure 4.33 Response curves of small mammal species on the environmental gradient "Land Uses". Only significant curves are demonstrated in the figure. Acronyms stand for: ***MicGue:*** Microtus guentheri, ***MusMus:*** Mus musculus, ***MusMac:*** Mus macedonicus, ***MusAve:*** Muscardinus avellanarius, ***CriMig:*** Cricetulus migratorius.

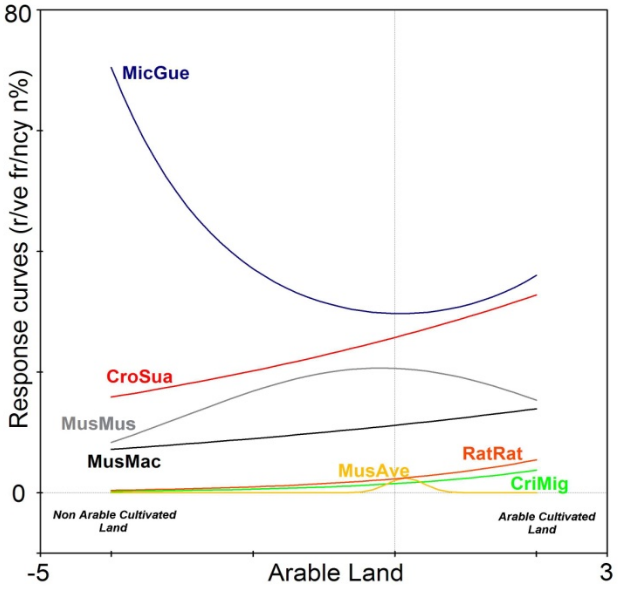


Figure 4.34 Response curves of small mammal species on the environmental gradient "Arable Land". Only significant curves are demonstrated in the figure. Acronyms stand for: ***MicGue:*** Microtus guentheri, ***CroSua:*** Crocidura suaveolens, ***MusDom:*** Mus domesticus, ***MusMac:*** Mus macedonicus, ***RatRat:*** Rattus rattus, ***CriMig:*** Cricetulus migratorius, ***MusAve:*** Muscardinus avellanarius.

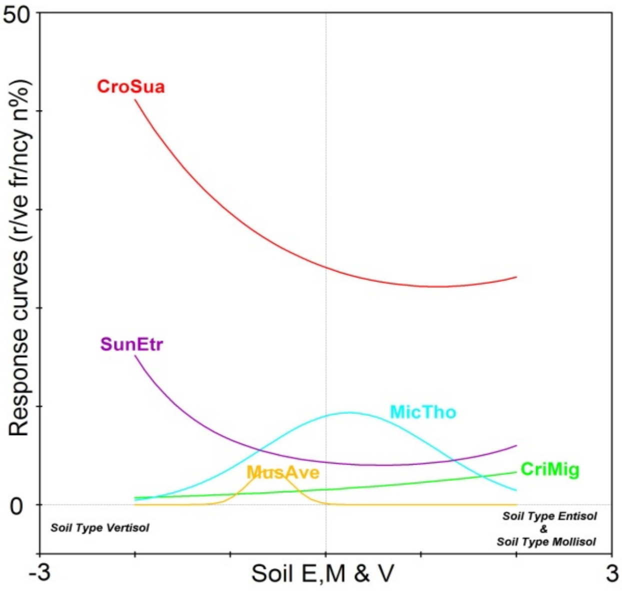


Figure 4.35 Response curves of small mammal species on the environmental gradient "Soil E,M&V". Only significant curves are demonstrated in the figure. Acronyms stand for: ***CroSua:*** Crocidura suaveolens, ***SunEtr:*** Suncus etruscus, ***MicTho:*** Microtus thomasi, ***CriMig:*** Cricetulus migratorius, ***MusAve:*** Muscardinus avellanarius.

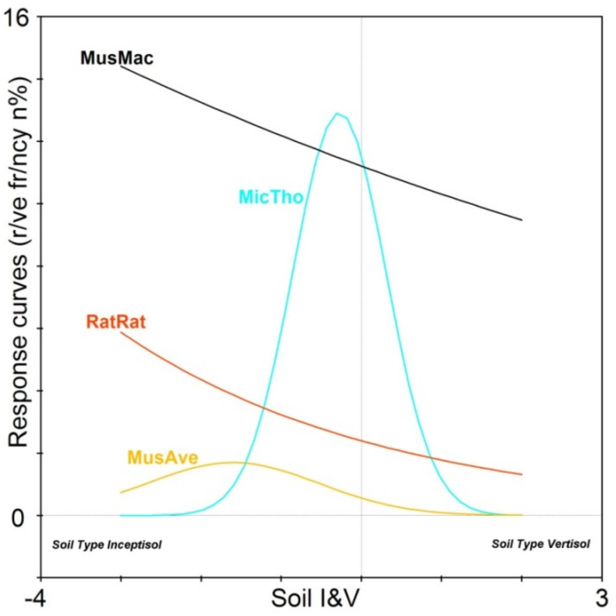


Figure 4.36 Response curves of small mammal species on the environmental gradient "Soil I&V". Only significant curves are demonstrated in the figure. Acronyms stand for: ***MusMac:*** Mus macedonicus, ***MicTho:*** Microtus thomasi, ***RatRat:*** Rattus rattus, ***MusAve:*** Muscardinus avellanarius.

4.3.3 Response of small mammal species, environmental variables and factors, on Latitudinal and Longitudinal gradients

The continuity change of species' composition along the measured environmental gradients reveals different space use and habitat selection patterns. In previous part a detailed approach was realized, testing the individual response of each species along each gradient separately, which demonstrated detailed response models. Once this analysis was completed, space use patterns were more clarified in Thessaly's agroecosystems. Nonetheless, since species' composition is tested on underlying gradients measured on a wide geographical scale, with data taken from sampling sites in distances of 90 km (east to west) and 80 km (north to south), latitude and longitude effect needs to be considered as well. In that case though specifically, the effect of latitude and longitude must not be tested only on small mammals' community composition, but also on independent variables. Environmental variables' response

Table 4.5 Response of factors, environmental variables and small mammal species on both longitude and latitude gradients. “Best fit” model selection was realized according to the criterion of Akaike (AIC), and model significance was tested with Generalized Linear Model analysis. Response models which were rejected through “null model” selection or were insignificant are not included in the table. Significant p_s are noted: $p < 0.01$ = *, $p < 0.001$ = **, $p < 0.0001$ = ***, $p < 0.00001$ = ****, $p < 0.000001$ = *****.

		Model Selection		**Generalized Linear Model results**	
	AIC	$b_0 + b_1X$	$b_0 + b_1X + b_2X^2$	F	p
LONGITUDE (X Coordinates)					
Land Uses	122.68		√	3.18	*
Arable Land	118.30		√	5.57	*
Soil Texture	97.30		√	20.04	*****
Altitude	390844.88		√	5.38	*
Soil E,M&V	94.15		√	22.77	*****
River Length	2427.85	√		22.86	*****
Road Length	880.80	√		9.85	*
Crocidura suaveolens	310.02		√	15.65	*****
Suncus etruscus	643.73		√	6.38	*
Microtus guentheri	693.22		√	21.92	*****
Microtus levis	334.36	√		4.29	*
Microtus thomasi	864.82		√	46.42	*****
Cricetulus migratorius	657.45		√	4.64	*
Apodemus flavicollis	338.222	√		4.64	*
Mus musculus	352.94	√		17.87	***
Mus macedonicus	334.97		√	19.70	*****
Muscardinus avellanarius	189.32		√	15.50	*****
LATITUDE (Ψ Coordinates)					
Land Uses	120.32		√	4.45	*
Arable Land	67.48		√	56.06	*****
Soil Texture	105.29		√	13.86	*****
Altitude	388030.50	√		9.64	*
Soil E,M&V	72.14		√	48.47	*****
Soil I&V	122.21	√		4.85	*
River Length	2002.127		√	28.33	*****
Crocidura suaveolens	272.62		√	26.69	*****
Suncus etruscus	645.02	√		10.21	*
Microtus guentheri	825.73	√		13.33	**
Microtus Levis	314.89	√		13.65	**
Cricetulus migratorius	661.48		√	3.89	*
Mus musculus	381.37	√		6.61	*
Mus macedonicus	400.20	√		4.32	*
Muscardinus avellanarius	315.11		√	15.88	*****

(River length, Road length & Altitude) as well as all factors produced from Factor analysis need to be tested along Latitudinal and Longitudinal gradients (X and Ψ coordinates respectively). Constructing such response models will complete the formulation of landscape ecology hypotheses in Thessaly, on a large spatial scale and always in respect to small mammal distribution patterns, space use and habitat selection.

Such an analysis could be realized with ANCOVA, using latitudinal and longitudinal gradients as covariables, or by using them as predictor variables and construct response models using small mammal species, environmental variables and factors as explanatory variables. The latter case was applied for the present thesis using Canoco, version 4.5 for Windows. As a result, species like Bicolored shrew, Long-tailed field mouse, Western broad-toothed mouse, Black rat and Brown rat didn't fit any response model along the Longitudinal gradient, whereas the species Bicolored shrew, Thomas's pine vole, Long-tailed field mouse, Yellow-necked field mouse, Western broad-toothed field mouse, Black rat and Brown rat were similarly rejected through "null model" selection along the Latitudinal gradient (Tab. 4.5). The other species fitted 1st and 2nd order models on both gradients (Tab. 4.5, Figs. 4.51 & 4.52).

In respect to environmental variables and factors, only factor "Intensive Cultivations" didn't fit any significant response model along both gradients, whereas factor "Soil I&V" was rejected when tested along longitude and variable "Road Length" was rejected when tested along latitude (Tab. 4.5). Factor "Arable Land" fitted significant 2nd order response models along both gradients (Tab. 4.5), indicating also that arable land was the dominating agricultural practice in most sampling sites with few exceptions (Figs. 4.37 & 4.38). Specifically along the longitudinal gradient, the arable land included in the sampling sites presents a slight decrease towards eastern locations

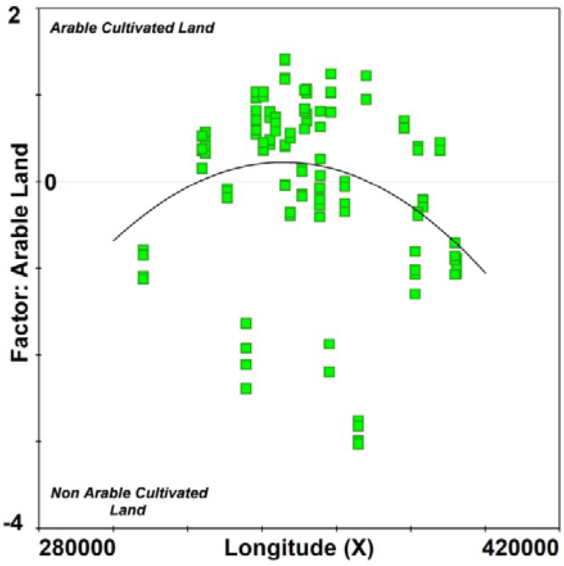


Figure 4.37 Response of factor "Arable Land" on the gradient "Longitude". Curved line summarizes the fitted regression model and green squares indicate the sampling sites.

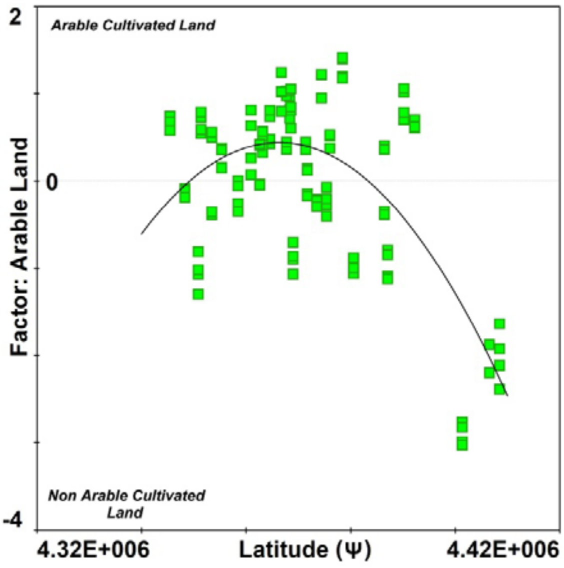


Figure 4.38 Response of factor "Arable Land" on the gradient "Latitude". Curved line summarizes the fitted regression model and green squares indicate the sampling sites.

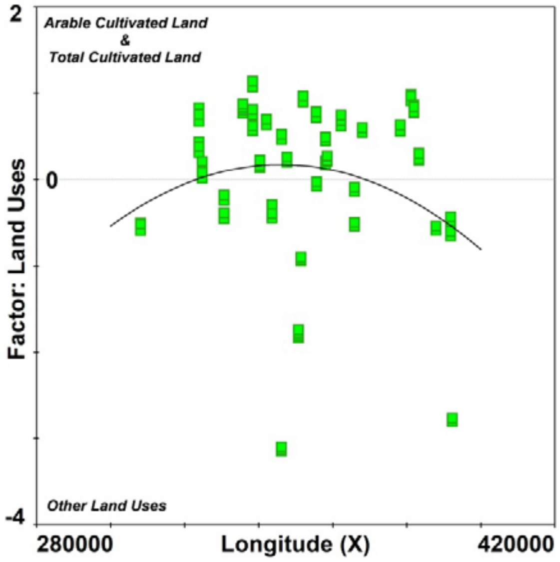


Figure 4.39 Response of factor "Land Uses" on the gradient "Longitude". Curved line summarizes the fitted regression model and green squares indicate the sampling sites.

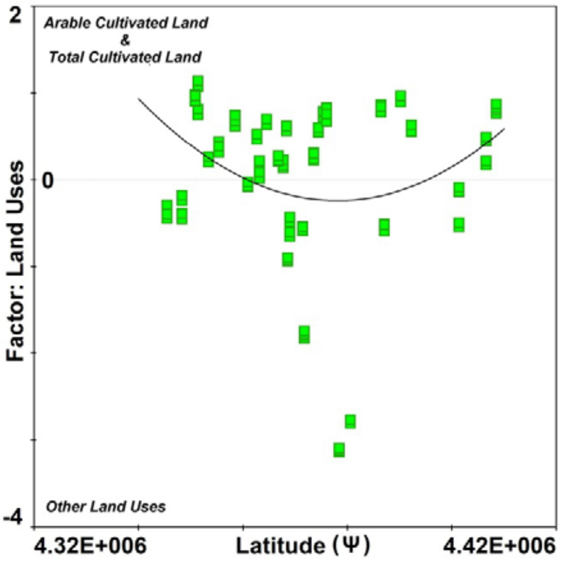


Figure 4.40 Response of factor "Land Uses" on the gradient "Latitude". Curved line summarizes the fitted regression model and green squares indicate the sampling sites.

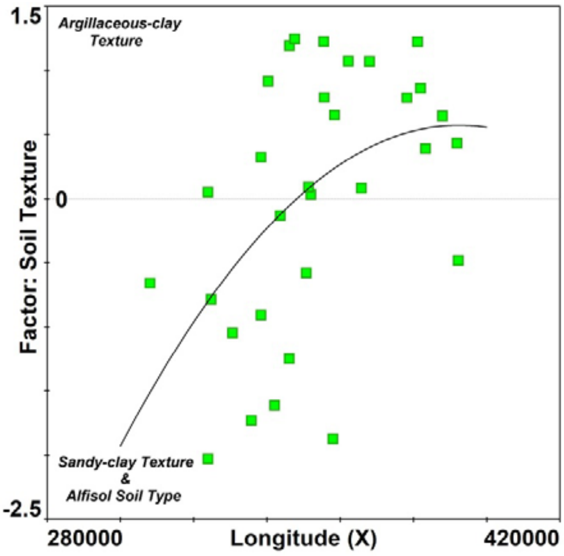


Figure 4.41 Response of factor "Soil Texture" on the gradient "Longitude". Curved line summarizes the fitted regression model and green squares indicate the sampling sites.

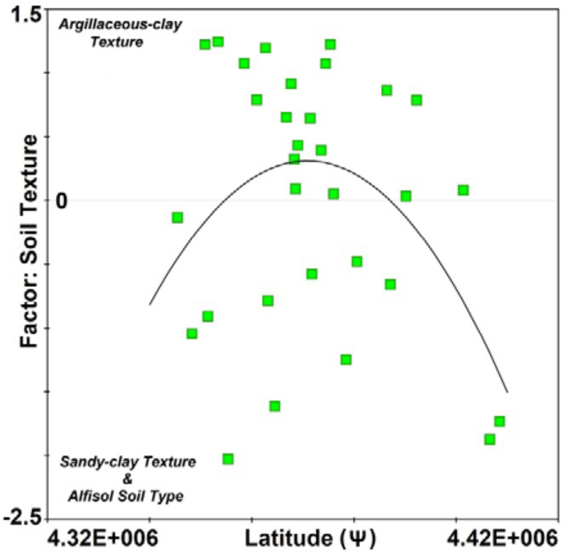


Figure 4.42 Response of factor "Soil Texture" on the gradient "Latitude". Curved line summarizes the fitted regression model and green squares indicate the sampling sites.

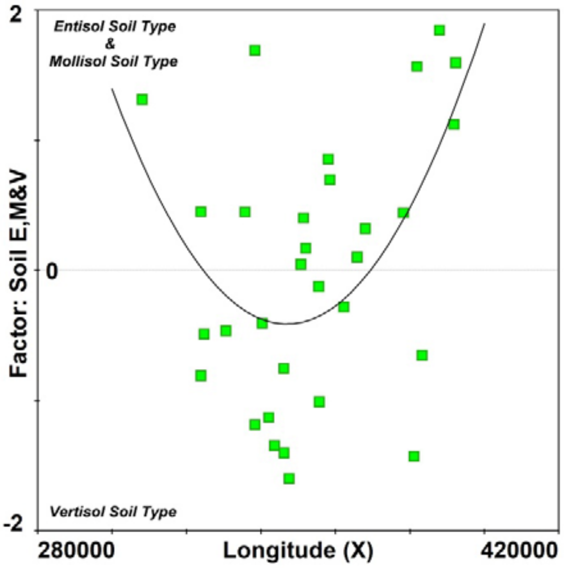


Figure 4.43 Response of factor "Soil E,M&V" on the gradient "Longitude". Curved line summarizes the fitted regression model and green squares indicate the sampling sites.

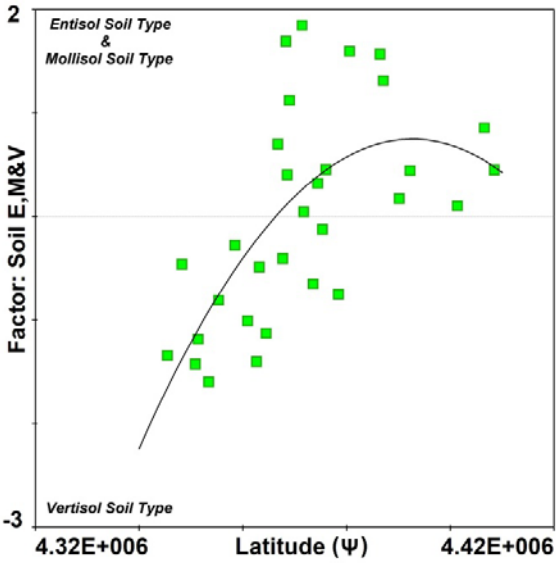


Figure 4.44 Response of factor "Soil E,M&V" on the gradient "Latitude". Curved line summarizes the fitted regression model and green squares indicate the sampling sites.

(Fig. 4.37) and a strong decrease along the latitudinal gradient towards northern locations (Fig. 4.38), whereas the factor's response on both gradients indicates that arable land areas is mainly located in study areas of central Thessaly. Factor "Land Uses" fitted 2nd order significant response models on both gradients (Tab. 4.5), indicating that most study areas are consisted of cultivated land mainly with arable crops, while very few exceptions of sampling sites dominated from natural grasslands, mountainous parts, larger urban areas, set-aside fields and fallow land are located in central Thessaly (Figs. 4.39 & 4.40).

Soil texture in Thessaly lowlands, fitted 2nd order significant response models on both gradients (Tab. 4.5). Along the latitudinal gradient, most study areas are consisted of soils with argillaceous-clay texture which are mainly encountered in central locations, with fewer sites dominated from sandy-clay texture being present along southern and northern parts of the bordering zone (Fig. 4.42). On the other hand, the response model along the longitudinal gradient indicates similarly that most sites are dominated from argillaceous-clay soil texture, but a significant increase of such sites is demonstrated from western to eastern locations (Fig. 4.41). Soil type E,M&V also fitted 2nd order significant response models on both gradients (Tab. 4.5), which revealed that study areas are actually equally divided between Vertisol and Entisol-Mollisol soil types (Figs. 4.43 & 4.44). More specific though, it can be observed that there is a slight increase for Entisol-Mollisol soil type locations from western to eastern locations (Fig. 4.43), whereas Vertisol soil type sites dominate southern study areas (Fig. 4.44).

Most study areas present low altitudes (< 150 m) except few sites located mainly in central Thessaly (4.45 & 4.46). The variable "Altitude" fitted significant 2nd order and 1st order response models on longitudinal and latitudinal gradients respectively (Tab. 4.5),

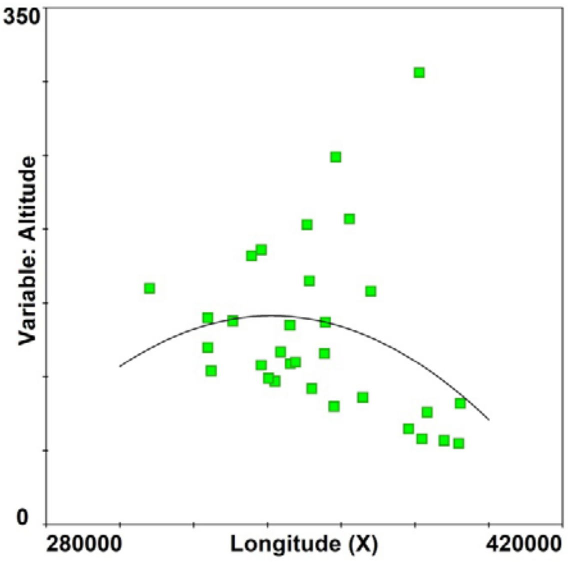


Figure 4.45 Response of variable "Altitude" on the gradient "Longitude". Curved line summarizes the fitted regression model and green squares indicate the sampling sites.

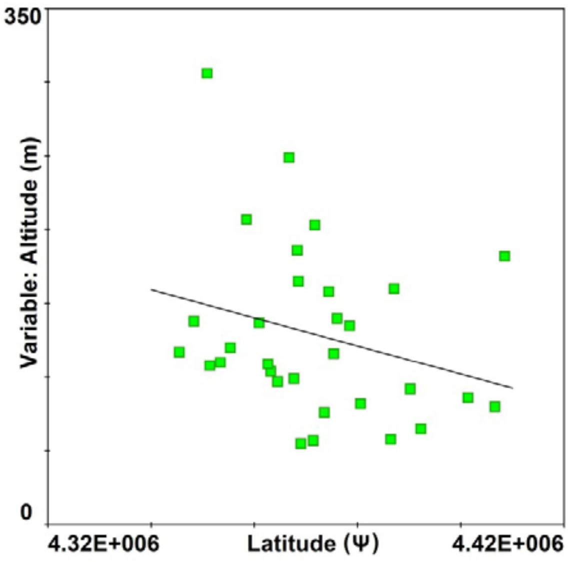


Figure 4.46 Response of variable "Altitude" on the gradient "Latitude". Straight line summarizes the fitted regression model and green squares indicate the sampling sites.

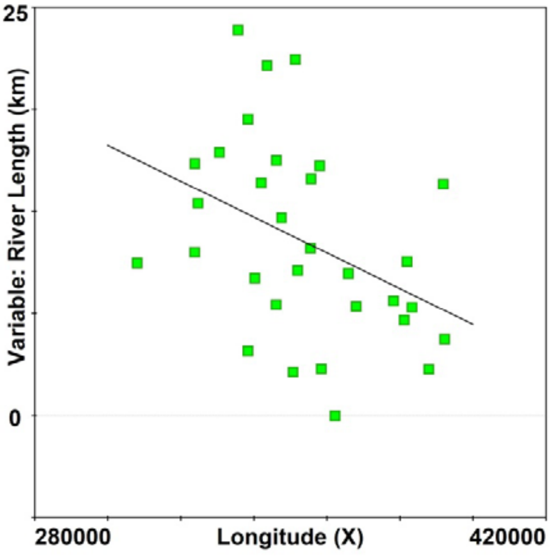


Figure 4.47 Response of variable "River Length" on the gradient "Longitude". Straight line summarizes the fitted regression model and green squares indicate the sampling sites.

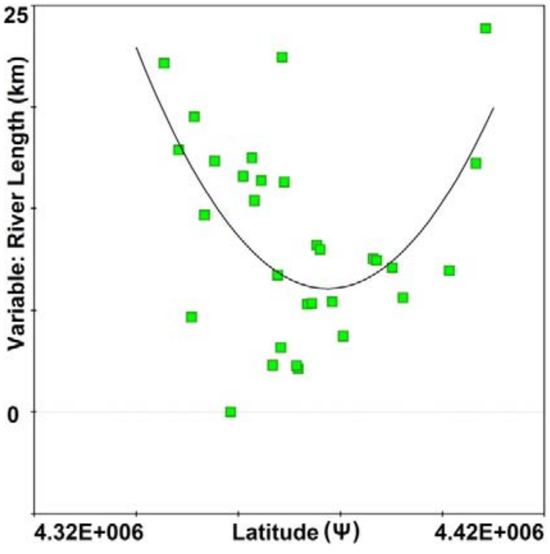


Figure 4.48 Response of variable "River Length" on the gradient "Latitude". Curved line summarizes the fitted regression model and green squares indicate the sampling sites.

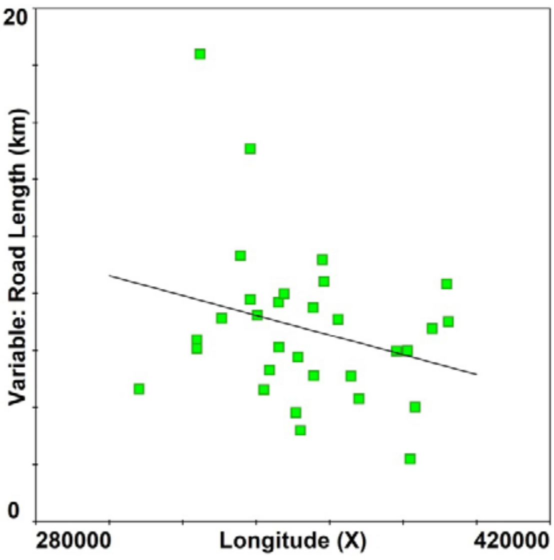


Figure 4.49 Response of variable "Road Length" on the gradient "Longitude". Straight line summarizes the fitted regression model and green squares indicate the sampling sites.

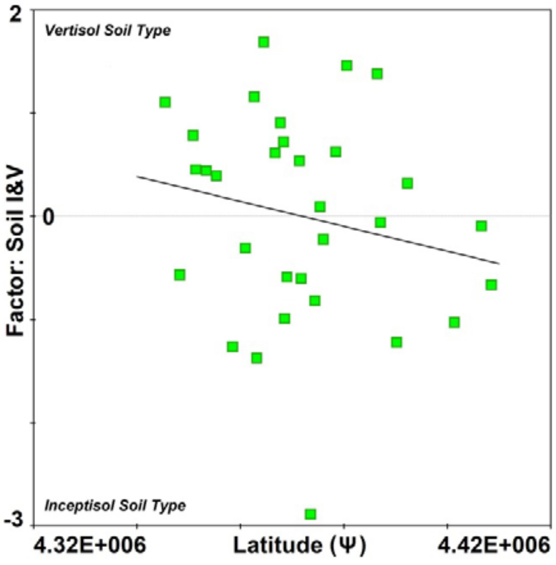


Figure 4.50 Response of factor "Soil I&V" on the gradient "Latitude". Straight line summarizes the fitted regression model and green squares indicate the sampling sites.

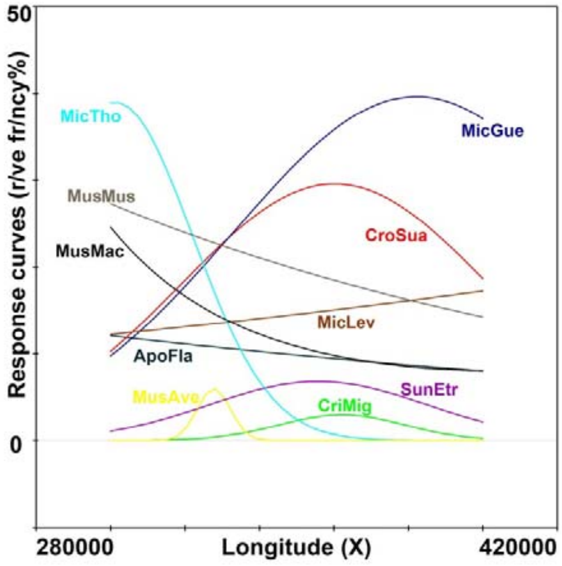


Figure 4.51 Response curves of small mammal species' relative frequency on the gradient "Longitude". Only significant curves are demonstrated in the figure. Acronyms stand for: ***ApoFla:*** Apodemus flavicollis, ***CriMig:*** Cricetulus migratorius, ***CroSua:*** Crocidura suaveolens, ***MigGue:*** Microtus guentheri, ***MicLev:*** Microtus levis, ***MicTho:*** Microtus thomasi, ***MusMus:*** Mus musculus, ***MusMac:*** Mus macedonicus, ***MusAve:*** Muscardinus avellanarius, ***SunEtr:*** Suncus etruscus.

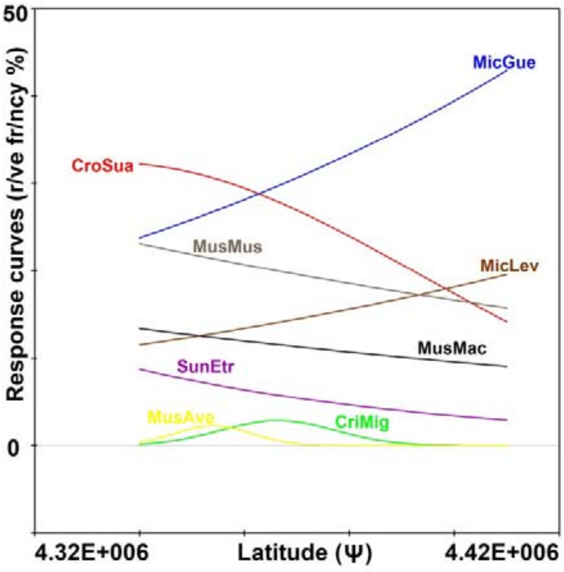


Figure 4.52 Response curves of small mammal species' relative frequency on the gradient "Latitude". Only significant curves are demonstrated in the figure. Acronyms stand for: ***CriMig:*** Cricetulus migratorius, ***CroSua:*** Crocidura suaveolens, ***MigGue:*** Microtus guentheri, ***MicLev:*** Microtus levis, ***MusMus:*** Mus musculus, ***MusMac:*** Mus macedonicus, ***MusAve:*** Muscardinus avellanarius, ***SunEtr:*** Suncus etruscus.

decreasing gradually along both eastern and northern locations (Figs. 4.45 & 4.46). Rriver, ditches' and irrigating canal lengths included within the 2 km radius around each sampling site varied from 0 to 25 km, and decreased significantly from western to eastern locations (Tab. 4.5 & Fig. 4.47). A similar decrease is observed along the latitudinal gradient where total river lengths within the sampling sites decreased from southern to northern locations (Fig. 4.48). Nonetheless, a few sites with larger river lengths on the northern border of the study areas produced the 2nd order significant response model (Tab. 4.5) and the strong arch effect in Figure 4.48.

Road lengths which were included within the 2 km radius in each study area didn't exceed 10 km except in a minimum of two cases (Fig. 4.49). "Road Length" variable fitted a 1st order significant response model but only along the longitudinal gradient, decreasing from western to eastern locations (Tab. 4.5 & Fig. 4.49). Finally, factor "Soil I&V" also fitted a 1st order significant response model but only along the latitudinal gradient (Tab. 4.5). As demonstrated from the summarized regression model, study areas with higher percentages of Vertisol soil types are located in southern sampling sites and decrease towards northern locations, while being substituted with higher percentages of Inseptisol soil types (Fig. 4.50).

4.4 DISCUSSION

In Greece eight species from the order Soricomorpha are found in mainland and island areas of the country (Mitchell-Jones et al., 1999; Wilson & Reeder, 2005). According to the results of this thesis, three of them also inhabit the agricultural plains of Thessaly, where they hadn't been recorded before. Firstly, the Bicolored shrew was until recently considered to be present only in the mountainous area of Pindus in western Thessaly in the location Pertouli (Peus, 1954, Krapp, 1999), and in the southern location Farsala (Niethammer, 1974; Krapp, 1999). Data of this work though demonstrated a much broader distribution of the specie in the lowlands of Thessaly (Bontzorlos et al., 2007e), in 28 of 31 sampled sites (Fig. 4.3). Possibly due to low percentages of frequency among sites (0.56% - 7.32%), the specie's change of composition didn't fit any response model along the total of measured environmental gradients (Tab. 4.3), neither did it present significant responses along each gradient separately (Tab. 4.4). On the other hand, its co-generic Lesser white-toothed shrew was recorded as the second most abundant small mammal specie in the studied areas, which was present in all 31 sampling sites (Fig. 4.4). According to its previously recorded distribution range, it was considered to be present only in bordering mountainous areas of Thessaly, and specifically in the locations of Pindus in western Thessaly, Olympus in the north and finally in mountain Oiti to the south (Ondrias 1965a, 1970; Vlasak & Niethammer 1990; Libois et al., 1999). Data of this work though indicated that the specie has an abundant established population in Thessaly plains as well (Bontzorlos et al., 2007e), which ranged from 6.32% to 41.16% among sampled locations (Fig. 4.4). The specie was syntopic and possibly sympatric with Bicolored shrew in all sites when the latter was also present (Figs. 4.3 & 4.4), and that is probably also the reason for Bicolored shrew's lower abundances in the study area. Bicolored shrew has been recorded from other authors as well, to demonstrate a subordinate character when sympatric with co-generic more abundant species (Shchipanov & Oleinichenko, 1993). Thus, the high numbers of Lesser white-toothed shrew population in Thessaly, probably indicate that it is functioning as the dominant specie among the two it terms of sympatry, not allowing Bicolored shrew to establish higher populations. Nonetheless, further experiments are required to prove that hypothesis.

Lesser white-toothed shrew in Thessaly is mainly attached to soil texture and not to specific cultivations or other habitat types (Tab. 4.3, Fig. 4.5). Its abundance increases strongly along the factors “Soil Texture” and “Soil E,M&V” (Fig. 4.5), and more specific it is attached to areas dominated from Vertisol soil types and argillaceous-clay soil texture (Tab. 4.4, Figs 4.29 & 4.35). In northern Europe, Lesser white-toothed shrew is encountered mainly in dry terraces with dry ground, and it is more synanthropic (Macdonald & Barrett, 1993; Libois et al., 1999), whereas in Mediterranean basin it occupies a variety of habitats but is mostly attached in humid habitats and wet places, with high and dense vegetation cover (Blanco, 1998a; Rey, 2002). In Thessaly however which is a typical Mediterranean agroecosystem, it didn’t respond significantly along the gradients “Intensive Cultivations” and “Land Uses” (Tab. 4.4, Figs. 4.32 & 4.33), and it was negatively correlated with study areas which included large river lengths (>10km) within the 2 km ratio (Fig. 4.30). Moreover, forward selection on both factors and independent variables indicated that factor “Intensive Cultivations” is the more important in the model to explain the variability within the data set of environmental gradients, which affects small mammal species’ response (Chapter 3, Tab. 3.9). Still, Lesser white-toothed shrew in Thessaly didn’t choose its habitat in relation to wet places with dense vegetation cover such as river banks, or irrigated crops like corn and cotton (Figs. 4.30 & 4.32), but mainly according to the soil texture of the area (Figs. 4.29 & 4.35). Additionally, since it is also significantly more encountered in sites dominated with arable cultivated land (Fig. 4.34), that means that it can be encountered in arable cultivations such as corn, cotton, cereals and in other not heavily arable sites such as orchards and vineyards, but again the main criterion is not the mosaic of crop types and land uses, but the soil type and soil texture. Vertisol soil types and argillaceous-clay soil texture which support abundant Lesser white-toothed shrew assemblages, actually do maintain higher levels of moisture and humidity than the rest soil types and soil texture of the study area (Yassoglou, 1964; U.S. Department of Agriculture, 1975), and therefore possibly meet that specific need of the specie. They probably also sustain cultivation types with high and dense vegetation cover. Nonetheless, this is probably one of the first recordings of such a strong Lesser white-toothed shrew habitat selection according to subterranean soil types and soil texture. What is curious is the fact that Lesser white-toothed shrew constructs its nests above ground with soft vegetation, and is not immediately related to subterranean soil properties. In order of course to determine the exact reasons of this specie-soil relationship, more research is necessary, to see if that specific soil types support certain vegetation or crops which create favorable habitat, or if the combination of this soil type with certain vegetation and crop types support insect assemblages favorable for the specie's diet, and other details.

Finally, it could be argued that the specie is not a specialist in habitat selection but it is encountered in areas other than those of dominant Guenther's vole. Nonetheless, that is not the case in Thessaly due to two reasons. Firstly, Guenther's vole which is the most abundant specie in Thessaly occupies strictly non arable areas and is very territorial as will be discussed hereafter, so it could possibly have ousted out the syntopic Lesser-white toothed shrew in arable land uses. That is probably true up to a point, since the two species follow completely different distribution patterns along the gradients of "Arable Land" and "Altitude" (Figs. 4.28 & 4.34). On the other hand though, Lesser white-toothed shrew doesn't present any significant response along the gradients "Intensive Cultivations" and "Land Uses" with which Guenther's vole is strongly correlated (Figs. 4.32 & 4.33), and Guenther's vole doesn't present any significant response along the gradients "Soil Texture" and "Soil E,M&V" (Figs. 4.29 & 4.35) which affect strongly Lesser white-toothed shrew's distribution. Therefore, the hypothesis of dominant and subordinate species which would be strongly supported by the reverse distribution patterns along these factors is not in effect. These facts finally indicate that although the Lesser white-toothed shrew is possibly encountered in arable areas due to the occupation of non arable habitats from the specialized and territorial Guenther's vole, it also presents an independent strong habitat selection according to subterranean soil types and soil texture.

If observed the distribution map of Lesser white-toothed shrew in the agroecosystems of Thessaly according to the data of this thesis (Fig. 4.4), it is clearly demonstrated that the specie presents higher abundances in southern-central locations (30% - 45%). The specie's response along the longitudinal and latitudinal gradients was in both cases highly significant (Tab. 4.5, Figs. 4.51 & 4.52). Figure 4.51 indicates that the specie's abundance increases from western to eastern locations presenting its peak though in central areas, whereas it also clearly increases from northern to southern locations (Fig. 4.52). That specific geographical distribution pattern is explained when the environmental factors and independent variables are also treated as dependent variables along the latitudinal and longitudinal gradients. In specific, higher altitude sites were present in central locations and in southern areas (Tab. 4.5, Figs. 4.45 & 4.46), whereas locations dominated from argillaceous-clay soil texture increase significantly towards central and eastern Thessaly, while those dominated from Vertisol soil type increase towards central and southern parts (Tab. 4.5, Figs. 4.41 - 4.44). Lesser white-toothed shrew as mentioned is significantly correlated to Vertisol soil type and argillaceous-clay soil texture, as well to higher altitudes and arable land. Thus, since all these factors and variables present the mentioned significant responses in these directions, the specie demonstrates its higher abundances in central and southern locations in the agroecosystems of Thessaly (Fig. 4.4).

The last representative of Soricomorpha order in Thessaly plains is the Etruscan shrew. It is still an unknown specie in most of its range (Libois & Fons, 1999), and a lack of studies exists for various aspects concerning its ecology and biology (Malmquist, 1985; Blanco, 1998a). In Greece it is considered to have a very scattered and scarce distribution, and it was also recorded to be completely absent from the plains of Thessaly, presenting only a very small population, unconfirmed though with recent studies, in a small southern mountainous region (Spitzenberger, 1990c; Libois & Fons, 1999). Nonetheless, data of this study indicated that the specie was present in 27 of 31 sampled sites with very low percentages of frequency though (Bontzorlos et al, 2007e), ranging from 0.15% to 5.85% (Fig. 4.6). Although it wasn’t present with high abundances, it presented a broad distribution range in the agroecosystems of Thessaly, occupying mainly central-southern and south-eastern locations (Fig. 4.6). Etruscan shrew is strictly attached to the Mediterranean basin and its climatic conditions, preferring places with July temperatures not less than 20^{o} C (Blanco, 1998a; Libois & Fons, 1999; Lopez-

Fuster, 2002). It mainly inhabits open places with maquis vegetation, natural grasslands, and is also often encountered in vineyards, olive groves and sometimes gardens, and avoids intensively cultivated land, and dense forests (Macdonald & Barrett, 1993; Libois & Fons, 1999). The specie's composition change among sites and along the environmental gradients in Thessaly revealed that in Thessaly as well, the specie's abundance increases significantly in study areas without intensive cultivations (Tab. 4.3, Fig. 4.7). Etruscan shrew also presented significantly higher abundances in sites with cereal crops and absence of intensive irrigation schemes (Tab. 4.4, Fig. 4.32). In addition, it didn't respond significantly along the gradient "Land Uses" neither was its distribution range and habitat selection affected from arable cultivated land (Tab. 4.4, Figs. 4.33 & 4.34), but similarly to Lesser white-toothed shrew it demonstrated a clear preference for areas dominated from Vertisol soil type (Tab. 4.4, Fig. 4.35). This is also one of the first recordings of a positive correlation between Etruscan shrew presence and specific soil properties. The specie finally presented significantly higher abundances in central-southern areas (Tab. 4.5, Figs. 4.51 & 4.52), because sampling sites which are dominated from Vertisol soil types are concentrated in central-southern parts of Thessaly (Tab. 4.5, Figs. 4.43, 4.44 & 4.50). Yet, Etruscan shrew's higher numbers in sampling sites which were fragmented from road networks (Tab. 4.4, Fig. 4.31), is possibly due to the fact that it was easier for Barn owl (which is the sampling method used in this study), to capture such small prey in habitats with multiple edge effects as explained in Chapter 3. It is also quite possible, since the Etruscan shrew is considered as "shy" specie and is not easily captured with the use of live traps, neither preyed with frequency from nocturnal raptors

(Taylor, 1994; Vohralik & Sofianidou, 2000), that it has a higher population in Thessaly lowlands than the one revealed from the present data (Bontzorlos, 2007d).

The 12 remaining small mammal species which were also recorded in Thessaly, all belong to the order Rodentia, and the most abundant among them was Guenther's vole (21.19%). The specie was previously recorded in the region and specifically in Larissa city and in a southern mountainous area (Ondrias, 1964, 1965a, 1965b, 1966; Niethammer, 1982c; Krystufek, 1999j), nonetheless, no recent studies had confirmed its existence or studied its distribution. The present work demonstrated that the specie is the most abundant small mammal in Thessaly region ranging from 4.22% to 48.55% among sites, and it was also present in all 31 sampled localities (Fig. 4.8). Its composition change fitted a highly significant 1st order polynomial model along the total of measured environmental gradients (Tab. 4.3), but still the general model should be interpreted cautiously, since the specie's abundance seems to increase in study areas with intensive cultivations and irrigation schemes (Fig. 4.9). Guenther's vole is endemic of the Balkan Peninsula, and is highly specialized in habitat selection. It prefers natural grasslands, well drained meadows, sparse vegetation, while it exhibits minimum tolerance in ploughing and fields with arable cultivations which destroy its shallow nests near to the surface (Macdonald & Barrett, 1993; Krystufek, 1999j; Krystufek & Vohralik, 2005). Therefore, it is quite odd that the produced general model in Thessaly indicates a significant abundance increase, towards study areas dominated from intensive cultivations like cotton or corn, which grow in heavily arable fields (Tab. 4.3, Fig. 4.9). This possible bias is most probably occurring due to the combination of two interacting reasons: 1) Firstly, as will also be demonstrated analytically in the next chapter, Guenther's vole presents quite higher abundances in Thessaly during spring and summer seasons, 2) When at the same time, industrial crops also dominate Thessaly plains (see Chapter 5 for details). As a result, it is quite possible that the combination of these two facts, the seasonal effect of industrial crop domination and higher Guenther's vole abundances, produces that kind of general model. In addition to these hypotheses, when the specie's response was tested along each environmental gradient separately, very different patterns were revealed in comparison to the general model, in concordance this time with the specie's specialized needs, corroborating the 3 hypothesized mentioned points. Specifically, Guenther's vole in Thessaly avoids strongly both cereal and intensive cultivated crops, while it increases significantly when these crops are minimized within the complex mosaic of cultivations, which comprise the sampled sites (Tab. 4.4, Fig. 4.32). Moreover, the specie also presented a clear distribution pattern according to which it strongly avoids heavily arable fields, while it is significantly more abundant in different land uses such as set-aside fields, fallow land, and especially natural grasslands (Tab. 4.4, Figs. 4.33 & 4.34). In addition, in all studied areas from Thessaly, Guenther's vole also presented significantly higher abundances in sites with low altitudes (Tab. 4.4, Fig. 4.28), corroborating the similar findings of Niethammer (1982c) in the Balkan Peninsula, as well as those of Krystufek & Vohralik (2005) in the eastern part of the specie's range in Anatolia. When observed the specie's distribution map in Thessaly (Fig. 4.8), Guenther's vole presents very low abundances in western locations, and it increases gradually towards central areas as mentioned, presenting finally its higher percentages of frequency (>45%) in north and north-eastern sites. That specific composition change was highly significant on both latitudinal and longitudinal gradients (Tab. 4.5, Figs. 4.51 & 4.52). That geographical distribution pattern is due to the fact that study areas including higher percentages of land uses other than arable land, such as natural grasslands, set aside fields and fallow land, which are highly favorable to the specialized Guenther's vole, increase significantly towards central (Tab. 4.5, Figs. 4.39 & 4.40) but mainly towards northern areas of Thessaly (Tab. 4.5, Figs. 4.37 & 4.38) as also explained before. Additionally, towards eastern and northern locations, sampled sites with low altitudes (<100m) are significantly more (Tab. 4.5, Figs 4.45 & 4.46), in which the specie also presents higher abundances (Fig. 4.28), similar to other parts of the Balkan region (Niethammer, 1982c; Krystufek & Vohralik, 2005).

The second member of voles' group in Thessaly in terms of abundance (7.23%), was East European vole. It is a Palearctic specie with a distribution range including the Balkan Peninsula as well (Zima, 1999c), occupying though only northern areas of Greece and a western location of the country (Ruzic et al., 1975; Petrov & Ruzic, 1982; Zima, 1999c; Wilson & Reeder, 2005). In Thessaly it was recorded in the area of Larisa city in two studies dating before the 70's (Ondrias 1965a, 1966), which were reviewed later on from other authors, but its distribution wasn't confirmed with recent field experiments (Petrov & Ruzic, 1982; Zima, 1999c). Data of this study though, demonstrate that East European vole's distribution range expands until central Greece and occupies the agricultural plains of Thessaly, being present in 30 out of 31 sampled sites (Fig. 4.10). Similarly to the abundance patterns of Guenther's vole it presents higher numbers in eastern and northern locations (Figs. 4.8 & 4.10), but its' percentages of frequency among sites were relatively low, exceeding 10% in a minimum of cases. It also didn't fit any significant response model along the total of measured environmental gradients (Tab. 4.3), neither along any environmental gradient separately (Tab. 4.4). On the other hand, East European vole's composition change among sites fitted a significant 1st order polynomial model along both longitudinal and latitudinal gradients (Tab. 4.5, Figs. 4.51 & 4.52), which demonstrated clearly that the specie's abundance increases significantly towards eastern and northern locations. Nonetheless, since no significant models were produced as mentioned along any of the measured environmental gradients, it can't be deduced with certainty why this pattern is present. The specie's habitat requirements in its Palearctic distributional range are meadows, agricultural land and windbreaks (Petrov & Ruzic, 1982; Zima, 1999c), and in its eastern range in Anatolia it also prefers tall and herbaceous vegetation and especially wet and marshy places (Krystufek & Vohralik, 2005). In Thessaly it was present in most of the studied areas along with Guenther's vole, but live-trapping sessions have to be realized in order to explore if they are sympatric species or just syntopic, if their trophic and habitat niches overlap, if Guenther's vole functions as the dominant specie in expense of East European vole, and what exactly are the specie's habitat selection and space use patterns.

The third representative of Microtus species in the agroecosystems of Thessaly is Thomas's pine vole. It is the most fossorial specie of all Balkan Microtus voles (Krystufek, 1999l), and its distribution is restricted to deeper soil, which can easily be excavated and which sustains tunnels that can be maintained in time (Niethammer, 1982e; Krystufek, 1999l). It is also an endemic specie to the south-western Balkans (Krystufek, 1999l), occupying in Greece mainly southern locations starting from central areas and including the whole of Peloponnesus (Krystufek, 1999l). In the region of Thessaly it was recorded to be present in the area of Platamon (Ondrias, 1965a;

Niethammer, 1974, 1982e), in the southeastern part of Pagasitikos Gulf and in Pindus mountain in western Thessaly (Ondrias, 1966; Krystufek, 1999l), but no recent studies have confirmed this distribution neither. Data of the present thesis though demonstrated that in the agroecosystems of Thessaly, Thomas's pine vole occupies a few central but mostly western localities (Fig. 4.11), being also the first of mentioned species until now to present such a distribution range. It was present in 12 of 31 sampled sites (Fig. 4.11), and its general response model indicated that the specie increases significantly and mainly along the environmental gradients of "Soil Texture" and "Soil Types E,M&V", following the opposite pattern that Lesser white-toothed shrew demonstrated (Tab. 4.3, Figs. 4.5 and 4.12). Specifically, Thomas's pine vole avoided strongly all studied areas which were dominated from Vertisol and Inceptisol soil types (Tab. 4.4, Fig. 4.36), as well as areas with Entisol and Mollisol soil types (Tab. 4.4, Fig. 4.35). Land uses and arable land didn't affect its habitat selection nor its distribution range (Tab. 4.4, Figs. 4.33 & 4.34), but it showed a clear preference for sites dominated from Alfisol soil type and sandy-clay texture (Tab. 4.4, Fig. 4.29). In contradiction to Guenther's vole, it presented higher numbers in areas with industrial cultivations and intensive irrigation schemes (Tab. 4.4, Fig. 4.32), demonstrating that since it is a highly fossorial specie, it is not affected by cultivations which require deep ploughing arable practices, but chooses its habitat mainly according to soil properties (Fig. 4.29). Obviously, Alfisol soil types which contain mineral soils relatively low in organic matter and relatively high base saturation, combined with sandy-clay texture are ideal for the high fossorial habits of Thomas's pine vole in Thessaly. Alfisol soil types occupy only 13% of the studied areas and sandy-clay texture is present in only 25% of the sample sites' areas (see Chapter 1, Part II for details). Moreover, areas which are occupied mainly by Alfisol soil type and sandy-clay texture increase significantly towards western and some central localities (Tab. 4.5, Figs. 4.41 & 4.42). Therefore, since only a small percentage of the total sampled sites are occupied by such soil properties, which also increase significantly towards western localities, consequently Thomas's pine vole distribution in Thessaly is confined in just 12 sampled sites situated in central-western areas (Fig. 4.11). The distribution pattern of the specie along the longitudinal gradient and its composition change corroborates these results, by being highly significant and increasing towards western coordinates (Tab. 4.5, Fig. 4.51). Finally, Thomas's pine vole in Thessaly was present only in altitudes ranging between 100m and 200m (Tab. 4.4, Fig. 4.28).

The last representative of voles' group in Thessaly was the Gray dwarf hamster. The specie's Palearctic distribution range is confined in the Balkan Peninsula with few isolated and small populations (Vohralik, 1999). Its subspecific status in the Balkans is uncertain since it is the most diverse among the hamsters' group, and especially in Greece the recent state of the species needs revision and should be cleared (Vohralik, 1999; Nechay, 2000). In Thessaly it was considered to be present only in a southern part in the city of Farsala, as recorded firstly by Niethammer (1974, 1982a) and later reviewed by Vohralik (1999). Results of the present work demonstrated that the specie has a broader distribution in Thessaly plains, confined yet only in eastern locations (Fig. 4.13). The Gray dwarf hamster's general response model indicated a strong correlation between the specie's presence and factors "Arable Land", "Land Uses" and "Soil E,M&V" (Tab. 4.3, Fig. 4.14). In specific, although Gray dwarf hamster was present in only 10 out of 31 sampled sites with low percentages never exceeding 7% (Fig. 4.13), it was the unique of all recorded mammal species to demonstrate significantly higher numbers in areas dominated from Entisol and Mollisol soil types (Tab. 4.4, Fig. 4.35), combined with argillaceous-clay soil texture (Tab. 4.4, Fig. 4.29). Its distribution range and habitat selection was independent of irrigation schemes and industrial or cereals crops (Tab. 4.4, Fig. 4.32), but it presented a clear preference for sites dominated from arable and cultivated land (Tab. 4.4, Figs. 4.33 & 4.34). In the agroecosystems of Thessaly, the studied areas dominated from arable cultivated land are significantly more concentrated in central locations (Tab. 4.5, Figs. 4.37 - 4.40), explaining thus why the specie presented its higher numbers in central sites (Fig. 4.13). Moreover, sites dominated from Entisol and Mollisol soil types with argillaceous-soil texture increase significantly towards eastern and northern locations (Tab. 4.5, Figs. 4.41, 4.43 & 4.44), explaining the specie's confined distribution to the eastern part (Fig. 4.13). In addition, when tested along the longitudinal and latitudinal gradients, the specie was significantly more abundant in central and eastern locations (Tab. 4.5, Figs. 4.51 & 4.52).

The original habitats of Gray dwarf hamster are dry grasslands, steppes and semideserts (Nechay, 2000), but it is also present in agricultural areas, gardens and is also often synanthropic (Niethammer, 1982a; Vohralik, 1999; Nechay, 2000). Since it exhibits high habitat plasticity as a specie (Vohralik, 1999), another possible reason explaining its presence in few eastern localities, could be the competitive exclusion of other voles which are present in Thessaly. Analytically, Guenther's vole which is highly specialized and dominant, presents higher abundances towards north-eastern sampled sites, preferring non-arable land, natural grasslands, set-aside fields, unfragmented habitats and low altitudes, whereas Thomas's pine vole which is the most fossorial specie, has higher numbers in western parts and is highly attached to Alfisol soil types with sandy-clay texture and habitats with intensive irrigation schemes and industrial cultivations. Thus, since the Gray dwarf hamster is the most adaptable of all voles in the area it could just occupy those locations in Thessaly plains which aren't claimed or inhabited by the other more specialized voles. Moreover, if observed the distribution of Thomas's pine vole and Gray dwarf hamster in Thessaly, they appear to have completely reverse ranges, with the former occupying western sites and the latter increasing and being present in eastern areas (Figs. 4.11 & 4.13). That fact occurs because of different habitat requirements as discussed before, but it could also be a strong allopatry phenomenon between the two species due to competition, since the two are found to be syntopic (not clear if sympatric) in just two sites (Doxaras & Nees Karyes, Fig. 4.11 & 4.13) with very low percentages (see Appendix C for details). Nonetheless, more detailed field research with live-trapping grids is required to test that hypothesis. On the other hand though, possible competitive exclusion is certainly not the only reason accounting for the specie's distribution range and habitat selection, because it also demonstrates a very significant positive correlation with Entisol and Mollisol soil types and argillaceous-clay soil texture as mentioned, which increase towards central-western locations. In addition, since it is also a fossorial specie with deep excavating habits reaching to 1.5m (Macdonald & Barrett, 1993), therefore it can also be present in heavily arable sites as also proved by the significant regression models discussed before. Moreover, apart its habitat plasticity, the specie specifically avoids forests, dense vegetation areas and humid places (Heptner et al., 1956; Poljakov, 1968). That fact is also corroborated by the findings in Thessaly plain: Firstly, the Gray dwarf hamster avoids strongly sampled sites with large river lengths within the

2km ratio (Tab. 4.4, Fig. 4.30) which support rich vegetation assemblages and high humidity. And secondly it presents higher abundances in sites with very low or inexistent river networks, sites which also increase significantly from western to eastern sites (Tab. 4.5, Fig. 4.47) where the specie's range is confined (Fig. 4.13). Therefore, the Gray dwarf hamster in Thessaly lowlands is probably occupying locations other than those of the specialized voles, but it undoubtedly presents as well, specific habitat, land uses and soil properties preferences. Finally, Gray dwarf hamster in the agroecosystems of Thessaly was also present in altitudes higher than 150m (Tab. 4.4, Fig. 4.28).

Mice in Thessaly account 5 species from which the three are co-generic and belong to the genus Apodemus. The most abundant among them was Long-tailed field mouse, which was present in all 31 sampled sites (Fig. 4.17), and its general model indicated a strong correlation between the specie's presence and the negative values of factor "Intensive Cultivations" (Tab. 4.3, Fig. 4.18). That correlation was confirmed by the individual response of the specie along each environmental gradient separately, where Long-tailed field mouse demonstrated only one significant model along the gradient "Intensive Cultivations" (Tab. 4.4, Fig. 4.32). The specie had higher numbers in areas with cereal crops and non-irrigated cultivations while it avoided intensive irrigation schemes and industrial crops (Fig. 4.32). Although in Spain its presence in cereal crops was considered only temporal (Jubete, 2002), in all European countries it is encountered in all types of agricultural, cultivated arable land (Macdonald & Barrett, 1993; Montgomery, 1999b). In the total of its Palearctic range it is considered to be the most generalist specie of all, occupying an extreme variety of habitats (Macdonald & Barret, 1993; Blanco, 1998; Montgomery, 1999b). That is also the reason why it fitted only one significant response model when tested along each environmental gradient (Tab. 4.4). Since the Long-tailed field mouse has an opportunistic behavior, it is quite possible that it presents higher numbers in cereal crops, because other species which were discussed before do not occupy such habitats, and therefore they are occupied by the less specialized one. Niethammer (1978c) investigated and recorded first, and then Montgomery (1999b) reviewed, that Long-tailed field mouse was present in Thessaly in parts of the bordering mountainous regions, and it was also considered to by totally absent from the lowlands, whereas data of this work indicate that the specie has a broad distribution in the plains of Thessaly, and a well established population (Fig. 4.17). The specie though didn't present any significant response along the latitudinal and longitudinal gradients (Tab. 4.5, Figs. 4.51 & 4.52), and its composition change among sites along the total of environmental gradients (Fig. 4.18), just supported its attachment to cereal cultivations.

The other two Apodemus species which were present in Thessaly are the Yellow-necked field mouse and the Western broad-toothed mouse. They were present in Thessaly with very low abundances exceeding 5% only in three sites (Figs. 4.15 & 4.16). In Thessaly, the Western broad-toothed mouse was priorly considered to be present in two mountainous areas in extreme western and eastern parts of the region (Niethammer, 1978b; Storch, 1999), whereas the Yellow-necked field mouse was recorded on a central location of the lowlands, but those data were collected before 1970 (Montgomery, 1999a; Niethammer, 1978a). Data of this work though demonstrated a broad distribution of the species in the agroecosystems of Thessaly, with Western broad-toothed field mouse being present in 22 of 31 sampled sited situated mainly in central-eastern areas (Fig. 4.16), and Yellow-necked field mouse occupied all 31 studied sites (Fig. 4.15). The Yellow-necked field mouse is primarily a specie of mature deciduous woodland and only in its southern part of range in the Balkans it is also present in the lowlands (Macdonals & Barret, 1993; Montgomery, 1999a). In Thessaly it also presented somewhat significantly higher numbers in western areas (Tab. 4.5, Fig. 4.51) but since it didn't fit no other response model this pattern cannot be interpreted. In Spain the Yellow-necked field mouse is reversely correlated to the Long-tailed field mouse (Arrizabalaga & Torre, 2002) as well as in other parts of Europe (Macdonald & Barrett, 1993). That could also be the case in Thessaly, which doesn't allow populations of the former to reach higher numbers. Western broad-toothed mouse is also a highly specialized specie also in its Mediterranean range, preferring rock debris since it is a typical rock dweller. Although in Thessaly it didn't fit any significant model, which is also probably due to its low percentages of frequency among sites, when more extensive surveys will be realized, its attachment to hills, rocky and mountainous areas will undoubtedly be strong.

The other two mice in Thessaly plains belong to Mus genus and are the House mouse and the Macedonian mouse. House mouse was the third more abundant among all species and was present in all 31 studied areas. Reichstein (1978) and Macholan (1999a) who reviewed a very broad field of publications concerning the specie, recorded it in Thessaly only in three small areas in the bordering mountainous region, while it was considered to be absent from the lowlands, whereas some of the reviewed data were collected before the 70's. On the other hand the present study demonstrates a broad distribution of the specie in the agroecosystems of central Greece, being present in all sites with high abundances (Fig. 4.22). The specie's general model was significant and it indicated a clear positive correlation with the negative values of horizontal Axis, which is mainly defined by the factors “Intensive Cultivations” and “Land Uses” (Tab. 4.3, Fig. 4.23). In specific, House mouse in Thessaly demonstrated significantly higher numbers in arable cultivated land (Tab. 4.4, Figs. 4.33 & 4.34) and it was present in both cereal and industrial crops, but it strongly avoided other types of habitat (Tab. 4.4, Fig. 4.32). If observed the specie’s distribution map it seems to increase from northern and eastern areas to south-western locations (Fig. 4.22), a pattern which was significant in both latitudinal and longitudinal gradients (Tab. 4.5, Figs. 4.51 & 4.52). Similarly to Thomas’s pine vole, the House mouse prefers arable cultivated fields which are mainly concentrated in central-western locations of Thessaly plains (Tab.4.5, Figs. 4.37-4.40) and therefore its numbers increase towards sampled sites in the west. In its Palearctic range the specie can be found in a great variety of habitats, although in central and northern Europe it is more commensal and synanthropic, whereas in its southern Mediterranean distribution including the Balkan Peninsula, it reverts to field existence and lives independently of humans (Macdonald & Barrett, 1993; Blanco, 1998b; Macholan, 1999a), exactly like it does in Thessaly plains. Moreover, apart the fact that ecologically it is a highly opportunistic animal like the Long-tailed field mouse, it is also a very weak competitor in interspecific competition (Reichstein, 1978; Macholan, 1999a). Therefore, since Guenther’s vole and Lesser-white toothed shrew in Thessaly which are the two more abundant species occupy respectively non arable fields in north-eastern sites (Fig. 4.8) and areas with specific soil properties (Vertisol soil types and argillaceous-clay texture) in south-eastern locations (Fig. 4.4), it is quite probable that due to interspecific competition and highly opportunistic behavior, House mouse occupies arable cultivated fields, and its high numbers are confined in western localities.

Finally the House mouse presented higher numbers in altitudes between 150m and 250m (Tab. 4.4, Fig. 4.28).

Macedonian mouse presented a similar pattern in Thessaly and it was also more abundant in western locations, as it was indicated from its significant response along both longitudinal and latitudinal gradients (Tab. 4.5, Figs. 4.51 & 4.52). Its population presented higher numbers in western studied areas but still it had lower numbers in comparison to House mouse and never exceeded 13% (Fig. 4.24). Its Palearctic distribution range is restricted to the south of the Balkan Peninsula, and in Greece it occupies only northern areas of the country (Vohralik, & Sofianidou, 1987; Macholan, 1999b). It was considered to be totally absent from Thessaly except a small northern mountainous area (Macholan, 1999b), but data of this study revealed a broad distribution of the specie in all 31 studied areas, with low percentages of frequency though which didn't exceed 5% in most cases (Fig. 4.24). Its response along the environmental gradients fitted a 2nd order polynomial model but its interpretation is not simple (Tab. 4.3, Fig. 4.25). The detailed individual response models revealed though that Macedonian mouse similarly to the House mouse was significantly more abundant in cultivated arable fields (Tab. 4.3, Figs. 4.33 & 4.34), in both cereal and industrial cultivations (Tab. 4.3, Fig. 4.32). Its distribution in Europe is quite limited only to the Mediterranean climatic zone and it has been recorded from a wide range of habitats such as agricultural cultivations, bushy banks, sand dunes beaches, orchards, olive groves and more (Macholan, 1999b). Therefore it is quite probable that similarly to the House mouse, it occupies with its opportunistic behavior habitats others than the specialized and abundant Guenther's vole and Lesser white-toothed shrew. In addition, Macedonian mouse also presented a clear preference for areas dominated from Inseptisol soil types (Tab. 4.4, Fig. 4. 36), which are mineral soils containing some developed horizons other than one of illuvial clay, they have a weak to moderate profile horizonation, and their moisture is available to mature a crop (see Chapter 1, Part II for details). It was one of only two small mammal species of the total 15 which were recorded in Thessaly, that presented such an attachment to Inceptisol soil types, and this is also the first recording of such a positive correlation. Finally, the Macedonian mouse similarly to House mouse presented its higher abundances in altitudes between 150m and 250m (Tab. 4.3, Fig. 4.28).

Rats were the small mammal species with the greater biomass which were recorded in the agroecosystems of central Greece. They had two representatives in Thessaly, the Brown rat and the Black rat. Brown rat was considered to be absent from Thessaly plains except from a small southern area which was sampled though before 1970 (Becker, 1978a; Amori & Cristaldi, 1999a). Results of the present thesis demonstrated that the specie occupies mainly south-eastern areas, being present in 24 out of 31 studied areas, and its composition change among sites was limited to very low abundances, less than 5% in almost all locations (Fig. 4.19). In continental Europe the Brown rat is mainly commensal and attached to human settlements where it is attached to waste, sewerage systems and refuse water produced by man (Macdonald & Barrett, 1993; Amori & Cristaldi, 1999a), whereas in its Mediterranean range it also demonstrates independent populations which are more attached to wet habitats, river banks, or irrigated cultivations (Becker, 1978a; Blanco, 1998; Rojas & Palomo, 2002). Therefore in the Mediterranean agroecosystems of Thessaly, its low percentages of frequency in combination with the possible exploitation of different habitats (urban and agricultural), unlike northern Europe where it is specialized, didn't produce any significant model (Tab. 4.3 & 4.4), neither did it present a significant distribution pattern along the latitudinal and longitudinal gradients (Tab. 4.5, Figs. 4.51 & 4.52). Black rat on the other hand, was also present in Thessaly and syntopic (and possibly sympatric) with the Brown rat in 22 of 31 studied sites in south-eastern locations (Fig. 4.20). Although it had almost half the population than that of its co-generic Black rat, it fitted a general significant response model, according to which it was correlated with factors "Road Length" and "Soil I&V" (Tab. 4.3, Fig. 4.21). In specific, it avoided sites dominated from Alfisol soil types (Tab. 4.4, Fig. 4.29) and it presented high abundances in areas dominated from Inceptisol soil types (Tab. 4.4, Fig. 4.36) along with the Macedonian mouse as discussed before. It is one of the first recordings indicating a positive correlation between Black rat presence and areas with Inceptisol soil types, and thus not enough data are provided in order to explain this pattern at the moment. In its Palearctic range, Black rat is more generalist than Brown rat, and is present in a variety of habitats such as deciduous forests, orchards, and generally any habitat with adequate dense vegetation cover (Blanco, 1998b; Zamorano & Palomo, 2002). In the Mediterranean Basin it is encountered in the countryside and in agricultural areas as well (Amori & Cristaldi, 1999b), but it also often inhabits human settlements, although it is less commensal than its co-generic Brown rat (Amori & Cristaldi, 199b; Zamorano & Palomo, 2002). Especially in central and northern Europe it almost never occurs in the open and is highly attached to urban areas and buildings, specifically those with cavity walls and wall paneling (Macdonald & Barrett, 1993). In Thessaly which is within the specie's Mediterranean distribution range, Black rat appears with higher numbers in sampled areas with large road networks more than 15km (Tab. 4.4, Fig. 4.31). That pattern indicates that the specie is possibly more commensal in Thessaly since larger road networks are included in larger urban centers, or that it just prefers agricultural habitats more fragmented from roads than large monoculture fields. In addition, although the specie was priorly considered to be completely absent from central Greece (Becker, 1978b; Amori & Cristaldi, 1999b), it has a broad distribution in central and south-eastern locations of Thessaly, with low percentages of frequency nonetheless (Fig. 4.20). No latitudinal or longitudinal distribution pattern fitted a significant response model in order to explain the specie's distribution in Thessaly plains (Tab. 4.5, Figs. 4.51 & 4.52).

Finally, the last recorded small mammal specie from Thessaly lowlands was the Hazel dormouse. In Greece it has a restricted and fragmented distribution in two western parts of the country, and it appears to be absent from all the rest continental and insular regions (Morris, 1999). In the agroecosystems of Thessaly it was until recently considered to be present only in a northern mountainous part of the region (Storch, 1978b; Morris, 1999), unconfirmed though with studies after 1970. Data of this study didn't demonstrate a great change in the specie's range in central Greece like in all previous species, since it was only present in 4 out 31 sampled areas in southern locations (Fig. 4.26), with very low abundances. The specie's absence from the agricultural plains of central Greece was expected, since it is a typical forest dweller of deciduous woodland, dense shrubbery and coppices (Macdonald & Barrett, 1993), and an arboreal sequential specialist feeder (Morris, 1999). Although it fitted many individual response models (Tab. 4.4, Figs. 4.28-4.31 & 4.33-4.36), as well as a significant general response model (Tab. 4.3, Fig. 4.27), its range was very limited and its numbers so low that no significant interpretation can de deduced to explain the specie's presence from ordination analysis (Ter Braak &

Smilauer, 2002; Leps & Smilauer, 2003). Nonetheless, according to personal observations on the 4 sites where Hazel dormouse was present, a river was traversing the area with dense vegetation and woodland edges, along with high diversity of trees and shrubs which are the best habitats for the specie in its European, but also in its Asiatic distribution range (Krystufek & Vohralik, 2005).

In conclusion, the following main points could be outlined concerning the small mammals present in Thessaly plain: Guenther's vole in Thessaly is highly specialized and strongly avoids arable cultivated fields, which due to deep ploughing destroy its shallow nests, while it shows a clear preference for natural grasslands, set-aside fields and fallow land, all situated in low altitudes. Its higher numbers occur in north-eastern locations where its preferable habitat characteristics are concentrated. East European vole follows the same spatial distribution pattern without fitting significant models, and it is possibly functioning as a subordinate specie to Guenther's vole, whereas Thomas's pine vole demonstrates an exactly reverse pattern with abundant populations in western Thessaly. It prefers Alfisol soil types with sandy-clay texture and avoids strongly other soil types, while it was also present in industrial cultivations. The last member of voles group, the Gray dwarf hamster, presents a possible allopatry phenomenon with Thomas's pine vole, by being syntopic with it in no more than just two central sites, and by occupying areas exactly at the opposite direction towards south-eastern locations. Unlike other vole species it has higher numbers in arable land, and in Entisols and Mollisol soil types with argillaceous-clay texture. Lesser white-toothed shrew followed a reverse pattern in comparison to Guenther's vole and it had higher numbers in arable land, and reversely to Thomas's pine vole its presence was also positively correlated with Vertisol soil types with argillaceous-soil texture, and altitudes more than 150m. Its higher numbers occurred in south-eastern areas where its favorable habitats dominated the studied areas. Bicolored shrew with low populations didn't fit significant models, and the Etruscan shrew preferred habitats with cereal crops and absence of irrigated schemes, while it was also attached to areas with Vertisol soil type just like Lesser white-toothed shrew. The House mouse which was also abundant in Thessaly occupied many sites but it was abundant towards western locations, and it was mainly present in arable cultivated fields, possibly because as a weak competitor that it is and an opportunistic animal, it was ousted from other areas by more specialized species. Macedonian mouse presented similar spatial and habitat distribution patterns, but it also demonstrated a strong attachment to Inceptisol soil types. From the other mice species, Yellow-necked field mouse and Western broad-toothed field mouse were present with low populations and didn't fit any significant models, whereas Long-tailed field mouse was more abundant in cereal cultivations with absence of irrigation schemes. In respect to the rats of Thessaly, both species were concentrated in central-eastern locations, but Brown rat didn't fit any significant response model although it was twice more abundant than the Black rat. On the other hand, Black rat was more abundant in sites dominated from Inceptisol soil types and it was also possibly more attached to human settlements and urban environments with large road networks. Finally, Hazel dormouse had a confined small population in a southern location where a river with dense forest banks traverses the studied areas, since it is a typical forest dweller.

4.5 RESUMEN

4.5.1 Introducción

Los micromamíferos son un grupo heterogéneo, e incluye entre otras, especies de las órdenes Insectivora y Rodentia. Está considerado como un grupo taxonómico ideal para servir como modelo, y dirigir hipótesis y preguntas en diferentes escalas espaciales y temporales. El trampeo es el método más común para muestrear comunidades de micromamíferos, pero siempre presenta sesgos según el tipo de trampas, el cebo y el tamaño de la muestra. Otras aproximaciones indirectas para muestrear micromamíferos, son el estudio de los contenidos de ciertos reptiles y anfibios, el análisis de los excrementos de mamíferos carnívoros, y finalmente el análisis de egagrópilas de estrigiformes. La técnica más efectiva de todas las aproximaciones indirectas es el análisis de egagrópilas de la Lechuza común. Ofrecen una imagen fiable de las proporciones de sus presas en campo, a pesar de la naturaleza generalista del depredador, y los cambios reflejados en las egagrópilas presentarían los cambios actuales en las comunidades de los vertebrados. Adicionalmente, se ha demostrado en trabajos recientes que en áreas de estudio estrictamente agrícolas con una altitud que no supere los 500m, el análisis de egagrópilas de la Lechuza común es más fiable para analizar ciertos aspectos de las comunidades de micromamíferos.

Por tanto, en la región de Tesalia a través de la dieta de la Lechuza común se analizaron las comunidades de los micromamíferos no voladores. Los objetivos principales del capitulo son: 1) Presentar mapas con nuevos datos de distribución para las especies de micromamíferos en la región de Tesalia, 2) Explorar las relaciones y interacciones entre especies de micromamíferos y el hábitat, tipos del suelo, cultivos y usos de tierra. 3)

Definir los patrones de la riqueza de las especies y de la diversidad de las poblaciones de micromamíferos siguiendo varios gradientes ecológicos.

4.5.2 Materiales y métodos

Cuatro muestras han sido realizadas en cada una de las 31 localidades estudiadas. La primera en Septiembre de 2003, la segunda en Marzo de 2004, la tercera en Septiembre de 2004, y la última en Marzo de 2005. Así, las egagrópilas regurgitadas reflejan dos periodos reproductoras y dos no reproductoras. Los nichos ecológicos han sido calculados a través de tres índices de diversidad. La riqueza de las especies, que es el índice más sencillo se calcula como el número de las especies presentes en la dieta de cada región. El índice de la diversidad H´ se calculo según Shannon y Wiener, con base logarítmica e. Sin embargo, las diferentes muestras se diferencian en tamaño, y por lo tanto ambos índices de riqueza de especies y de diversidad se calculan con la aplicación de rarefacción, al nivel de la muestra con el tamaño menor. El índice de equitabilidad J´ se calculo también en respecto a Shannon y Wiener, sin la aplicación de rarefacción porque no había algún software disponible para realizar el algoritmo.

4.5.3 Análisis estadístico

En este capitulo el análisis esta enfocada en la composición de las comunidades de los micromamíferos y sus cambios hacia varios gradientes ecológicos. La diferencia principal con el análisis realizado en el capitulo 3, es que en este caso el proceso ha sido realizado a nivel de especie, analizando cada una de las 15 especies de micromamíferos presentes en el área de estudio.

En primer lugar un Análisis Factorial ha sido aplicado en las variables independientes, para reducir su número, detectar la estructura y relaciones entre ellas, y producir nuevos factores no correlacionados, combinando las variables independientes originales. El Análisis Factorial ha sido aplicado a dos grupos de variables ambientales homogéneos, en "Cultivos Agrícolas & Usos de Tierra", y "Tipos & Estructura del Suelo". Tres variables ambientales de naturaleza diferente (Longitud de ríos y carreteras, y Altitud) no han sido incluidas en el Análisis Factorial.

Una vez que fueron producidos los nuevos factores, se construyeron dos matrices. Una incluyo los "scores"- parámetros- factoriales y las tres variables ambientales no analizadas, con sus valores por cada muestra y cada estación, y otra con las frecuencias relativas de los grupos de las especies de micromamíferos presentes en las áreas estudiadas, y transformadas con el método de arcosino a nivel de género. Ambas matrices fueron introducidas en el CANOCO. En primer lugar, un Análisis de Correspondencias (DCA) ha sido aplicado en la matriz de las variables dependientes (especies), y demostró un valor menor de 3, indicando que los métodos lineares deben de utilizados. Luego, un Análisis de Redundancias (RDA) ha sido aplicado en ambas las matrices, y del espacio multifactorial de las variables independientes, se producen nuevos ejes canónicos en dos dimensiones, los cuales reflejan la varianza máxima de los valores de las variables dependientes que pueda ser explicada por las variables independientes. Estos ejes funcionan en las próximas pruebas como variables independientes; para explorar su efecto en la composición de las especies de micromamíferos, y producir modelos polinomiales de 1era, 2nda y 3ra orden, según los Modelos Lineares Generalizables y el criterio del Akaike (AIC).

4.5.4 Resultados y discusión

La especie *Microtus guentheri* aparece muy especializado en Tesalia, y evita las parcelas de tierra cultivada, tal vez porque el arado profundo destruye sus nidos y corredores subterráneos. También demuestra una preferencia clara por las praderas naturales, parcelas de tierra no cultivada y barbecho, situadas en altitudes bajas. La especie presenta números elevados en localidades situadas en el nororiente de Tesalia donde se sitúan las características de hábitat preferidas. Otra especie, *Microtus levis* presento la misma distribución espacial sin producir ningún modelo significativo, y probablemente funciona como especie subordinante a *Microtus guentheri*. Un tercer microtino, *Microtus thomasi* demostró un patrón de distribución exactamente reverso, siendo más abundante en el oeste de Tesalia. Prefiere tipos del suelo Alfisol con textura arenosa, y evita otros tipos del suelo, estando también presente en cultivos industriales. El ultimo miembro del grupo de los topillos, *Cricetulus migratorius*, presenta posiblemente un fenómeno de alopatría con *Microtus thomasi*. Ambas especies están presentes juntos solamente en dos ocasiones, y sus poblaciones ocupan localidades en diferentes direcciones; así *Microtus thomasi* presenta números elevados en el sureste de Tesalia. En contraste con todos los demás topillos de la región, esta especie es la única más abundante en usos de tierra arada, y también en suelos de Entisoles y Mollisoles con textura arcillosa.

Crocidura suaveolens demostró un patrón de distribución reverso en comparación con *Microtus guentheri*, y presento números elevados en los usos de tierra arada, y también reversamente a *Microtus thomasi*. Su presencia ha sido positivamente correlacionada con suelos Vertisoles y de textura arcillosa, en altitudes más altas de 150 msnm. Sus números más altos se muestran en localidades del sureste de Tesalia, donde están sus hábitats preferidos. *Crocidura leucodon* presenta poblaciones bajas, y su cambio de composición no produjo ningún modelo significativo. Por otra parte, *Suncus etruscus* aunque esta presente en los ecosistemas agrícolas de Tesalia con números bajos, demostró una preferencia para los cultivos cereales con ausencia de regadío, y también se ajusta a las áreas con suelos Vertisoles, similarmente a *C. suaveolens*.

Mus musculus es abundante en la región, y ocupa varios tipos de hábitat, pero sus números más altos se dan en localidades occidentales. Ha sido principalmente encontrado en parcelas cultivadas y de tierra arada, posiblemente por ser competidor débil y un animal oportunista, fue expulsado de otras regiones por especies más especializadas y territoriales como el *Microtus guentheri* y *Crocidura suaevolens*. Otro ratón, *Mus macedonicus* presenta un patrón de distribución similar, pero también ha demostrado una correlación fuerte con suelos Inceptisoles. De las demás especies del grupo de las ratones, *Apodemus flavicollis* y *A. epimelas* presentan poblaciones con números bajos, y el cambio de su composición hacia varios gradientes ecológicos no produjo ningún modelo significativo. Por otra parte, *A. sylvaticus* que ha sido, entre otras, una de las especies más abundantes, presenta números elevados en cultivos cereales con ausencia de regadío.

Respecto a las ratas, ambas especies están presentes en la región de Tesalia, pero concentradas en localidades del suroriente. *Rattus norvegicus* no produjo ningún modelo significativo aunque su población fue el doble de abundante que *Rattus rattus*. Por otra parte, *R. rattus* fue mas abundante en áreas dominadas por suelos Inceptisoles y posiblemente como especie más ligada en áreas urbanas con redes de carreteras extensas. Finalmente, *Muscardinus avellanarius* presento un población muy restringida y limitada a cuatro localidades del sur de Tesalia, donde un rio atraviesa la zona ofreciendo un hábitat ribereño ideal para la especie.

CHAPTER 5

Small Mammal Populations in Mediterranean Agroecosystems. Seasonal Fluctuations, Temporal Space-Use Patterns, and Crop Rotation Effect: The Case of Thessaly, Central Greece

5.1 INTRODUCTION

From tropics to poles, small mammal populations experience dramatic seasonal, interannual and multiannual variations in abundance, both from numerical and structural points of view (Stenseth & Ims, 1993; Meserve et al., 1995; Leirs et al., 1996; Lima & Jaksic, 1999; Torre, 2004), being these fluctuations either regular or not. The answer to the causes of variation in population density lies in the study of population dynamics (Krebs, 2002), and the central theme in every aspect of these studies is to understand why a population fluctuates in space and time (Lima & Jaksic, 1999). Dynamics of natural populations are a mixture of deterministic and stochastic factors, and the main objective of population dynamics studies is to determine the roles of density-dependent, density-independent, biotic and abiotic factors that affect these processes (Lima & Jaksic, 1999). The role played by each one of these regulatory factors still remains as an open and “hot” debate for most investigators (Meserve et al., 2001).

Abiotic factors belong of course to the category of density-independent regulating processes and they are actually two: temperature and rainfall, being rainfall among the two the most important, especially in the Mediterranean basin (Blondel & Aronson, 1999). Low temperatures during winter produce harsh environments for all species and especially for small mammals which have high metabolism and small size (Krebs, 2006). Nonetheless, summer high temperatures combined with drought, are much more limiting environmental factors for living organisms than low winter temperatures (Terradas, 1996; Blondel & Aronson, 1999). On the other hand, precipitation is used as a surrogate of primary productivity in Mediterranean climates (Rosenzweig, 1995; Mittelbach et al., 2001), applied to interpret seasonal and annual changes to productivity available for small mammals. Mediterranean climate, with its unpredictability in seasonal and interannual precipitation, provides a very fertile terrain to study the effects of abiotic factors in small mammal dynamics (Blondel & Aronson, 1999; Meserve et al., 2001). High rainfall years increase herb cover and seed densities (Gutierrez et al., 1993; Meserve et al., 1995; Meserve et al., 2001), a fact followed usually with insect outbreaks (Fuentes & Campusano, 1985), which finally produces a significant increase in food availability for granivorous, folivorous and insectivorous small mammals (Meserve et al., 1995; Lima et al., 2001).

Biotic factors on the other hand include both density-dependent and independent regulating mechanisms. Density-independent biotic factors are food availability, predation pressure, vegetation and habitat structure, and last but not least are the human perturbations, which can be summarized in the main categories of forest fires, forest management, land clearance for livestock and grazing, land urbanization and finally intensification of agriculture (Barret & Peles, 1999; Torre, 2004). In addition, density-dependent biotic factors are actually a variety of intrinsic regulating demographic processes within the populations of small mammals, such as reproduction status, survival, mortality, emigration, in-migration, evolutionary history, specialization degree, behaviour, territoriality, and of course intraspecific and interspecific competition (Barret & Peles, 1999; Lima et al., 2001; Meserve et al., 2001).

In order to test the effect of all above mentioned factors on small mammal populations, multiple approach experiments have to be realized in the field. Moreover, the relative influence of some factors on community structure and behaviour such as competition still remains poorly understood and subject to debate (Kelt et al., 1995). Interspecific and sometimes intraspecific relationships are difficult to establish in complex communities, a fact that will probably produce inconsistent patterns when competition and niche overlap between species are compared (Morris, 1989).

In the case of Thessaly more specific, as far as abiotic factors are concerned, the Greek National Meteorological Service hasn't constructed yet maps with temperature and precipitation isolines for the study area. Moreover, no other sources exist for meteorological data concerning the sampling sites. Thus, these two important abiotic factors couldn't be assessed and included in the analyses, except the available data for each one of the capitals of the four prefectures of Thessaly. In respect with biotic factors, this chapter explores the possible human impact on the fluctuations of small mammal populations in Thessaly, as produced from the seasonal crop rotation.

As mentioned in previous chapters, the study area of Thessaly is a strictly agricultural region, very homogeneous from that point of view, and within this pattern quite heterogeneous in respect to the cultivation types and land uses among sampling sites. Therefore, small mammals' habitat which is mainly agricultural in the study area is actually shaped by man. Additionally, since the highest percentage of agricultural cultivation types are cereals and industrial cultivations, the harvesting and replanting of the crops produces a very strong seasonal change in the habitat where small mammals live. Consequently, this chapter deals both with habitat structure and small mammal associations but this time including two more factors in the analysis, which are the seasonal change of agricultural habitat scenery, and the strong seasonal fluctuations in small mammal populations.

Although there is a probable predation pressure on small mammal populations in Thessaly from Buzzard populations during winter, Lesser kestrel populations during summer and Little owls during all year long, as well as from foxes, martens and reptiles, that effect wasn't assessed and will only be taken into account in theoretical level if possible. Similarly, intrinsic regulation processes weren't tested in the field with live-trapping sessions due to time limitations, but they will be incorporated in the discussion according to bibliography concerning the same small mammal species in similar Mediterranean-type agroecosystems.

The harvest of cereal crops in Thessaly during June, as well as industrial crops in September alters radically the habitat shape and vegetation structure in the region. The study area is actually left "naked" for autumn and winter months and also without grain and seed production, possibly affecting many small mammals' feeding habits, until the new crops are planted again after December. In addition, the repeated ploughing of the land at the end of each harvesting season also alters the nesting habitat of most small mammal species in the area. As a result, the human impact on the landscape and habitat in the region of Thessaly is quite strong. The seasonal human interventions are creating a dynamic agroecosystem, where small mammals possibly have to redefine their movements, habitat and nesting habits according to the alteration of habitat structure, not only above ground but also subterranean as well. Although various studies have been realized in order to test small mammals' habitat selection between forest, grasslands and agricultural land at various landscape scales and environmental gradients (Delibes, 1985; Buechner, 1989; Bennett, 1990; Delattre et al., 1996; Torre et al., 1996; Collins & Barrett, 1997, and references within these publications), very few studies have been realized exclusively in Mediterranean dynamic agroecosystems like that of Thessaly (Williams et al., 1994; Burke & Taylor, 2002; Escribano & Martinez, 2006; D' Andrea et al., 2007; Rodriguez & Peris, 2007), focusing moreover, in seasonal changes specifically.

A proper understanding on how human-induced changes in habitats and landscapes affect small mammal populations is crucial to undertake the management and conservation of dynamic Mediterranean agroecosystems. Small mammals play a very important role as food resources for several carnivores, raptors and reptiles, as predators for insects, and also as pests for agricultural production. Thus, further investigation is necessary to comprehend their dynamics in agricultural ecosystems, especially in an era where agricultural intensification is a global trend and is also proved to harm biodiversity in agroecosystems across the world (Chauveau, 2005; Jonhnson & Lewis, 2006). Therefore, the aims of this chapter are:

1). Test the hypothesis that seasonal change in the agricultural habitat structure affects seasonal abundance fluctuations in small mammal populations of the study area.

2). Explore and define which environmental gradients between seasons affect each species separately, towards which direction (increase, decrease or non-significant), and evaluate the human impact on small mammal seasonal variations in abundance.

3). Use the species' intrinsic density-dependent demographic processes according to bibliography from similar Mediterranean agroecosystems, and combine them with the effect of seasonal crop rotation on small mammals' abundance fluctuations, in order to give the "best-fit" discussion for these seasonal differences.

5.2 METHODS AND MATERIAL

As mentioned in Chapter 4, the indirect and non-invasive method of Barn owl pellet analysis was followed in the region of Thessaly, in order to study the non-volant small mammal populations of the study area. Although trapping is the most common method to sample small mammal communities (Gurnell & Flowerdew, 1990), Barn owl pellet analysis presents specific benefits. Those benefits, along with certain advantages of that methodology related to the peculiarities of the study area are analytically explained in Chapter 4 (pp: 196-197). Thus, for these reasons, the same small mammal sampling methodology was followed in the present chapter, with a quite different approach of course in the afterwards statistical analysis. Hence, in order to evaluate the human impact and test the hypothesis that seasonal crop rotation and change of agricultural habitat scenery has a significant effect on small mammal seasonal fluctuations, small mammal seasonal abundance fluctuations were firstly assessed through Barn owl pellet analysis.

The study was realized in 31 sampling sites (Figure 3.1, Chapter 3 p: 131) and their coordinates are demonstrated in Table 3.1 (Chapter 3, pp: 129-130). Four consequent samplings were realized in each one of the studied areas, once all the sampling sites had been cleared from old pellets in April 2003. The first sampling took place in September 2003, the second in March 2004, the third in September 2004 and the 4th and last one in March 2005. A total of 10.065 pellets were collected which were afterwards analyzed in the laboratory according to the “dry” method (Marti, 1987; Yalden, 2003), and small mammal prey items were identified with reference books (Toschi & Lanza, 1959; Toschi, 1965; Chaline et al., 1974; Lawrence & Brown, 1974; Niethammer & Krapp, 1977, 1982, 1990; Krystufek & Vohralik, 2005). The pellet analysis finally produced 29.061 small mammal prey items.

Since all sampling sites were cleared from old pellets in April of 2003, the samplings realized afterwards in September 2003 and September 2004, reflected small mammal abundances in the seasons of spring and summer for the two consequent years of 2003 and 2004, whereas the samplings realized in March 2004 and March 2005, reflected respectively the small mammal abundances for autumn and winter months of the two consequent year-periods of 2003-2004 and 2004-2005.

Apart from assessing small mammals’ fluctuations, niche indices were also calculated in the study area between seasons. Species richness which is the oldest and the simplest concept of species diversity was calculated as the number of species in a community or in a sample. Small mammal diversity was calculated according to the Shannon-Wiener diversity index (Pianka, 1980):

$$H' = -\sum_{i=1}^{n} pi \ln pi$$

where pi = proportion of species i in each sample (seasonal or total) and ln = natural logarithm (base e). In order to avoid bias in the data, diversity was calculated using the rarefaction method due to differences in the sampling effort between seasons, with the softwares: Ecosim (Gotelli & Entsminger, 2001), Biodiversity Pro (McAleece et al., 1997) and Past (Hammer et al., 2001). Evenness was calculated with the Shannon-Wiener function J' (Krebs, 1999) using the software Biodiversity Pro (McAleece et al., 1997) and Ecological Methodology (Krebs, 2002), according to the equation:

$$J' = \frac{Observed Shannon Measure of Niche Breadth H'}{Maximum Possible Shannon Measure}$$

Evenness was calculated without prior rarefaction of the data, since no available software could perform the task. Hence, there is possibility of some bias in certain cases, although it would be possibly insignificant due to the large size of each sample (Krebs, 1999).

5.2.1. Statistical analysis

In order to test which environmental gradients have a significant effect on small mammals' seasonal abundance and structure, the first step is to define which environmental variables will be included in the analysis (Ter Braak & Smilauer, 2002). In the present analysis unlike previous chapters, the recorded independent variables were tested for correlations between them but this time in seasonal terms, since the hypotheses that will be tested have to do with seasonal fluctuations in small mammals' populations, and seasonal change in agricultural habitat. Many of them were highly correlated, so Factor analysis was applied in order to reduce the variables, explore the structure and relationships between them, and produce new non-correlated factors (Lindeman et al., 1980; Hurley et al., 1997; Stevens, 2001; Costello & Osborne, 2005). Factor analysis was similarly applied like in Chapters 3 and 4 on two groups of independent variables: "Agricultural Crops & Land Uses" and "Soil Types & Soil Texture". Nonetheless, this time it was applied twice in each group in order to take into account the seasonal differences within these groups. The categories of independent variables included in each one of these two groups, are presented analytically in Chapter 3 (pp: 149 & 154).

The categories "Cereals", "Industrial Cultivations", "Irrigated Land" and "Non - Irrigated Land", which are included in the group of "Agricultural Crops & Land Uses" were those categories which presented important differences between the seasons of autumn-winter and spring-summer. On the other hand all the categories included in the group "Soil Types & Soil Texture" didn't present any seasonal differences, since no alteration was realized in their properties. Cereals are planted in November or December, but do not start to grow until the beginnings of February. They actually begin to differentiate the habitat since mid March, and they are harvested in the end of June. Industrial cultivations on the other hand and especially cotton, are planted during April, they begin to grow and differentiate the habitat in the beginnings of June and are harvested in September and October. Consequently, during the season of spring-summer which is defined from April to September, the dominating agricultural crops which are cereals (mainly wheat) and industrial cultivations (mainly cotton) occupy the greatest percentage of the study area, forming a strictly agricultural vegetation structure. At the same period, both cereals but mostly the industrial crops which belong in the category of “Arable Cultivated Land” are intensely irrigated. After September, and once cotton is also harvested, the landscape in the study area is left actually “naked” until next March that cereal crops begin to grow again. Thus, during the season autumn-winter which is defined from October to March, the dominating agricultural crops which form the main habitat vegetation structure are completely removed, producing a strong change in the landscape. As a result, the percentage of the study area occupied by cereals and industrial crops becomes inexistent during autumn-winter season, a fact which goes along with a strong change in “Irrigated Land” and “Non Irrigated Land” categories. The percentage of the study area which was occupied mainly by cereals and industrial cultivations and was also heavily irrigated during spring-summer season, is actually left “naked” during autumn-winter season, and these field plots of intensively irrigated land turn to non-irrigated arable land without crops.

In order to perform a Factor analysis which will afterwards produce new non-correlated factors and will also demonstrate these seasonal differences mentioned above, the procedure was performed twice in each group of independent variables, once for every season. Firstly, two matrices were constructed for each one of the two groups of predictor variables. One matrix was demonstrating the percentages of each independent variable included in each group, for each sampling site but only for spring-summer seasons (April-September) of both 2003 and 2004. The other matrix was demonstrating the same percentages but only for autumn-winter seasons (October-March) of both 2003-2004 and 2004-2005 periods. Once constructed these matrices, they were then introduced in the software Statistica version 6.0, and Factor analysis was applied on each one of them, after all the percentages were transformed with the arcsine method. The new non-correlated factors which were produced were consequently also divided in two seasonal groups, incorporating in their respective factor scores the seasonal differences wherever and whenever they were present. Factor loadings, or else the original variables which actually define the new factors, derived from a correlation matrix between the transformed independent variables and the produced factor scores, on which the Bonferroni correction was applied, in order to correct the level of significance.

Once the factor analysis procedure was completed, and new non-correlated factors along with their factor scores and loadings were produced, the problem of multicollinearity was avoided for the next steps of statistical analysis. Since the new factors for each season were now ready, the next part was to test the change of composition in small mammals' seasonal abundance along these environmental gradients. As it was repeatedly stated in this thesis, in order to explore the continuity change of species' abundance along various environmental gradients, ordination techniques are the tools to be used (Ter Braak & Smilauer, 2002; Leps & Smilauer, 2003). Before that, small mammals' abundances also had to be assessed and then introduced along with the respective factors for the appropriate ordination analysis. Therefore, two matrices were constructed for small mammals' frequency percentages as well, one for each pair of seasons. In order to coincide with the changes of agricultural habitat structure, Barn owl pellet samplings were divided in the periods autumn-winter (October – March) and spring-summer (April-September). These sampling periods also coincide with the owl's non-breeding and breeding season respectively. Thus, two matrices were also constructed for small mammals' seasonal percentages of frequency. One matrix demonstrated the percentage of frequency for each species, for each sampling site but only for spring-summer seasons (April-September) of both 2003 and 2004. The other matrix was demonstrating the same percentages but only for autumn-winter seasons (October-March) of both 2003-2004 and 2004-2005 year periods. Once these matrices were constructed as well, the continuity change of species' abundance along the environmental gradients remained to be tested with an appropriate ordination technique (Leps & Smilauer, 2003).

Therefore, the species' matrices were introduced in software Canoco, version 4.5 for Windows (Ter Braak & Smilauer, 2002), along with the matrices which included the new produced factors and their respective factor scores. Although there are various ordination techniques and various statistical softwares performing the task, they are best and thoroughly summarized within Canoco (Leps & Smilauer, 2003). The methodology followed hereafter in order to test the effect that environmental gradients (new non-correlated factors) have on the change of continuity in small mammal abundances, was the same as it is analytically explained in Chapter 4 (pp: 200-204). The only difference is that in this case it was performed twice, once for each season, including in the analysis the respective seasonal matrices of both environmental gradients, and small mammal species' percentages of frequency.

Additionally, the seasonal differences of small mammal abundances in the total of 31 sampling sites were tested with one-way ANOVA tests, and in order to explore which seasonal samplings produced significant tests, post-hoc Tukey HSD tests were also applied afterwards.

5.3 RESULTS

5.3.1 Seasonal differences in small mammal abundances

Firstly one-way ANOVA tests were applied, in order to test the differences in small mammal abundances between sampling seasons. The results of analysis of variance

Table 5.1 Results of one-way ANOVA tests from seasonal comparisons, on the fifteen small mammal species which were recorded in Thessaly. Level of significance is set at a = 0.05. Significant p_s for one-way ANOVA tests are noted: $p < 0.01$ = *, $p < 0.001$ = **, $p < 0.0001$ = ***, $p < 0.00001$ = ****, $p < 0.000001$ = *****. Significant differences between seasonal samples indicated from Tukey HSD post-hoc tests are noted: *. Seasons stand for: ***Season 1***: April – September 2003, ***Season 2***: October – March 2003-2004, ***Season 3***: April – September 2004, ***Season 4***: October – March 2004-2005.

	One-Way ANOVA	Sum of squares	df	Mean square	F	p	*Tukey – HSD post hoc tests*	Season 1	Season 2	Season 3	Season 4
Crocidura leucodon	***Between groups***	966.26	3	322.09	6.56951	**	***Season 1***				*
	Within groups	5883.3	120	49.027			***Season 2***			*	*
	Total	6849.56	123				***Season 3***		*		
							Season 4	*	*		
Crocidura suaveolens	***Between groups***	13699.44	3	4566.48	2.91216	*	***Season 1***				
	Within groups	188168.8	120	1568.073			***Season 2***			*	
	Total	201868.24	123				***Season 3***		*		
							Season 4				
Suncus etruscus	***Between groups***	290.23	3	96.74	2.97274	*	***Season 1***				*
	Within groups	3905.2	120	32.543			***Season 2***				
	Total	4195.43	123				***Season 3***				
							Season 4	*			
Microtus guentheri	***Between groups***	64854.02	3	21618.01	10.03937	****	***Season 1***				*
	Within groups	258398.8	120	2153.323			***Season 2***				*
	Total	323252.82	123				***Season 3***				*
							Season 4	*	*	*	
Microtus levis	***Between groups***	388.71	3	129.57	0.92020	0.43	***Season 1***				
	Within groups	16896.7	120	140.806			***Season 2***				
	Total	17285.41	123				***Season 3***				
							Season 4				
Microtus thomasi	***Between groups***	557.64	3	185.88	0.24638	0.86	***Season 1***				
	Within groups	90533	120	754.441			***Season 2***				
	Total	91090.64	123				***Season 3***				
							Season 4				
Cricetulus migratorius	***Between groups***	7.32	3	2.44	0.1652	0.91	***Season 1***				
	Within groups	1773	120	14.775			***Season 2***				
	Total	1780.32	123				***Season 3***				
							Season 4				

Table 5.1 (continued)

	One-Way ANOVA	**Sum of squares**	**df**	**Mean square**	**F**	p	***Tukey – HSD post hoc tests***	**Season 1**	**Season 2**	**Season 3**	**Season 4**
Apodemus flavicollis	***Between groups***	359.19	3	119.73	3.82835	*	***Season 1***				*
	Within groups	3752.9	120	31.274			***Season 2***				
	Total	4112.09	123				***Season 3***				
							Season 4	*			
Apodemus epimelas	***Between groups***	247.64	3	82.55	5.31539	**	***Season 1***				*
	Within groups	1863.5	120	15.530			***Season 2***				*
	Total	2111.14	123				***Season 3***				*
							Season 4	*	*	*	
Apodemus sylvaticus	***Between groups***	6651.68	3	2217.23	28.03829	*****	***Season 1***		*		*
	Within groups	9489.4	120	79.078			***Season 2***	*			*
	Total	16141.08	123				***Season 3***				*
							Season 4	*	*	*	
Rattus norvegicus	***Between groups***	813.87	3	271.29	3.19729	*	***Season 1***		*		
	Within groups	10182	120	84.850			***Season 2***	*			
	Total	10995.87	123				***Season 3***				
							Season 4				
Rattus ratus	***Between groups***	110.41	3	36.8	2.08171	0.10	***Season 1***				
	Within groups	2121.5	120	17.68			***Season 2***				
	Total	2231.91	123				***Season 3***				
							Season 4				
Mus musculus	***Between groups***	15447.94	3	5149.31	14.03545	*****	***Season 1***				*
	Within groups	44025.5	120	366.879			***Season 2***				*
	Total	59473.94	123				***Season 3***				*
							Season 4	*	*	*	
Mus macedonicus	***Between groups***	280.15	3	93.38	1.03685	0.37	***Season 1***				
	Within groups	10807.9	120	90.066			***Season 2***				
	Total	11088.5	123				***Season 3***				
							Season 4				
Muscardinus avellanarius	***Between groups***	7.06	3	2.35	0.89772	0.44	***Season 1***				
	Within groups	314.8	120	2.623			***Season 2***				
	Total	321.86	123				***Season 3***				
							Season 4				

are analytically demonstrated in Table 5.1. According to them, 9 species presented significant variations in their abundances between seasons. On the other hand, species such as East European vole, Thomas's pine vole, Gray dwarf hamster, Black rat, Macedonian mouse and Hazel dormouse, although they varied between seasons, their differences weren't significant (Tab. 5.1).

Analytically, all three insectivorous species which were present in Thessaly presented significant variations between seasons (Tab. 5.1). Lesser white-toothed shrew demonstrated higher frequencies during spring-summer seasons (Fig. 5.1), but yet significant differences (one-way ANOVA, $F_{0.05(3,123)} = 2.91$, $p < 0.01$) were located only between autumn-winter seasons of 2003-2004, and spring-summer seasons of 2004 according to post-hoc Tukey HSD tests (Tab. 5.1). With a different pattern, Bicolored shrew presented a decrease during autumn-winter of 2003-2004, but then it increased continuously for the next sampling seasons (Fig. 5.1). The specie's seasonal variations were significant (one-way ANOVA, $F_{0.05(3,123)} = 6.56$, $p < 0.001$) and can be observed in various comparisons between samples as deduced from post-hoc Tukey HSD tests (Tab. 5.1). Finally, the Etruscan shrew followed exactly the opposite pattern from that of Lesser white-toothed shrew, presenting higher frequencies during autumn-winter seasons of both 2003-2004 and 2004-2005 year periods (Fig. 5.2). The significant differences though between its seasonal abundances (one-way ANOVA, $F_{0.05(3,123)} = 2.97$, $p < 0.01$), are located only between spring-summer seasons of 2003 and autumn-winter seasons of 2004-2005, according to post-hoc Tukey HSD tests (Tab. 5.1). Voles were represented in Thessaly with four species. Three of them were co-generic and belonged in the genus Microtus and the fourth specie was the Gray dwarf hamster which belonged to the genus Cricetulus. From Microtus species, Guenther's vole was the only one which presented highly significant differences between sampling seasons (one-way ANOVA, $F_{0.05(3,123)} = 10.03$, $p < 0.00001$), although the significance of the test derives

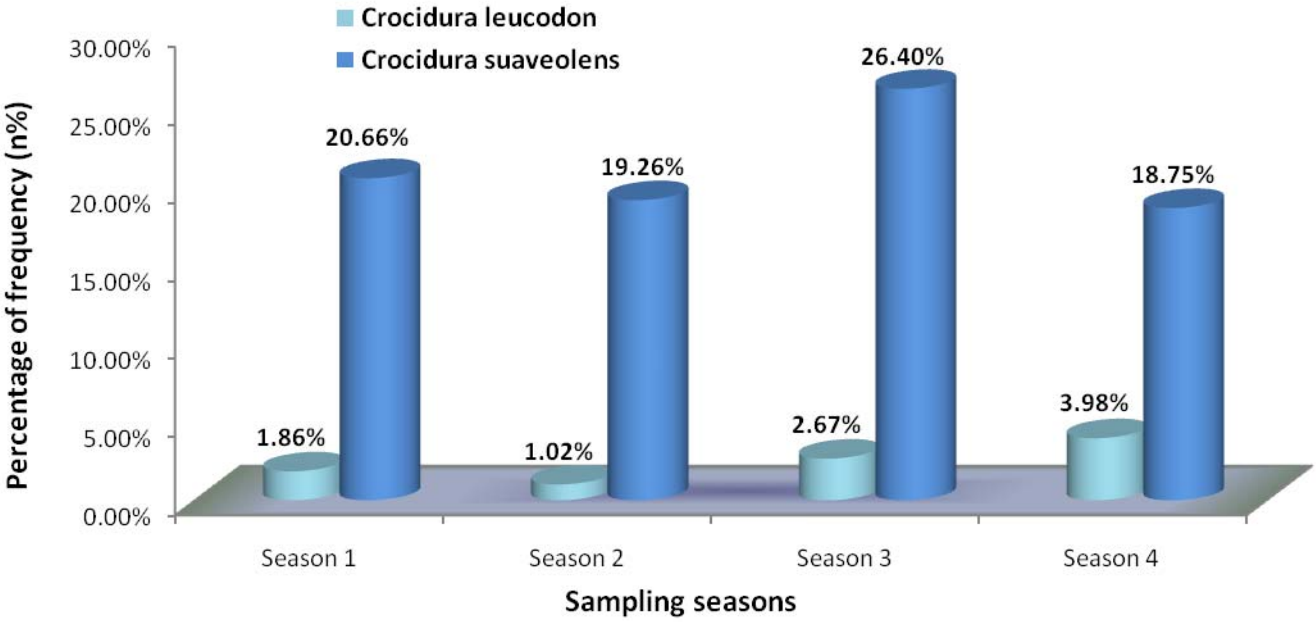


Figure 5.1 Seasonal comparisons in percentages of frequency (n%) between Crocidura species, recorded in the agroecosystems of Thessaly. Seasons stand for: ***Season 1***: April – September 2003, ***Season 2***: October – March 2003-2004, ***Season 3***: April – September 2004, ***Season 4***: October – March 2004-2005.

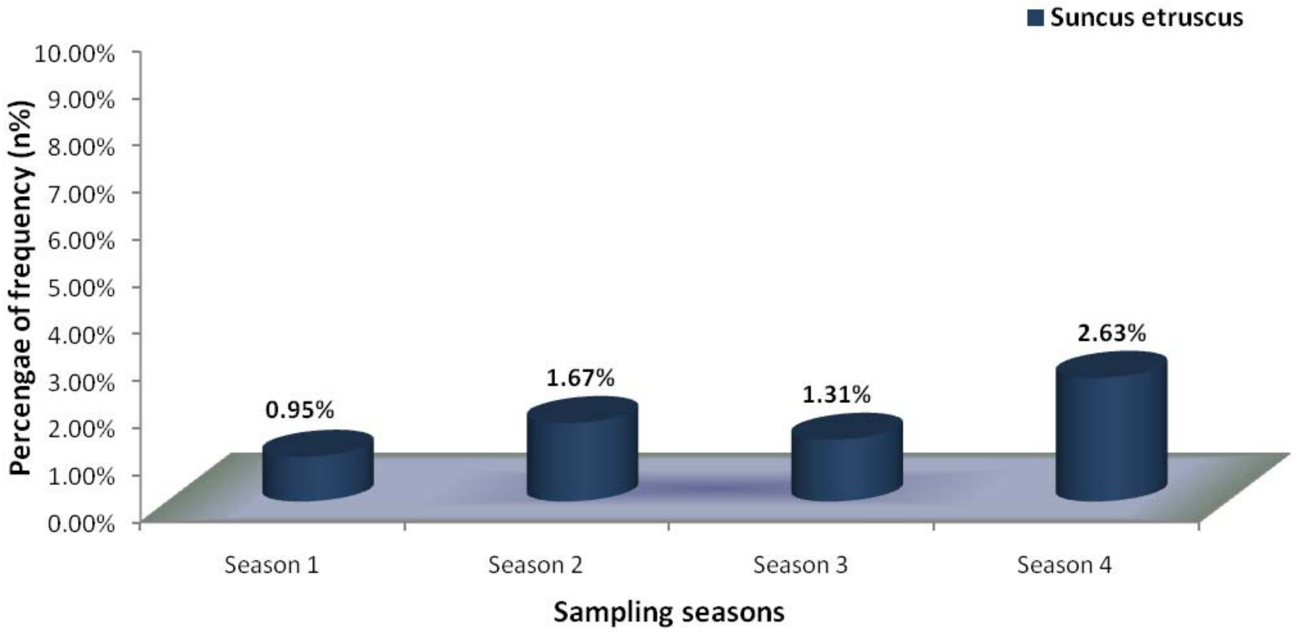


Figure 5.2 Seasonal comparisons in percentages of frequency (n%) of Etruscan shrew, recorded in the agroecosystems of Thessaly. Seasons stand for: ***Season 1***: April – September 2003, ***Season 2***: October – March 2003-2004, ***Season 3***: April – September 2004, ***Season 4***: October – March 2004-2005.

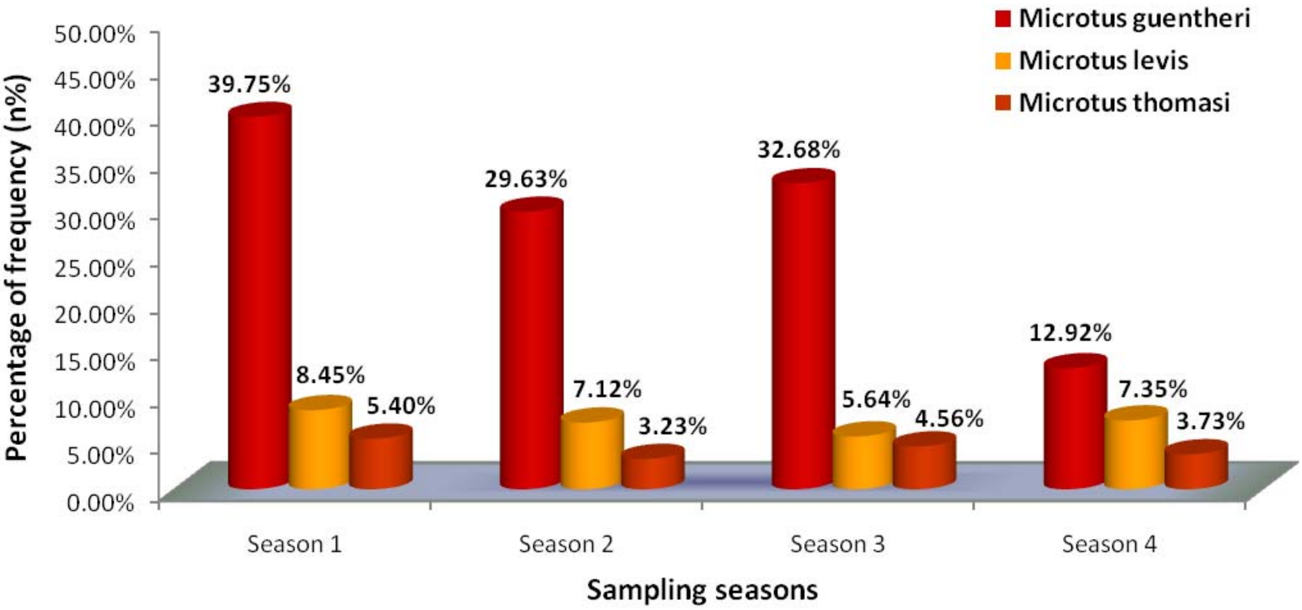


Figure 5.3 Seasonal comparisons in percentages of frequency (n%) between Microtus species, recorded in the agroecosystems of Thessaly. Seasons stand for: ***Season 1***: April – September 2003, ***Season 2***: October – March 2003-2004, ***Season 3***: April – September 2004, ***Season 4***: October – March 2004-2005.

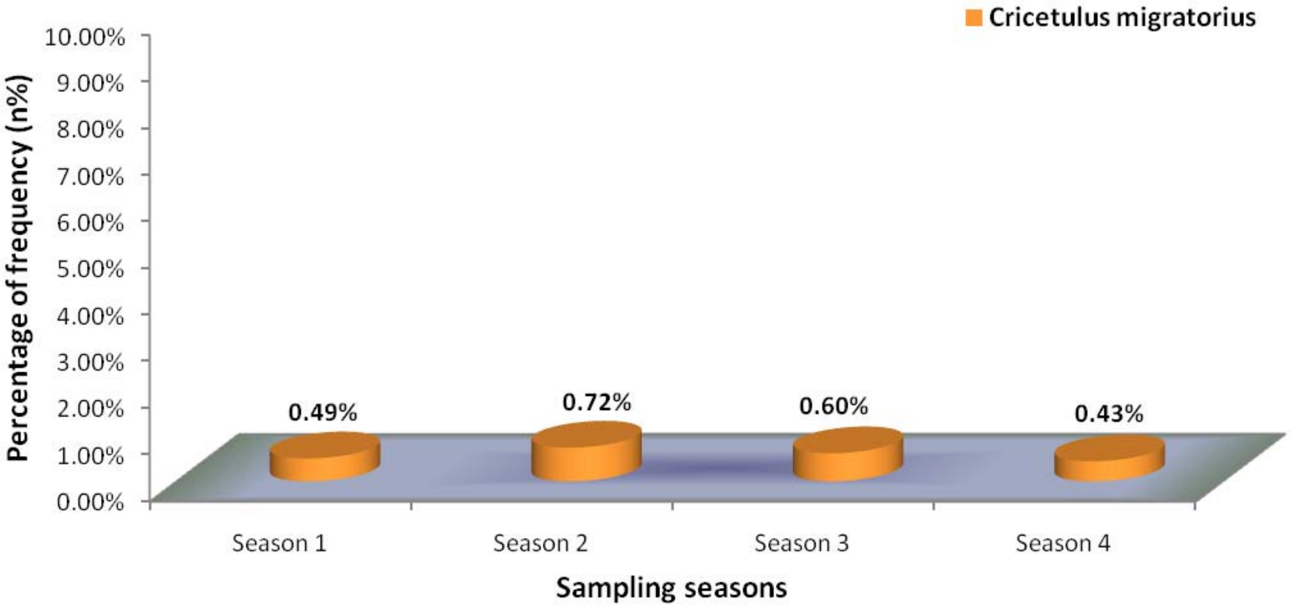


Figure 5.4 Seasonal comparisons in percentages of frequency (n%) of Gray dwarf hamster, recorded in the agroecosystems of Thessaly. Seasons stand for: ***Season 1***: April – September 2003, ***Season 2***: October – March 2003-2004, ***Season 3***: April – September 2004, ***Season 4***: October – March 2004-2005.

only from comparing the autumn-winter sample of 2004-2005 with prior seasonal samples (Tab. 5.1). Guenther's vole presented higher frequencies during spring-summer seasons of 2003 and 2004, but within this pattern it also presented a significant decrease during the three year study (Fig. 5.3).

Oppositely, the other two members of Microtus group, East European vole and Thomas's pine vole didn't present statistical differences between seasons (one-way ANOVA, $F_{0.05(3,123)} = 0.93$, $p = 0.43$ & $F_{0.05(3,123)} = 0.24$, $p = 0.86$ respectively). Moreover, East European vole didn't demonstrate any specific pattern in its seasonal abundance, since it decreased for the first three consequent seasons and finally slightly increased during autumn-winter of 2004-2005 (Fig. 5.3). Although Thomas's pine vole had no significant seasonal differences either, it demonstrated a clearer pattern between seasons, being more frequent during spring-summer seasons of both 2003 and 2004 (Fig. 5.3). Finally, the fourth member of Cricetidae family in the study area, the Gray dwarf hamster, was minimally recorded (Fig. 5.4). The specie didn't present significant seasonal differences (one-way ANOVA, $F_{0.05(3,123)} = 0.16$, $p = 0.91$) and neither did it demonstrate a more distinctive pattern between seasons. Its percentage of frequency increased during autumn-winter of 2003-2004 only to decrease for the next consequent sampling seasons (Fig. 5.4).

Mice were present in the study area with three Apodemus and two Mus species. The genus Apodemus was represented with Long-tailed field mouse, Yellow-necked field mouse and Western broad-toothed mouse, and all of them presented significant seasonal differences (Tab. 5.1). Long-tailed field mouse was more abundant during autumn-winter seasons of 2003-2004 and 2004-2005, and within this pattern it also demonstrated a continuous increase through the three year study and the four consequent samplings (Fig. 5.5). Although it presented highly significant seasonal differences (one-way ANOVA, $F_{0.05(3,123)} = 28.03$, $p < 0.000001$), post-hoc Tukey HSD test indicated that the ANOVA was significant only when comparing autumn-winter of 2004-2005 with all prior samples. One more significant difference is also observed between autumn-winter season of 2003-2004 and the previous sample of spring-summer 2003 (Tab. 5.1). Similarly, the Yellow-necked field mouse which presented significant seasonal differences (one-way ANOVA, $F_{0.05(3,123)} = 3.82$, $p < 0.01$), also demonstrated the same pattern with Long-tailed field mouse. It was more frequent during autumn-winter seasons of both 2003-2004 and 2004-2005 periods, and within this pattern it also slightly increased during the three year study (Fig. 5.5). Nonetheless, the significant ANOVAs for the specie were produced as indicated from post-hoc Tukey HSD tests, only from differences between the seasonal samples of spring-summer 2003 and autumn-winter 2004-2005 (Tab. 5.1). Finally, the third representative of Apodemus species in the study area which is the Western broad-toothed mouse, was minimally preyed when compared to its co-generic species, but it presented significant seasonal differences though (one-way ANOVA, $F_{0.05(3,123)} = 5.31$, $p < 0.001$). It didn't present any specific frequency pattern between seasons, since it had very low percentages during the first three samplings, and it only increased during autumn-winter seasons of 2004-2005 (Fig. 5.5). For the same reason, the significant ANOVAs concerning the specie are located in the differences between the final sampling of autumn-winter 2004-2005 and each one of all prior three seasons (Tab. 5.1).

Mice in Thessaly also included two Mus species, the House mouse and the Macedonian mouse. House mouse presented highly significant seasonal differences (one-way ANOVA, $F_{0.05(3,123)} = 14.03$, $p < 0.000001$), and it was more frequent during autumn-winter seasons of 2003-2004 and 2004-2005, and within this pattern it also

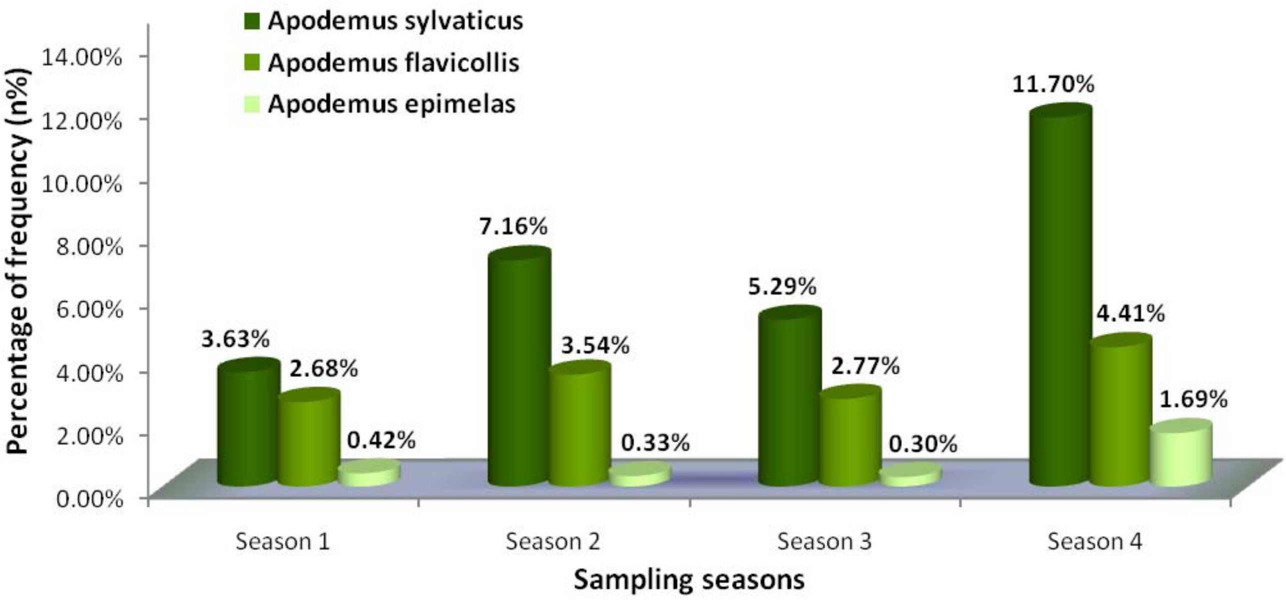


Figure 5.5 Seasonal comparisons in percentages of frequency (n%) between Apodemus species, recorded in the agroecosystems of Thessaly. Seasons stand for: ***Season 1***: April – September 2003, ***Season 2***: October – March 2003-2004, ***Season 3***: April – September 2004, ***Season 4***: October – March 2004-2005.

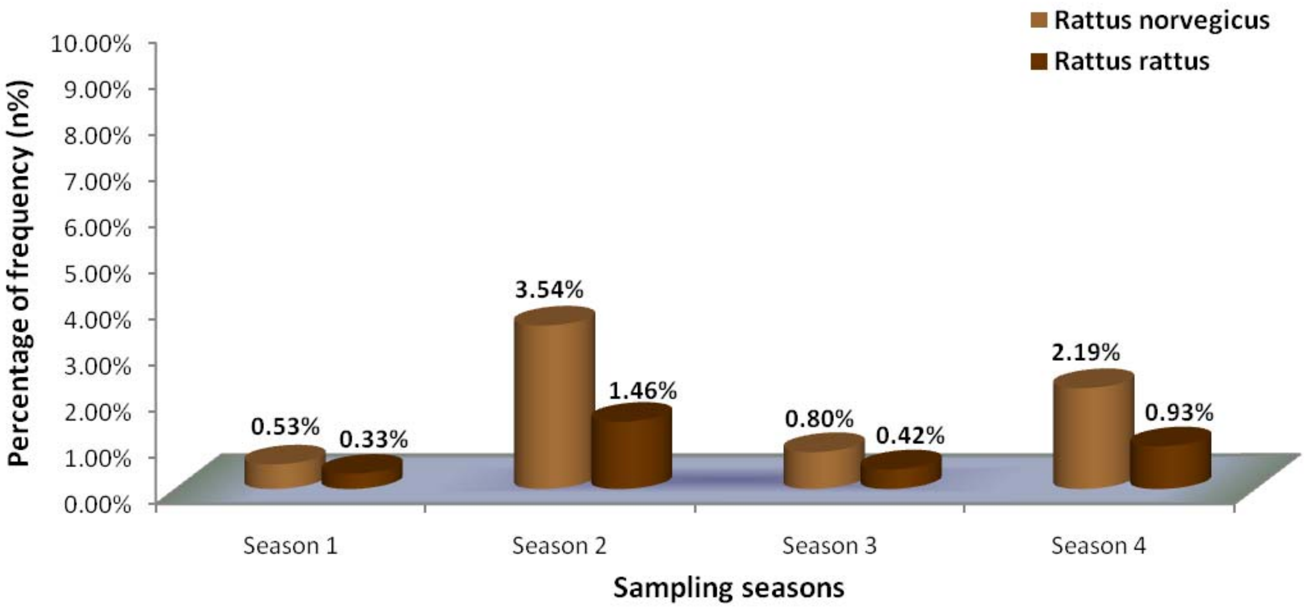


Figure 5.6 Seasonal comparisons in percentages of frequency (n%) between Rattus species, recorded in the agroecosystems of Thessaly. Seasons stand for: ***Season 1***: April – September 2003, ***Season 2***: October – March 2003-2004, ***Season 3***: April – September 2004, ***Season 4***: October – March 2004-2005.

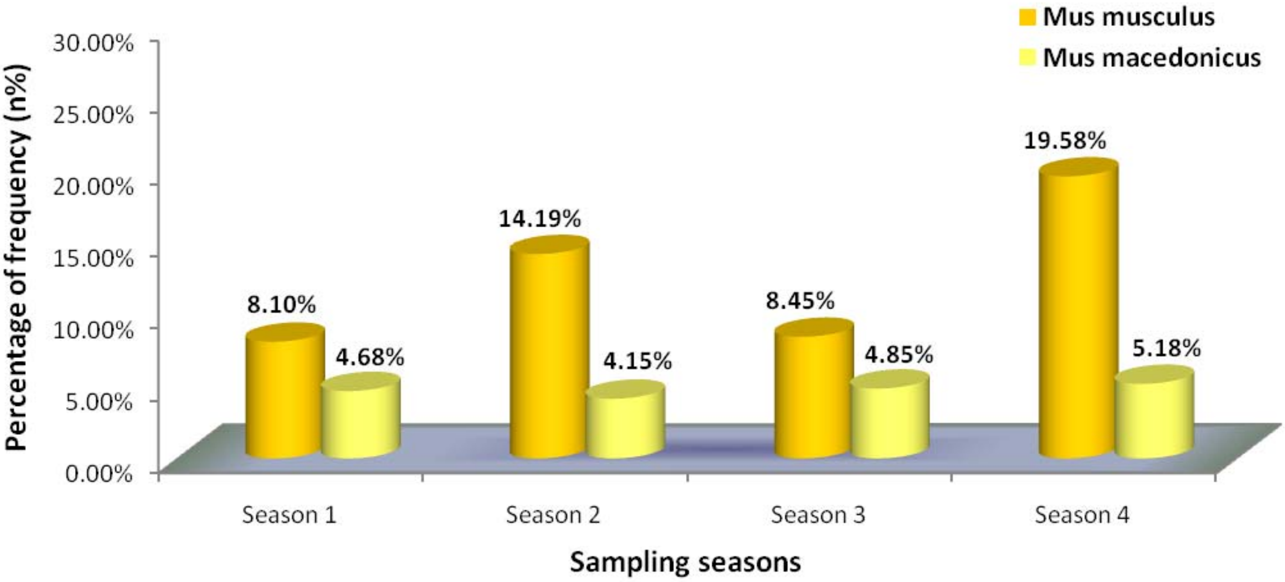


Figure 5.7 Seasonal comparisons in percentages of frequency (n%) between Mus species, recorded in the agroecosystems of Thessaly. Seasons stand for: ***Season 1***: April – September 2003, ***Season 2***: October – March 2003-2004, ***Season 3***: April – September 2004, ***Season 4***: October – March 2004-2005.

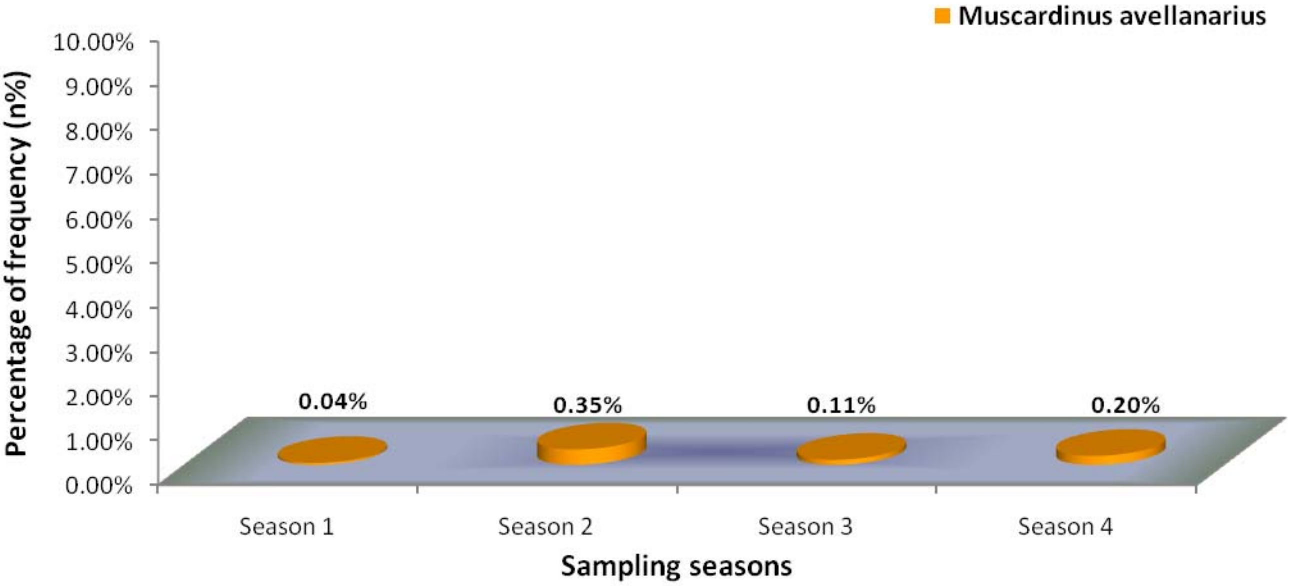


Figure 5.8 Seasonal comparisons in percentages of frequency (n%) of Common dormouse, recorded in the agroecosystems of Thessaly. Seasons stand for: ***Season 1***: April – September 2003, ***Season 2***: October – March 2003-2004, ***Season 3***: April – September 2004, ***Season 4***: October – March 2004-2005.

increased during the four consequent samplings of the three year study (Fig. 5.7). Yet, only the last sample of autumn-winter 2004-2005 presented significant differences when compared with each one of all prior seasons as revealed from post-hoc Tukey HSD tests (Tab. 5.1). On the other hand, the Macedonian mouse had no significant differences between seasons (one-way ANOVA, $F_{0.05(3,123)} = 1.03$, $p = 0.37$), and it was quite less frequent than the House mouse. Its percentages of frequency were almost the same for the first three consequent seasons, and only slightly increased during the autumn-winter season of 2004-2005 (Fig. 5.7), but still without producing significant differences.

Brown rat and Black rat were the two Rattus species that were present in the lowlands of Thessaly. Brown rat was more abundant than Black rat, and among the two it was the only one which presented significant seasonal differences (one-way ANOVA, $F_{0.05(3,123)} = 3.19$, $p < 0.01$). It had higher frequencies during autumn-winter seasons of both 2003-2004 and 2004-2005 year periods, presenting the highest percentages during autumn-winter of 2003-2004 (Fig. 5.6). The significant ANOVA though is only located in the difference between the samples of spring-summer seasons of 2003 and autumn-winter seasons of 2003-2004 (Tab. 5.1). On the other hand, although the co-generic Black rat varied between seasons, it didn’t present significant differences (one-way ANOVA, $F_{0.05(3,123)} = 2.08$, $p = 0.10$). Nonetheless, similarly with Brown rat the Black rat as well had higher frequencies during autumn-winter seasons of both 2003-2004 and 2004-2005 year periods, being also more abundant during autumn-winter of 2003-2004 (Fig. 5.6).

Finally, the last small mammal specie which was recorded in the agroecosystems of Thessaly was the Hazel (or else Common) dormouse, which presented the lower percentages of frequency among all recorded species. It didn’t present significant seasonal differences (one-way ANOVA, $F_{0.05(3,123)} = 0.89$, $p = 0.44$), and it had very low frequencies during all seasons, with minor increases during autumn-winter periods of 2003-2004 and 2004-2005 (Figure 5.8).

5.3.2 Factor analysis in seasonal terms

As mentioned analytically in methodology, independent variables were priorly tested for correlations between them in seasonal terms. Many of them were highly correlated, and thus Factor analysis was applied on both groups of independent variables. The pairs of matrices were introduced in the software Statistica, the percentages were transformed with the arcsine method and Factor analysis was applied in each group twice, once for every seasonal matrix.

From the group “Agricultural Crops & Land Uses” and according to Kaiser criterion, for spring-summer seasons (April-March) of both 2003 and 2004, three new factors were produced according to the eigenvalues whose values were more than 1 (Fig. 5.9), and they explained 95% of variance (Tab. 5.2). For autumn-winter seasons (October-March) of both 2003-2004 and 2004-2005 periods, two new factors were produced (Fig. 5.10) which explained 90% of variance (Tab. 5.2). On the other hand, from the group of “Soil Types & Soil Texture” and again according to Kaiser criterion, for spring-summer seasons (April-March) of both 2003 and 2004, three new factors were produced according to the number of eigenvalues higher than 1 (Fig. 5.11), which explained 80% of variance (Tab. 5.3). Since no changes affected neither the Soil Types of the area nor the Soil Texture between seasons, these three produced factors remained exactly the same for autumn-winter seasons (October-March) of both 2003-2004 and 2004-2005 periods (Fig. 5.12, Tab. 5.2).

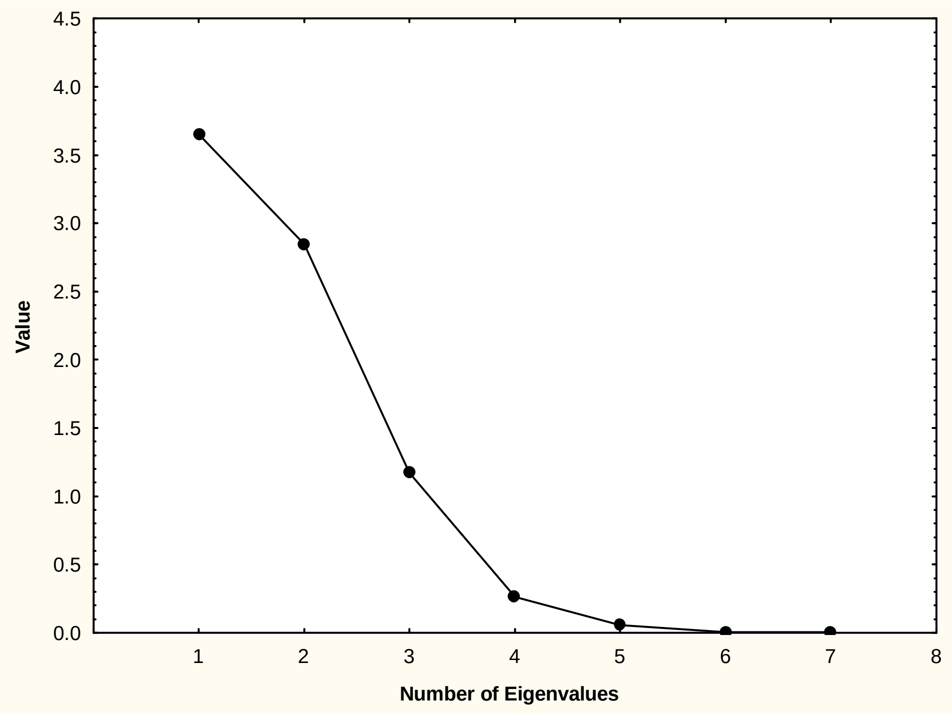


Figure 5.9 Plot of total number of eigenvalues vs. their values, produced from Factor analysis on the group "Agricultural Crops & Land Uses" for spring-summer seasons (April-September) of both 2003 and 2004. Value equal to 1 is considered the minimum eigenvalue according to Kaiser criterion.

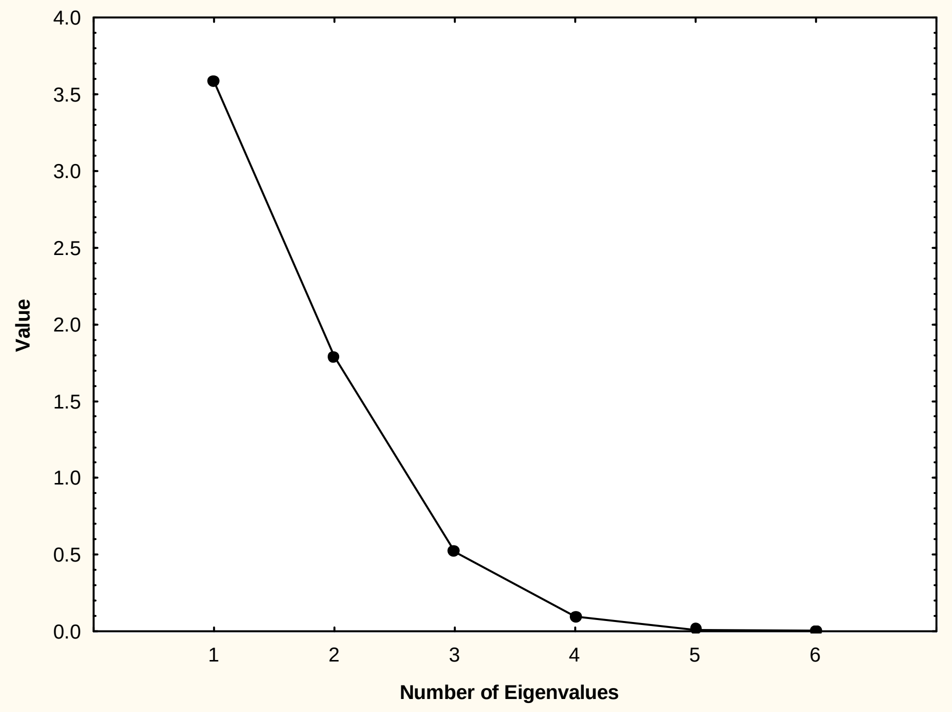


Figure 5.10 Plot of total number of eigenvalues vs. their values, produced from Factor analysis on the group "Agricultural Crops & Land Uses" for autumn-winter seasons (October-March) of both 2003-2004 and 2004-2005 periods. Value equal to 1 is considered the minimum eigenvalue according to Kaiser criterion.

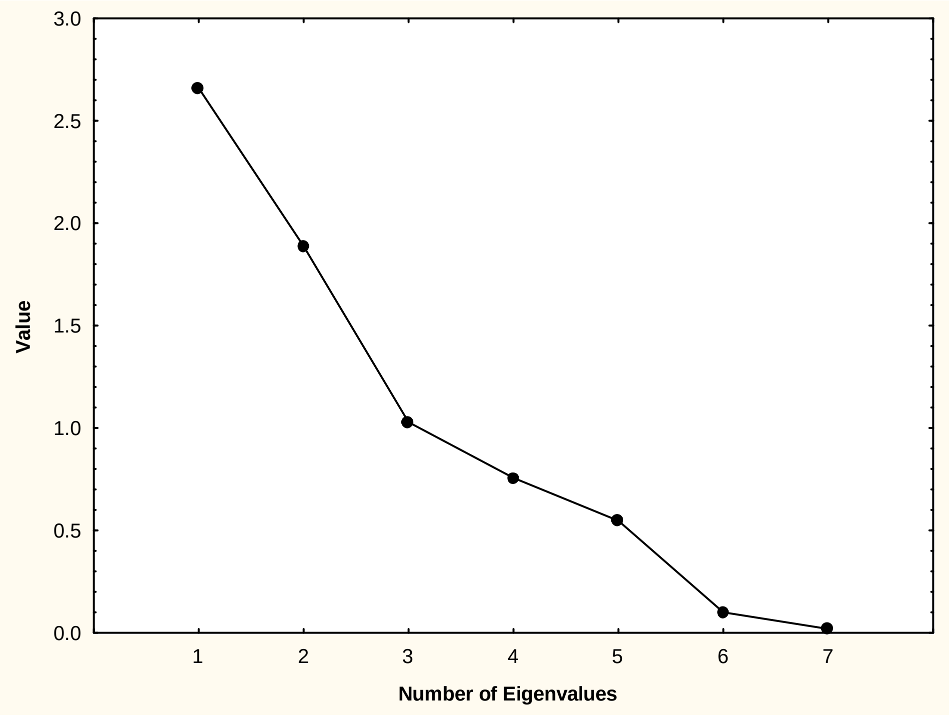


Figure 5.11 Plot of total number of eigenvalues vs. their values, produced from Factor analysis on the group "Soil Types & Soil Texture" for spring-summer seasons (April-September) of both 2003 and 2004. Value equal to 1 is considered the minimum eigenvalue according to Kaiser criterion.

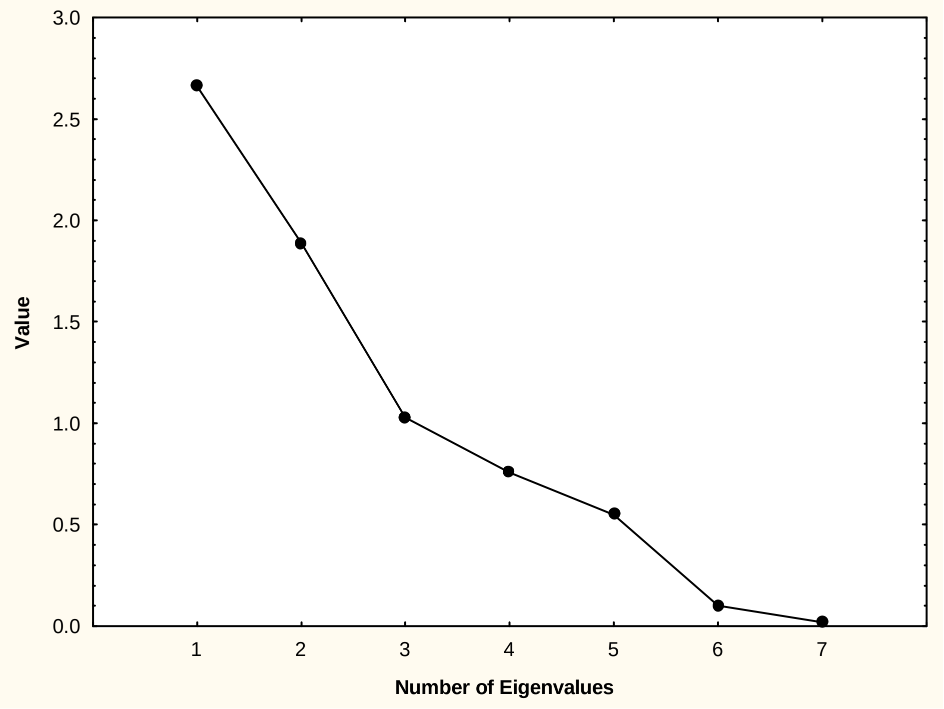


Figure 5.12 Plot of total number of eigenvalues vs. their values, produced from Factor analysis on the group "Soil Types & Soil Texture" for autumn-winter seasons (October-March) of both 2003-2004 and 2004-2005 periods. Value equal to 1 is considered the minimum eigenvalue according to Kaiser criterion.

Table 5.2 Eigenvalues produced from Factor analysis on the group of independent variables "Agricultural Crops & Land Uses". Principal components extraction was followed, and rotation was realized with the "varimax" normalized method. Seasons stand for: ***Season 1***: April-September 2003, ***Season 2***: October-March 2003-2004, ***Season 3***: April-September 2004, ***Season 4***: October-March 2004-2005.

	Eigenvalues	**Total Variance (%)**	**Cumulative Eigenvalue**	**Cumulative Variance (%)**
Seasons 1&3 (April-September)				
1	3.652275	45.65344	3.652275	45.65344
2	2.844921	35.56152	6.497197	81.21496
3	1.171327	14.64158	7.668523	95.85654
Seasons 2&4 (October-March)				
1	3.582782	59.71303	3.582782	59.71303
2	1.788601	29.81002	5.371383	89.52305

Table 5.3 Eigenvalues produced from Factor analysis on the group of independent variables "Soil Types & Soil Texture". Principal components extraction was followed, and rotation was realized with the "varimax" normalized method. Seasons stand for: ***Season 1***: April-September 2003, ***Season 2***: October-March 2003-2004, ***Season 3***: April-September 2004, ***Season 4***: October-March 2004-2005.

	Eigenvalues	**Total Variance (%)**	**Cumulative Eigenvalue**	**Cumulative Variance (%)**
Seasons 1&3 (April-September)				
1	2.661136	38.01623	2.661136	38.01623
2	1.887137	26.95910	4.548273	64.97533
3	1.026794	14.66848	5.575067	79.64381
Seasons 2&4 (October-March)				
1	2.661136	38.01623	2.661136	38.01623
2	1.887137	26.95910	4.548273	64.97533
3	1.026794	14.66848	5.575067	79.64381

In order to decide which factor loadings or else which ones from the original variables actually define the newly produced non-correlated factors, four matrices were constructed. In each matrix were introduced separately each one of the groups of independent variables (“Agricultural Crops & Land Uses” and “Soil Types & Soil Texture”) along with their respective categories for each one of the seasons to be tested in this chapter (spring-summer & autumn-winter). Independent variables’ percentages were transformed with the arcsine method and then in each matrix were added the respective produced factor scores. Each matrix was then introduced in Statistica software and was tested for correlations between independent variables’ categories and factor scores. Then the Bonferroni correction was applied to each one of the correlations, in order to reset the level of significance, and the remaining significant correlations actually indicated which factor loadings (original variables) explain and define the new factors (Tabs. 5.4 & 5.5).

Once the new factors were produced and defined through their respective factor loadings, they were renamed according to their attributes for each group of independent variables and for each season. Since the group “Soil Types & Soil Texture” didn’t present any seasonal differences in the categories that included, the number of factors in that case, their factor scores, factor loadings and thus their names were the same between seasons (Tab. 5.5). Oppositely, the group “Agricultural Crops & Land Uses” presented significant differences between seasons in its included categories of variables. Therefore a different number of factors were produced for each season, with different factor loadings and a different meaning. Thus, some factors according to their different attributes were differently named between seasons (Tab. 5.4). The variables River length, Road length and Altitude were used as they were and weren’t processed with Factor analysis, because they were quite

Table 5.4 Correlations between independent variable categories of group “Agricultural Crops & Land Uses” and factor scores which were produced through Factor analysis for each season. Significant p_s(*) are presented after the level of significance was corrected with the Bonferroni correction (a = 0.05 / (number of variables) x (number of factors)). The significant p_s suggest which factor loadings (original variables) actually “define” the new factors, and are noted: p < 0.01 = *, 0.001 = **, p < 0.0001 = ***, p < 0.00001 = ****, p < 0.000001 = *****.

Season 1& 3	Factor 1	Factor 2	Factor 3	***Season 2 & 4***	Factor 1	Factor 2
	Land Uses	Intensive Cultivations	Arable Land		Irrigation & Cult. Land	Arable Land & Land Uses
Cereals		**-0.9253** ***		Cereals		
Industrial Cultivations		**0.7603** ***		Industrial Cultivations		
Arable Cultivated land	**0.8942** ***		**-0.4410** ***	Arable Cultivated land		**0.9491** ***
Non Arable Cultivated land			**0.9757** ***	Non Arable Cultivated land	**-0.8789** **	
Irrigated Cultivated land		**0.8785** *****		Irrigated Cultivated land	**-0.9086** *****	
Non Irrigated Cultivated land		**-0.9578** *****		Non Irrigated Arable land	**0.6715** ***	
Other land uses	**-0.9972** *****			Other land uses		**-0.9896** ***
Total Cultivated land	**0.9972** *****			Total Cultivated land	**-0.9279** ***	

Table 5.5 Correlations between independent variable categories of group “Soil Types & Soil Texture” and factor scores which were produced through Factor analysis for each season. Significant p_s(*) are presented after the level of significance was corrected with the Bonferroni correction (a = 0.05 / (number of variables) x (number of factors)). The significant p_s suggest which factor loadings (original variables) actually “define” the new factors, and are noted: p < 0.01 = *, 0.001 = **, p < 0.0001 = ***, p < 0.00001 = ****, p < 0.000001 = *****.

Season 1& 3	Factor 1	Factor 2	Factor 3	***Season 2 & 4***	Factor 1	Factor 2	Factor 3
	Soil texture	Soil type E, M & V	Soil type I & V		Soil texture	Soil type E, M & V	Soil type I & V
Alfisol soil type	**-0.7208** **			Alfisol soil type	**-0.7208** **		
Entisol soil type		**0.8441** **		Entisol soil type		**0.8441** **	
Inceptisol soil type			**-0.9503** **	Inceptisol soil type			**-0.9503** **
Mollisol soil type		**0.6666** *****		Mollisol soil type		**0.6666** *****	
Vertisol soil type		**-0.6750** *****	**0.4700** ***	Vertisol soil type		**-0.6750** *****	**0.4700** ***
Sandy-clay texture	**-0.9345** *****			Sandy-clay texture	**-0.9345** *****		
Argillaceous-clay texture	**0.9463** *****			Argillaceous-clay texture	**0.9463** *****		

heterogeneous from the rest independent variables included within the two groups of categories. In addition, they weren't correlated with any of the other variables neither between them.

5.3.3 Ordination analysis in seasonal terms

Once Factor analysis was successfully applied on the groups of predictor variables as demonstrated in previous part, and the new non-correlated seasonal factors along with their respective factor loadings and scores were defined for each group, multicollinearity was avoided from the next parts of statistical analysis. Hence, the following step was to explore the continuity change of small mammal species' seasonal abundance, along the recorded environmental gradients (new non-correlated factors), and therefore ordination techniques were used. As explained analytically in methodology, two matrices were constructed for small mammals' percentages of frequency in each season. One matrix included the percentages of each species, in each sampling site for spring-summer seasons (April-September) of both 2003 and 2004, and the second matrix included the same percentages but for autumn-winter seasons (October-March) of both 2003-2004 and 2004-2005 periods. Both matrices were introduced in Canoco in order to decide if linear or unimodal methods should be used on the data. Indirect gradient analysis was applied on the two seasonal matrices of species' percentages, or else a Detrended Correspondence Analysis (DCA), which actually measures the beta diversity in community composition (the extent of species turnover along various communities). DCA measurements are expressed in gradient lengths. For spring-summer seasons, the largest gradient length value was 2.182 (Tab. 5.6), and for autumn-winter seasons the largest gradient length value was 1.454 (Tab. 5.6). Since both values were smaller than 3, linear methods should be used.

Table 5.6 Indirect gradient analysis (DCA) taking into account only the variability of response variables, and direct gradient analysis (RDA) taking into account the variability of both response and predictor variables. DCA was applied on species' matrices; RDA was applied on both species' and environmental variables' matrices, and in each case for both seasons: spring-summer (April-September) of 2003 and 2004, and autumn-winter (October-March) of periods 2003-2004 and 2004-2005.

spring-summer (April-September) of 2003 & 2004				
Detrended correspondence analysis (DCA)				
Axes	**1**	**2**	**3**	**4**
Eigenvalues	0.177	0.083	0.053	0.026
Lengths of gradients	2.182	1.101	1.285	0.922
Cumulative percentage variance of species data	32.1	47.2	56.9	61.7
Redundancy analysis (RDA)				
Axes	**1**	**2**	**3**	**4**
Eigenvalues	0.237	0.119	0.022	0.013
Species & Environmental variables correlations	0.740	0.696	0.537	0.555
Cumulative percentage variance of species data	23.7	35.6	37.8	39.1
Cumulative percentage of species & environmental variables relation	57.3	86.1	91.5	94.6
autumn-winter (October-March) of 2003-2004 & 2004-2005				
Detrended correspondence analysis (DCA)				
Axes	**1**	**2**	**3**	**4**
Eigenvalues	0.166	0.079	0.043	0.027
Lengths of gradients	1.454	1.337	1.045	0.944
Cumulative percentage variance of species data	31.3	46.2	54.3	59.3
Redundancy analysis (RDA)				
Axes	**1**	**2**	**3**	**4**
Eigenvalues	0.113	0.074	0.036	0.015
Species & Environmental variables correlations	0.684	0.522	0.583	0.620
Cumulative percentage variance of species data	11.3	18.7	22.3	23.8
Cumulative percentage of species & environmental variables relation	43.3	71.5	85.1	90.7

Once linear methods were indicated as the appropriate ones for the next parts of ordination analysis, two more "environmental" matrices were introduced. The first one included the factor scores of each new factor and for each sampling site, which corresponded to spring-summer seasons (April-September) of both 2003 and 2004. The second matrix was similarly constructed but its values corresponded to autumn-winter seasons (October-March) of both 2003-2004 and 2004-2005 periods. In each matrix were also included the values of the variables River Length, Road Length and Altitude. The "environmental" matrices were introduced in Canoco and a forward stepwise selection was firstly realized on the predictor variables, using Monte Carlo permutation tests (see Chapter 4, pp: 202 & 207for details).

Each independent variable (factors & variables) included in the spring-summer seasonal matrix was tested for its effect on the species' composition, as if it was the only explanatory variable in the model. Marginal effects indicated that variables "Road Length", "River Length", and factor "Soil Types I & V" are the least important in affecting small mammals' abundances (Tab. 5.7). The next step of forward stepwise selection was to build a total model, where each time the next more important explanatory variable was added in it. As a result, the model's conditional effects demonstrated that variables "River Length" and "Road Length" produced non significant models when added in it (Tab. 5.7). On the other hand, during autumn-winter seasons (October-March) of both 2003-2004 and 2004-2005 periods, the marginal effects of predictor variables indicated that factor "Soil Type I & V" is the one affecting the least small mammals' abundances during these seasons (Tab. 5.8). When a total model was built testing the predictor variables' conditional effects for the same seasons, factor "Soil Type I & V" along with the variables "River Length" and "Road Length" produced a non-significant model when added in it (Tab. 5.8).

Table 5.7 Results of forward selection on predictor variable categories for spring-summer seasons (April-September) of both 2003 and 2004. Summary of their marginal and conditional effects. Marginal effects rank variables according to their variance, and conditional effects show the variation explained by the environmental variables in the rank order of their inclusion in the model.

Marginal effects		***Conditional effects***			
Variable	Lambda 1	*Variable*	Lambda A	F	p
Soil Texture	0.09	Soil Texture	0.09	5.65	0.002
Land Uses	0.06	Altitude	0.07	6.11	0.002
Arable Land	0.05	Land Uses	0.06	4.69	0.002
Altitude	0.04	Arable Land	0.05	3.75	0.008
Intensive Cultivations	0.04	Intensive Cultivations	0.05	3.32	0.010
Soil type E, M & V	0.04	Soil Type I & V	0.04	2.90	0.022
Road Length	0.03	Soil Type E,M & V	0.03	2.88	0.030
River Length	0.02	Road Length	0.02	1.59	0.150
Soil Type I & V	0.01	River Length	0.00	0.58	0.686

Table 5.8 Results of forward selection on the predictor variable categories for autumn-winter seasons (October-March) of both 2003-2004 and 2004-2005 periods. Summary of their marginal and conditional effects. Marginal effects rank variables according to their variance, and conditional effects show the variation explained by the environmental variables in the rank order of their inclusion in the model.

Marginal effects		***Conditional effects***			
Variable	Lambda 1	*Variable*	Lambda A	F	p
Soil texture	0.08	Soil texture	0.08	4.91	0.002
Irrigation & Cult. Land	0.05	Soil type E, M & V	0.04	2.65	0.016
Soil E,M & V	0.04	Arable Land & Land Uses	0.03	2.71	0.026
Altitude	0.04	Altitude	0.03	2.23	0.038
Road Length	0.03	Irrigation & Cult. Land	0.02	1.93	0.046
River Length	0.03	Road Length	0.02	1.22	0.264
Arable Land & Land Uses	0.03	River Length	0.02	1.20	0.272
Soil Type I & V	0.02	Soil I & V	0.01	1.02	0.396

Once the forward stepwise selection on the predictor variables was completed, and since the Detrended Correspondence Analysis indicated that linear methods should be used in the next parts of ordination analysis (gradient lengths < 3, Tab. 5.6), both “environmental” and “species” matrices were introduced in Canoco, in season pairs. Then, a direct gradient analysis was applied on both cases, which according to the suggested appropriate linear methods was the Redundancy Analysis (constrained ordination). Redundancy analysis was realized on both “environmental” and “species” matrices respectively for each season, and it produced new axes in two dimensions which summarized the greatest data set variability from the response variables (“species” matrix) that can be best explained by the predictor variables (“environmental” matrix). The first two axes produced from Redundancy Analysis (RDA) for spring-summer seasons of both 2003 and 2004 explained 86.1% of the variability, whereas the third and fourth axes only added 8% more (Tab. 5.6). Similarly, for autumn-winter seasons of both 2003-2004 and 2004-2005 periods, RDA results indicated that the first two axes explained 71.5% of the variability, whereas the third and fourth axes explained 13% and 6% respectively (Tab. 5.6). Since the first two axes in both seasons according to RDA results explain a high percentage of the variability (> 70%), they were used in order to test the effect they have on each response variable, summarizing the total of predictor variables. They actually summarize the largest variability within the data set of “environmental” matrix, which best explains the variability occurring in small mammal species’ abundances. The response of each dependent variable (small mammal species) on these two axes for each season respectively, was tested with the use of Generalized Linear Models (Tabs. 5.9 & 5.10). The model which fitted best the response of each dependent variable on the two axes produced from Redundancy Analysis, was explored with the criterion of

Akaike (AIC), which appointed certain small mammal species to be fitting best a 1st order whereas some others a 2nd order polynomial model .

Before the response of each small mammal specie's abundance on the total of predictor factors and variables is checked, the utility Canodraw which is included in Canoco 4.5 for Windows, visualized the results of constrained ordination (Redundancy Analysis) on a biplot, presenting the total of both predictor and response variables in the form of vectors (Figs. 5.13 & 5.14). Small mammal species are demonstrated with black arrows and environmental variables (factors & independent variables) are indicated with red. Length of response variables (small mammal species) indicates the relative frequency of each species, and direction indicates positive and negative correlations between species. On the other hand, length of environmental variables indicates which one explains best the variability of response variables, whereas direction of predictor variables indicates associations among them, as well as negative and positive correlations between environmental variables and small mammal species. In Figure 5.13 which demonstrates the biplot ordination diagram produced from Redundancy Analysis results for spring-summer seasons (April-September) of both 2003 and 2004, some quite different patterns can be observed from the ones indicated in the biplot ordination diagram produced from Redundancy Analysis results for autumn-winter seasons (October-March) of 2003-2004 and 2004-2005 periods (Fig. 5.14). That is due to the seasonal differences which are produced in the habitat structure of main cultivation types in the study area, which are primarily wheat (in Cereals category) and cotton (in Industrial Cultivations category). As mentioned earlier, these cultivations are harvested before October and thus, during autumn and winter the land remains actually "naked" until the seeds are replanted from November - December and on.

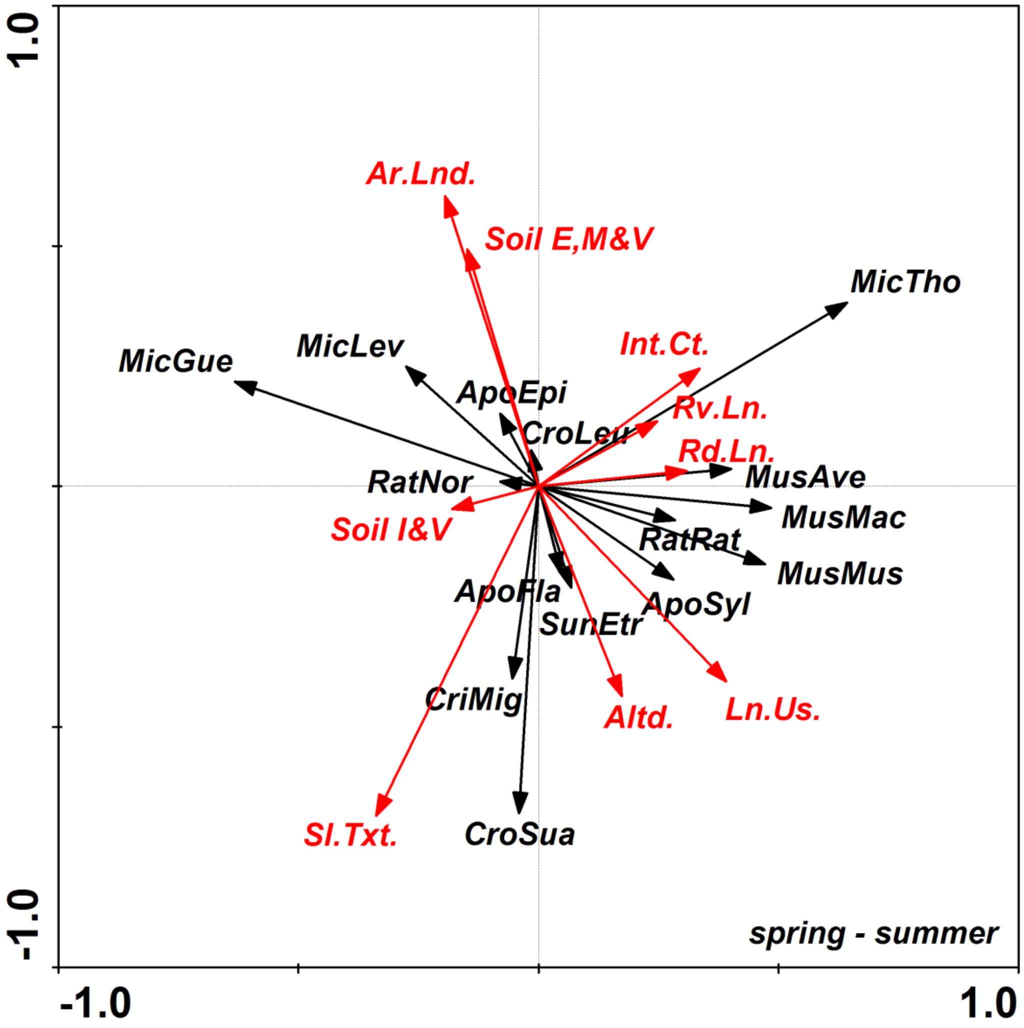


Figure 5.13 Biplot ordination diagram of response (small mammal species) and explanatory (environmental) variables on Axis 1 & 2 of Redundancy Analysis (RDA), for spring-summer seasons (April-September) of both 2003 and 2004. Scaling is based on inter-species distances. Small mammal species are demonstrated with black arrows whereas environmental variables with red. Length and direction of vectors indicate respectively strength and associations between them. Length of response variables indicates the amount of their relative frequency, and direction indicates the positive and negative correlations between them. Length of predictor variables indicates which environmental variables explain best the variability of response variables, whereas the direction of predictor variables indicates associations between them, and also negative and positive correlations between environmental and response variables. Acronyms stand for: ***Altd***: Altitude, ***Sl.Txt***: Soil Texture, ***Soil I & V***: Soil Type Inseptisol and Vertisol, ***Int.Ct***: Intensive Cultivations, ***Soil E, M & V***: Soil Type Entisol, Mollisol and Vertisol, ***Rd.Ln***: Road Length, ***Rv.Ln***: River Length, ***Ln.Us***: Land Uses, ***Ar.Lnd***: Arable Land, ***CroLeu***: Crocidura leucodon, ***CroSua***: Crocidura suaveolens, ***SunEtr***: Suncus etruscus, ***MicGue***: Microtus guentheri, ***MicLev***: Microtus levis, ***MicTho***: Microtus thomasi, ***CriMig***: Cricetulus migratorius, ***ApoSyl***: Apodemus sylvaticus, ***ApoEpi***: Apodemus epimelas, ***ApoFla***: Apodemus flavicollis, ***MusMus***: Mus musculus, ***MusMac***: Mus macedonicus, ***RatRat***: Rattus rattus, ***RatNor***: Rattus norvegicus, ***MusAve***: Muscardinus avellanarius.

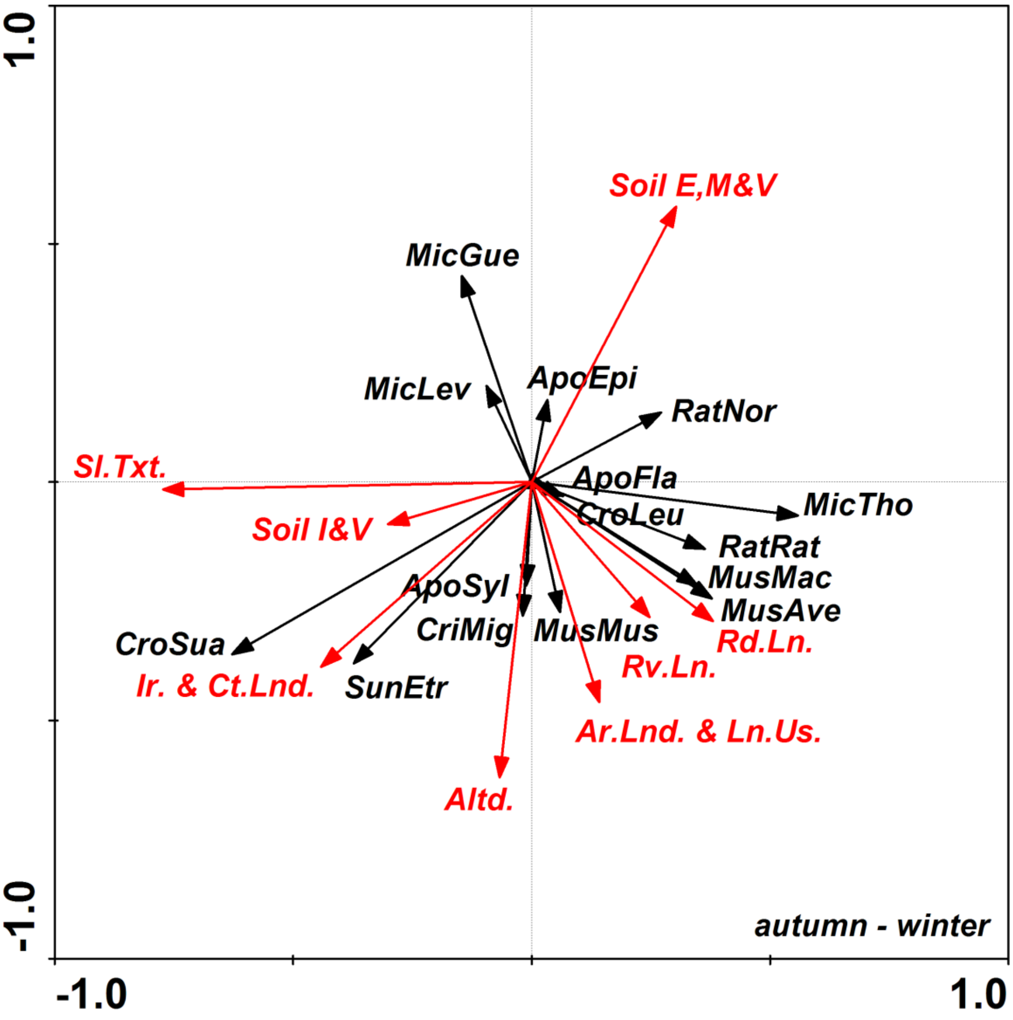


Figure 5.14 Biplot ordination diagram of response (small mammal species) and explanatory (environmental) variables on Axis 1 & 2 of Redundancy Analysis (RDA), for autumn-winter seasons (October-March) of periods 2003-2004 and 2004-2005. Scaling is based on inter-species distances. Small mammal species are demonstrated with black arrows whereas environmental variables with red. Length and direction of vectors indicate respectively strength and associations between them. Length of response variables indicates the amount of their relative frequency, and direction indicates the positive and negative correlations between them. Length of predictor variables indicates which environmental variables explain best the variability of response variables, whereas the direction of predictor variables indicates associations between them, and also negative and positive correlations between environmental and response variables. Acronyms stand for: ***Altd***: Altitude, ***Sl.Txt***: Soil Texture, ***Soil I & V***: Soil Type Inseptisol and Vertisol, ***Int.Ct***: Intensive Cultivations, ***Soil E, M & V***: Soil Type Entisol, Mollisol and Vertisol, ***Rd.Ln***: Road Length, ***Rv.Ln***: River Length, ***Ln.Us***: Land Uses, ***Ar.Lnd***: Arable Land, ***CroLeu***: Crocidura leucodon, ***CroSua***: Crocidura suaveolens, ***SunEtr***: Suncus etruscus, ***MicGue***: Microtus guentheri, ***MicLev***: Microtus levis, ***MicTho***: Microtus thomasi, ***CriMig***: Cricetulus migratorius, ***ApoSyl***: Apodemus sylvaticus, ***ApoEpi***: Apodemus epimelas, ***ApoFla***: Apodemus flavicollis, ***MusMus***: Mus musculus, ***MusMac***: Mus macedonicus, ***RatRat***: Rattus rattus, ***RatNor***: Rattus norvegicus, ***MusAve***: Muscardinus avellanarius.

Therefore, during this season these two crop categories actually disappear and do not occupy any extensions in the studied areas. Consequently, areas occupied by "Irrigated Land" and "Non Irrigated Land", which are also included in the same group of independent variables, are respectively reduced and increased radically. The final result is that when Factor analysis is applied to the group "Agricultural Crops & Land Uses" for autumn-winter seasons of both 2003-2004 and 2004-2005 periods, the mentioned changes produce one less factor in contrast to spring-summer seasons of both 2003 and 2004 (Tab. 5.4). The two produced factors from "Agricultural Crops & Land Uses" group during autumn-winter seasons are also renamed differently according to their new and differentiated attributes (Tab. 5.4). These differences can also be observed in the biplot constrained ordination graphics. Specifically in Figure 5.13, six factors and three variables (indicated with red vectors) are demonstrated to explain the small mammal species' (black vectors) variability for spring-summer seasons, whereas in Figure 5.14 and for autumn-winter seasons, 5 factors and three variables are respectively indicated as the predictor variables affecting the continuity change of response variables. Moreover, except the differences in the number of factors produced between seasons, the patterns explaining these changes are also different as it can be observed in the altered correlations (negative & positive) between small mammal species and environmental gradients (Figs. 5.13 & 5.14).

In order to explore better and explain these differences, the response of each dependent variable (small mammal species) on the total of environmental gradients, which are summarized on the first two axes produced from Redundancy Analysis (RDA) as mentioned (Tab. 5.6), was also tested separately for both seasons. Each small mammal specie's response was tested with Generalized Linear Models, a statistical approach also included in Canoco, and the “best fit” model for each species was chosen with the criterion of Akaike (AIC).

More specific, for spring-summer seasons (April-September) of both 2003 and 2004, the species Bicolored shrew, Etruscan shrew, Yellow-necked field mouse, Western broad-toothed field mouse and Brown rat, didn’t fit any regression model and were rejected through “null model” selection (Tab. 5.9). Oppositely, the remaining 10 species all fitted significant regression models, from which some were 1st order and others 2nd order polynomial models (Tab. 5.9). On the other hand, for autumn-winter seasons (October-March) of both 2003-2004 and 2004-2005 periods, the species East European vole and Yellow-necked field mouse were rejected through “null model” selection and didn’t fit any regression model, whereas three more species, the Bicolored shrew, the Long-tailed field mouse and the House mouse fitted 2nd order polynomial models which were non-significant though (Tab. 5.10). The remaining 10 species in that case similarly all fitted significant regression models (Tab. 5.10).

The composition increase of Long-tailed field mouse and House mouse abundance, on the total of environmental gradients during spring-summer seasons, was significantly correlated with the factors “Land Uses” and “Arable Land”, which actually define the vertical axe (Figs. 5.15 & 5.19). The species also presented higher abundances when correlated with the variables “River Length” and “Road Length” which actually define the horizontal axe (Figs. 5.15 & 5.19). In respect to East European vole’s composition change, it fitted a significant 2nd order polynomial model along the total of environmental variables, but only during spring-summer seasons (Tabs. 5.9 & 5.10). It presented exactly the opposite pattern from Long-tailed field mouse and House mouse, and it was similarly correlated with factors “Land Uses” and “Arable Land” increasing though to opposite directions, whereas the variables “River Length”

Table 5.9 Response of each dependent variable (small mammal species) to the first two axes produced from RDA for spring-summer seasons (April-September) of both 2003 and 2004. The two axes summarize the total variability within the "environmental" matrix. The response of each dependent variable was tested with Generalized Linear Models (GLM), and the "best fit" regression model was chosen with the criterion of Akaike (AIC) in each case. Level of significance was set at $a = 0.05$, and significant p_s are noted: $p < 0.01$ = *, $p < 0.001$ = **, $p < 0.0001$ = ***, $p < 0.00001$ = ****, $p < 0.000001$ = *****.

		Model Selection			**Generalized Linear Model**	
Response Variable	AIC	b_0+b_1X	$b_0+b_1X+b_2X^2$	Null model	F	P
Crocidura leucodon	-			√	-	-
Crocidura suaveolens	142.81	√			25.30	*****
Suncus etruscus	-			√	-	-
Microtus guentheri	234.42		√		17.70	*****
Microtus levis	158.02		√		6.88	***
Microtus thomasi	435.22	√			30.60	*****
Cricetulus migratorius	280.08	√			7.22	**
Apodemus flavicollis	-			√	-	-
Apodemus epimelas	-			√	-	-
Apodemus sylvaticus	155.30	√			3.82	*
Rattus norvegicus	-			√	-	-
Rattus rattus	298.02		√		4.05	**
Mus musculus	152.24	√			9.68	***
Mus macedonicus	194.52		√		5.35	**
Muscardinus avellanarius	0.464		√		4.2	*****

Table 5.10 Response of each dependent variable (small mammal species) to the first two axes produced from RDA for autumn-winter seasons (October-March) of both 2003-2004 and 2004-2005 periods. The two axes summarize the total variability within the "environmental" matrix. The response of each dependent variable was tested with Generalized Linear Models (GLM), and the "best fit" regression model was chosen with the criterion of Akaike (AIC) in each case. Level of significance was set at $a = 0.05$, and significant p_s are noted: $p < 0.01$ = *, $p < 0.001$ = **, $p < 0.0001$ = ***, $p < 0.00001$ = ****, $p < 0.000001$ = *****.

		Model Selection			**Generalized Linear Model**	
Response Variable	AIC	b_0+b_1X	$b_0+b_1X+b_2X^2$	Null model	F	P
Crocidura leucodon	484.25		√		2.33	0.066
Crocidura suaveolens	65.44		√		19.50	*****
Suncus etruscus	254.69	√			10.84	***
Microtus guentheri	306.93	√			7.93	**
Microtus levis	-			√	-	-
Microtus thomasi	401.67		√		22.37	*****
Cricetulus migratorius	321.482		√		3.91	*
Apodemus flavicollis	-			√	-	-
Apodemus epimelas	392.88		√		2.87	*
Apodemus sylvaticus	113.58		√		2.38	0.061
Rattus norvegicus	610.37		√		3.06	*
Rattus rattus	441.18		√		3.83	*
Mus musculus	114.93	√			2.58	0.083
Mus macedonicus	161.56		√		4.98	**
Muscardinus avellanarius	105.75		√		24.83	*****

and “Road Length” seemed to have a negative effect on its abundance (Fig. 5.17). Nonetheless, its general response should be analyzed further and carefully since 2nd order polynomial models produce some not so straightforward relationships.

The Etruscan shrew on the other hand was positively correlated with the negative values of factors “Irrigation & Cultivated Land” and “Soil E, M & V” only during autumn-winter seasons (Tab. 5.10), factors which actually define the vertical axe (Fig. 5.16). In comparison with the Brown rat’s response, it fitted a more complex 2nd order polynomial model but it seems to present exactly the opposite pattern, having higher frequencies when correlated with the positive values of factors “Irrigation & Cultivated Land” and “Soil E, M & V” (Fig. 5.20).

Nonetheless, other insectivorous species, as well as certain representatives of mice, rats and voles have responded with significant models in both seasons on the total of environmental gradients, with some of them presenting quite distinct patterns between seasons. Specifically, Lesser white-toothed shrew fitted a significant 1st order polynomial model in spring-summer seasons of both 2003 and 2004, whereas it fitted a significant 2nd order polynomial model during autumn-winter seasons of both 2003-2004 and 2004-2005 periods (Tabs. 5.9 & 5.10). During spring-summer seasons the specie presented higher frequencies when correlated with the variable “Altitude” and factors “Soil Texture” and “Land Uses” (Fig. 5.21), and during autumn-winter seasons it was more abundant when correlated with the negative values of factors “Irrigation & Cultivated Land”, “Soil Texture” and “Soil E,M&V” (Fig. 5.22).

From the group of voles, although East European vole only fitted a significant response model during spring-summer seasons as mentioned before (Tabs. 5.9 & 5.10, Fig. 5.17), whereas the other three representatives of the group fitted significant response models on the total of environmental gradients for both seasons.

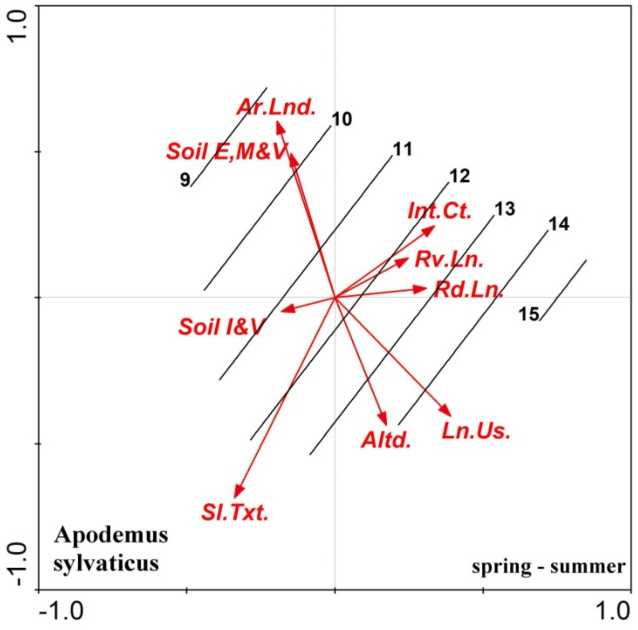


Figure 5.15 Response of Long-tailed field mouse on the environmental gradients for spring-summer seasons of both 2003 and 2004. Increase in contour isolines' values indicates increase in the specie's relative frequency.

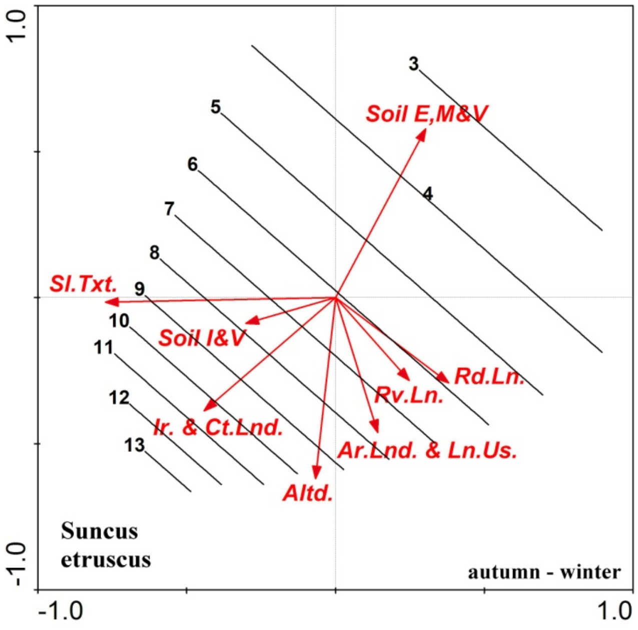


Figure 5.16 Response of Etruscan shrew on the environmental gradients for autumn-winter seasons of both 2003-2004 and 2004-2005 periods. Increase in contour isolines' values indicates increase in the specie's relative frequency.

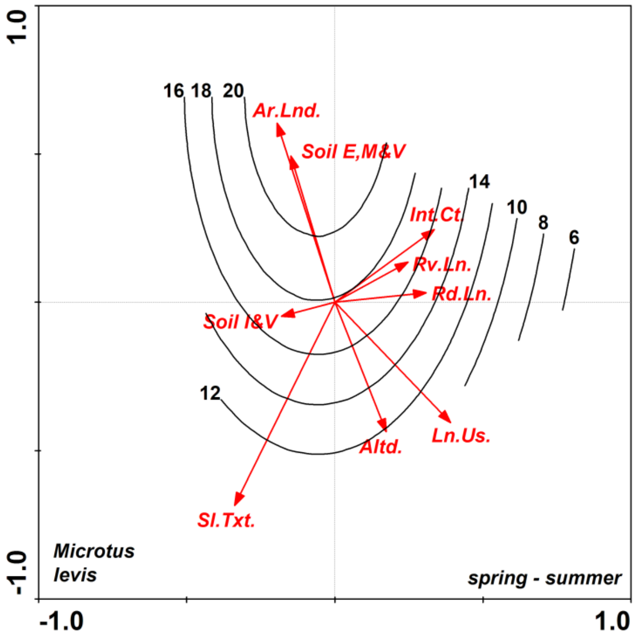


Figure 5.17 Response of East European vole on the environmental gradients for spring-summer seasons of both 2003 and 2004. Increase in contour isolines' values indicates increase in the specie's relative frequency.

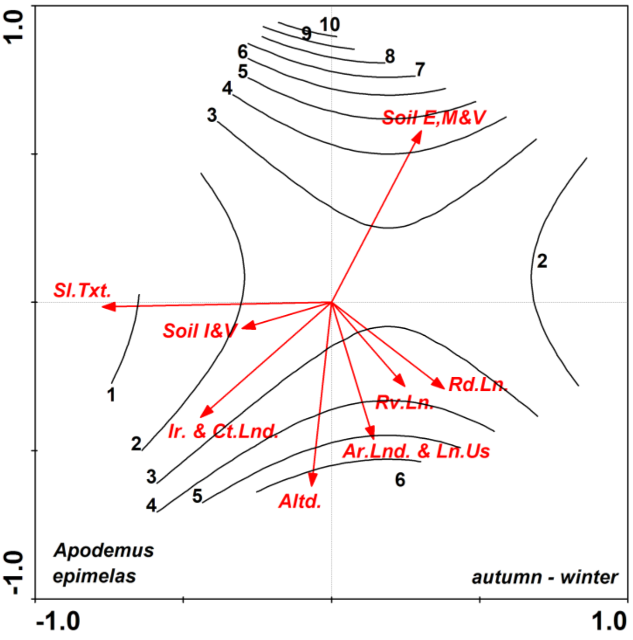


Figure 5.18 Response of Western broad-toothed field mouse on the environmental gradients for autumn-winter seasons of both 2003-2004 and 2004-2005 periods. Increase in contour isolines' values indicates increase in the specie's relative frequency.

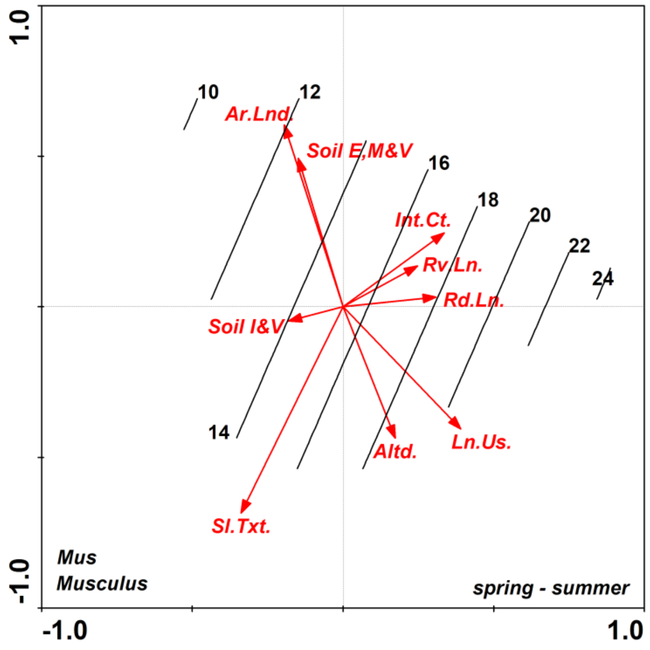


Figure 5.19 Response of House mouse on the environmental gradients for spring-summer seasons of both 2003 and 2004. Increase in contour isolines' values indicates increase in the specie's relative frequency.

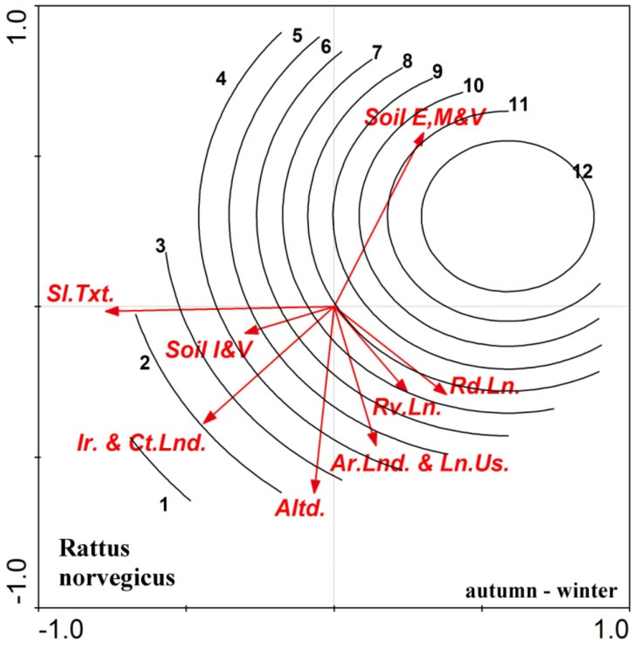


Figure 5.20 Response of Brown rat on the environmental gradients for autumn-winter seasons of both 2003-2004 and 2004-2005 periods. Increase in contour isolines' values indicates increase in the specie's relative frequency.

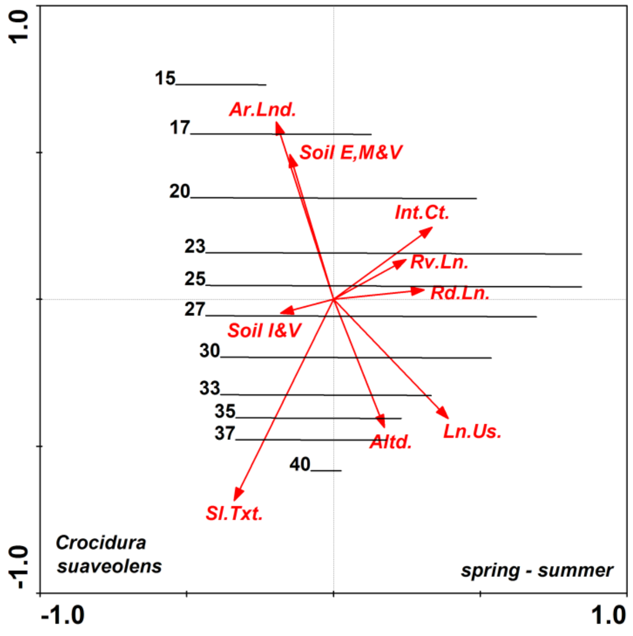


Figure 5.21 Response of Leser white-toothed shrew on the environmental gradients for spring-summer seasons of both 2003 and 2004. Increase in contour isolines' values indicates increase in the specie's relative frequency.

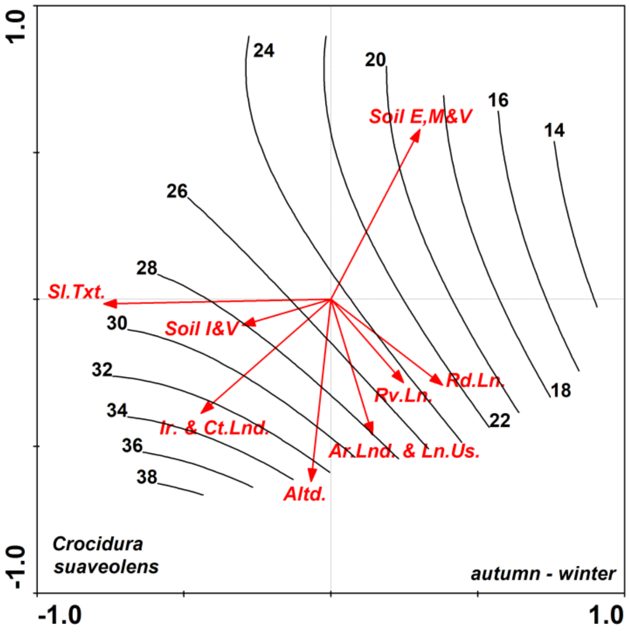


Figure 5.22 Response of Leser white-toothed shrew on the environmental gradients for autumn-winter seasons of both 2003-2004 and 2004-2005 periods. Increase in contour isolines' values indicates increase in the specie's relative frequency.

Guenther's vole responded with a significant 2nd order polynomial model during spring-summer seasons of both 2003 and 2004 (Tab. 5.9), and although the relationship is not straightforward it is obvious that the specie has higher frequencies when correlated with the factors "Arable Land" and "Land Uses" (Fig. 5.23). During autumn-winter seasons the specie is more abundant when correlated with the variable "Altitude" and the factor "Arable Land & Land Uses" (Fig. 5.24), and fitted a 1st order polynomial model (Tab. 5.10). On the other hand, the Gray dwarf hamster presented exactly the opposite patterns from Guenther's vole for both seasons. It fitted a 1st order polynomial model for spring-summer seasons and a 2nd order polynomial model for autumn-winter seasons (Tab. 5.9 & 5.10). In spring-summer seasons of both 2003 and 2004, it increased when correlated with the variable "Altitude" and the factors "Arable Land" and "Land Uses" (Fig. 5.27), whereas during autumn-winter seasons of both 2003-2004 and 2004-2005 periods, it was more abundant when correlated with the variable "Altitude" and factor "Arable Land & Land Uses" (Fig. 5.28). The third representative of voles' group which presented significant response models for both seasons was Thomas's pine vole. It fitted a 1st order polynomial model during spring-summer seasons of both 2003 and 2004 and a 2nd order polynomial model during autumn-winter seasons of both 2003-2004 and 2004-2005 periods (Tabs. 5.9 & 5.10). In spring-summer seasons the specie was more abundant when correlated with the variables "River Length", "Road Length" and the positive values of factor "Intensive Cultivations" (Fig. 5.25), and during autumn-winter seasons it had higher frequencies when correlated with the positive values of factor "Irrigation & Cultivated Land" (Fig. 5.26).

In respect to rat species, Black rat fitted a 2nd order significant polynomial model for both seasons (Tabs. 5.9 & 5.10). Although the relationship between the specie's

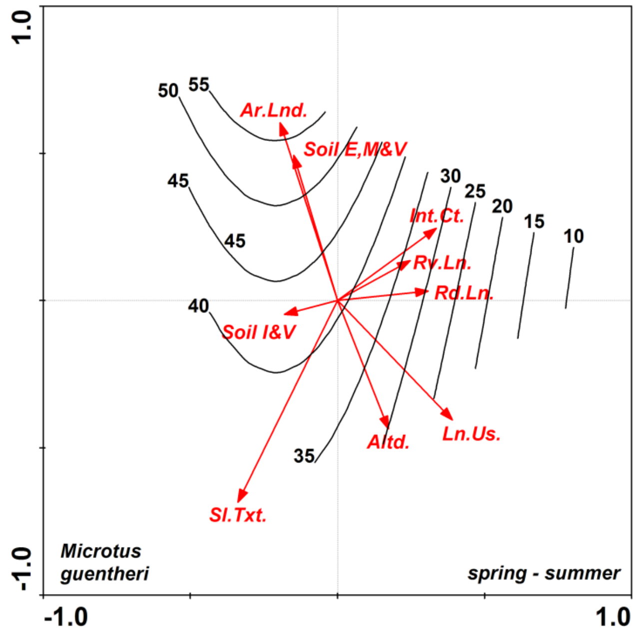


Figure 5.23 Response of Guenther's vole on the environmental gradients for spring-summer seasons of both 2003 and 2004. Increase in contour isolines' values indicates increase in the specie's relative frequency.

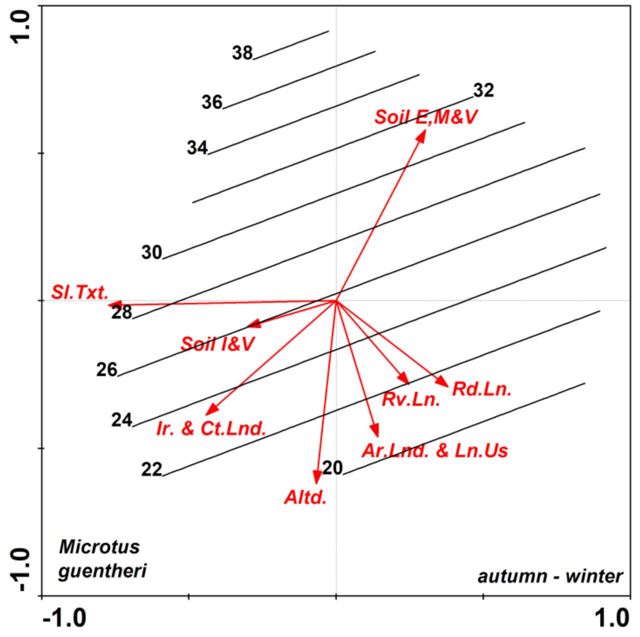


Figure 5.24 Response of Guenther's vole on the environmental gradients for autumn-winter seasons of both 2003-2004 and 2004-2005 periods. Increase in contour isolines' values indicates increase in the specie's relative frequency.

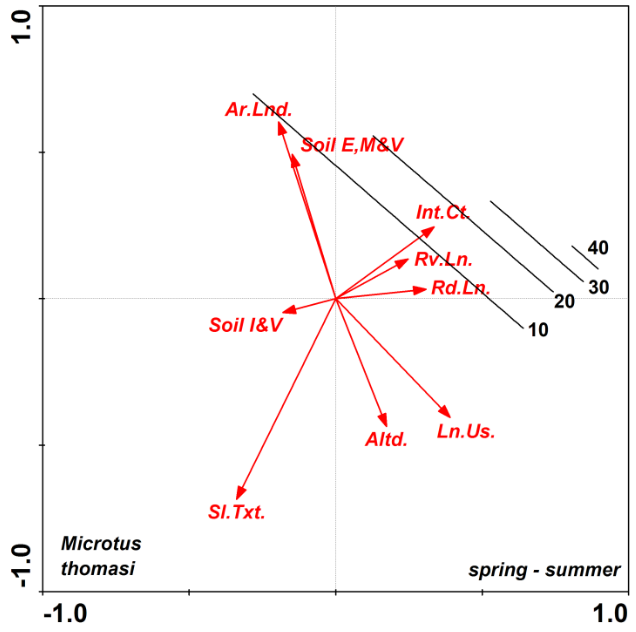


Figure 5.25 Response of Thomas's pine vole on the environmental gradients for spring-summer seasons of both 2003 and 2004. Increase in contour isolines' values indicates increase in the specie's relative frequency.

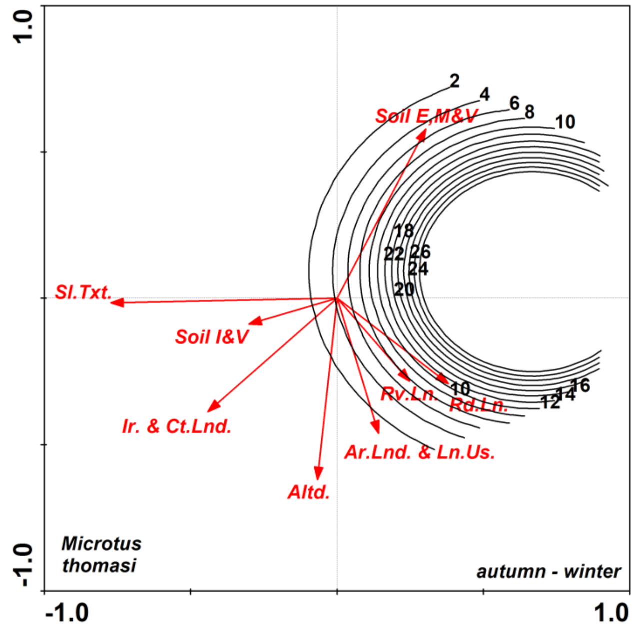


Figure 5.26 Response of Thomas's pine vole on the environmental gradients for autumn-winter seasons of both 2003-2004 and 2004-2005 periods. Increase in contour isolines' values indicates increase in the specie's relative frequency.

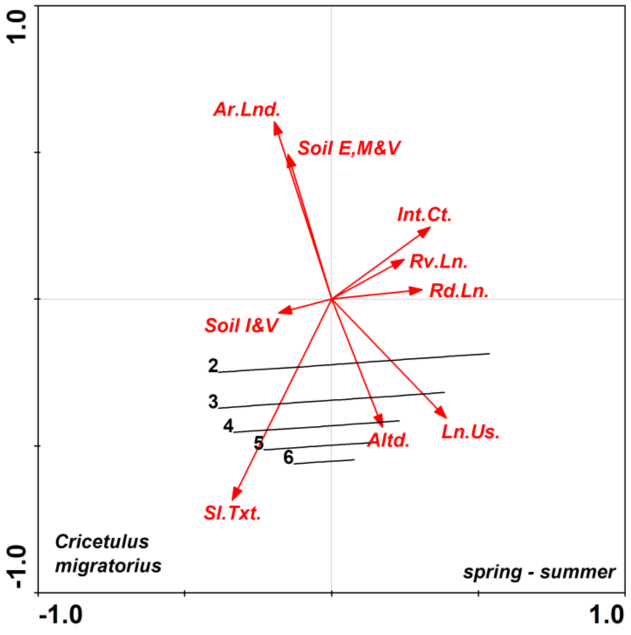


Figure 5.27 Response of Gray dwarf hamster on the environmental gradients for spring-summer seasons of both 2003 and 2004. Increase in contour isolines' values indicates increase in the specie's relative frequency.

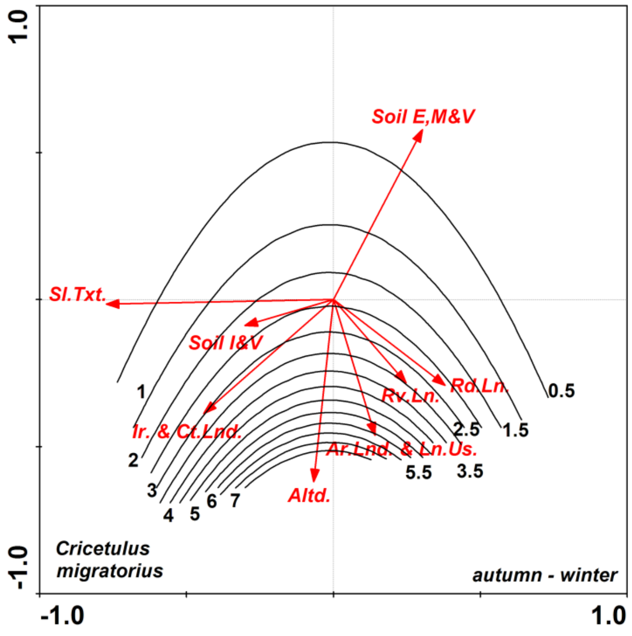


Figure 5.28 Response of Gray dwarf hamster on the environmental gradients for autumn-winter seasons of both 2003-2004 and 2004-2005 periods. Increase in contour isolines' values indicates increase in the specie's relative frequency.

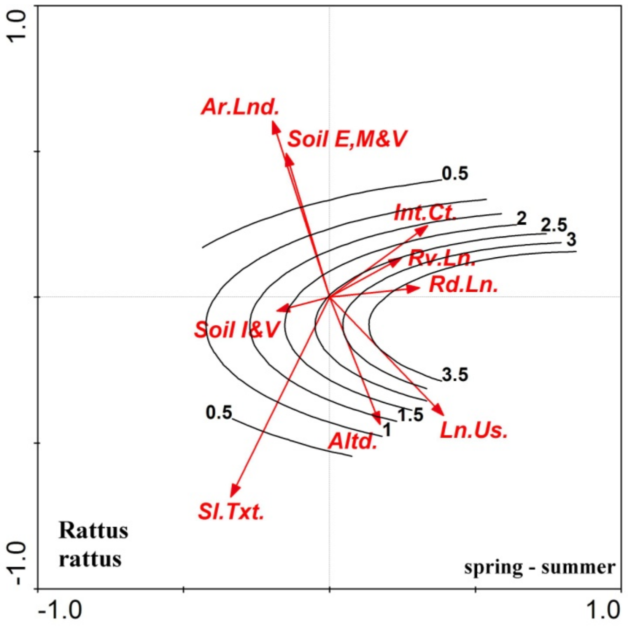


Figure 5.29 Response of Black rat on the environmental gradients for spring-summer seasons of both 2003 and 2004. Increase in contour isolines' values indicates increase in the specie's relative frequency.

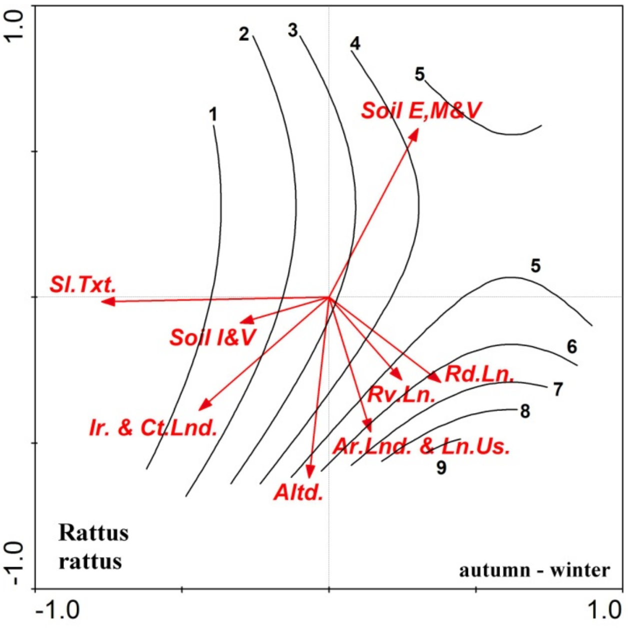


Figure 5.30 Response of Black rat on the environmental gradients for autumn-winter seasons of both 2003-2004 and 2004-2005 periods. Increase in contour isolines' values indicates increase in the specie's relative frequency.

abundance along the environmental gradients is complex and not straightforward, it is undoubtedly deduced that for both seasons, Black rat is more frequent when correlated with the variables “River Length” and “Road Length” (Figs. 5.29 & 5.30). Similarly, the Macedonian mouse fitted significant 2nd order polynomial models for both seasons (Tab. 5.9 & 5.10). During spring-summer seasons the specie was more abundant when correlated with the variables “River Length” and “Road Length”, whereas factors “Arable Land” and “Soil E,M&V” seemed to have a negative effect on its frequency (Fig. 5.29). During autumn-winter seasons, the variables “River Length” and “Road Length” also had a positive effect on the specie’s abundance, along with factor “Arable Land & Land Uses” (Fig. 5.30). Finally, the Hazel dormouse also fitted significant 2nd order polynomial models for both seasons (Tabs. 5.9 & 5.10). Although the contour isolines which reflect the specie’s response are quite complex, it can be observed that for spring-summer seasons of 2003 and 2004, the variable “Altitude” along with factors “Arable Land” and “Land Uses” are positively correlated with higher abundances of Hazel dormouse (Fig. 5.33). Additionally, during autumn-winter seasons of 2003-2004 and 2004-2005, the specie presented higher frequencies when correlated with the variables “River Length” and “Road Length” and the negative values of factor “Arable Land & Land Uses” (Fig. 5.34). Nonetheless, as mentioned also in Chapter 4, since the specie’s relative frequency presented very low percentages in a minimum of just four studied areas, although it fitted significant response models they should be interpreted very carefully, and it is quite possible that some bias is included in them due to very low presence and area occupation. It can be observed from the total of general response models, that some small mammal species such as Western broad-toothed mouse, East European vole, Thomas’s pine vole and Macedonian mouse, fitted 2nd order

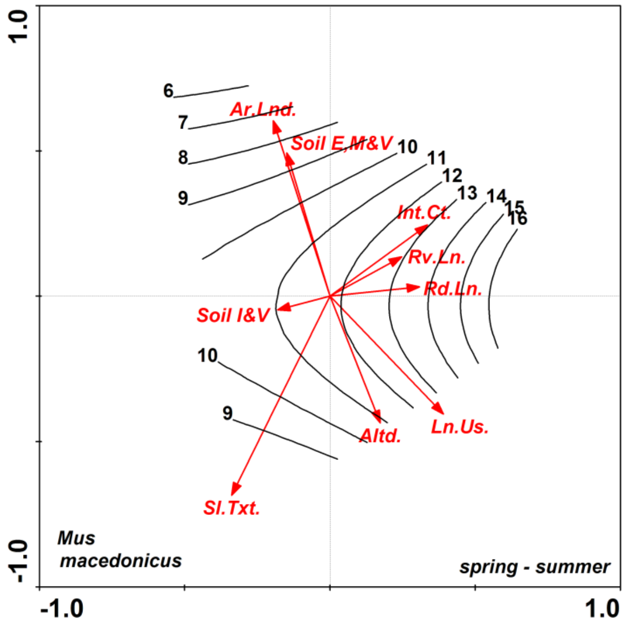


Figure 5.31 Response of Macedonian mouse on the environmental gradients for spring-summer seasons of both 2003 and 2004. Increase in contour isolines' values indicates increase in the specie's relative frequency.

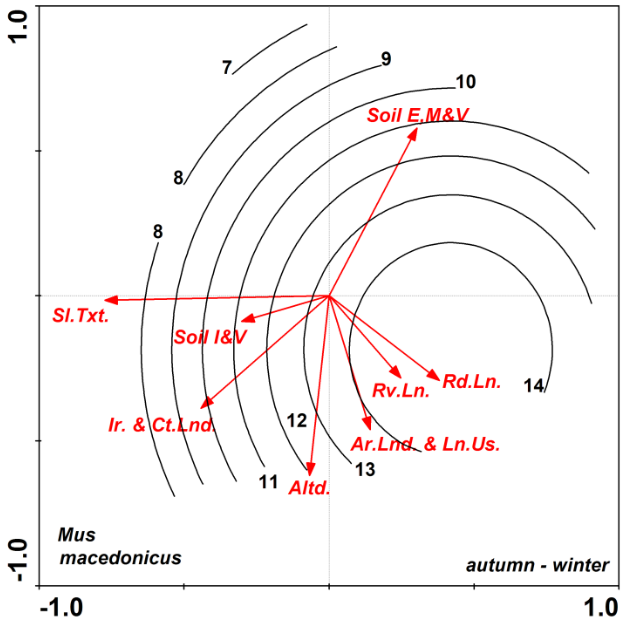


Figure 5.32 Response of Macedonian mouse on the environmental gradients for autumn-winter seasons of both 2003-2004 and 2004-2005 periods. Increase in contour isolines' values indicates increase in the specie's relative frequency.

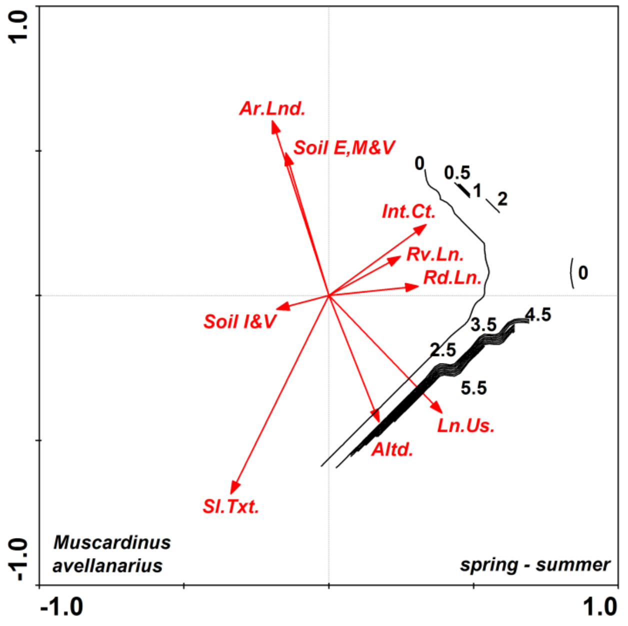


Figure 5.33 Response of Hazel dormouse on the environmental gradients for spring-summer seasons of both 2003 and 2004. Increase in contour isolines' values indicates increase in the specie's relative frequency.

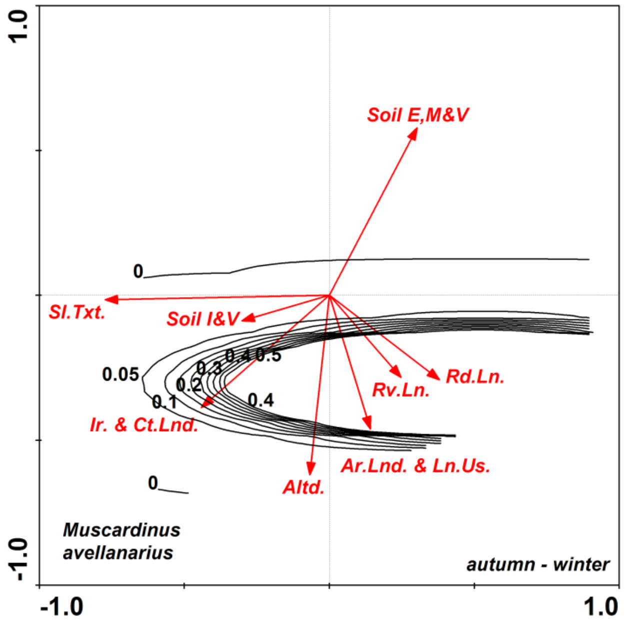


Figure 5.34 Response of Hazel dormouse on the environmental gradients for autumn-winter seasons of both 2003-2004 and 2004-2005 periods. Increase in contour isolines' values indicates increase in the specie's relative frequency.

polynomial models on the total of environmental gradients, as mentioned previously. The exact relationships between these species' abundance changes and the measured environmental gradients, is not straightforward, neither can it be easily interpreted due to the model's complexity. Moreover, although these response models offer a great amount of information, some gradients' effect cannot be deduced with certainty. Consequently, the response of each species, on each environmental gradient and for each season was also tested separately. The species' response was tested with Generalized Linear Models, and the "best fit" model was also chosen in this occasion with the criterion of Akaike (AIC). The results are demonstrated in detail on Tables 5.11 and 5.12, for each season respectively. When tested the response of each species on each gradient separately, supplementary detailed information is offered, which completes the image that the general response models offer. These results are also visualized with Canodraw, and are demonstrated analytically in Figures 5.35 to 5.51.

Finally, species diversity (after rarefaction) and evenness which were calculated according to Shannon-Wiener and Shannon index respectively, were tested for their response along the total of measured environmental gradients for both seasons. During spring-summer seasons, the variation in diversity and evenness indices among studied sites fitted respectively significant 1st order ($F = 11.77$, $p = 0.00005$, $AIC = 2.461$) and 2nd order ($F = 5.21$, $p = 0.001207$, $AIC = 0.048$) polynomial models, which are demonstrated in Figures 5.52 and 5.53. Diversity seems to be mainly affected by the land uses among sites and arable agricultural practices, and species appear to be more evenly distributed along a similar response pattern. During autumn-winter seasons, evenness index didn't fit any response model among studied areas, whereas diversity fitted a 2nd order polynomial model ($F = 4.3$, $p = 0.004149$, $AIC = 2.147$), increasing towards areas with larger river and road length networks, and it was also affected by arable agricultural practices and land uses (Fig. 5.54).

Table 5.11 Response of small mammal species' composition to each environmental gradient separately for spring-summer seasons (April-September) of both 2003 and 2004. "Best fit" model selection according to the criterion of Akaike (AIC) with Generalized Linear Model analysis. Response variables which didn't fit any model and were rejected through "null model" hypothesis are not included in the table. Significant p_s are noted: p < 0.01 = *, p < 0.001 = **, p < 0.0001 = ***, p < 0.00001 = ****, p < 0.000001 = *****.

		Model Selection		**Generalized Linear Model results**	
	AIC	$b_0 + b_1X$	$b_0 + b_1X + b_2X^2$	F	p
ALTITUDE					
Apodemus flavicollis	173.07		√	3.66	*
Cricetulus migratorius	243.55		√	11.29	***
Crocidura suaveolens	218.17	√		10.04	*
Microtus guentheri	421.27		√	3.47	*
Microtus levis	187.53	√		7.04	*
Microtus thomasi	841.47		√	10.28	***
Mus macedonicus	212.82		√	4.54	*
Muscardinus avellanarius	129.50		√	4.90	*
SOIL TEXTURE					
Cricetulus migratorius	251.60		√	13.32	****
Crocidura suaveolens	211.73	√		11.95	**
Microtus thomasi	793.94	√		18.82	***
Muscardinus avellanarius	43.060		√	79.52	*****
INTENSIVE CULTIVATIONS					
Cricetulus migratorius	187.91	√		36.36	*****
Crocidura leucodon	257.83		√	5.43	*
Microtus levis	174.82		√	7.12	**
Microtus thomasi	1057.80	√		4.40	*
Muscardinus avellanarius	74.793		√	29.49	*****
LAND USES					
Apodemus sylvaticus	156.44		√	3.55	*
Crocidura leucodon	263.13		√	4.34	*
Microtus guentheri	402.26	√		8.67	*
Mus musculus	149.66		√	10.31	***
Muscardinus avellanarius	115.32		√	7.82	**
ARABLE LAND					
Crocidura suaveolens	216.01	√		10.39	*
Mus macedonicus	218.92	√		4.61	*
Muscardinus avellanarius	99.232		√	12.48	***
Rattus rattus	324.18		√	3.33	*
RIVER LENGTH					
Cricetulus migratorius	280.35	√		11.66	**
Microtus thomasi	1000.59		√	4.99	*
Mus musculus	176.93		√	3.76	*
Muscardinus avellanarius	98.241		√	8.94	**
ROAD LENGTH					
Crocidura leucodon	270.13		√	3.17	*
Mus musculus	165.23		√	6.42	*
Muscardinus avellanarius	56.130	√		23.53	****
Rattus rattus	259.83		√	9.59	**
Suncus etruscus	332.88	√		5.70	*
SOIL E,M&V					
Cricetulus migratorius	330.91	√		4.25	*
Crocidura suaveolens	213.32	√		11.27	**
Muscardinus avellanarius	6.283		√	969.86	*****
SOIL I&V					
Microtus thomasi	911.38		√	7.88	**
Muscardinus avellanarius	91.051		√	10.34	***
Rattus rattus	314.84	√		6.11	*

Table 5.12 Response of small mammal species' composition to each environmental gradient separately for autumn-winter seasons (October-March) of both 2003-2004 and 2004-2005 periods. "Best fit" model selection according to the criterion of Akaike (AIC) with Generalized Linear Model analysis. Response variables which didn't fit any model and were rejected through "null model" hypothesis are not included in the table. Significant p_s are noted: $p < 0.01$ = *, $p < 0.001$ = **, $p < 0.0001$ = ***, $p < 0.00001$ = ****, $p < 0.000001$ = *****.

		Model Selection		**Generalized Linear Model results**	
	AIC	$b_0 + b_1X$	$b_0 + b_1X + b_2X^2$	F	p
ALTITUDE					
Cricetulus migratorius	292.82	√		13.24	**
Crocidura suaveolens	125.68	√		5.30	*
Microtus guentheri	333.85		√	4.37	*
Microtus thomasi	716.90		√	10.87	***
Mus musculus	110.79		√	3.88	*
Mus macedonicus	176.40		√	3.89	*
Muscardinus avellanarius	181.11		√	13.60	****
SOIL TEXTURE					
Cricetulus migratorius	281.08		√	10.30	***
Crocidura suaveolens	109.25	√		15.11	**
Microtus thomasi	672.51		√	10.62	***
Muscardinus avellanarius	170.46		√	18.32	*****
Rattus rattus	469.32		√	3.39	*
Suncus etruscus	295.71	√		5.10	*
IRRIGATION & CULTIVATED LAND					
Crocidura leucodon	478.19	√		4.33	*
Crocidura suaveolens	106.44	√		17.20	***
Microtus thomasi	824.87		√	5.78	*
Muscardinus avellanarius	154.27		√	16.19	****
Suncus etruscus	294.29	√		5.59	*
ARABLE LAND & LAND USES					
Apodemus epimelas	394.80		√	3.53	*
Cricetulus migratorius	250.36		√	15.22	****
Mus musculus	111.78	√		5.09	*
Muscardinus avellanarius	174.40		√	15.81	****
RIVER LENGTH					
Apodemus epimelas	393.77	√		5.15	*
Apodemus sylvaticus	111.64	√		4.94	*
Cricetulus migratorius	223.57	√		36.32	*****
Microtus thomasi	862.13		√	4.72	*
Muscardinus avellanarius	164.26		√	19.09	*****
ROAD LENGTH					
Crocidura suaveolens	123.87		√	4.17	*
Mus macedonicus	178.01		√	3.47	*
Muscardinus avellanarius	231.94	√		7.15	*
Rattus rattus	463.61	√		5.27	*
SOIL E,M&V					
Crocidura suaveolens	105.81		√	10.11	***
Muscardinus avellanarius	141.89		√	17.89	*****
Rattus norvegicus	597.28		√	4.88	*
Suncus etruscus	271.32		√	7.65	**
SOIL I&V					
Apodemus epimelas	379.14		√	4.98	*
Microtus thomasi	787.82		√	7.24	**

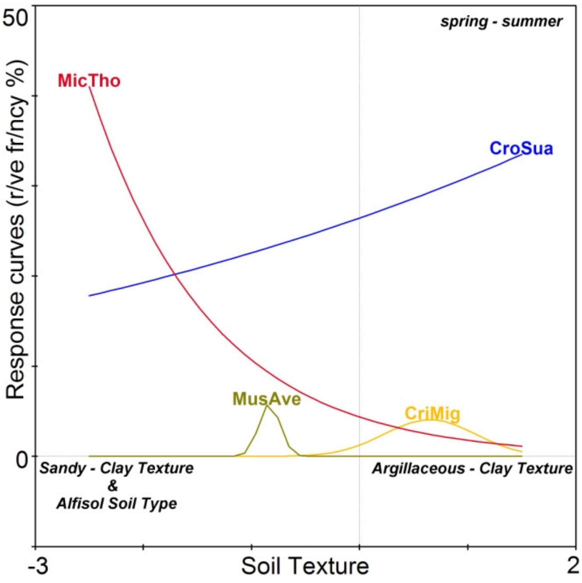


Figure 5.35 Response curves of small mammal species' composition on the environmental gradient "Soil Texture" for spring-summer seasons (April-September) of both 2003 and 2004. Only significant curves are demonstrated in the figure. Acronyms stand for: ***MiTho:*** Microtus thomasi, ***CroSua:*** Crocidura suaveolens, ***MusAve:*** Muscardinus avellanarius, ***CriMig:*** Cricetulus migratorius.

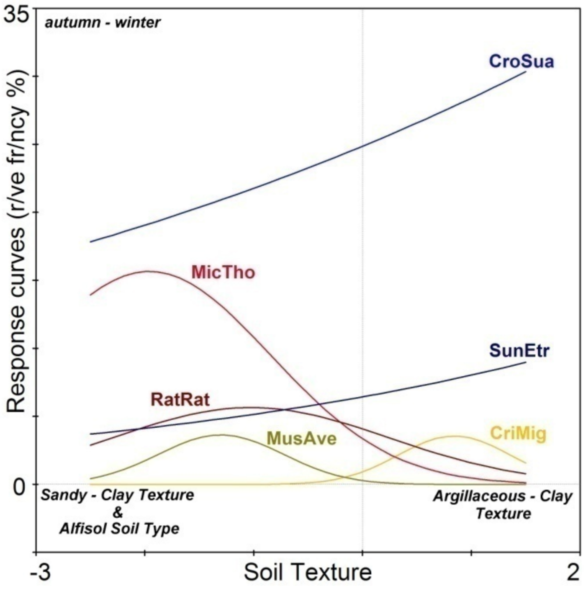


Figure 5.36 Response curves of small mammal species' composition on the environmental gradient "Soil Texture" for autumn-winter seasons (October-March) of both 2003-2004 and 2004-2005 periods. Only significant curves are demonstrated in the figure. Acronyms stand for: ***CroSua:*** Crocidura suaveolens, ***MiTho:*** Microtus thomasi, ***SunEtr:*** Suncus etruscus, ***RatRat:*** Rattus rattus, ***MusAve:*** Muscardinus avellanarius, ***CriMig:*** Cricetulus migratorius.

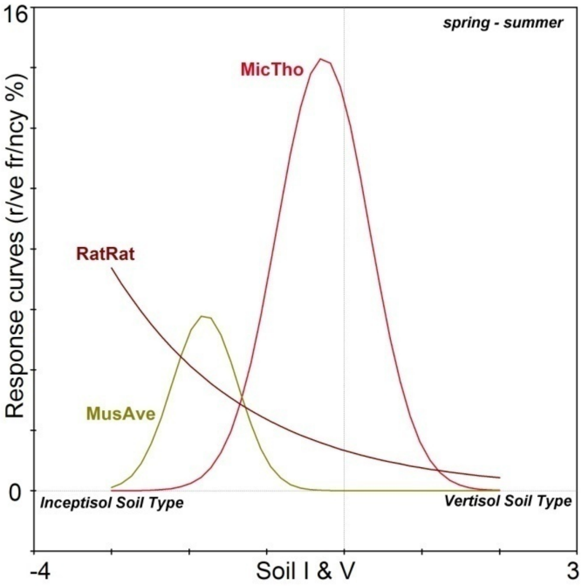


Figure 5.37 Response curves of small mammal species' composition on the environmental gradient "Soil I&V" for spring-summer seasons (April-September) of both 2003 and 2004. Only significant curves are demonstrated in the figure. Acronyms stand for: ***MiTho:*** Microtus thomasi, ***RatRat:*** Rattus rattus, ***MusAve:*** Muscardinus avellanarius.

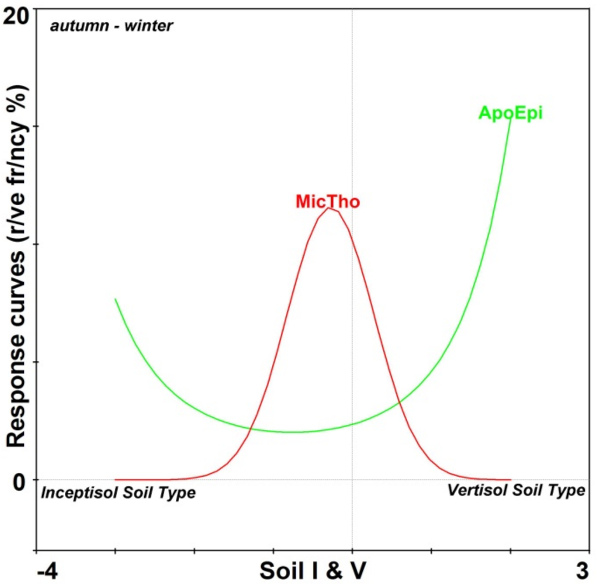


Figure 5.38 Response curves of small mammal species' composition on the environmental gradient "Soil I&V" for autumn-winter seasons (October-March) of both 2003-2004 and 2004-2005 periods. Only significant curves are demonstrated in the figure. Acronyms stand for: ***MiTho:*** Microtus thomasi, ***ApoEpi:*** Apodemus epimelas.

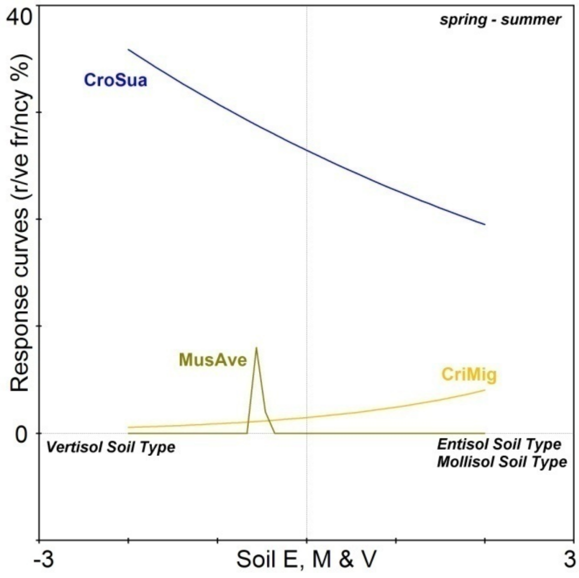


Figure 5.39 Response curves of small mammal species' composition on the environmental gradient "Soil E,M&V" for spring-summer seasons (April-September) of both 2003 and 2004. Only significant curves are demonstrated in the figure. Acronyms stand for: ***CroSua:*** Crocidura suaveolens, ***MusAve:*** Muscardinus avellanarius, ***CriMig:*** Cricetulus migratorius.

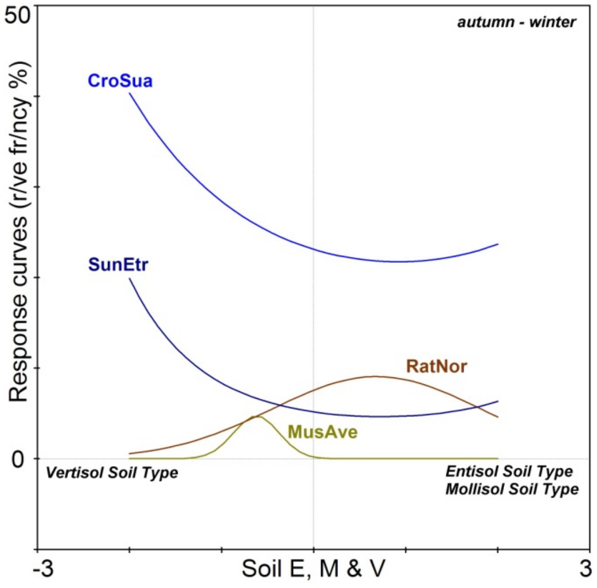


Figure 5.40 Response curves of small mammal species' composition on the environmental gradient "Soil E,M&V" for autumn-winter seasons (October-March) of both 2003-2004 and 2004-2005 periods. Only significant curves are demonstrated in the figure. Acronyms stand for: ***CroSua:*** Crocidura suaveolens, ***SunEtr:*** Suncus etruscus, ***RatNor:*** Rattus norvegicus, ***MusAve:*** Muscardinus avellanarius.

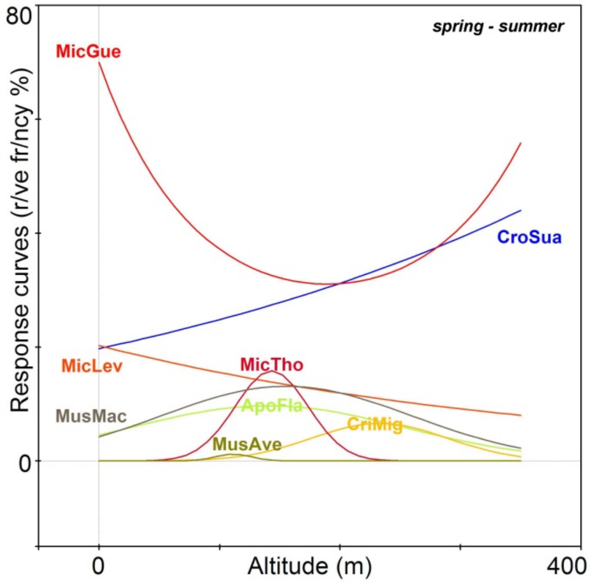


Figure 5.41 Response curves of small mammal species' composition on the environmental gradient "Altitude" for spring-summer seasons (April-September) of both 2003 and 2004. Only significant curves are demonstrated in the figure. Acronyms stand for: ***MicGue:*** Microtus guentheri, ***CroSua:*** Crocidura suaveolens, ***MicLev:*** Microtus levis, ***MusMac:*** Mus macedonicus, ***ApoFla:*** Apodemus flavicollis, ***MicTho:*** Microtus thomasi, ***MusAve:*** Muscardinus avellanarius, ***CriMig:*** Cricetulus migratorius.

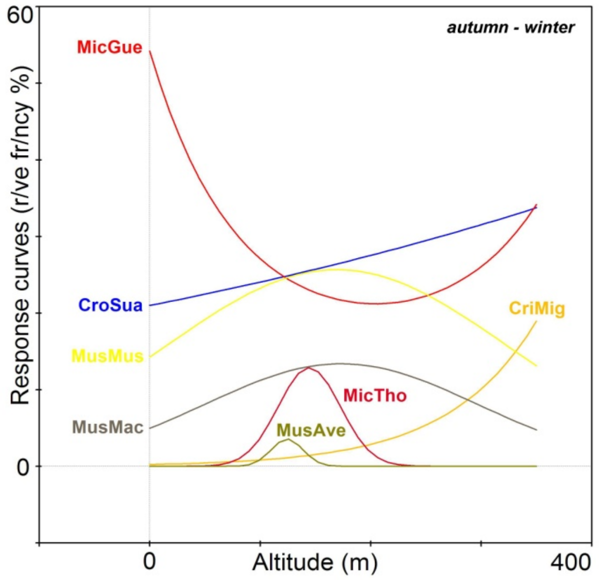


Figure 5.42 Response curves of small mammal species' composition on the environmental gradient "Altitude" for autumn-winter seasons (October-March) of both 2003-2004 and 2004-2005 periods. Only significant curves are demonstrated in the figure. Acronyms stand for: ***MicGue:*** Microtus guentheri, ***CroSua:*** Crocidura suaveolens, ***MusMus:*** Mus musculus, ***MusMac:*** Mus macedonicus, ***MicTho:*** Microtus thomasi, ***MusAve:*** Muscardinus avellanarius, ***CriMig:*** Cricetulus migratorius.

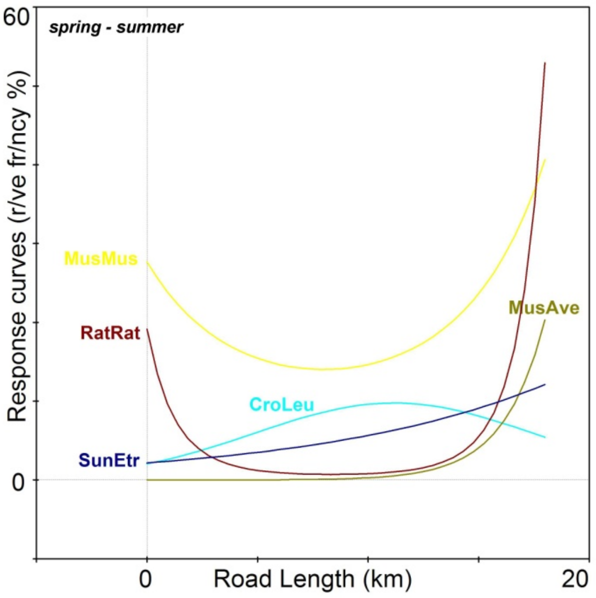


Figure 5.43 Response curves of small mammal species' composition on the environmental gradient "Road Length" for spring-summer seasons (April-September) of both 2003 and 2004. Only significant curves are demonstrated in the figure. Acronyms stand for: ***MusMus:*** Mus musculus, ***RatRat:*** Rattus rattus, ***SunEtr:*** Suncus etruscus, ***CroLeu:*** Crocidura leucodon, ***MusAve:*** Muscardinus avellanarius.

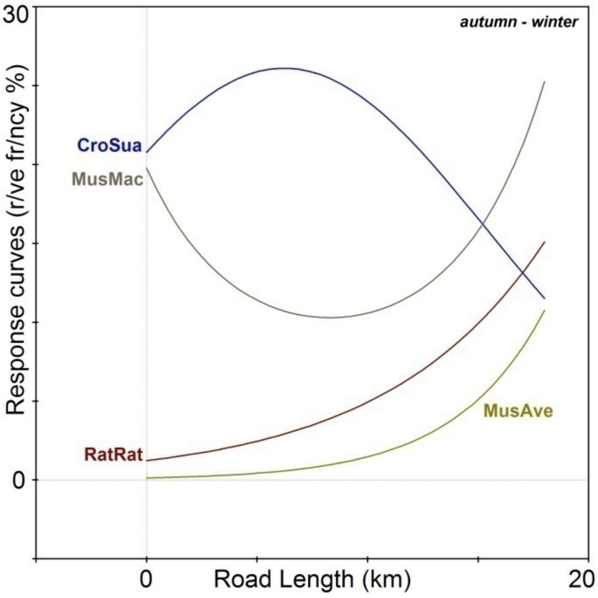


Figure 5.44 Response curves of small mammal species' composition on the environmental gradient "Road Length" for autumn-winter seasons (October-March) of both 2003-2004 and 2004-2005 periods. Only significant curves are demonstrated in the figure. Acronyms stand for: ***CroSua:*** Crocidura suaveolens, ***MusMac:*** Mus macedonicus, ***RatRat:*** Rattus rattus, ***MusAve:*** Muscardinus avellanarius.

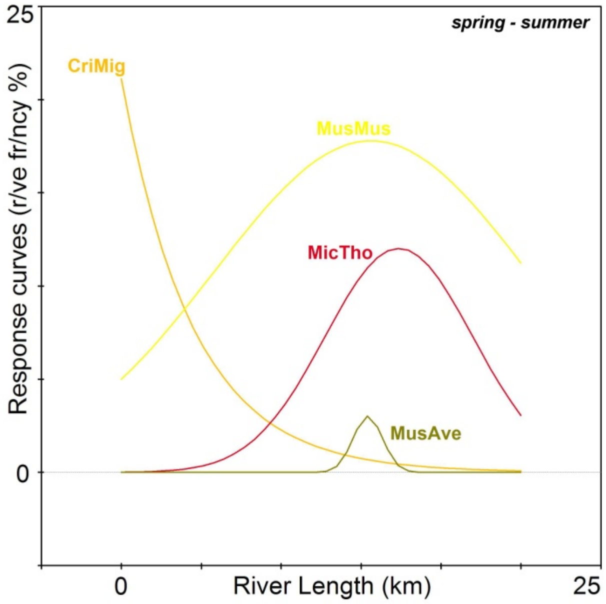


Figure 5.45 Response curves of small mammal species' composition on the environmental gradient "River Length" for spring-summer seasons (April-September) of both 2003 and 2004. Only significant curves are demonstrated in the figure. Acronyms stand for: ***CriMig:*** Cricetulus migratorius, ***MusMus:*** Mus musculus, ***MicTho:*** Microtus thomasi, ***MusAve:*** Muscardinus avellanarius.

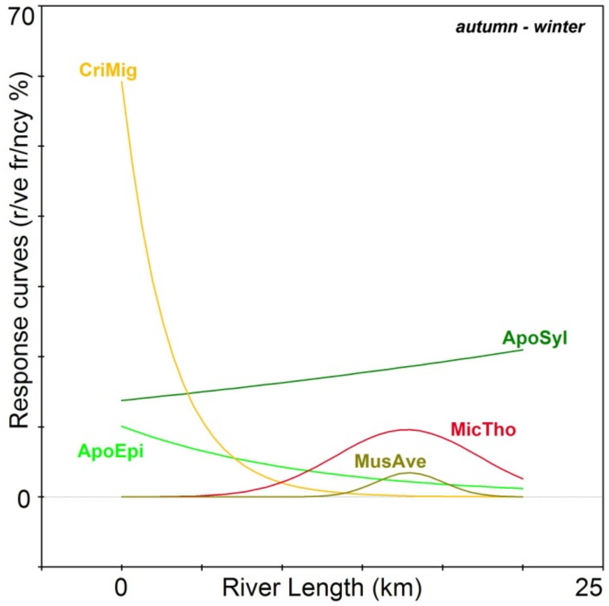


Figure 5.46 Response curves of small mammal species' composition on the environmental gradient "River Length" for autumn-winter seasons (October-March) of both 2003-2004 and 2004-2005 periods. Only significant curves are demonstrated in the figure. Acronyms stand for: ***CriMig:*** Cricetulus migratorius, ***ApoSyl:*** Apodemus sylvaticus, ***ApoEpi:*** Apodemus epimelas, ***MicTho:*** Microtus thomasi, ***MusAve:*** Muscardinus avellanarius.

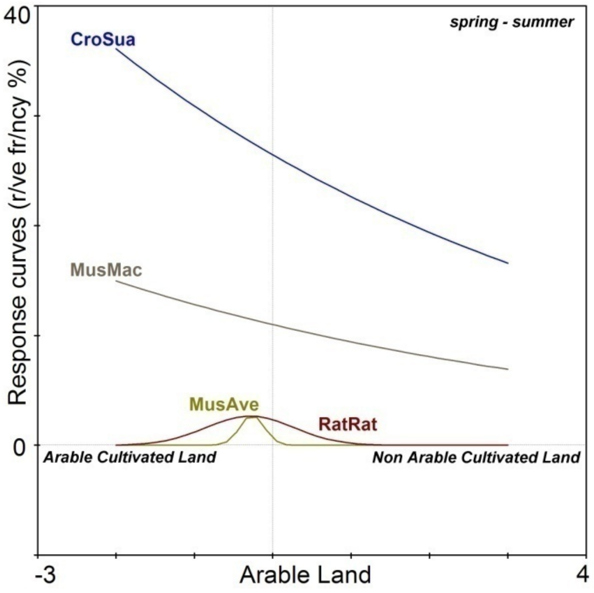


Figure 5.47 Response curves of small mammal species' composition on the environmental gradient "Arable Land" for spring-summer seasons (April-September) of both 2003 and 2004. Only significant curves are demonstrated in the figure. Acronyms stand for: ***CroSua:*** Crocidura suaveolens, ***MusMac:*** Mus macedonicus, ***RatRat:*** Rattus rattus, ***MusAve:*** Muscardinus avellanarius.

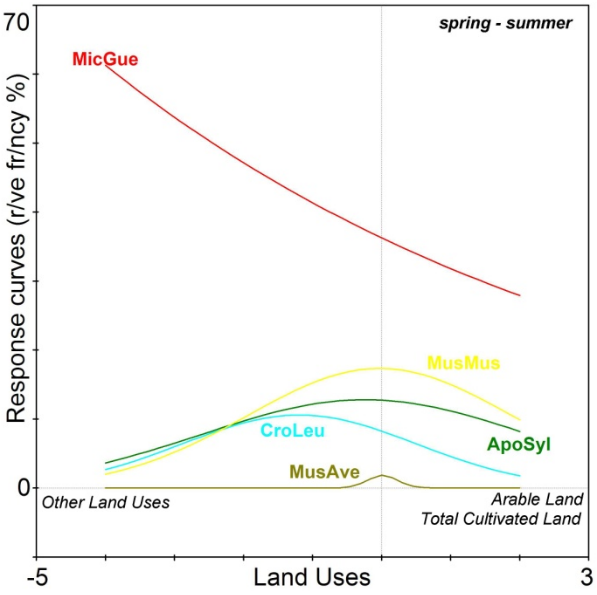


Figure 5.48 Response curves of small mammal species' composition on the environmental gradient "Land Uses" for spring-summer seasons (April-September) of both 2003 and 2004. Only significant curves are demonstrated in the figure. Acronyms stand for: ***MicGue:*** Microtus guentheri, ***MusMus:*** Mus musculus, ***ApoSyl:*** Apodemus sylvaticus, ***CroLeu:*** Crocidura leucodon, ***MusAve:*** Muscardinus avellanarius.

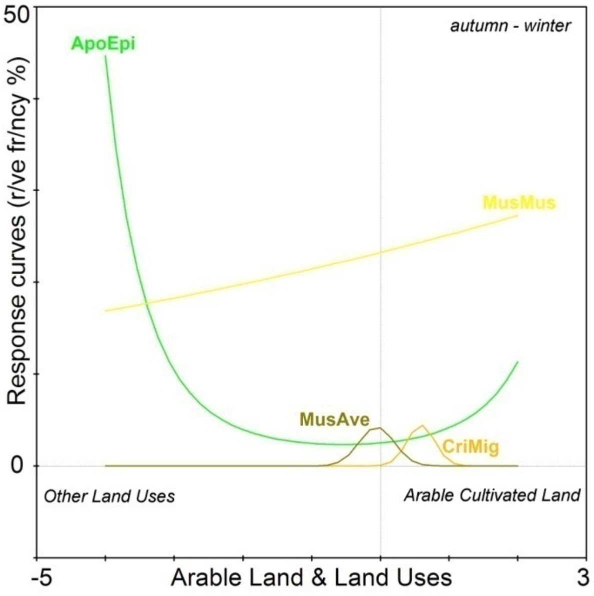


Figure 5.49 Response curves of small mammal species' composition on the environmental gradient "Arable Land & Land Uses" for autumn-winter seasons (October-March) of both 2003-2004 and 2004-2005 periods. Only significant curves are demonstrated in the figure. Acronyms stand for: ***ApoEpi:*** Apodemus epimelas, ***MusMus:*** Mus msuculus, ***CriMig:*** Cricetulus migratorius, ***MusAve:*** Muscardinus avellanarius.

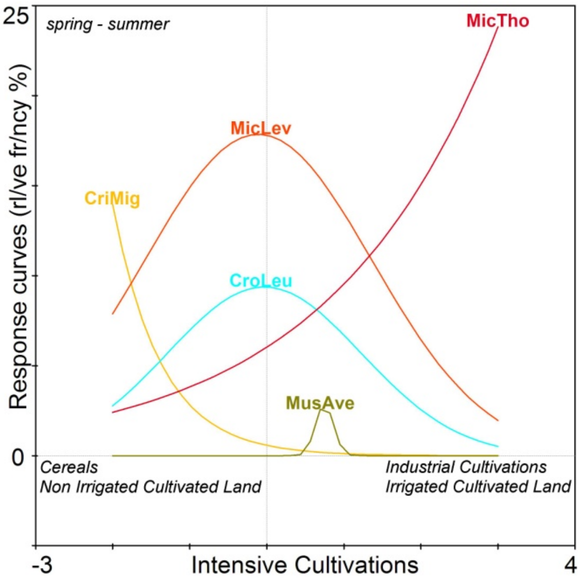


Figure 5.50 Response curves of small mammal species' composition on the environmental gradient "Intensive Cultivations" for spring-summer seasons (April-September) of both 2003 and 2004. Only significant curves are demonstrated in the figure. Acronyms stand for: ***CriMig:*** Cricetulus migratorius, ***MiLev:*** Microtus levis, ***CroLeu:*** Crocidura leucodon, ***MicTho:*** Microtus thomasi, ***MusAve:*** Muscardinus avellanarius.

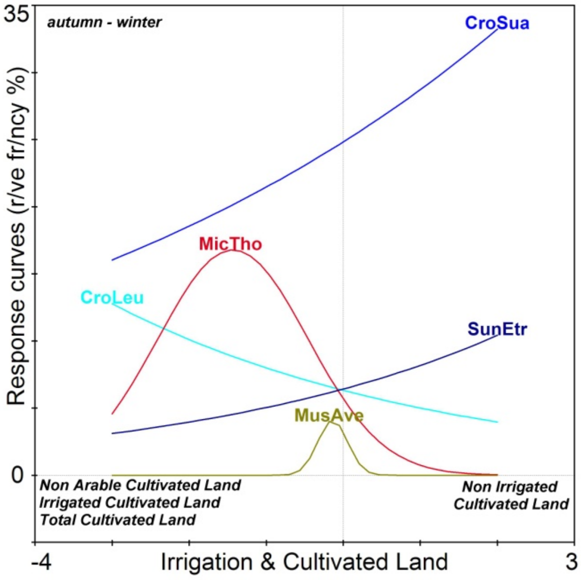


Figure 5.51 Response curves of small mammal species' composition on the environmental gradient "Irrigation & Cultivated Land" for autumn-winter seasons (October-March) of both 2003-2004 and 2004-2005 periods. Only significant curves are demonstrated in the figure. Acronyms stand for: ***CroSua:*** Crocidura suaveolens, ***CroLeu:*** Crocidura leucodon, ***MicTho:*** Microtus thomasi, ***SunEtr:*** Suncus etruscus, ***MusAve:*** Muscardinus avellanarius.

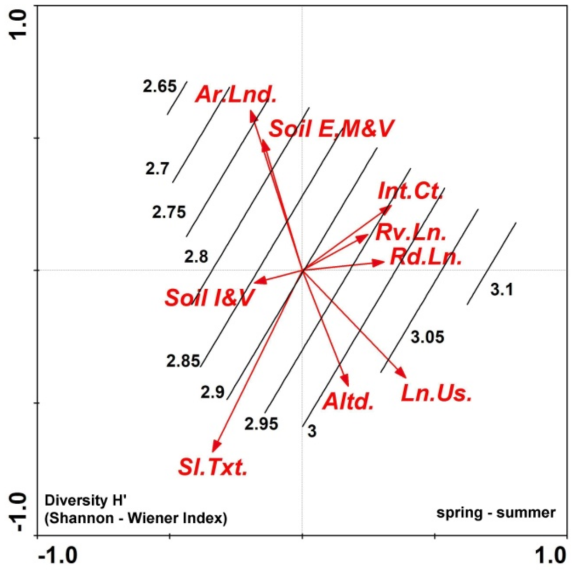


Figure 5.52 Variation of Diversity Index H' according to Shannon-Wiener among studied areas, and its response along the total of environmental gradients, during spring-summer seasons (April-September) of both 2003 and 2004.

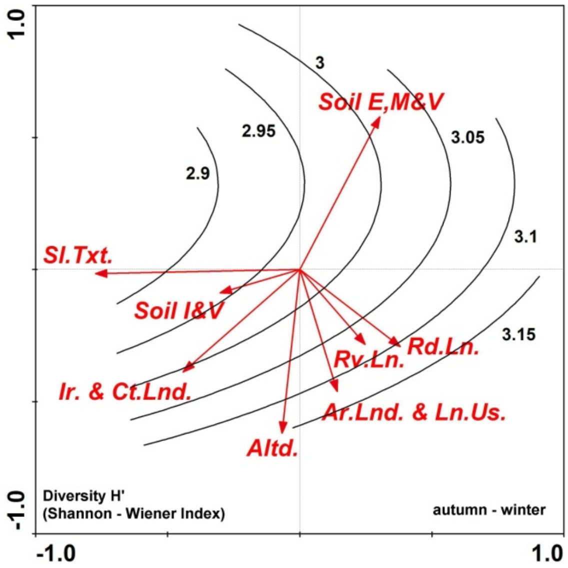


Figure 5.53 Variation of Diversity Index H' according to Shannon-Wiener among studied areas, and its response along the total of environmental gradients, during autumn-winter seasons (October-March) of both 2003-2004 and 2004-2005 periods.

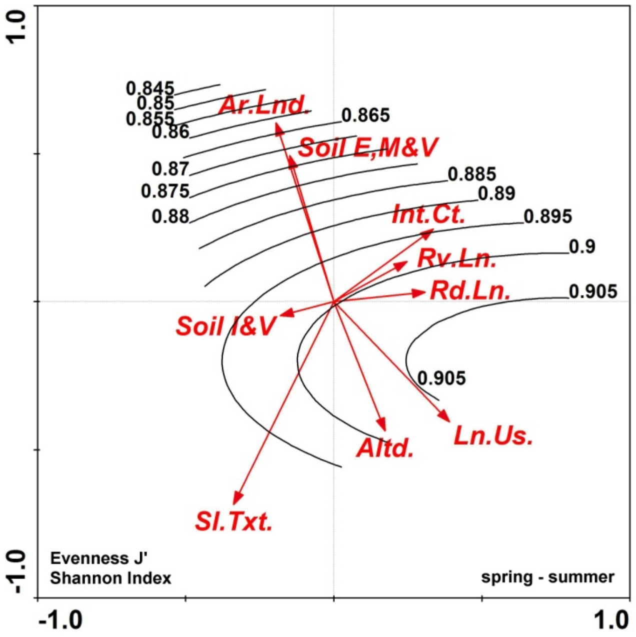


Figure 5.54 Variation of Evenness Index J' according to Shannon among studied areas, and its response along the total of environmental gradients, during spring-summer seasons (April-September) of both 2003 and 2004.

5.4 DISCUSSION

All fifteen small mammal species which were recorded in Thessaly plains presented seasonal fluctuations. As it was indicated from ANOVA tests (Tab. 5.1) and also mentioned in previous part, six of the recorded species varied insignificantly among seasons. Those species were East European vole, Thomas's pine vole, Gray dwarf hamster, Black rat, Macedonian mouse and Hazel dormouse. Moreover, when observed the total species' seasonal fluctuations, some of them didn't present any specific repeated pattern, whereas some presented very concrete fluctuations. For example, Bicolored shrew, East European vole, Gray dwarf hamster, Western broad-toothed mouse and Macedonian mouse demonstrated inconsistent variations between seasons, whereas two more groups fluctuated seasonally with specific repeated patterns. Lesser white-toothed shrew, Guenther's vole and Thomas's pine vole increased during spring-summer seasons and presented lower numbers during autumn-winter seasons, whereas Etruscan shrew, Long-tailed field mouse, Yellow-necked field mouse, Black rat, Brown rat, House mouse and Hazel dormouse presented a reverse pattern, with lower abundances during spring-summer seasons which increased during autumn and winter.

In a more analytic context, and beginning with the group of species which didn't present repeated patterns in their seasonal variations, the following can be deduced. A total of 5 species fluctuated inconsistently, while three of them also varied insignificantly among seasons, according to ANOVA tests (Tab. 5.1). The other two with significant ANOVAs, are Bicolored shrew and Western broad-toothed mouse.

Although low in numbers, Bicolored shrew varied significantly among seasons (Tab. 5.1) without presenting though any specific pattern. It decreased during autumn-winter season of 2003-2004 and then it increased for the next two samplings (Fig. 5.1). In similar Mediterranean agroecosystems, its breeding season begins in March and the last gestating females are observed in the beginnings of October (Krapp, 1990; Macdonald & Barrett, 1993). In Thessaly however, a specific increase during spring-summer months wasn't observed. Moreover, it also didn't fit any general response model in seasonal ordination analysis (Tabs. 5.9 & 5.10). Thus, and since the specie's population in Thessaly is also very low in numbers, it is quite possible that a high pressure exists from other syntopic (and possibly sympatric), more abundant species. As a result, the specie fluctuates seasonally possibly due to interspecific pressure and not that much in relation to biotic and abiotic factors. Nonetheless, although Bicolored shrew didn't fit any distribution model in 4th Chapter, and neither did it present significant general response models in seasonal ordination analysis, during spring-summer seasons it avoided strongly both fields with cereal and industrial cultivations (Tab. 5.11, Fig. 5.50). Intensive agriculture schemes and large-scale monocultures have previously also been recorded in various cases in Europe, to affect negatively Bicolored shrew populations (Krapp, 1990; Krapp, 1999). Similarly, it avoided crops which grow on heavily arable fields, and at the same time it wasn't present on different land uses such as natural grasslands, set-aside fields and fallow land (Tab. 5.11, Fig. 5.48). On the other hand, during autumn and winter months, the specie was significantly more encountered in non arable, cultivated and also irrigated land (Tab. 5.12, Fig. 5.51). Other authors have also recorded the specie within its Balkan distribution range, in open agricultural areas and moist localities as well (Krapp, 1999 and references within). Consequently, Bicolored shrew in Thessaly presents three seasonal patterns which depend on the following. During spring-summer seasons, both cereal and industrial crops grow on heavily arable fields and dominate the area, and Lesser white-toothed shrew occupies them with high numbers, while at the same season, Guenther's vole occupies strictly non arable land uses and mainly natural grasslands (see Chapter 4 for details). Bicolored shrew on the other hand, avoids both cereal and industrial crops, since they are unfavourable habitats and also probably to exclusive competition from Lesser white-toothed shrew. It is also quite possibly ousted from the dominant Guenther's vole from non arable land uses, such as natural grasslands. During autumn-winter seasons on the other hand, both Guenther's vole and Lesser white-toothed shrew's numbers decrease (Figs. 5.1 & 5.3) and both cereals and cotton are harvested leaving the land actually naked. Therefore, during this season Bicolored shrew probably due to lower competition presents slightly higher numbers, attached though to irrigated cultivation schemes and non arable land uses (Tab. 5.12, Fig. 5.51), which form a favourable but minor habitat for the specie. Cultivated land offers land cover and irrigation schemes create higher humidity (Krapp, 1990, 1999). However, non arable land uses occupy a minimum extension in Thessaly (see Appendix A for details), and especially during autumn and winter, when combined with cultivated irrigation schemes are confined in small extensions of horticulture fields, orchards and other tree cultivations. Finally, the specie increases in numbers during the three year study possibly due to the parallel decrease of Guenther's vole (Fig. 5.3), pattern observed in various species. Consequently, Bicolored shrew in Thessaly certainly undergoes a high interspecific pressure which seems to be the main regulator of its abundance variations among seasons, but at the same time its preferred habitats in the plains, even if they are chosen from exclusive competition, occupy minimum extensions specifically after the harvest of the crops. Thus, the human impact on the specie's population in Thessaly is also strong, leaving very small extensions to be exploited by the specie.

The second specie with inconsistent seasonal fluctuations but significant ANOVAs was Western broad-toothed mouse (Tab. 5.1). Seasonal ordination analysis didn't present any significant response model during spring-summer seasons (Tab. 5.9). On the other hand, during autumn-winter seasons the specie demonstrated a strong preference for non cultivated and non arable areas, and it was present with higher numbers in other land uses which included hills and mountainous areas, which are rich in rock debris (Fig. 5.49). The specie is considered to be a specialized typical rock dweller preferring forested habitats, and sites with rock debris rich in crevices (Macdonald & Barrett, 1993; Storch, 1999). That's why it presented its higher numbers in the village Kalamaki (3.39%, n=38) which is adjacent to the hills of mountain Mavrovouni. As a result, in Thessaly as well the Western broad-toothed mouse is mainly present in specific habitats of its specified preference, a fact which wasn't clear in 4th Chapter's statistical models. The specie is also supposed to have a continuous breeding season all over the year. Although Macdonald & Barrett (1993) propose 3 litters per year like maximum, Harrison (1972) and Atallah (1978) have recorded within the specie's Mediterranean range, pregnant females in April and September, younglings in April, May and October and lactating females from June to August. These facts suggest a continuous breeding season with the possibility of 2 litters per season and not 3 litters per year maximum. In Thessaly, Western broad-toothed mouse decreased slightly and insignificantly for the first three sampling seasons, and it presented a unique high increase during autumn-winter seasons of 2004-2005 (Fig. 5.5), which produced the significant ANOVA according to Tukey HSD post-hoc tests (Tab. 5.1). That is the reason why it also fitted a significant model during autumn-winter seasons (Tab. 5.10, Fig. 5.49), because it presented a four times higher population in the last season than the previous samplings, and multivariate analysis could detect significant correlations. Since the specie probably presents in Thessaly as well an all year breeding season, it can be argued that its significant increase in the last season is due to the high decrease of Guenther's vole (Fig. 5.3), which minimized competition and pressure, and not to seasonal breeds. Nonetheless, Abramsky (1981) demonstrated that the specie's different habitat niches play the main role in its seasonal abundances and not interspecific competition with other species like its co-generic Long-tailed field mouse. That fact could probably be in effect in Thessaly agroecosystems as well, since Western broad-toothed mouse is present in confined specific habitat types of small extension, which aren't occupied by other abundant species (see Chapter 4 for details). Nonetheless, there is certainly interaction with other species, like the generalists House mouse and Long-tailed field mouse, but also the specialized Guenther's vole. It is very likely that Guenther's vole is often exploiting same habitat types with Western broad-toothed mouse, even temporally, except the natural grasslands which are its strictly preferred habitat. Lower hill areas with rock debris and some vegetation cover can also be ideal for Guenther's vole (Krystufek & Vohralik, 2005). Therefore, in Thessaly lowlands, interspecific competition with Guenther's vole which is the dominant and abundant specie in the studied areas, which in high number seasons also exploits temporally different habitats, could be regulating up to a point the specie's seasonal variations, along of course with abiotic and biotic factors. Nonetheless, detailed live trapping sessions have to be realized to explore in detail these hypotheses. What is certain though is that human impact in the agroecosystems of Thessaly is not affecting immediately the specie's seasonal fluctuations, since Western broad-toothed mouse occupies areas not exploited by man. The effect of human agricultural practices is probably secondary on the specie, by affecting other species' populations which up to a point overlap in their trophic and habitat niches with the Western broad-toothed mouse.

The remaining three small mammal species with inconsistent seasonal fluctuations which didn't present significant ANOVAs, are East European vole, Gray dwarf hamster and Macedonian mouse. East European vole didn't present any specific pattern in its seasonal variations either. Similarly to Western-broad toothed mouse (Fig. 5.5), it decreased gradually for the first three samplings only to increase during autumn-winter seasons of 2004-2005 (Fig. 5.3), without significant variations among seasons (Tab. 5.1). Nonetheless, seasonal ordination analysis indicated that during spring-summer seasons it presented a significant response (Tab. 5.9). The 2^{nd} order polynomial model is quite complex to be easily interpreted (Fig. 5.17), but the specie seems to increase in non arable cultivated land. Its individual response also demonstrated clearly that during spring-summer seasons, the specie avoided strongly both cereal crops and industrial cultivations, similarly to Bicolored shrew (Tab. 5.11, Fig. 5.50). Since cereal and industrial cultivations at these seasons dominate the studied areas, the specie can occupy a confined and minimum number of non arable and cultivated habitat types. In the Balkans it is encountered in meadows but mainly in wet places with dense and tall vegetation as well as river banks (Zima, 1999c; Krystufek & Vohralik, 2005), but in Thessaly it didn't present any distribution pattern (see Chapter 4 for details). Moreover, in Thessaly the specie increases significantly in eastern and northern areas (Chapter 4, Figs. 4.51 & 4.52, p: 258), towards which river networks decrease (Chapter 4, Figs. 4.47 & 4.48, p: 257) and Guenther's vole numbers increase (Chapter 4, Figs. 4.51 & 4.52, p: 258), both significantly. In addition to the similar spatial increase patterns between Guenther's vole and East European vole, they also appear as syntopic in all sampled sites (Chapter 4, Figs. 4.8 & 4.10, pp: 221-223), a fact also observed in other parts of the species' European distribution (Krystufek, 1999j). As a result, East European vole certainly exploits up to a point same habitat types with Guenther's vole. Due to their syntopic and possibly sympatric presence, East European vole is possibly functioning as subordinate specie, regulating its population numbers mainly in dependence to its co-generic Guenther's vole, and not according to density-independent biotic and abiotic factors. Moreover, in the European distribution range of East European vole, its breeding season takes place between March and October (Macdonald & Barrett, 1993; Zima, 1999c; Krystufek & Vohralik, 2005). In the case of Thessaly though, no significant increase is demonstrated during spring-summer seasons (Tab. 5.1, Fig. 5.3), corroborating the hypothesis that its low numbers in total, as well as its inconsistent seasonal fluctuations mainly depend on the population numbers of the dominant, syntopic and quite possibly sympatric Guenther's vole. Thus, seasonal crop rotation and habitat change in Thessaly plains is not primarily affecting East European vole's fluctuations, but its competition with Guenther's vole plays probably the main role.

Gray dwarf hamster was one of the species with the lowest populations in Thessaly, forming only 0.57% (n=162) of the total recorded small mammal species. It didn't exceed 1% in any of the seasonal samplings (Fig. 5.4), and its fluctuations among seasons were thus insignificant according to ANOVA tests (Tab. 5.1). The specie presented a slight increase during autumn-winter seasons of 2003-2004 while it slightly decreased for the next two samplings (Fig. 5.4). Nonetheless, seasonal ordination analysis indicated that for both seasons the specie presented higher numbers in arable cultivated land and higher altitudes (Tabs. 5.9 & 5.10, Figs. 5.27 & 5.28), although autumn-winter response model is not very easy to interpret. When the specie's individual response was tested though on each gradient separately, it fitted various more clear and significant models (Tabs. 5.11 & 5.12). It was specifically indicated that Gray dwarf hamster for both spring-summer and autumn-winter seasons, presented significantly higher numbers in altitudes more than 200m (Figs. 5.41 & 5.42), it was attached to soils with argillaceous-clay texture (Figs. 5.35 & 5.36), and it seemed to avoid areas with large river networks (Figs. 5.45 & 5.46). In Chapter 4, similar findings were produced from the total models, and all these distribution and spatial use patterns were analytically discussed. What is important though in seasonal ordination analysis is that during spring-summer seasons, the specie was also present with significantly higher numbers in cereal crops and it avoided irrigation schemes (Tab. 5.11, Fig. 5.50), whereas during autumn-winter seasons it preferred arable land (Tab. 5.12, Fig. 5.49), which was actually left naked after the harvesting. As explained in Chapter 4, the specie's extreme habitat plasticity and deep fossorial habits possibly led it to occupy the south-eastern areas of Thessaly (Chapter 4, Fig. 4.13, p: 227). In the sites where it was present, it was syntopic with Guenther's vole with low numbers of the latter (Chapter 4, Fig. 4.8, p: 221), which also occupied strictly non arable land uses and especially natural grasslands (see Chapter 4 for details). Therefore, the two voles' habitat niches do not overlap, leaving strong territorial competition among the two out of the equation. Moreover, although Lesser white-toothed shrew is also abundant in these sites (Chapter 4, Fig. 4.4, p: 216) and also prefers arable cultivated land (Chapter 4, Fig. 4.34, p: 250), it is also specifically attached to Vertisol soil type areas whereas Gray dwarf hamster prefers Mollisol and Entisol soil type areas (Chapter 4, Fig. 4.35, p: 250). Thus, different habitat niches exclude strong competition with Lesser white-toothed shrew as well, which is the second most abundant specie in Thessaly. Nonetheless, since Gray dwarf hamster occupies only a small area in south-eastern Thessaly with very low numbers, and since it also exhibits high habitat plasticity (Macdonald & Barrett, 1993; Vohralik, 1999), that fact is certainly due to exclusive competition from other species. Although it doesn't compete strongly for trophic or habitat resources with dominant and abundant species, its very low numbers in Thessaly and its habitat plasticity indicate that it occupies these specific areas because they aren't defended by other species, as discussed analytically in Chapter 4 as well. Thus, its low population in Thessaly lowlands is primarily due to density-dependent interspecific competition, and not to independent biotic factors. Nonetheless, as was proved before, during spring-summer seasons the specie prefers cereal crops without irrigation schemes verifying this way its desertic origin (Vohralik, 1999; Nechay, 2000). Even if this habitat selection is a product of interspecific competition and habitat plasticity, once the crops are harvested in autumn and since during winter the specie remains in the arable "naked" land, it is highly vulnerable to predation, since no vegetation cover protects it. Thus, in addition to density-dependent factors, seasonal crop rotation and change of habitat scenery also affects negatively the specie, limiting even more its population in low numbers. The exact quantification of these environmental and intrinsic regulating parameters though, in order to explore the importance of each one, requires long term and detailed experiments, with intense live trapping sessions.

Finally, the last specie with inconsistent and insignificant seasonal variations is the Macedonian mouse (Tab. 5.1). From the five species of the group, along with East European vole it had higher populations than Western broad-toothed mouse, Bicolored shrew and Gray dwarf hamster, forming 4.83% (n=1375) of the total small mammal species, and presenting a minimum of 4% in all seasonal samplings (Fig. 5.7). Seasonal ordination analysis produced significant 2nd order polynomial models for both spring-summer and autumn-winter seasons (Tab. 5.9 & 5.10). Although they were complex, both indicated that Macedonian mouse increases towards sites with larger road and river networks (5.31 & 5.32). Its general distribution patterns in 4th Chapter indicated the same trend (Chapter 4, Fig. 4.25, p: 243), but also demonstrated that the specie prefers arable cultivated land indifferently of cereals, industrial cultivations or other crop types (Chapter 4, Figs. 4.32 – 4.34, p: 250). Macedonian mouse is known to exploit various habitat types and is considered a generalist anyhow (Sage, 1981; Macdonald & Barret, 1993; Macholan, 1999b), but the specie's seasonal individual response along each gradient separately revealed something more specific. During spring-summer seasons Macedonian mouse has higher numbers in arable cultivated land no matter the type of crops (Tab. 5.11, Fig. 5.47), whereas during autumn-winter seasons, when arable land is left without vegetation cover because of the harvesting of the crops, the specie is significantly more encountered in areas with large road networks (Tab. 5.12, Fig. 5.44). The specie is also known to avoid strongly human dwellings (Macholan, 1999b), so when its presence is higher in areas with larger road networks, it doesn't mean that it approaches urban centres, villages, and human constructions which go along with larger road lengths, but it more likely moves to dense roadside bushy vegetation and also at dense river banks (Fig. 5.32), habitats which it also generally exploits, within its Balkan distribution range (Macholan, 1999b). Additionally, as demonstrated in 4th Chapter, Macedonian mouse presents an exactly opposite distribution pattern from House mouse, presenting lower numbers in sites where House mouse is abundant and reversely (Chapter 4, Figs. 4.22 & 4.24, pp: 239 & 242). Since those two co-generic species are always sympatric and never syntopic in Europe (Macholan, 1999b), and since House mouse is also the 3rd more abundant specie in Thessaly (see Chapter 3 & 4 for details), it is quite possible that their sympatry in Thessaly and their interspecific competition, limits the population numbers of Macedonian mouse. Consequently, Macedonian mouse in Thessaly presents inconsistent and insignificant seasonal fluctuations probably due to interspecific competition with the abundant co-generic House mouse, and probably from interspecific pressure from other species as well. Nonetheless, it also presents different habitat selection patterns between seasons, being more frequent in arable cultivated land during spring and summer, and moving further into roadside vegetation and river banks during autumn and winter, apparently in order to avoid predation pressure, and to find vegetation cover and food resources. In total, although its seasonal fluctuations seem to be mainly regulated by density-dependent factors and interspecific competition, the seasonal change of habitat scenery in Thessaly also affects the specie, which occupies due to its generalist habits, different habitats between seasons.

Another group comprised of three small mammal species, presented a specific repeated pattern with higher abundances during spring-summer seasons, and lower numbers during autumn and winter as mentioned in the beginning. The species which presented these patterns are Guenther's vole, Lesser white-toothed shrew and Thomas's pine vole. Guenther's vole was the dominant and most abundant specie in Thessaly (see Chapter 4 for details). It is widely accepted that the specie is a prolific breeder with high breeding potentials, and rapid recycling at the population level (Cohen-Shlagman et al., 1984a, 1984b; Krystufek & Vohralik, 2005), which partly explains its high populations in the studied areas. What is odd though and doesn't consort with the specie's high numbers during spring and summer, is the fact that Guenther's vole in Thessaly, avoids strongly heavily arable areas, and thus also avoids both fields with cereal and industrial crops, while it prefers non arable cultivated land along with natural grasslands (Chapter 4, Figs. 4.32 – 4.34, p: ..). Yet, as discussed extensively in 4th Chapter, natural grasslands and non arable or at least lightly arable cultivated fields, occupy minimum extensions in the studied areas (see Appendix A for details), while cereals, industrial cultivations and arable land uses dominate. Moreover, when observed the specie's seasonal fluctuations, it is clear that during spring and summer the specie has higher numbers (Fig. 5.3), whereas for both spring-summer and autumn-winter seasons it is significantly more abundant in non arable land uses and in natural grasslands (Tab. 5.9 & 5.10, Figs. 5.23 & 5.24). In respect to crop rotation, during spring and summer months all crops are grown and offer vegetation cover, and they also aren't ploughed until after June for cereals and September for cotton. Thus, it could be speculated that Guenther's vole presents higher numbers during spring and summer because it also exploits temporally different habitat types, which provide food resources, vegetation cover and aren't ploughed during this seasons, a pattern also observed from other authors (Colak et al., 1998; Krystufek & Vohralik, 2005). If that is the case, it would also corroborate the hypotheses stated before, that interspecific competition exists with some mentioned species which have different habitat niches from Guenther's vole in Thessaly, something that will also be discussed hereafter for other species. On the other hand, during autumn and winter when all arable areas are left naked after the harvesting, the specie is confined in the natural grasslands and set-aside fields which are its preferred habitat and provide shelter all year long, are untouched by man and of course remain unploughed. Additionally, another striking difference occurs at the point with Guenther's vole population in Thessaly. The specie is known to be a seasonal breeder, which mainly produces litters of young from September to late May as maximum (Colak et al., 1998a, 1998b, Krystufek & Vohralik, 2005). If that was the case in Thessaly, a reverse pattern should be demonstrated with lower numbers during spring and summer and higher populations during autumn and winter. Moreover, if that was the case in Thessaly in combination with the harvested land which provides no vegetation cover at these seasons, it would certainly be noticed in Barn owl's diet since it is its optimum prey, and since it would be very easily captured (see Chapter 3 for details). On the contrary though, Guenther's vole in Thessaly as mentioned, presents higher populations during spring and summer (Fig. 5.3). That fact could suggest that in Thessaly plains, due to the seasonal agricultural habitat change, the limited optimum habitats, and absence of vegetation cover and thus food resources from arable land during autumn and winter, the specie's breeding season probably starts later, at the beginning or at the end of winter (January, February or March), and not in the beginning of autumn (September and October), while it possibly lasts all spring. Or, that the specie functions with auto-regulating mechanisms keeping low the density of pregnant of females during autumn, which increase after February that various crops begin to grow again in the plains, and produce a population explosion. Of course at this point, these possibilities can be stated as mere speculations, and form hypotheses to be tested in the future with intensive trapping sessions. Present data nonetheless suggest such a pattern strongly. Finally, another important seasonal pattern unique for Guenther's vole in Thessaly and not observed in any other of the recorded species, is the fact that it presents a severe decline during the four seasonal samplings. During spring and summer of 2003 it formed almost 40% of all recorded small mammals, and in the final sampling during autumn and winter of 2004-2005, it decreased to less than 13% (Fig. 5.3). Guenther's vole populations in general undergo large fluctuations, and such declines in the Balkans have been previously recorded by other authors as well (Niethammer, 1982c; Krystufek, 1999j). Nonetheless, this is the first recording of such a seasonal pattern for a Greek population, which should be subject for long term studies of 10 to 15 years, in order to explore as well possible vole cycle explosions in Mediterranean agroecosystems, an issue practically unknown in the Mediterranean basin. In conclusion, the seasonal change of agricultural habitat in Thessaly doesn't seem to affect Guenther's vole habitat niche, since the specie is specialized in inhabiting natural grasslands and non arable land uses, which are actually untouched by human agricultural practices. Nonetheless, it is almost certain that the specie is exploiting other less favourable habitats during spring and summer, as in other studies. And there is a strong possibility, that this heavy seasonal habitat change causes a delayed beginning to the specie's breeding season, in comparison with other places of its distribution, or that it produces intrinsic intraspecific regulating mechanisms, which maintain pregnant females' density low until the end of the winter.

The second specie with higher populations during spring and summer is Lesser white-toothed shrew, which is also the second most abundant specie in the agroecosystems of Thessaly (21.88%, n=6229), after Guenther's vole. It was a specie which presented primarily a very strong attachment to soil texture and soil properties and not to land uses or habitat types (see Chapter 4 for details). Similarly in seasonal ordination analysis, general response models indicated that for both spring-summer and autumn-winter seasons, Lesser white toothed shrew is significantly more attached to sites with Vertisol soil types and argillaceous-clay soil texture (Tabs. 5.9 & 5.10, Figs. 5.21 & 5.22). This spatial use is also corroborated from the individual response models, which indicated the same findings for both season pairs along each gradient separately (Tabs. 5.11 & 5.12, Figs. 5.35 - 5.36, 5.39 – 5.42). Nonetheless, individual seasonal ordination analysis revealed another pattern. During spring and summer, Lesser white toothed shrew is primarily attached to areas with specific soil properties, but it is also mainly encountered in arable land uses (Fig. 5.47). Arable fields in Thessaly are dominated from cereals and industrial cultivations during these seasons. In addition, Lesser white-toothed shrew during spring and summer, is present with significant higher numbers in arable land uses (Fig. 5.47), indifferently though of crop types (e.g. cereals or cotton), since it is mainly attached to soil texture and soil properties. That was also the specie's distribution pattern in 4th Chapter. What is interesting though is that during autumn and winter the specie presents significantly higher numbers in non irrigated cultivated land (Tab. 5.12, Fig. 5.51). The harvested cereal and industrial crops which grow on arable fields leave the land "naked" as stated repeatedly, and during autumn and winter, these harvested extensions which dominate the area comprise the category of "Non Irrigated Arable Land", which appears at the positive values of factor "Irrigation & Cultivated Land" (Tab. 5.4, Fig. 5.51). Thus, Lesser white-toothed shrew during autumn-winter seasons is significantly more encountered in harvested arable land, which doesn't provide vegetation cover, shelter, or food resources, and avoids strongly the few remaining patches in Thessaly of non arable and cultivated land (Fig. 5.51). At the point, this habitat selection during autumn and winter cannot be answered with certainly. Data though suggest that since the dominant and territorial Guenther's vole occupies strictly and mainly non arable land uses as proved (natural grasslands, set aside fields etc.), and is also present in other cultivated and not heavily arable fields during winter such as orchards and other tree cultivations, exclusive competition could be the reason why Lesser white-toothed shrew avoids such sites. Nonetheless, the shrew's strong correlation with soil properties is another important factor except this possible exclusive competition. As a result, during autumn and winter the main bulk of Lesser white-toothed shrew population remains in arable fields without vegetation cover, exposed to predation. As mentioned in the beginning, during these seasons there is high predation pressure from Buzzard populations which are present in Thessaly plains (personal observations), as well as from nocturnal birds of prey like Barn owl, Long-eared owl and Little owl, and other mammals like foxes, martens, badgers and weasels. That is quite probably the reason for the specie's lower numbers during autumn and winter (Fig. 5.1). Moreover, the species higher numbers during spring and summer are also in concordance with the specie's breeding season. Lesser white-toothed shrew is a seasonal breeder, giving litters of 1 to 6 young, from March to September (Vlasak & Niethammer, 1990; Macdonald & Barrett, 1993; Macdonald & Tattersall, 2001). Thus, the production of young during spring and summer is also one more reason for the specie's higher numbers during these seasons. Nonetheless, Lesser white-toothed shrew maintains high numbers even in winter when its population decreases, with a minimum of 18% in both autumn-winter seasons (Fig. 5.1). That fact could probably indicate that it manifests mechanisms of quick recycling in population level, or that it also moves to habitat edges like roadside vegetation, dense banks of small irrigation canals (when present in the area), hedges, vineyards, or it even becomes more synanthropic in order to find vegetation cover and food resources. Yet, with the present large spatial scale multivariate analysis, these small scale possible movements cannot be identified, and thus more intensive live-trapping sessions have to be realized to explore these hypotheses. However, it is certain that the harvest of the arable fields like cereals and cotton during autumn and winter, produces a strong impact on Lesser white-toothed shrew, whose population remains mainly in the harvested areas, vulnerable to predation without cover and food resources, which as a matter of fact probably reduces its population numbers during these seasons.

The last member of this group was Thomas's pine vole, which also demonstrated higher numbers during spring-summer seasons (Fig. 5.3). Its seasonal fluctuations weren't significant (Tab. 5.1), but it presented a clear repeated pattern with populations which decrease during autumn-winter, and increase during spring and summer. Moreover, although it didn't vary significantly, seasonal ordination analysis produced significant response models for both season pairs (Tabs. 5.9 & 5.10). Similarly to Lesser white-toothed shrew, it was the second specie which presented strong correlations to soil types and soil texture. It was however strongly attached to Alfisol soil types and sandy-clay soil texture, avoiding other soil types, and also preferred industrial irrigated cultivations (see Chapter 4 for details). Seasonal ordination analysis revealed similar patterns for both seasons, demonstrating a strong correlation for both season pairs to the mentioned soil properties (Figs. 5.25 & 5.26). More specific though, an important strong correlation was also revealed from individual seasonal ordination analysis, along each gradient separately. The specie firstly fitted various individual significant models in concordance to its general space use in Thessaly plains as mentioned (Tabs. 5.11 & 5.12, Figs. 5.35 – 5.38, 5.41 &

5.42, 5.45 & 5.46). Moreover though, it demonstrated during spring and summer, significantly higher numbers in industrial cultivations which are mainly comprised from cotton (Fig. 5.50), whereas during autumn and winter its population is concentrated in non arable and cultivated land (Fig. 5.51). What is interesting in this seasonal pattern, is the fact that as stated before, during autumn and winter the areas of non arable cultivated land with irrigation schemes, occupy minimum extensions in the studied areas (tree cultivations, horticulture), and the rest arable land is harvested and left "naked". Thus, Thomas's pine vole during spring and summer presents higher numbers in industrial cultivations which are dominated from cotton and also dominate the studied areas, and when the crops are harvested after September, a movement is observed within different habitat types of smaller extension. It is the unique specie of those recorded in Thessaly, which demonstrates such a strong habitat change among seasons. Although it mainly chooses its habitat to soil properties as proved, parallel to this pattern it appears to need vegetation cover during all seasons. Therefore, during spring-summer seasons it presents higher numbers since adequate vegetation cover is provided along with food resources, and after September it changes completely habitat and is confined in smaller areas, thus with decreased numbers. As discussed in 4th Chapter, it is a specie of deep fossorial habits, preferring deep soil, so it probably isn't affected by deep ploughing which takes place in arable areas. Nonetheless, this habitat change between seasons after the ploughing of the land, possibly also suggests differently. Its distribution in western Thessaly (Chapter 4, Fig. 4.11, p: 225) also indicated minimum interspecific competition, since geographical distribution patterns with other dominant species are different, and almost reversely correlated in some occasions (see Chapter 4 for details). Guenther's vole presents higher numbers in north-eastern areas, Lesser white-toothed shrew in southern-central areas, and Gray dwarf hamster in south-eastern locations (Chapter 4, Figs. 4.51 & 4.52, p: 258). Whereas other species which increase towards western localities like House mouse, Macedonian mouse and Yellow-necked field mouse (Chapter 4, Figs. 4.51 & 4.52, p: 258), are weak competitors, generalists, occupy different habitats, or have very low populations and present higher numbers reversely to Thomas's pine vole in other seasons. Consequently, the seasonal population fluctuations and the specie's habitat change are almost entirely due to density-independent biotic factors. Moreover, since among seasons correlation to soil properties remains the same as mentioned, these seasonal changes are produced exclusively from the harvesting and the replanting of the crops. That fact places Thomas's pine vole among the most affected species from human agricultural practices in the agroecosystems of Thessaly.

Finally, the last group of small mammals with different seasonal patterns, presenting higher populations during autumn-winter seasons and decreasing in spring and summer, is comprised of 7 species. Among them is also the Hazel dormouse, which was present in Thessaly with the lowest population among all recorded small mammals, forming just the 0.18% (n=50). Hazel dormouse presented very slight increases in its numbers during autumn and winter (Fig. 5.8), which were of course insignificant (Tab. 5.1). Moreover, as also discussed in 4th Chapter, the specie's presence in Thessaly was so limited, that ordination analysis cannot actually detect any important information about its distribution. In addition, since it is a typical forest dweller (Macdonald & Barrett, 1993; Morris, 1999), and since in Thessaly it was only present in 4 sites adjacent to dense river banks away from agricultural uses, it is actually meaningless to search for ordination models which explain its distribution patterns, or explore its seasonal fluctuations. Although it fitted many significant models in seasonal ordination analysis as well (Tabs. 5.9 – 5.11, Figs. 5.33 – 5.51), none of them actually offered available or reasonable explanations, more than the obvious. Therefore, it can only be referred to, as new data on its geographical distribution range in Thessaly and Greece.

Etruscan shrew also demonstrated significantly higher populations during autumn and winter (Tab. 5.1, Fig. 5.2). Its geographical distribution indicated higher numbers in areas dominated from Vertisol soil types similarly to Lesser white-toothed shrew, and also to cereal crops, avoiding intensive irrigation schemes (see Chapter 4 for details). Seasonal ordination analysis produced a general significant response model only during autumn and winter, probably due to its higher numbers at the season, which also corroborated the specie's strong correlation to Vertisol soil types as well (Tab. 5.10; Fig. 5.16). When the specie's response though was tested along each gradient separately, a clearer pattern was observed among seasons. Again only during autumn and winter the specie was significantly more encountered in Vertisol soil types and argillaceous-soil texture (Tab. 5.12, Figs. 5.36 d& 5.40), but it was also proved that after the harvesting of the crops it remains along with Lesser white-toothed shrew, in the "naked" and thus non irrigated arable land (Tab. 5.12, Fig. 5.51). Therefore, Etruscan shrew is quite possibly sympatric with Lesser white-toothed shrew exploiting same habitats in Thessaly, with the difference that the former is more specialized in cereal crops at least from February until June (see Chapter 4 for details), whereas the latter indifferently of crop types it prefers arable land and is mainly attached to soil properties. In the case of Etruscan shrew though especially, it would be quite risky to conclude with certainty anything about its seasonal fluctuations in the studied areas. The reason is that since small mammals are studied through the spectrum of Barn owl diet in the present thesis, and although for all the rest species it is a very accurate method as discussed in previous chapters, for

Etruscan shrew it possibly doesn't apply with safety. The problem occurs due to the fact that the specie is the smallest small mammal in Europe, weighting between 1.5 to 3 gr. As a prey it compensates minimally a predator like Barn owl, but its presence of course in the owl's diet indicates thus a possibly higher population in the area than the observed (see Chapter 4 for details). Nonetheless, its higher numbers during autumn and winter when most of its population is encountered in the harvested land, are possibly due to the fact that there is higher predation pressure since it is easier to be captured without vegetation cover. Moreover, another fact which supports this possibility is that Etruscan shrew is also a seasonal breeder, known to give litters of 1 to 6 young from March to September (Macdonald & Barrett, 1993; Lopez-Fuster, 2002). Thus it should present higher numbers during spring and summer and not reversely (Fig. 5.2), and since at these seasons it is provided with adequate vegetation cover, its minimum size possibly help it to avoid predation easier. Therefore, its fluctuation patterns among seasons will not be discussed further to reach possible conclusions, but its seasonal variations will just be mentioned.

Long-tailed field mouse was one of the abundant species in Thessaly plains forming 7.11% (n=2024) of the recorded specimens, and along with House mouse are considered to be highly opportunistic species (Macdonald & Barrett, 1993; Montgomery, 1999b). In Thessaly, the specie just presented a higher correlation to cereal crops and no other significant space use or distribution pattern due to its generalist habits (see Chapter 4 for details). It demonstrated though very significant seasonal fluctuations (Tab. 5.1) and quite higher numbers during autumn and winter seasons, varying among seasons from 4% to 12% (Fig. 5.5). Seasonal ordination analysis provided a significant general response model only for spring-summer seasons (Tab. 5.9 & 5.10), which indicated higher populations in arable land uses which support cereal crops among others (Fig. 5.15). Individual response models also supported these results (Tab. 5.11, Fig. 5.48). Obviously, Long-tailed field mouse occupies cereal crops while at the same time it didn't present any specific latitudinal or longitudinal pattern (Chapter 4, Tab. 4.5, Figs. 4.51 & 4.52, pp: 252 & 258), because as an opportunistic animal it occupies a variety of habitats, and areas not defended by other specialized and territorial species. Moreover, during spring and summer seasons cereal crops occupy a great percentage of the studied areas (see Appendix A for details), and offer vegetation cover and adequate food resources, and thus the specie, although with lower numbers is significantly more present in such habitats. That is also the reason why it just fitted these significant models during spring and summer. No matter if during autumn and winter it presented higher populations, it is quite possible that the harvest of cereal crops after June obliges Long-tailed field mouse to alter its niches and exploit different habitats afterwards. And since it is a generalist specie probably occupies a variety of different habitat types, and thus its movements do not produce any significant model during autumn and winter. Such seasonal movements have previously been recorded in Mediterranean studies, where between summer and winter different habitat occupations have been observed, and they were explained as avoidance to predation, and search for vegetation cover and food resources (Blanco, 1998b). Moreover, all over the specie's European distribution, its fluctuations were similar without any local latitudinal or longitudinal effect. The specie's populations almost always decrease during spring, present lower numbers during summer and increase after autumn (Blanco, 1998b). These fluctuations have been appointed to intraspecific density-dependent factors because of aggressive adult males' behaviour towards sub-adults, and auto-regulating mechanisms that control the numbers of pregnant females when in high densities (Blanco, 1998b). In Thessaly these dynamics have to be explored with live-trappings sessions though. Nonetheless, there is an absolute coincidence in seasonal fluctuations from Thessaly populations in concordance to the European bibliography. Additionally, in respect to the Long-tailed field mouse's breeding season, there is a very strong latitudinal effect in Europe. In colder areas of Northern Europe breeding season is located between March and October with a peak in mid July (Macdonald & Barrett, 1993; Jubete, 2002). In the Mediterranean basin though and especially in areas with higher temperatures, a strict reproductive cycle cannot be claimed since it seems to depend on various biotic and abiotic factors, such as food resources and climate (Blanco, 1998b; Jubete, 2002). Nonetheless, in various occasions like in Doñana national park in Spain, breeding season starts after August and its peak occurs in autumn and winter, and is related with the production of fruits which comprise its diet (Jubete, 2002). It is quite probable that in Thessaly as well, the specie's higher numbers during autumn and winter are also due to production of young during these seasons, and to a breeding season located between September and February. The exact reasons that produce that phenomenon in Thessaly of course remain to be explored, if in effect. However, this is the first recording from Greece for the specie with such strong seasonal fluctuations, which also corroborate similar Long-tailed field mouse's dynamics recorded in other Mediterranean agroecosystems. In conclusion, even if some of the reasons that produce these seasonal fluctuations in Thessaly require more research, it is certain that since during spring and summer the specie is attached to cereal crops, and after the harvest when its population increases it disperses to exploit various other habitat types, without producing any significant model, that agricultural practices in Thessaly and seasonal crop rotation affect strongly at least the specie's movements.

The co-generic Yellow-necked field mouse, which didn't fit any general or individual distribution pattern in 4th Chapter, similarly in seasonal ordination analysis didn't produce any significant model along the total or along any environmental gradient separately (Tabs. 5.9 – 5.12). It fluctuated among seasons similarly to Long-tailed field mouse, presenting higher numbers during autumn and winter (Fig. 5.5), nonetheless among the first three samplings no significant variation was present (Tab. 5.1). The specie's higher numbers during autumn-winter of 2004-2005 produced the significant ANOVAs according to Tukey HSD post-hoc tests (Tab. 5.1, Fig. 5.5). Nonetheless, the absence of any significant ordination model doesn't allow much terrain for explication, neither for the specie's space use in 4th Chapter and neither for its seasonal fluctuations, or seasonal habitat use. In northern Europe the specie's breeding season is located between February and October, mainly in spring-summer months (Macdonald & Barrett, 1993). These dates though differ in the specie's southern distribution range. In Atlantic Spain and northern Italy, breeds occur at the same time with central and northern Europe, but in their southern parts they depend highly on climate and food resources and can occur all year long (Blanco, 1998b). Nonetheless, in the warmer Mediterranean regions, although Yellow-necked field mouse can breed all year long, its numbers always decrease during summer (Blanco, 1998b; Arrizabalaga & Torre, 2002). Moreover, the specie's abundance fluctuations in most countries where it was studied, independently of latitudinal effect or breeding season dates, always present their higher numbers at the end of autumn and the first months of winter, whereas they decrease after February to reach their lowest values in beginnings of spring (Blanco, 1998b; Arrizabalaga & Torre, 2002). Thus, it can at least be concluded that the specie's seasonal fluctuations in Thessaly present the same abundance patterns with its European and Mediterranean trends. In addition, in

Mediterranean but also central and northern Europe it has also been observed, that Yellow-necked mouse presents the same annual population cycles with Long-tailed field mouse (Montgomery, 1999a), with similar seasonal peaks and minimum densities, a fact also observed in Thessaly plains (Fig. 5.5). Yellow-necked field mouse especially in its northern distribution range is a typical specie of mature deciduous woodland in high altitudes usually more than 500m (Macdonald & Barrett, 1993; Montgomery, 1999a). In its southern range though, and especially in the Balkan Peninsula it is also encountered (not very frequently though) in lowlands, and open agricultural fields, avoiding usually extensive and intensively cultivated land (Montgomery, 1999a). When present of course in agricultural fields, it is always less frequent than Long-tailed field mouse (Macdonald & Barrett, 1993), and in certain areas of their southern distribution range their presence is also reversely correlated (Arrizabalaga & Torre, 2002; Jubete, 2002). That is quite possibly one more reason for the low numbers of Yellow-necked mouse in Thessaly plains as well. Additionally, when Yellow-necked mouse is present in agricultural plains like those of Thessaly, it occupies not specific habitat types but patches like orchards, field margins, wooded gardens, hedgerows and buildings in rural areas (Macdonald & Tattersall, 2001). That fact also explains why the specie's composition change is not fitting any significant response model. Therefore, except the similar annual cycles between Thessaly population and the European studied trends, something more cannot be concluded at the moment for Yellow-necked field mouse's fluctuations in Thessaly lowlands.

Another member of the group of small mammal species which presented higher populations during autumn and winter in the agroecosystems of Thessaly is the House mouse. It was also an abundant specie forming 12.80% (n=3644) of the total recorded specimens, being third in rank of abundance after Guenther's vole and Lesser white-toothed shrew. As discussed analytically in 4th Chapter, House mouse is a highly opportunistic animal occupying an extreme variety of habitat types in all of its European distribution (Macholan, 1999a). In Thessaly moreover unlike northern Europe, and as in other parts of its Mediterranean distribution range, it is not strictly commensal but also lives outdoors (see Chapter 4 for details). The specie's seasonal fluctuations in Thessaly lowlands were highly significant (Tab. 5.1) like those of Long-tailed field mouse, and it varied with great difference between seasons ranging from 8% to 20%, and presenting as stated its population peaks in autumn and winter months (Fig. 5.7). In the specie's Mediterranean range where it mainly forms wild populations, independent of human environments, seasonal population cycles are also always observed. For example in southern France and southern Spain, wild House mouse populations present their peaks in November and December, then a small decrease is observed during March, and finally the lower values occur during summer (Blanco, 1998b). These data coincide exactly with the specie's fluctuations in Thessaly as well (Fig. 5.7). The reasons for these cycles vary, but the most important are available food resources (Blanco, 1998b; Sans, 2002). In Thessaly though, during spring-summer seasons when cereal and industrial crops occupy the greatest percentage of the studied areas offering vegetation cover, food resources and high temperatures, House mouse has quite lower numbers, whereas after autumn that most crops are harvested, it increases (Fig. 5.7). In addition to that, when observed the specie's habitat use through seasonal ordination analysis, it is clear that during spring-summer seasons it is significantly more encountered in arable land uses indifferently of cultivation types (Tabs. 5.9 & 5.11, Figs. 5.19 & 5.48). It is also somewhat more attached to cereal crops as concluded from 4th Chapter (Fig. 4.32, p: 250), which are dominant crops (after cotton) in Thessaly at the period, offering a broad terrain for exploitation. On the other hand though, in autumn and winter months the specie presents quite higher numbers and it is significantly more encountered within the mosaic of arable cultivated land (Tab. 5.12, Fig. 5.49). During these seasons though, arable cultivated land is mainly comprised of horticulture cultivations, and various pastures (see Appendix A for details), which occupy minimum extensions in Thessaly after the harvesting of cereals and industrial cultivations. The reason for that contradictory phenomenon is most probably due to the fact that House mouse as mentioned, except from being an opportunistic animal is also a very weak competitor (Macholan, 1999a). As demonstrated in 4th Chapter, the specie presents its higher numbers in south-western Thessaly, because as a weak competitor it was reversely correlated and ousted from Guenther's vole which dominates north-eastern locations, and Lesser white-toothed shrew which is abundant in central-southern areas (Chapter 4, Figs. 4.22, 4.51 & 4.52, pp: 239 & 258). Moreover, except the fact that its highest numbers were concentrated in south-western locations due to exclusive competition, in the rest studied sites it was syntopic and quite probably sympatric with dominant and abundant species (see Chapter 4 for details), whereas in south-western locations it also occurs with Macedonian mouse and higher densities of Thomas's pine vole (Chapter 4, Figs. 4.51 & 4.52, p: 258). Therefore, as a weak competitor for habitat and food resources, it has probably adapted its spatial-temporal patterns for its benefit. As a result, exclusive interspecific competition obliged the specie to concentrate its main population in south-western areas. Then, it also possibly auto-regulated its population peaks in seasons of less territorial and food resources conflicts, with other more dominant and specialized species, like Guenther's vole and Lesser white-toothed shrew which decrease strongly after September (Figs. 5.1 & 5.3). As a specie moreover, it has repeatedly manifested in various studies the capacity to control the density of pregnant females in adversely dependent or density-independent situations (Blanco, 1998b; Sans, 2002 and references within). Additionally, the specie's seasonal population peaks, indicate almost always a coincidence with the breeding season and the production of young (Blanco, 1998b). It is generally accepted that population dynamics of House mouse's wild populations depend on the specie's reproductive cycle, which is regulated according to local biotic and abiotic factors (Sans, 2002 and references within). That's why in various latitudes in Spain for example, exist various different dates for breeding seasons. In the north-east in Tarragona, breeding season is located between February and October, in south-eastern areas pregnant females occur from November to June, and in southern France females breed only for the short period from March to June (Blanco, 1998b; Sans, 2002). Thus, in Thessaly it is quite possible that the specie's higher numbers which begin to increase after September are also related with the production of young, dates which also coincide with those of south-eastern Spain. Moreover, in the beginnings of autumn when the specie starts to increase in various places of its Mediterranean distribution similarly to Thessaly, 80% of its population is comprised of young (Blanco, 1998b). That fact though produces two more contradictory patterns. As mentioned before, during autumn and winter seasons the House mouse presents quite higher numbers (Fig. 5.7), and its main population is coinstantaneously encountered in the limited extensions of arable cultivated land, such as horticultures and pastures. When the specie though presents population peaks most probably due to higher breeding success and production of young as stated before, and especially when this increased population is confined in habitats of small extension like it happens during autumn and winter in Thessaly, adult males become very aggressive and violent towards the younger, and oblige them to immigrate (Blanco, 1998b; Sans, 2002). Immigration takes place usually in the months of autumn when the population is at its peak, and since the specie is also considered as a very capable colonizator among most European small mammal species (Blanco, 1998b), and also highly opportunistic, it occupies new territories and various habitats easily (Blanco, 1998b; Sans, 2002). In a general overview additionally, House mouse population in Thessaly is quite high, ranking third in abundance among all 15 species. These facts suggest that although the specie's higher numbers are concentrated in arable cultivated land during autumn and winter, there are quite possibly small scale movements and colonization of other habitat types like roadside vegetation, orchards, tree cultivations, irrigation canals banks, river banks, gardens and probably human constructions. However, since these small scale movements are realized from young individuals in such heterogeneous habitats, multivariate analysis cannot detect these patterns. In conclusion, although House mouse is recorded to vary among seasons mainly due to available food resources in its Mediterranean distribution, in Thessaly its fluctuations probably also depend on interspecific and intraspecific density-dependent factors as well. That fact along with the specie's high habitat adaptability and opportunistic behaviour, indicate that human perturbations and crop rotation affects minimally the specie's annual cycles.

Finally, the last two species which presented higher numbers during autumn and winter are two rat species, Brown rat and Black rat. Brown rat was more abundant than Black rat (1.56%, n=500 and 0.78%, n=223 respectively), but the former's distribution patterns didn't produce any significant model in 4th Chapter. As discussed it was probably due to the fact that the highly commensal specie partly converts to wild populations in southern areas of its Mediterranean distribution, and thus its low numbers in combination with exploitation of different habitats (Macdonald & Barrett, 1993; Blanco 1998b), didn't respond significantly to ordination analysis. In seasonal ordination analysis though, although it didn't fit any individual model along any gradient separately (Tab. 5.11 & 5.12), its composition change produced a general response significant model during autumn-winter seasons (Tab. 5.10, Fig. 5.20). It is not easily interpreted due to its 2nd order polynomial nature, but it suggests that after September the Brown rat is significantly more encountered in non irrigated arable land which is "naked" after the harvest. Of course this is not the only trend, but no other models derived to clarify more correlations. Black rat on the other hand, presented significant general response models for both season pairs (Tab. 5.9 & 5.10, Figs. 5.29 & 5.30). Similarly to the general trends revealed in 4th Chapter, during spring and summer it was significantly more encountered in Inceptisol soil types (Tab. 5.9 & 5. 11, Figs. 5.29 & 5.37), but moreover, it avoids during spring and summer both arable and non arable land uses (Tab. 5.11, Fig. 5.47), whereas it presents very higher numbers in sites with large road networks (Tabs. 5.9 – 5.11, Figs. 529 & 5.30, 5.43 & 5.44). As a result, Black rat in Thessaly appears to be more commensal and attached to human constructions, because it avoids both arable and non arable land uses which dominate the Thessaly plains, and it is encountered in areas with large road networks which are primarily present in urban centres. Thus, a fact which wasn't clear in 4th Chapter is that although Brown rat is more commensal than Black rat in Mediterranean Europe (Amori & Cristaldi, 1999a, 1999b; Blanco, 1998b; Rojas & Palomo, 2002; Zamorano & Palomo, 2002), in Thessaly it appears that Black rat for both season pairs is more frequent in urban areas and Brown rat lives more independently in agricultural areas. Nonetheless, the models produced from seasonal ordination analysis and the species' space use between seasons, cannot give an explanation to the higher numbers that both Brown and Black rat present during autumn and winter (Fig. 5.6). Moreover, the population increase of both rat species during autumn and winter is also contradictory with the species' breeding patterns within their Mediterranean range, where they breed between March and October (Macdonald & Barrett, 1993; Blanco, 1998b; Rojas & Palomo, 2002; Zamorano & Palomo, 2002). On the other hand, this seasonal breeding pattern is mostly in effect for non commensal populations, since the species which are attached in human environments can reproduce all year long. Thus, it can be deduced that seasonal ordination analysis revealed a somewhat reverse pattern concerning the species' attachment to human and agricultural environments from the one that was expected, completing that way the image set in 4th Chapter, but live-trapping sessions have to be realized anyhow in order to give more concrete answers about the rats' higher numbers during autumn and winter, and about their detailed habitat selection among seasons.

Summarizing all the seasonal ordination analyses and the species' temporal space uses, the following points can be outlined: Firstly, there was a group of 5 species which were strongly affected from the crop rotation among seasons, the harvesting and the strong agricultural habitat change. Lesser white-toothed shrew, whose main population remained in the harvested arable land during autumn and winter, vulnerable to predation and without vegetation cover, which presented quite lower numbers during these seasons. Thomas's pine vole, which exploits different habitat types among seasons, and after the harvesting of the land is confined in smaller habitat patches with lower numbers, in order to find vegetation cover and food resources. Long-tailed field mouse, which although it is a generalist specie and can exploit a variety of habitats, it also exploits different habitat types between seasons due to the harvesting of the cultivations. Bicolored shrew, whose population fluctuations although they are mainly regulated from interspecific competition, its preferred habitats especially during autumn and winter are of minimum extension in Thessaly plains. And finally, Macedonian mouse which although with inconsistent variations between seasons was highly affected from the seasonal harvesting of the land, since it occupied different habitat types between spring-summer and autumn-winter seasons. Another group was formed of 5 more species, which suffered a medium or secondary impact from crop rotation. Guenther's vole which was also the more abundant specie in the studied areas, inhabits mainly natural grasslands or multiannual pastures which are not affected from agricultural practices, but still there is a possibility that seasonal crop rotation delays the starting of its breeding season. Western broad-toothed mouse which similarly to Guenther's vole inhabits habitats unaffected by man, such as rocky areas rich in crevices in hills and lower mountain parts, and thus isn't primarily suffering from arable practices and seasonal crop rotation. A medium impact is also occurring upon East European vole's population, which is mainly regulated from interspecific competition with its co-generic Guenther's vole. Gray dwarf hamster which although it is an adaptable specie with high habitat plasticity and its fluctuations are also mainly regulated from interspecific competition, during autumn and winter remains in the harvested arable land, vulnerable to predation and with limited food resources. And finally House mouse population which was minimally affected, since it is an opportunistic specie and a weak competitor, and thus its seasonal fluctuations were mainly regulated from intra and interspecific competition. The last group included 5 more species whose abundance variations were not possible to be significantly explained with seasonal ordination analyses. For Yellow-necked field mouse, no trends or patterns were detected that could correlate the species' fluctuations with other environmental factors, or seasonal habitat selection. Hazel dormouse on the other hand, was minorly represented in the studied areas, in just 4 sites which were adjacent to a river with dense vegetation, and thus ordination analysis didn't offer anything important. Etruscan shrew presented specific fluctuation patterns and some seasonal significant models, but its numbers are probably biased due to Barn owl prey use and the prey's minimum size. And finally, both Black rat and Brown rat, although proved to have a somewhat reverse habitat use pattern in Thessaly, their higher numbers during autumn and winter weren't explained from any environmental gradient correlation.

5.5 RESUMEN

5.5.1 Introducción

La respuesta a las causas de la variación en las abundancias de los micromamíferos en campo, se encuentra en el estudio de la dinámica de sus poblaciones. El tema central en cada aspecto de estos estudios es explorar y explicar porque ocurren fluctuaciones espaciales y temporales. Los factores que influyen estas fluctuaciones se dividen en dos categorías. Los factores abióticos, como la temperatura y principalmente la precipitación, y los factores bióticos, que también se dividen en densidad-dependientes y densidad-independientes. Los de densidad-independientes son la disponibilidad de recursos de alimento, depredación, vegetación, estructura de hábitat, y perturbaciones humanas. Por otra parte, los factores bióticos de densidad-dependientes son una variedad de procesos demográficos intrínsecos de las poblaciones de los micromamíferos, como el estatus de reproducción, mortalidad, supervivencia, emigración, inmigración, grado de especialidad, comportamiento, territorialidad y por supuesto competición inter e intraspecífica. Este capitulo intenta explorar hasta cierto punto, las consecuencias del manejo humano en el ecosistema agrícola de Tesalia sobre las poblaciones de los micromamíferos, a través del fuerte cambio producido en el hábitat agrícola por la rotación estacional de cultivos. Además, este capitulo también analiza asociaciones entre tipos de hábitat y especies de micromamíferos, pero esta vez incluyendo en los análisis dos factores mas; sus fluctuaciones estacionales y el cambio estacional del hábitat. La cosecha de los cereales en Junio y de los cultivos industriales en Septiembre, que deja la tierra "desnuda" durante otoño e invierno, sin duda tiene un impacto fuerte sobre los micromamíferos, por la perdida de cobertura vegetal y recursos de alimentación. Los objetivos principales del capítulo son: 1) Explorar la hipótesis que el cambio estacional del hábitat agrícola influye en las fluctuaciones estacionales y el uso de hábitat por los micromamíferos en el área de estudio. 2) Definir e investigar cuales de los gradientes ecológicos entre estaciones afectan a las especies de micromamíferos, y en que dirección (aumento, decrecimiento o no significativo), y evaluar el impacto humano 3) Utilizar el conocimiento sobre los nichos ecológicos de las especies presentes en la región de Tesalia, estudiados en ecosistemas similares mediterráneos, y combinarlos con los resultados para atribuir la mejor posible discusión.

5.5.2 Materiales y métodos

El análisis de egagrópilas ha sido utilizado en este capítulo como también en los anteriores, para evaluar las fluctuaciones estacionales de los micromamíferos. Como se mencionó anteriormente, cuatro muestras han sido realizadas en cada una de las 31 localidades estudiadas. La primera en Septiembre de 2003, la segunda en Marzo de 2004, la tercera en Septiembre de 2004 y la última en Marzo de 2005. De tal manera, las egagrópilas regurgitadas reflejan dos periodos reproductoras y dos no reproductoras. Los nichos ecológicos se calculan a través de tres índices de diversidad. La riqueza de las especies que es el índice más sencillo se calculo como el número de las especies presentes en la dieta de cada región estudiada. El índice de la diversidad H΄ se calculo según Shannon y Wiener, con base logarítmica e. Sin embargo, las diferentes muestras se diferencian en tamaño y por lo tanto ambos índices de la riqueza de las especies y de la diversidad se calculan con la aplicación de rarefacción, al nivel de la muestra con el tamaño menor. El índice de equitabilidad J΄ se calculo también en respecto a Shannon y Wiener, sin la aplicación de rarefacción porque no había algún software disponible para realizar el algoritmo.

5.5.3 Análisis estadístico

En principio, y similarmente al Cap. 4 un Análisis Factorial ha sido aplicado en las variables independientes. Específicamente, a dos grupos de variables ambientales homogéneos, en “Cultivos Agrícolas & Usos de Tierra”, y “Tipos & Estructura del Suelo”. La diferencia ha sido que esta vez antes que aplicar el Análisis Factorial se construyeron dos matrices por cada grupo, una para otoño e invierno, y otra para primavera y verano. Tres variables ambientales de naturaleza diferente (Longitud de ríos y carreteras, y Altitud) no han sido incluidas en el Análisis Factorial, por ser de naturaleza diferente. Una vez que fueron producidos los nuevos factores, se construyen para el Análisis de Ordinación estacional, cuatro matrices. Dos incluyen las frecuencias relativas de las especies de micromamíferos transformadas con el método de arcosino, para las estaciones otoño-invierno y primavera-verano, y además por cada muestra. Las otras dos incluyen los “scores”-sectores - factoriales y las tres variables ambientales no analizadas, con sus valores para cada muestra y cada una de las estaciones mencionadas.

Luego, las cuatro matrices son introducidas en el software CANOCO, y similarmente a la metodología del Cap. 4, un Análisis de Correspondencias se aplica en las matrices con las especies de micromamíferos. Los valores producidos fueron menores de 3, indicando que métodos lineares deben de ser utilizadas en los análisis posteriores. Por lo tanto, un Análisis de Redundancias (RDA) ha sido aplicado en cada una de las cuatro matrices, una por cada estación.

5.5.4 Resultados y discusión

Un grupo de cinco especies son fuertemente afectadas por la rotación de los cultivos y el cambio del hábitat agrícola entre estaciones. En principio, una vez que fue coleccionada la cosecha de cultivos industriales en Septiembre, la población de *C. suaveolens* permaneció en la tierra desnuda durante otoño e invierno sin cobertura vegetal y vulnerable a la depredación. Paralelamente, su población decreció significativamente más en esta época. *M. thomasi* ha explotado diferente tipos de hábitat entre estaciones aparentemente para encontrar cobertura vegetal y alimento. Después de Septiembre ha ocupado hábitats más limitados en extensión como cultivos arbolados y vegetales, y con poblaciones significativamente más bajas. *A. sylvaticus*, siendo una de las especies más generalistas que puede explotar una gran variedad de hábitats, también demostró una ocupación de hábitat totalmente diferente entre estaciones, a pesar de la rotación de los cultivos. Las fluctuaciones de la población de *C. leucodon,* aunque es posible que haya sido regulada por competición interespecífica, durante otoño y invierno la especie ocupa áreas que mantienen cobertura vegetal, evitando la tierra “desnuda” sin cultivos. Finalmente, aunque *M. macedonicus* presento fluctuaciones inconsistentes entre estaciones, también exploto diferentes tipos de hábitat después la colección de las cosechas.

Otro grupo de cinco especies más, sufrió un impacto medio o secundario respecto al grupo anterior, a pesar del cambio estacional del hábitat. *M. guentheri* que fue también la especie más abundante, ocupa estrictamente hábitats como praderas naturales, pastos, barbechos y parcelas de tierra no cultivada que no son afectadas por las practicas agrícolas. De todos modos, es muy posible que la rotación de los cultivos produzca un retraso en el inicio de su época reproductora, aunque esta asunción es más teorica y debe ser confirmada en campo con sesiones de trampeo. *A. epimelas* similarmente a *M. guentheri* ocupa hábitats no afectados por practicas agrícolas, y específicamente áreas con restos rocosos, collados, y partes montañosas en altitudes bajas, y por lo tanto no afectadas. También un impacto secundario se ha observado para *M. levis* cuya población se regulo probablemente por competición interespecífica con su especie con-genérica *M. guentheri*. Similarmente, aunque *C. migratorius* es una especie con plasticidad de hábitat fuerte, sus fluctuaciones han sido posiblemente reguladas también por competición interespecífica, y durante otoño-invierno su población permaneció en tierra "desnuda" después la colección de la cosecha, sin cobertura vegetal y vulnerable a la depredación. Finalmente *M. musculus* ha sido mínimamente afectado, al ser una especie oportunista, explota una variedad de hábitats diferentes, y sus fluctuaciones parecen ser principalmente reguladas por competición interespecífica con otras especies más territoriales y especializadas.

En fin, para cinco especies más que presentaron fluctuaciones estacionales, el análisis multivariante no demostró ningún modelo significativo a través de los Análisis de ordenación estacionales, para correlacionarlas con el cambio del hábitat agrícola. Estas especies son *S. etruscus*, *A. flavicollis*, *M. avellanarius*, *R. rattus* y *R. norvegicus*.

De todas formas, es necesario mencionar que para deducir con certeza los mecanismos que producen las fluctuaciones de los micromamíferos en Tesalia, y para cuantificar con precisión la importancia de cada factor biótico o abiótico que afecta estos procesos, incluyendo el cambio estacional del hábitat agrícola, sesiones de trampeo tendrían que realizarse en campo. El presente capitulo ha presentado datos para las fluctuaciones de los micromamíferos en la región, y su uso espacial entre estaciones, pero para la exploración de los mecanismos intrínsecos demográficos, no se puede profundizar más, sin la aplicación de trampeos en los ecosistemas agrícolas.

CHAPTER 6

General Discussion and Implications for Conservation

6.1 Common Agricultural Policy (CAP) and biodiversity issues

When the founding members of the EU were emerging from a decade of food shortages, around 50 years ago, the Common Agricultural Policy (CAP) was born. Since then it is the oldest, and for a long time it has been the only common European policy concerning management of farmland habitats and their production. When it was created, it focused exclusively on subsidizing production of basic foodstuffs, in the interests of self-sufficiency and food security. Nevertheless, as European agriculture evolved through the decades, so did the CAP, trying to adapt to the new environment. It gradually moved away from price and production support, which was primarily its unique goal, to a more comprehensive policy, including the preservation and management of natural resources.

Since 1992, the CAP has progressively focused on environmental protection and tried to serve better the aims of sustainability. That was intended by means of a reform process designed to a policy of direct income aid towards farmers, and a series of rural development measures. Two important changes took place in 1999 and 2003, which were steps of high significance in this reform process. Since then, further reforms have been implemented (reforms of the tobacco, hops, olive oil and cotton sectors in 2004, and the reform of the sugar regime in 2006). During the last two decades though, as important environmental issues emerged from agricultural management in farmland habitats, the orientation of rural development policy towards environmental protection has become an overall EU priority.

Nonetheless, the CAP has been repeatedly and openly criticized by many diverse sources since its inception. Even the same European Commission has since long been persuaded of the numerous defects of the policy. Moreover, in May 2007, the country of Sweden became the first EU country to take the position that all EU farm subsidies should be abolished, except those related to environmental protection. The important problems that have occurred from the CAP, and the topics which were mainly criticized during the years, can be summarized in the four following points. Firstly, the problem referred to as anti-development. The West spends high amounts on agricultural subsidies every year, which amounts to unfair competition. In addition to that, it is argued that in creating an oversupply of agricultural products which are then sold in the Third World, simultaneously the export of its agricultural goods to the West is prevented, increasing thus Third World poverty, and putting its farmers out of business. Secondly, the CAP has been criticized because price intervention has been creating artificially high food prices throughout the EU. With food prices dropping over the past thirty years in real terms, many products have been making less than their cost of production when sold at the farm gate. Thirdly, although most policy makers in Europe agree that they want to promote "family farms" and smaller scale production, in fact the CAP has been rewarding larger producers. Because the CAP has traditionally rewarded farmers who produce more, larger farms have benefited much more from subsidies than smaller farms. Since 2003 reforms though, subsidies have been linked to the size of farms, and thus this effect has started to reduce. Last but not least, CAP has traditionally promoted a large expansion in agricultural production since the 60's. At the same time, it has allowed farmers to employ unecological ways of increasing production, such as the indiscriminate use of fertilizers and pesticides, and the use of heavy machinery, with serious environmental consequences. These facts in combination with the increase of monocultures in most agroecosystems, led inevitably to great intensification of agricultural habitats, loss of traditional practices, and damage of biodiversity in multiple levels (avian fauna, mammal fauna, insect fauna, water resources, soil degradation, pollution and more).

With the dawn of 21st century, the problem of intensified agriculture and its negative consequences in biodiversity, along with the limitation of water resources and climate change, has become the main ecological issue in agricultural ecosystems' management. More and more researchers have been studying exhaustively and publishing on these eminent negative results, appointing as the source of the evil, the following decades of intensified exploitation of agricultural land, according to the directives of CAP and also to regional policies from the 50's to the 80's. It is a fact on the other hand, that recent CAP reforms have been oriented, towards reversing these negative effects. Consequently, the new legal framework functions clearly on boosting growth and creating jobs in rural areas (in line with the Lisbon Strategy) as well as on improving sustainability (in line with the Goteborg sustainability goals). Today, the CAP includes a series of concrete measures that contribute to the protection of the environment, nature conservation and biodiversity. More specific, the Rural Development policy set for the years 2007-2013 focuses mainly on three priority areas: (a) preservation of biodiversity, and development of farming, forestry ecosystems and traditional agricultural landscapes of high nature value, (b) water, and (c) climate change. These are translated into national strategy plans, which in turn form the basis for the national and regional rural development programs. Each one of the member states afterwards, decides which measures wishes to include in their rural development programs according to their specific priorities, needs and situations (subsidiary principle).

Nonetheless, it is still of question, whether the adding negative consequences of multiple years of intensified agricultural practices, could possibly be avoided, stopped, or reversed, even if environmental "friendly" agricultural policies will be applied, starting now. Moreover, it should also be taken into consideration as additional difficulties to the existing problematic status in European agroecosystems, each country's peculiarities, needs, culture, political decisions, established agricultural practices, economic status, and of course the level of the existing ecological and biodiversity threats, in each specific region.

6.2 Intensified agroecosystems and overpopulation in Europe at 21st century. Facing the challenge

The total area of cultivated land worldwide has increased with a rate of 466% from 1700 to 1980. Although this rate of expansion has slowed in the last three decades, yields (food produced per area of land) have increased dramatically, and have outpaced global human population growth. This remarkable scientific and technological achievement is based largely on the intensification of management on land under agricultural practices. It was accomplished through the use of high-yielding crop varieties, chemical fertilizers and pesticides, irrigation, and mechanization.

Concerns have developed, however, over the long-term sustainability and environmental consequences of the intensification of agricultural systems. It is now clear that agricultural intensification has various negative consequences in multiple levels: In *local level*, such as increased erosion, lower soil fertility, and reduced biodiversity; in *regional level*, such as pollution of ground water and eutrophication of rivers and lakes; and in *global level*, including impacts on atmospheric constituents and climate. Concerns about the ability to maintain a long-term intensive agriculture are also growing.

At the same time that environmental concerns are increasing, so are concerns about feeding a rapidly growing human population and reducing hunger. Demographers predict that the population will grow to between 8 billion and 10 billion in the 21st century. Meanwhile, some 800 million people are malnourished today. Although malnutrition and hunger are currently more related to poverty and inequitable food access than to inadequate food production per se, many regions of the world, particularly parts of Africa, are not self-sufficient in food production. Thus, agricultural intensification remains a major target of research and development. Reconciliation of these two needs (increased world food production with greater environmental protection for the future) is subsumed under the umbrella of “sustainable development”, and presents a major challenge for science in the 21st century. Understanding how ecosystems are altered by intensive agriculture, and developing new strategies that take advantage of ecological interactions within agricultural systems, are crucial to the continuance of high-productivity agriculture in the future, without harming them further.

A sensitive “key” point to this delicate synthesis of integrating biodiversity in agricultural intensification, while optimizing at the same time agricultural production for global nutrition, is the fact that no technological quick fixes are available to harmonize environmental conservation and agricultural development. Policy distortions need to be removed firstly, and research institutes along with the dissemination of their studies’ results need to be strengthened. More support for further development of technologies, particularly those related to managing agrobiodiversity, is also clearly warranted. Finally, biodiversity will be successfully mainstreamed in agricultural development only if the ultimate managers of biodiversity, which are the farmers and livestock raisers, are involved in the implementation and design of research and development projects. Without local participation of farmers and their communities, major stakeholders in biodiversity management will be cut off from decision-making, thereby undercutting the chances for success. A blend of indigenous knowledge and scientific research will be needed to further the transformation of agricultural ecosystems, so that they are more biodiversity friendly and at the same time able to achieve higher productivity.

6.3 Birds in European farmlands and population trends

One of the most striking negative effects that intensification of agriculture associated with the Common Agricultural Policy (CAP) has entailed in local, national and regional level, is the extinction of numerous species of the European flora and fauna. The processes which were mentioned in the previous two parts, have induced a degradation of habitat quality and caused the decrease in diversity and abundance of food resources used by both herbivorous and predatory species. Rain-fed cereals have been replaced with irrigated, heavily fertilized and pesticide-treated crops. Pastures and rangeland have been overgrazed, leading to excessive soil erosion and compaction. Semi-natural habitat features have been lost from the farm landscape, including strips of meadow, natural hedgerows, groves, small wetlands and tree stands along wetlands. Vast and highly managed monoculture landscapes have replaced the diverse crop mosaics that were formerly essential in resting the soil and combating pests. Such processes are actually those which underlie species loss in European farmlands.

In specific, recent researches have demonstrated that Europe’s farmland birds have declined by almost 50% in the past 25 years. The results which were released recently, bring together the most comprehensive biodiversity indicators of their kind in Europe, collated by the *Pan-European Common Bird Monitoring Scheme* (*PECBMS*), a partnership led by scientists from the European Bird Census Council, BirdLife International, the RSPB (BirdLife in the UK) and Statistics of Netherlands. The data were collected from 20 independent breeding bird surveys across Europe over the last 25 years, all of which were coordinated thanks to the concerted efforts of national programs involving thousands of dedicated volunteer birdwatchers, and of course specialists and researchers. Moreover, using birds as indicators has many advantages: excellent data, based on the volunteer efforts of skilled birdwatchers; a stable taxonomy; a thorough knowledge of ecology and behavior; meaningful responses to environmental change, and great resonance and symbolic value with the public and decision-makers. In addition, bird populations integrate a set of environmental changes, because they are mobile and often wide-ranging. And finally, bird numbers also respond more slowly than those of smaller organisms, and at a larger spatial scale. Thus, common bird indicators can help measure progress towards reducing the rate of biodiversity loss at the national, regional and global levels.

The “UK common bird indicator” which is a national example, is based on population trends of common breeding birds within the UK, and it is one of UK Government's 15 headline indicators of the sustainability of lifestyles in the UK. It has showed that common birds have increased by 10% on average, while on the other hand woodland and farmland birds have fallen by 15% and 42% respectively, from 1970 to 2002. Farmland birds have actually halved their population in the UK within three decades. Another regional indicator this time is the “Pan-European common bird indicator”. The “Pan-European common bird indicator” shows average population trends of a suite of common breeding birds across 18 European countries. Data are collected through national annual breeding bird surveys conducted by skilled volunteers. National species’ indices are weighted by national species population sizes; regional indicators are calculated by averaging the resulting indices. They show that common farmland birds in Europe have declined steeply over the last two decades, whereas common woodland birds have not. The farmland bird index has also been formally adopted by the European Union as a Structural Indicator for Europe.

Scientific evidence as also mentioned before, have proved that recent farmland bird declines in north and west Europe have been driven by changes in agricultural methods, and especially intensification and specialization. The most important changes affecting birds have been hedgerow loss, land drainage, increased mechanization, increased fertilizer and pesticide use, reduction of spring cultivation, simplification of crop rotations, changes in crop use, and loss of farm diversity. On the other hand, this hypothesis is supported by a contrast in population trends in EU and EU Accession countries. In Accession countries, farmland birds showed signs of recovery from 1990, as the former Eastern Bloc broke up and agricultural intensity was reduced. On the contrary, there has been no similar recovery of farmland birds in the EU, where intensification has continued.

6.4 Greek fauna as part of Mediterranean Europe, Balkan Peninsula and border with Anatolia

Greece has since long been part of the European Union, and was obliged to follow all of its directives as a state member, along of course with the Common Agricultural Policy and its reforms through the years. On the other hand, except from being a state member of the EU, Greece presents biogeographically three concrete special characteristics. It is situated in the eastern part of the Mediterranean Basin, it is also the southern frontier of the Balkan Peninsula, and it is also bordering to the east with Turkey and therefore Asia. Floristically and faunistically, these geographical proximities, along with the long term processes which have occurred during the centuries, appoint Greece with a very interesting extant biodiversity.

As also mentioned in the discussions of Chapters 4 and 5, the extant biodiversity of the Mediterranean is a legacy of long term processes of immigration, extinction and endemicity that have occurred during the last million years. In faunistic biodiversity terms, the poorest regions are found in the western Mediterranean, with the Iberian and Italian peninsulas being the poorest, whereas peak richness values are found in Central Europe. Contrastingly, the number of endemic and rare species shows a contrary pattern, with highest values in the Iberian Peninsula (endemicity) and the Balkan Peninsula (rarity), and lowest values in Northern Europe. The presence of physical barriers running East-West in the Mediterranean Basin, and the complex climatic and land-use changes experienced by the Basin during the Holocene, are the main reasons which formed these patterns. In addition to that, the geographical proximity with Asia through the borders with Turkey, have also influenced flora and fauna in Greece. That is especially observed in northern biotas in Thrace, where the river Evros functions as a natural border between the two countries. Various immigration processes, mainly in fauna terms have also been observed from the western Turkey coasts towards Greek islands of Eastern Aegean Sea. Therefore Greece, because of its high level of endemism, and long term processes of immigration, it actually comprises one of the last refuges of many threatened, endangered and rare species in a European, Mediterranean and Balkan scale.

Nonetheless, and although existing data demonstrate clearly that the extant biodiversity in Greece is especially high with regard to the wild fauna and flora, the largest part of its species and their genetic structure remains unexplored. It is estimated that there are approximately 50.000 animal species, 15.000 have been studied up to a point, of which up to 25% are endemic. Similarly, there are over 5.500 species of plants of which over 1.000 are endemic. The protected species by law are comparatively few (appr. 700 animal species and 900 plant species), and specific management measures have actually been taken for only a part of them. For many organisms such as micro-organisms, fungi etc., there are no reliable collective data, although all the indications suggest that they present great diversity as well.

6.5 Raptors guild and small mammal assemblages in the agroecosystems of central Greece

The largest agricultural ecosystem of Greece is situated in the central-eastern part of the mainland, forming the plain of Thessaly, which was also the study area during the realization of this thesis. As explained analytically in the second part of the introduction (Chapter 1), Thessaly is considered among the largest (both in extension and production) agroecosystems in the Mediterranean Basin. Such dynamic and productive agroecosystems though, present a very specific characteristic and an important difference, unlike other ecosystem types. That is the seasonal and continuous change of the habitat scenery, caused by crop rotation, planting of seeds, growing of the plants, and finally the harvesting of the crops, and the ploughing of the land. In an intensive agroecosystem like the one of Thessaly, which has been exploited since many decades, this seasonal habitat alteration actually forms a strictly agricultural landscape, which is totally shaped by human actions. In addition, activities like application of irrigation schemes, planting of different crop types, formulation of cultivation mosaics, various soil properties, use of fertilizers, machinery impact, different inclinations, along with abiotic factors as well, form an intensively exploited agroecosystem which hosts important representatives of the Greek fauna under specific conditions.

It was previously analyzed in paragraphs 6.1, 6.2 and 6.3, that during the late decades, European agroecosystems were given special attention for the first time not only in productivity terms but also because of their faunistic value. Even the EU has been oriented to more sustainable and environmental friendly agricultural policy. Avian species due to their special ecology and behavior have functioned as very good indicators, which unfortunately demonstrated compelling evidence of a severe decline on most farmland birds due to the intensified exploitation. In Greece however, and especially in the region of Thessaly which is a highly intensified agroecosystem, very few long term studies have been realized in the field, in order to study possible negative effects on biodiversity. Moreover, absence of data exists even from simpler points of view concerning national surveys in order to record populations of many avian species in the country. The Hellenic Ornithological Society is making intense and important efforts towards that goal, along with many other independent scientists and researchers, but a lot of terrain has yet to be covered to reach a more thorough and complete knowledge.

For instance, in the present thesis the first chapters covered aspects of the feeding ecology of Barn owl in Thessaly. These results actually also form the first long term survey and official recording of a Barn owl population in Thessaly. Although it is a nocturnal raptor highly and strictly attached to farmland habitats, which has also declined severely in many countries, also becoming a flag-specie in some of them (e.g. UK, see Chapter 1 for details), never before had an official survey been realized in central Greece. Therefore, up to the moment there was absolutely no indication if the specie's population has decreased in Thessaly and in Greece as well, as it happens in other parts of Europe. Apart that fact, the agroecosystem of Thessaly is also hosting various other important raptor species except Barn owl. Other nocturnal raptors are also nesting and breeding in the region, such as the Little owl and Long eared owl, with the latter being a winter visitor mainly, with various couples though remaining all year long in the region in order to reproduce. Scops owl is also one abundant summer visitor which is reproducing in the region, but still not even one study has offered additional information about the specie and its biology and ecology in the area. In addition, diurnal raptors like Common buzzards are quite often observed foraging over the fields, as well as the endangered Lesser kestrel, which apparently holds in Thessaly its higher population in the country, with many breeding colonies in various points. And last but not least, various songbirds and other farmland birds comprise the avian guild of Thessaly, without any specific knowledge of their status though.

Therefore, one of the main problematic issues in Greece generally and of course in Thessaly specifically, is the absence of organized national surveys which would keep recording the trends of various avian species' populations. Countries with well organized volunteer networks and a tradition in ornithological studies, like England or Netherlands, have since many decades been realizing every two or three years national surveys with the participation of thousands of volunteers. These surveys are coordinated by specialists while the results are processed by groups of analysts, and afterwards a bird atlas is published yearly, or every couple years. As a result, when it was realized that Barn owl decreased severely in the Netherlands during the 90s, a national recuperation plan was undertaken. After 15 years of application, new results indicated that recuperation actions managed to increase and stabilize Barn owl's population, with positive population trends. The UK has undertaken similar national action plans after the year 2000.

In the case of Thessaly though specifically, it is quite possible that Barn owl has declined during the last decades, similarly to the European population trend. That can be assumed since natural nesting sites decrease gradually, and tree and forests patches are of minimum extension in the intensified agroecosystem of central Greece and cannot offer a natural nesting site alternative. Of course, University scientific groups which realize research in the field, offer valuable information, an example being the present thesis. Nonetheless, if these results are not properly disseminated and not hosted or at least assessed afterwards by a national scientific "umbrella", with organized and continuously updated protocols and databases, conservation measures can be proposed but their actual value wouldn't be more than theoretical, and it is also quite possible that they would partially be disoriented.

In addition to that, apart the avian fauna, a very important complex of mammal assemblages is present in the agricultural ecosystems of Thessaly as well. The second half of the present thesis and specifically chapters 4 and 5, analyze in detail through the Barn owl's diet spectrum, a total of 15 different small mammal species which were present in Thessaly plain, and their habitat associations, seasonal fluctuations, and population structure. As was also demonstrated in chapters 4 and 5, mammal species are ideal organisms to serve as models for ecological questions and hypotheses tested in a large spatial scale, for a variety of reasons. Moreover, only recently have researchers, mammalogists and ecologists in the globe started to address questions in a broad spatial scale in small mammal studies. In addition to that, Greece as was demonstrated in previous chapters has a complete absence of any kind of ecological study concerning small mammals in the country, except the recent realization of a PhD study in the island of Lesvos, in eastern Aegean. All other published works have dealt exclusively with the distribution of the species in the country, but since no official survey has ever been realized in Greece yet for any specie, even in that direction a lot of work needs still to be done. Thus, similarly to the case of Barn owl in Thessaly, no previous knowledge existed up to date about small mammal assemblages in central Greece, and neither if there was a negative correlation between certain species' presence and diversity, and specific aspects of intensification on the agricultural land. Moreover, except the fact that for most of the 15 small mammal species new distribution patterns were presented in this work, it is also the first time that such a small mammal case study in dynamic changing agroecosystems has been conducted in Greece, associating their structure and distribution with crop types, soil properties and land uses, and exploring their seasonal fluctuations in relationship to the seasonal change of the agricultural habitat.

In a general overview, and taking into account the total of the conclusions as they are presented in the 7th Chapter which are produced from the present thesis, and independently of the fact that no previous regional surveys exist in the area of Thessaly for the Barn owl nor small mammal assemblages, a series of propositions for conservation can and will be discussed hereafter, along with their particularities and difficulties.

6.6 Predator - prey relationships in a dynamic agroecosystem. Proposals for conservation, problems and constraints

Barn owl in Thessaly was proved to prey heavily on small mammal species, while other prey group types were minimally captured, and in comparison with other mainland and insular Barn owl diets it was among those with the highest mammalian intake. Nonetheless, that specific result was more or less expected, since the accumulated knowledge on the specie's diet in global level always indicates similar trends, except in a minimum of cases. What was interesting though in the case of Thessaly is that the owl's diet diversity and species richness indices were the highest among all mainland and insular Greek diets, as well as among most studied diets in Mediterranean Europe. Moreover these indices were calculated after the seasonality effect was avoided, since semester samplings were realized during the three year study, and local bias are not in effect since a total of 31 localities were sampled repeatedly, covering all the region of Thessaly lowlands. In addition, when a comparison was realized with other Barn owl diet indices from Greece, a standardization technique was applied, and results were rarefied to the basis of the smallest prey sample. Therefore, these facts clearly suggest two things: Firstly, that the present mammalian diversity in the agroecosystems of Thessaly is actually low. And secondly that Barn owl requires more energy for hunting and capturing its prey, than in other regions where higher mammalian diversity, and assemblages which sustain abundant optimum prey produce narrower diet diversities, and thus easier foraging and hunting results. Therefore, an important deduction is that low mammalian diversity in the agricultural ecosystems of Thessaly, impose a higher energetic investment by the Barn owl in order to capture its prey.

Moreover, although voles dominated Barn owl's diet in Thessaly forming almost half of its captured prey both in frequency and biomass terms, nonetheless diversity indices as proved were actually high. In relevance to that phenomenon, Barn owl's seasonal diet trends indicated that as voles apparently decreased in the field, both diet diversity and species richness increased significantly during all the three years. That kind of prey use suggests clearly that voles are optimum prey for Barn owl in Thessaly, as well as in many other studied regions of the world. The combination of these facts though indicates that in a possible crash in vole populations in Thessaly, Barn owl will eventually exploit other mammalian species since it is an opportunistic predator, but energetically it will profit less as also proved in the present thesis, and will invest more time hunting as was demonstrated by all calculated seasonal indices. That fact, in an agroecosystem like that of Thessaly where mammalian diversity seems to be low, could actually have negative consequences in the owl's breeding success. It can be argued of course that since Barn owls depend on existing prey assemblages, they have and will always suffer from such seasonal decreases. Nonetheless, specifically in the region of Thessaly where the specie's population trend is unknown and never studied before, and taking also into account Barn owl's European decrease in intensified agroecosystems, these facts lead to two necessary action steps that need to be undertaken: Firstly, the recording of all natural nesting sites and the continuous monitoring of occupied nests, and secondly the recording of the specie's breeding success for consequent years, in order to form an image of the population in Thessaly and its existing trends. In the case that Barn owls demonstrate a limited population with negative trends in Thessaly lowlands, another necessary conservation measure would be to emerge artificial nest boxes, which have helped recuperating populations in various European countries.

One more alarming issue is the fact that Barn owl in Thessaly captured voles mainly in non arable land uses and especially in natural grasslands and set-aside fields. As proved though, these habitat types occupy a minimum extension in the region of no more than 15% from the total of studied locations, in which especially during breeding seasons the owl preyed heavily and significantly more on voles. Although voles in high numbers also disperse in less favorable habitats, multivariate statistical analysis indicated clearly that they were mainly captured in non arable land uses during all seasons, which is also their main dispersal tank and preferred habitat. Thus, this confined habitat selection in vegetation types of minimum extension, which is also significantly higher during breeding seasons, reveals limited resources for capturing optimum prey, which could function as an additional negative factor to the specie’s breeding success during a crash period in vole populations. Since natural grasslands in each village of Thessaly are left unexploited mainly for grazing purposes, it could be discussed with local authorities as a potential conservation measure, the establishment of two cores of natural grasslands instead of just one, and possibly of slightly larger extension. Taking into consideration that voles are proved to be preyed by many other species when abundant, such as Lesser kestrel, Long eared owl and Buzzards, such a measure could function not only in benefit for Barn owl population, but also for many other species which comprise the raptor assemblage of the region, as it was presented in a previous paragraph of this chapter.

On the other hand, it is obligatory when studying Barn owl’s population trends to also realize a parallel study of available prey assemblages. Moreover, for proposing such conservation measures and in order for them to be complete, a detailed long term study should also be realized on the population dynamics of small mammals in the field. For instance, the present thesis revealed new and unrecorded until now information, concerning small mammal distribution in the agricultural ecosystems of Thessaly, and their associations with habitat types, land uses and soil properties. One of the most interesting results was the fact that certain small mammal species, like Lesser white-toothed shrew, Thomas’s pine vole and Gray dwarf hamster were proved to be mainly attached to specific soil properties and not to habitat types or land uses. Due to the complete and highly detailed soil mapping of the whole region of Thessaly, realized from the National Agricultural Research Foundation during the last 20 years, valuable results surfaced after the multivariate statistical analysis. For the first time it was demonstrated that Lesser white-toothed shrew was mainly attached to Vertisol soil types and argillaceous-clay texture, Thomas's pine vole avoided strongly all soil types except Alfisol soils with sandy-clay texture, and Gray dwarf hamster was mainly encountered in areas with Entisol and Mollisol soil types. Moreover, although all of the 31 studied areas in Thessaly lowlands didn't exceed 300m in altitude, which is practically low in order to present a significant effect, it was finally proved that the altitudinal gradient even in such a small scale was highly significant affecting the distribution of certain species, and specifically the two most abundant, Lesser white-toothed shrew and Guenther's vole. Longitudinal and latitudinal gradients also proved that many species presented different and specific spatial distributions in Thessaly, which were partially explained by the different distribution of environmental gradients as well.

Additionally, certain of the studied small mammal species of the region, present high endemism or are quite rare and thus their ecology and biology are barely studied up to date. For example, Etruscan shrew is a specie mainly confined in the Mediterranean basin, it is the smallest European mammal and most aspects of its biology and ecology are still unknown. It was supposed to be absent from Thessaly, but it was proved to be distributed broadly in most of the studied localities, and it is quite possible that its population is more abundant than the one demonstrated. Western broad-toothed mouse is a specie strictly endemic of the Balkan peninsula, and is also present in Thessaly although unrecorded before. Macedonian mouse which is mainly a specie of Asia Minor and Middle East is also present only in southern Balkans, and it is also broadly distributed in Thessaly, and finally Thomas's pine vole which is also a specie strictly endemic of the southern Balkans, was also present in western localities of Thessaly.

It is a fact that this broad spatial study which produced all these results couldn’t have been realized in so many localities during three years with the use of live traps, due to serious time limitations. Live trapping in such a vast region, in multiple sites with synchronized trapping efforts and equal trapping nights among localities, would either be impossible to achieve, or would require many volunteers. Moreover, as discussed thoroughly in Chapters 4 and 5, analysis of Barn owl pellets although it has certain limitations as a technique, in agroecosystems like that of Thessaly produces more accurate results in certain aspects. Through the spectrum of the Barn owl diet, a complete recording of small mammal species present in the agroecosystems of central Greece was achieved, along with new information concerning species’ associations with habitat, cultivations, land uses and soil properties. Unfortunately, the absence of organized databases from the National Meteorological Service in respect to temperature and precipitation isolines in the study area, deprived this study from one more valuable environmental gradient, which would certainly function as a significant independent variable on certain species’ distribution, like in so many other studies.

On the other hand, other aspects of small mammal population dynamics cannot be easily assessed through Barn owl pellet analysis. In Chapter 5 seasonal fluctuations of small mammal species were also analyzed in Thessaly, since they are clearly reflected in the owl’s diet. The best fit discussion was realized taking into consideration each species ecological niches, and it was actually proved from seasonal ordination analysis that 4 species were strongly affected from the crop-rotation effect, 5 were secondary affected and to five more the effect was insignificant. In addition, two important differences were revealed, according to which Lesser white-toothed shrew is more abundant during spring and summer in contrast to the majority of Palearctic studies, and it was also suggested that Guenther’s vole probably has a delayed starting date for its breeding season in Thessaly, although the latter derived from theoretical analysis and is not experimentally proved. Nonetheless, in order to study the exact intrinsic demographic mechanisms and density dependent factors which produce these seasonal fluctuations, and explore processes such as immigration, emigration, territoriality, breeding rates, exploitation of food resources, inter and intraspecific competition and many more, in situ detailed live trapping sessions have to be realized in a long term basis.

Moreover, the agroecosystems of Thessaly host an important raptor assemblage which preys on small mammals, from which Lesser kestrel is globally endangered and Barn owl although with unknown population trends in the country, it has been declining all over Europe. Furthermore, since rare and endemic small mammal species which are confined to the Mediterranean Basin and the south of the Balkan Peninsula are also present in the region, another necessary pro-conservation measure is the realization of national and specifically regional surveys, concerning small mammal distribution and population dynamics. Only such well organized bottom-up studies can offer a complete image, analyzing habitat-prey-predator relationships. An additional factor which imposes the need for detailed and long term live-trapping sessions in the agroecosystems of Thessaly, is the phenomenon which was analyzed in 5th Chapter, demonstrating a severe decline in Guenther's vole population in the region during the three year study. Guenther's vole was the most abundant vole and most abundant specie as well, and although it has been recorded in the Balkans that the specie suffers severe declines in its population, it was never studied in a long term basis to see if there is a cyclicity in these population crashes. Specifically in the region of Thessaly it would be of great interest to explore these dimensions, since Guenther's vole in high numbers is considered a pest for agriculture, and in low numbers produces diet shifts in Barn owl and consequently to other species which prey on it as well, probably with negative results.

Finally, and more importantly, very few studies both on raptor and small mammal assemblages have been realized in strictly agricultural and intensively exploited habitats like that of Thessaly. The farmland birds’ decline all over Europe, the multiple factors affecting the complex small mammal assemblages and the way they interact with a seasonally changing agricultural habitat, and the challenge of optimizing agricultural production in a sustainable and environmental friendly way, are reasons for further research and of course the application of concrete conservation measures, in order to halt the loss of biodiversity, in ecosystems highly exploited by man. The present thesis, by studying Barn owl feeding ecology, and through that spectrum the small mammal distribution and seasonal fluctuations, was actually the first long-term research project of such nature to be realized in the largest agroecosystem of Greece. The present work tried and achieved to give answers to many questions discussed above, and set some pillars of knowledge on a priorly non studied environment. As expected of course, with the completion of the thesis even more questions are now raised, oriented nonetheless, to a more concrete direction.

6.7 RESUMEN

6.7.1 Política Agrícola Común (PAC) y temas de biodiversidad

A principios de su fundación, la meta central de la Política Agrícola Común (PAC) ha sido apoyar las cosechas de los agricultores, y asegurar la producción de suficientes productos básicos de alimentación. A lo largo de los años y durante la segunda mitad del siglo XX, gradualmente tuvo lugar un cambio en esta meta principal y ha cambiado a ser una política más comprehensiva, incluyendo también la preservación y el manejo de recursos naturales.

De todos modos, desde 1950 hasta 1980, la PAC y las políticas agrícolas regionales y locales de cada país miembro, produjeron en Europa un manejo de los ecosistemas agrícolas y una explotación intensiva. Consiguientemente, durante las dos ultimas decenas de años, surgieron temas ambientales importantes y relevantes con el manejo de hábitats agrícolas; obligando a la PAC a un cambio de orientación, hacia una producción agrícola más sostenible. Al amanecer del siglo XXI, los problemas de la agricultura intensificada y sus consecuencias negativas en la biodiversidad, junto con la limitación de recursos acuáticos y el cambio climático, volvieron al ser los temas ecológicos principales en el manejo de los ecosistemas agrícolas.

De todos modos, todavía esta en duda si las añadidas consecuencias negativas de tantos años de practicas agrícolas intensificadas, podrían ser evitadas, paradas o invertidas, si políticas agrícolas mas sostenibles empezaron a ser aplicadas.

6.7.2 Ecosistemas agrícolas intensificados y sobrepoblación en Europa del siglo XXI. Enfrentar el reto

El área total de la tierra cultivada ha aumentado a nivel global por 466% desde 1700 hasta 1980. Aunque este aumento ha sido más lento durante los 30 últimos años, los productos agrícolas per unidad de tierra han seguido aumentando dramáticamente. Este logro científico y tecnológico ha sido posible por la intensificación del manejo de hábitats agrícolas y prácticas mecanizadas. Fertilizantes, pesticidas, irrigación y mecanización han sido las armas en esta lucha. Por otra parte, desde 1980 empezaron paralelamente las preocupaciones sobre la sostenibilidad a largo término y las consecuencias ambientales de la intensificación descontrolada de los ecosistemas agrícolas. Hoy en día, ha sido demostrado que la intensificación agrícola produce varias consecuencias negativas en niveles múltiples: A nivel local produce erosión, baja fertilidad del suelo, y reducida biodiversidad; a nivel regional polución de agua subterránea y eutrofización de ríos y lagos, y a nivel global impactos atmosféricos y problemas climáticos.

Al mismo tiempo ha sido predicho que la población humana va a aumentar entre 8 y 10 billones hasta los finales del siglo XXI, y se pone en cuestión si será posible producir adecuados productos de alimento de manera sostenible. La reconciliación de estas dos necesidades contradictorias es el reto principal que tiene que enfrentarse la sociedad científica en el siglo XXI.

6.7.3 Aves en hábitats agrícolas Europeos

La consecuencia negativa más importante de la intensificación agrícola asociada con la PAC a nivel local, regional y global, ha sido la extinción de varias especies de flora y fauna europea. Los procesos mencionados anteriormente, y específicamente la substitución de cereales por cultivos de regadío, con el uso de fertilizantes y pesticidas, el uso excesivo de pastos, la pérdida de hábitats medio-naturales, y el cambio de practicas tradicionales a grandes monocultivos, producen una degradación de hábitat, erosión del suelo, y finalmente un decrecimiento de recursos alimentarios para ambos especies herbívoras y carnívoras que resulto a un decrecimiento de la diversidad.

Estudios recientes demostraron que las aves de hábitats agrícolas Europeos han disminuido un 50% en los últimos 25 años. Estos datos han sido colectados a partir de 20 censos independientes, realizados durante los últimos 25 años en varios países de Europa. Adicionalmente, en el Reino Unido el “Índice de aves comunes” presento datos, desde 1970 hasta 2002, donde las aves de hábitats agrícolas disminuyeron un 42% en el país.

6.7.4 La fauna de Grecia como parte de Europa Mediterránea, Península Balcánica y frontera con Asia Oriental

Desde un punto faunístico y florístico, la proximidad de Grecia con la Península Balcánica, Asia Oriental y su pertenencia a la Cuenca Mediterránea, en combinación con todos los procesos biogeográficos de inmigración, emigración, extinción y endemismo que ocurrieron durante los últimos miles de años, atribuyen a Grecia una biodiversidad existente muy interesante. A nivel Europeo, la riqueza de las especies presenta sus valores máximos en Europa central, mientras tanto las regiones de la Cuenca Mediterránea son las más pobres en este aspecto. Por otra parte, endemismo y rareza demuestran patrones reversos, así la Península Ibérica incluye un alto nivel de endemismo, y la Península Balcánica presenta altos valores de especies raras.

Aunque Grecia presenta una biodiversidad florística y faunística alta, a pesar de los procesos mencionados, muy pocas especies han sido estudiadas en el país hasta hoy en día. Específicamente en los ecosistemas de Grecia central, aunque la presente tesis doctoral ha investigado la ecología trófica de la Lechuza común y los ensamblajes de micromamíferos de la región, aun más rapaces diurnas y nocturnas y otros mamíferos forman el mosaico faunístico, anteriormente no explorado en Tesalia.

6.7.5 Relaciones entre hábitat, depredador y presa en los ecosistemas agrícolas mediterráneos de Grecia central. Proposiciones para conservación

El desconocimiento total de las tendencias anteriores de la población de la Lechuza común hasta hoy en día, no permite cuantificar y calcular si la agricultura intensiva de la zona ha causado algún decrecimiento. La presente tesis ha servido también como el primero censo de la población de la especie en Grecia central. Aunque ha sido anticipado que la Lechuza se nutre principalmente de micromamíferos en la región de Tesalia, lo que es interesante es que los índices de diversidad y la riqueza de las especies en la dieta presentaron los valores más altos en comparación con otras dietas del país y también de la Europa Mediterránea. Este hecho, producido una vez que todos los sesgos han sido eliminados, sugiere que la diversidad de micromamíferos en la zona es baja. Consiguientemente, la Lechuza debe invertir enérgicamente mas tiempo para capturar sus presas. Aunque los topillos dominaron la dieta en ambos términos de frecuencia relativa y biomasa consumida, todos los índices de diversidad han tenido valores altos. Adicionalmente, cuando los topillos aparentemente decrecieron, todos los índices estacionales aumentaron, un hecho que sugiere que los topillos son la presa optima para la Lechuza en Grecia central como también ocurre en otros estudios. Este hecho en combinación con la diversidad baja de los ensamblajes de micromamíferos, sugiere que un posible declive de los topillos podría causar consecuencias negativas en el éxito reproductor de la Lechuza. Por lo tanto, las primeras proposiciones de conservación serian un censo nacional y también regional que debe de establecerse, para el seguimiento de la población de la Lechuza. El censo debe aplicarse a largo término especialmente en nivel local, una vez que Tesalia es el ecosistema agrícola más grande de Grecia, y probablemente sostiene la población más numerosa del país. Es imprescindible registrar todos los lugares naturales de anidamiento en Tesalia, y observar por una serie de años el éxito reproductor de la especie. Si las tendencias son negativas, y la población es limitada, deben instalarse cajas artificiales de anidamiento, que ayudaron en varios países a la recuperación de las poblaciones.

Otro dato preocupante, es el hecho que la Lechuza ha capturado los topillos y especialmente el *M. guentheri* que ha sido el mas abundante, estrictamente en praderas naturales, que ocupan no más del 15% de las áreas estudiadas. Esta selección de hábitat limitado, específicamente durante la época reproductora, probablemente sugiere la necesidad del aumento de la extensión de las praderas naturales o por lo menos de las parcelas de tierra no cultivada y de barbecho, una vez que sostienen la presa optima. Por otra parte, para aplicar con seguridad propuestas parecidas, y para que sea completo el estudio del éxito reproductor de la Lechuza en Tesalia, hay que realizar estudios de las dinámicas de las poblaciones de los micromamíferos en campo.

Esta tesis ha ofrecido información sobre nuevos datos de distribución de micromamíferos, y sus asociaciones con varios gradientes ecológicos. Ha sido la primera vez que especies como *C. suaveolens*, *C. migratorius* y *M. thomasi* demostraron una correlación fuerte con propiedades del suelo y no con tipos de hábitat y usos de tierra. También se demostró que los gradientes latitudinales, longitudinales y altitudinales, jugaron un papel importante en la distribución de otros gradientes ecológicos, y en consecuencia, de varias especies de micromamíferos. Adicionalmente, se demuestra que el cambio estacional del hábitat agrícola ha afectado fuertemente a 3 especies, mientras solo en segundo nivel a otros 5, como se analiza en el Cap. 5. Sin embargo, para explorar en detalle los mecanismos demográficos de inmigración, emigración, y competición intra e interespecífica, sesiones con trampeo en vivo tienen que aplicarse en campo a lo largo de varios años. Solamente así se podrá proponer sugerencias para la conservación de especies en la zona, a través del conocimiento de las interacciones ecológicas entre el hábitat agrícola, los depredadores y sus presas.

El presente trabajo es el primer estudio realizado en un ecosistema anteriormente no explorado, e intenta contestar varias hipótesis ecológicas respecto a la ecología trófica de la Lechuza común, y los ensamblajes de los micromamíferos en la zona. Como ha sido anticipado, más preguntas surgieron con la presente tesis, pero por lo menos, orientadas a una dirección mas concreta.

CHAPTER 7

Conclusions

7.1 Conclusions

1) The Barn owl diet in the agroecosystems of Thessaly depends heavily and exclusively on small mammalian intake, similarly to the majority of the studies realized in global level.
2) In respect to other mainland and insular Barn owl diets from Greece, in the agroecosystems of Thessaly Barn owl diet presented the higher diet diversity among all. That fact suggests strongly that the available small mammal prey assemblages of central Greece demonstrate low diversity.
3) Barn owl diets in wetland ecosystems of northern Greece are mainly comprised from insectivorous small mammal species. On the other hand, the absence of voles from all studied islands' mammalian fauna, produced insular diets which included other prey groups such as avian, reptile and insect species. Nonetheless, Barn owls preyed heavily on a different mammal specie in each island according to the available prey assemblages, presenting thus the lower evenness, diversity and species richness values among all Greek diets.
4) Barn owls in Greece demonstrated an opportunistic predation pattern among all studied regions, according to the existing prey assemblages and the different habitat structures which sustained them. Nonetheless, they also presented a clear optimum foraging technique, when the existing assemblages supported higher mammalian diversity and specifically abundant vole species, which in that case were the mainly captured mammal prey.
5) In the agroecosystems of Thessaly in specific, Barn owl captured 18 different small mammal species and various insect and avian species. On the other hand, the main bulk of its diet both in frequency and biomass terms depended mainly on 5 mammalian species.

6) Voles dominated Barn owl's diet in Thessaly forming 40% in frequency and 50% in biomass terms, with mostly captured specie the Guenther's vole. Both geographical and seasonal trends indicated that voles are the optimum prey. When abundant they dominated the diet, whereas when they decreased in the field all diet diversity indices increased, and other mammalian species as well as other prey groups were captured.
7) In the agroecosystems of Thessaly, Barn owl captured voles strictly in non arable land and specifically in natural grasslands, set-aside fields, or non-arable tree cultivations like orchards and vineyards. Since these habitat types form a minimum percentage of no more than 15% of the studied areas, and at the same time voles also dominated the diet, a strong habitat selection is demonstrated especially during breeding seasons.
8) The second most captured mammal prey in Thessaly in frequency terms were shrews and specifically the Lesser white-toothed shrew. Shrews though compensated minimally the Barn owl in energetic terms, forming 25% and 5% respectively. Unlike the majority of Palearctic studies where shrews are preyed alternatively during non breeding seasons, in contradiction, voles and shrews in Thessaly were both significantly more captured during breeding seasons. A reverse pattern was observed on mice and rats which were significantly more captured during non breeding seasons.
9) Mice were captured at quite diverse habitats, with a reverse pattern to that of voles, not present in arable land. Since the most captured species which were the House mouse and Long-tailed field mouse are opportunistic species and weak competitors, they were preyed in various arable land uses of different type, in both cereal and industrial cultivations.

10) Rats were the less preyed mammalian group in the agroecosystems of Thessaly, forming only 3% in frequency terms. On the other hand they were highly compensating in energetic terms forming 27% of the consumed biomass. Since they were significantly more preyed during non-breeding seasons, Barn owl winter energetics depended highly on rat predation, which is also one of the highest in Mediterranean Europe.
11) For all fifteen small mammal species which were recorded in Thessaly plain, except the order of Chiroptera which was minimally represented, new data demonstrated that they have a broad distribution in the agroecosystems of central Greece where they hadn't been recorded before.
12) Lesser white-toothed shrew was mainly encountered in arable land uses but indifferently of crop types. It was found both in cereal and industrial crops, whereas it was mainly attached to soil properties and specifically in areas with Vertisol soil types and argillaceous-clay texture, and also in locations above 150m. It presented significantly higher numbers in southern-central localities of Thessaly.
13) Etruscan shrew was mainly encountered in cereal crops with absence of irrigation schemes, which also specifically grow in areas with Vertisol soil types. It presented significantly higher numbers in southern-central localities of Thessaly.
14) Guenther's vole avoided strongly both cereal and industrial crops and generally arable land uses. It was mainly encountered in non arable land uses and specifically in natural grasslands, as well as in set-aside fields, fallow land, and in non-arable, or even lightly arable crops such as tree cultivations

and vineyards. It presented significantly higher numbers in north-eastern locations of Thessaly in locations with altitudes lower than 150m.

15) Thomas's pine vole avoided strongly all areas with Entisol, Mollisol, Vertisol and Inceptisol soil types, whereas it was mainly encountered in areas with Alfisol soil types and sandy-clay texture. It also presented significantly higher numbers in industrial cultivations with irrigation schemes. Its population increased significantly in western areas of Thessaly located below 200m, where it was also strictly confined.
16) Gray dwarf hamster was mainly encountered in areas with Entisol and Mollisol soil types with argillaceous-clay texture. It also presented higher numbers in arable land uses indifferently though of cereal or industrial cultivations, and it avoided localities with dense river networks. Its population increased significantly in eastern locations of Thessaly with altitudes higher than 150m, where it was also strictly confined.
17) House mouse was mainly encountered in arable land uses both in cereal and industrial cultivations, whereas it avoided strongly other crop types and land uses. It presented significantly higher numbers in south-western locations of Thessaly.
18) Black rat was mainly encountered in areas with large road networks, and it also avoided strongly areas with Alfisol soil types, whereas its numbers increased significantly towards areas with Inceptisol soil types.
19) The seasonal crop rotation which produces a strong change in the habitat scenery in the agroecosystems of Thessaly, affected strongly 3 small mammal species: Lesser white-toothed shrew, Thomas's pine vole and Macedonian mouse.

20) Once the harvest of both cereal and industrial crops was completed after September, Lesser white-toothed shrew’s main population remained in the “naked” arable land, without vegetation cover and vulnerable to predation. During all seasons though the specie was mainly attached to soil properties and not to land uses or habitat types, and in autumn and winter its numbers also decreased significantly.
21) During spring and summer Thomas’s pine vole exploited mainly industrial cultivations in arable land, and specifically cotton which dominated the area. Nonetheless, although the specie always remained attached to specific soil properties, after September’s harvest its habitat niche was differentiated strongly, and was present in non arable cultivated land such as tree cultivations and horticultures, which occupy minimum extensions in the studied areas.
22) Macedonian mouse during spring and summer seasons had higher numbers in fields with arable land uses indifferently of crop types, whereas after the harvest of both cereal and industrial cultivations it moved to dense roadside bushy vegetation.

7.2 Conclusiones

1) La dieta de la Lechuza común en ecosistemas agrícolas de Tesalia (Grecia central) depende exclusivamente de la captura de micromamíferos, similar a lo encontrado en la mayoría de estudios realizados a nivel mundial.
2) Comparando con las dietas insulares, y de Grecia continental, la dieta de la Lechuza en ecosistemas agrícolas de Tesalia, tiene valores más altos de diversidad de especies. Este hecho sugiere fuertemente que la diversidad de las

comunidades de micromamíferos en Grecia central demuestran una diversidad baja.

3) La dieta de la Lechuza común en hábitats acuáticos del norte de Grecia, esta principalmente constituida por especies de micromamíferos insectívoros. Por otra parte, la ausencia de topillos de la fauna de las islas estudiadas, ha provocado dietas insulares que incluyen otros grupos de presas, como aves, reptiles e insectos. Sin embargo, la Lechuza común se alimenta en cada isla principalmente de una diferente especie de micromamíferos, siempre según los ensamblajes existentes, dando valores más bajos de diversidad, riqueza de especies y equitabilidad, en comparación con las demás dietas estudiadas en el país.
4) La Lechuza común en Grecia demuestra un patrón de depredación oportunista en todas las regiones estudiadas. Sin embargo, también presenta una técnica óptima para cazar, cuando los ensamblajes sostuvieron una diversidad de micromamíferos alta, y especialmente cuando incluyen especies de topillos en abundancia, los cuales en este caso han sido la presa principalmente capturada.
5) En ecosistemas agrícolas de Tesalia, la Lechuza ha capturado 18 diferentes especies de micromamíferos, y varias especies de aves e insectos. Por otra parte, en ambos términos de frecuencia relativa y biomasa consumida, su dieta esta principalmente basada en 5 especies de micromamíferos.
6) Los topillos dominan la dieta de la Lechuza, formando el 40% de la frecuencia relativa y el 50% de la biomasa consumida. La especie mas capturada es *Microtus guentheri*. Las tendencias geográficas y estacionales indican que los topillos son la presa óptima. Cuando son abundantes, dominan la dieta,

mientras cuando disminuyen, todos los índices de diversidad aumentan, porque otras especies de micromamíferos son también capturadas.

7) En los ecosistemas agrícolas de Tesalia, la Lechuza captura topillos estrictamente en praderas naturales, parcelas de tierra no cultivadas, o cultivos de arboles no aradas, huertas y viñedos. Dado que estos hábitats forman un porcentaje menor al 15% de las áreas estudiadas, y al mismo tiempo los topillos dominan la dieta, una fuerte selección de hábitat esta demostrada para la Lechuza, especialmente durante la época de reproducción.

8) El segundo grupo de presas más capturadas en términos de frecuencia relativa han sido las musarañas, y específicamente *Crocidura suaveolens*. No obstante, las musarañas compensan de manera mínima, en términos energéticos, formando el 25% y el 5% respectivamente. En contraste con la mayoría de los estudios Paleárcticos, donde las musarañas son capturadas alternativamente durante la época no reproductora, en Tesalia, topillos y musarañas han sido significativamente más capturados en la época de reproducción. Un patrón reverso ha sido observado en la captura de ratas y ratones, los cuales han sido significativamente más cazados durante la época no reproductora.

9) Los ratones han sido cazados en hábitats diversos, con un patrón contrario al de topillos, y no están presentes en tierra no arada. Las especies más capturadas son *Mus musculus* y *Apodemus sylvaticus*, dado que son especies generalistas, son cazados en diferentes tipos de tierra arada, cereales y cultivos industriales.

10) Las ratas son el grupo menos cazado en los ecosistemas agrícolas de Tesalia formando solamente el 3% de la frecuencia relativa. Por otra parte,

compensaron en términos energéticos con el 27% de la biomasa consumida. Como han sido significativamente más capturadas durante la época no reproductora, en términos energéticos la Lechuza depende fuertemente de la depredación de ratas, que también aparece como una de las más altas en la Cuenca Mediterránea.

11) Para las 15 especies de micromamíferos documentadas en la llanura de Tesalia, excepto el orden Chiroptera que fue apenas representada, se ofrecen nuevos datos, demostrando una distribución más amplia en los ecosistemas agrícolas de Grecia central, y no registrada anteriormente.

12) *Crocidura suaveolens* se encuentra principalmente en tierra arada con indiferencia del tipo de cultivo; tanto cereales como cultivos industriales, pero al mismo tiempo esta significativamente ligada con las propiedades del suelo. Específicamente en suelos tipo Vertisol de textura arcillosa, y en localidades de altitud superiores a los 150msnm. Su población presento números más altos en localidades del sur y en Tesalia central.

13) *Suncus etruscu*s es principalmente encontrada en cultivos de cereales con ausencia de regadío, los cuales maduran sobre suelos de tipo Vertisol. Ha presentado números significativamente más altos en localidades centrales y del sur.

14) *Microtus guentheri* evita áreas cerealistas y de cultivos industriales, y en general, la tierra arada. Ha sido principalmente encontrado en praderas naturales, barbechos, viñedos, arbolados y otras parcelas de tierra no cultivadas. Presenta números significativamente más altos en localidades de Tesalia norte-oriental, en altitudes menores que los 150 msnm.

15) *Microtus thomasi* evita todas las áreas que incluyen suelos de tipo Mollisol, Vertisol, Entisol y Inceptisol; mientras es principalmente encontrado en localidades con suelo Alfisol de textura arenosa. También tiene números significativamente más altos en cultivos industriales de regadío. Su población aumenta hacia localidades del oeste, donde se recluye en altitudes menores de 200 msnm.
16) *Cricetulus migratorius* se encuentra en áreas con suelo Entisol y Mollisol, de textura arcillosa. Presenta números más elevados en tierra arada indiferentemente al tipo de cultivo, cereales o cultivos industriales, y evita localidades con red densa de ríos. Su población aumenta significativamente en localidades de Tesalia oriental, en altitudes superiores a los 150msnm.
17) *Mus musculus* se presenta en tierra arada, con cultivos cerealistas o industriales. Evita otros tipos de cultivos y usos de tierra. Presenta significativamente números más elevados en localidades del suroeste
18) *Rattus rattus* se encuentra en áreas que incluyen una red de carreteras túpida, y evita áreas con suelos del tipo Alfisol. Su población aumenta significativamente hacia localidades con suelos de tipo Inceptisol.
19) La rotación estacional de cultivos en la llanura de Tesalia, produce un cambio sustancial en el hábitat de los ecosistemas agrícolas que forman la vegetación de la región, y afecta fuertemente a un total de 3 especies: *Crocidura suaveolens, Microtus thomasi* y *Mus macedonicus*.
20) Cuando la cosecha de cultivos cerealistas y industriales se completa en Septiembre, la población principal de *Crocidura suaveolens* permanece en tierra arada "desnuda", sin cobertura vegetal y vulnerable a la depredación. Durante todas las estaciones la especie esta principalmente ligada a las

propiedades del suelo y no al uso de la tierra ó tipo de hábitat. Durante otoño e invierno sus números decrecen significativamente.

21) En primavera y verano *Microtus thomasi* explota principalmente cultivos industriales, específicamente cultivos de algodón que es el tipo de hábitat dominante. Sin embargo, y aunque la especie permanece ligada a las propiedades del suelo, después de Septiembre su selección de hábitat se transforma, y elige áreas cultivadas no aradas como arbolados y vegetales, las cuales ocupan mínimas extensiones en la región.

22) Durante primavera y verano, *Mus macedonicus* tiene números elevados en tierra arada, indiferentemente del tipo de cultivo. Después de la cosecha de cultivos de cereales y industriales, se traslada a la vegetación densa en la cuneta de carreteras.

BIBLIOGRAPHICAL REFERENCES

Abramsky Z. 1981. Habitat relationships and competition in two Mediterranean Apodemus species. *Oikos, 36: 219-225*

Agnelli P. & Marinis M.A. 1992. Comparison between barn owl pellet and fox scat analysis in small mammal survey. *Hystrix, 4(2): 65-68*

Akriotis T. 1981. Food ecology of five sympatric owls. First Degree Dissertation, University of Exeter. 32 pp

Alasdair R.L., Webon C., Glue E.D. & Harris S. 2000. Changes in the food of British Barn Owls (*Tyto alba*) between 1974 and 1997. *Mammal Review, 30(2): 107-129*

Alcantara M. 1998. Los insectívoros, Pp: 39-113 & 433-442, in: Juan Carlos Blanco (Ed), Mamíferos de España I. Insectivoros, Quiropteros, Primates y Carnivoros de la peninsula Iberica, Baleares y Canarias. Editorial Planeta, Barcelona. 464 pp

Alcantara M. & Telleria J.M. 1991. Habitat selection of the Wood mouse (*Apodemus sylvaticus*) in cereal steppes of Central Spain. *Zeitschrift für Säugetierkunde, 56: 347-351*

Alegre J., Hernandez A., Purroy F. & Sanchez A. 1989. Distribución altitudinal y patrones de afinidad trófica geográfica de la Lechuza común (*Tyto alba*) en Leon. *Ardeola, 36(1): 41-54*

Alivizatos H. & Goutner V. 1999. Winter diet of the Barn owl (*Tyto alba*) and Long eared owl (*Asio otus*) in Northeasten Greece: A comparison. *Journal of Raptor Research, 33(2): 160-163*

Alivizatos H., Goutner V. & Zogaris S. 2005. Contribution to the study of the diet of four owl species (Aves, Strigiformes) from mainland and island areas of Greece. *Belgian Journal of Zoology, 135(2): 109-118*

Alivizatos H., Goutner V., Athanasiadis A. & Poirazidis K. 2006. Comparative temporal prey use by Barn owl (*Tyto alba*) and little owl (*Athene noctua*) in the Evros Delta, northeastern Greece. *Journal of Biological Research, 6: 177-186*

Amori G. 1999. Chionomys nivalis (Martins, 1842). Pp: 256-257, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Amori G. & Cristaldi M. 1999a. Rattus norvegicus (Berkenhout, 1769). Pp: 278-279, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Amori G. & Cristaldi M. 1999b. Rattus rattus (Linnaeus, 1758). Pp: 280-281, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Andera M. 1999. Sorex araneus (Linnaeus, 1758). Pp: 42-43, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Angelici F., Latella L., Luiselli L. & Riga F. 1997. The summer diet of the Little owl (*Athene noctua*) on the island of Astipalaia (Dodecanese, Greece). *The Journal of Raptor Research, 31(3): 280-282*

Angelici F.M. & Riga F. 1994. Primi dati sull' alimentazione del Barbagianni Tyto alba nell' isola Astypalaia (Dodecanisa, Grecia). *Atti Convegno Italiano di Ornitologia, 6: 419-420*

Archibold O.W. 1995. Ecology of World Vegetation. Chapman & Hall, London U.K. 528 pp

Arrizabalaga A. & Torre I. 2002. Apodemus flavicollis (Melchior, 1834). Pp: 400-403, in: Palomo J. & Gisbert J. (Eds), Atlas de los mammiferos terrestres de España. Ministerio de Medio Ambiente. Dirección General de la Conservación de la Naturaleza. 564 pp

Atallah S.I. 1978. The mammals of the Eastern Mediterranean region: Their ecology, systematics and zoogeographical relationships (Part 2). *Säugetierkundliche Mitteilungen, 26: 1-50*

Auffray J.C., Marshall J.T., Thaler L. & Bonhommer F. 1990. Focus on the nomenclature of European species of Mus. *Mouse Genome, 88: 7-8*

Auffray J.C., Tchernov E., Bonhomme F., Heth G., Simson S. & Nevo E. 1990. Presence and ecological distribution of Mus spretoides and Mus musculus domesticus in Israel. Circum- Mediterranean variance in the genus Mus. *Zeitschrift für Säugetierkunde, 55: 1-10*

Avery D. M., Avery G. & Palmer N. G. 2005. Micromammalian distribution and abundance in the Western Cape Province, South Africa, as evidenced by Barn owls *Tyto alba* (Scopoli). *Journal of Natural History, 39(22): 2047-2071*

Bagnouls F. & Gaussen H. 1952. L' indice xerothermique. *Bulletin de la Association Geographique de France, Paris. Janv-Fev: 222-223*

Bakaloudis D. 2000. The ecology of short toed eagle (*Circaetus gallicus*) in Dadia - Lefkimi - Soufli forest complex, Thrace, Greece. Phd Thesis. University of Reading, School of Animal and Microbial Sciences, Division of Zoology. 162 pp

Baleiauskiene L., Jovaidas A., Narudevieius V., Petradka A. & Skuja S. 2006. Diet of the Tawny owl (*Strix aluco*) and Long eared owl (*Asio otus*) in Lithuania as found from pellets. *Acta Zoologica Lituanica, 16(1): 37-45*

Baquero R.A. & Telleria J.L. 2001. Species richness, rarity and endemicity of European mammals: a biogeographical approach. *Biodiversity and Conservation, 10: 29-44*

Barbosa A., Lopez-Sanchez M.J. & Nieva A. 1992. The importance of geographical variation in the diet of *Tyto alba* Scopoli in central Spain. *Global Ecology and Biogeography Letters, 2: 75-81*

Barome P.O., Lymberakis P., Monnerot M., & Gautun J.C. 2001. Cytochrome b sequences reveal Acomys minous (Rodentia, Muridae) paraphyly and answer the question about the ancestral karyotype of Acomys dimidiatus. *Molecular Phylogenetics and Evolution, 18(1): 37-46*

Barret G.W. & Peles J.D. 1999. Landscape Ecology of Small Mammals. Springer Verlag, New York. 372 pp

Baudvin H. 1975. Biologie de reproduction de la Chouette Effraie (*Tyto alba*) en Cote d'Or: premier resultats. *Le Jean le Blanc14: 1-51*

Baudvin H. 1983. La regime alimentaire de Chouette Effraie (*Tyto alba*). *Le Jean le Blanc, 22: 1-108*

Baudvin H. 1986. Le reproduction de la Chouette Effraie (*Tyto alba*). *Le Jean le Blanc, 25: 1-125*

Baverstock P.R., Adams M., Maxson L.R. & Yosida T.H. 1983. Genetic differentiation among karyotypic forms of the Black rat (*Rattus rattus*). *Genetics, 105(4): 969-983*

Becker K.A. 1978a. Rattus norvegicus - Wanderratte (Berkenhout, 1769). Pp: 401-420, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas. Band 1/I, Rodentia I. Akademische Verlagsgesellschaft, Wiesbaden. 476 pp

Becker K.B. 1978b. Rattus rattus - Hausratte (Linnaeus, 1758). Pp: 382-399, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas. Band 1/I, Rodentia I. Akademische Verlagsgesellschaft, Wiesbaden. 476 pp

Behboudi A., Roshani L., Kost-Alimova M., Sjostrand E., Montelius-Alatalo K., Rohme D., Klinga-Levan K. & Stahl F. 2002. Detailed chromosomal and radiation hybrid mapping in the proximal part of rat chromosome 10 and gene order comparison with mouse and human. *Mammalian Genome, 13: 302-309*

Belcheva R.G., Topashka-Ancheva M.N. & Atanasov N.I. 1992. Chromosome polymorphism in the Norway rat (*Rattus norvegicus*, Berk 1769) populations in Bulgaria. *Acta Zoolobica Bulgarica, 44: 36-43*

Bellocq M.I. 1998. Prey selection by breeding and non breeding Barn Owls in Argentina. *The Auk, 115(1): 224-229*

Bellocq M.I. 2000. A review of the trophic ecology of the Barn owl in Argentina. *Journal of Raptor Research, 34(2): 108-119*

Bennett A.F. 1990. Habitat corridors and the conservation of small mammals in a fragmented forest environment. *Landscape ecology, 4(2/3): 109-122*

Berry R.J. 1981. Population dynamics of the House mouse. Pp: 395-425, in: Berry R.J. (Ed), Biology of the House mouse. Academic Press, London. 715 pp

Besenecker H., Spitzenberger F. & Storch G. 1972. Eine holozane Kleinsauger Fauna von der Insel Chios, Agais (Mammalia: Insectivora, Rodentia). *Senckenbergiana Biologica, 53: 145-177*

Birks H.J.B., Indrevaer N.E. & Rygh C. 1998. An annotated bibliography of canonical correspondence analysis and related constrained ordination methods (1996 - 1998). Bergen, Norway, Botanical Institute, University or Bergen. 62 pp

Birks H.J.B., Peglar S.M. & Austin H.A. 1996. An annotated bibliography of canonical correspondence analysis and related constrained ordination methods (1986 – 1993). *Abstracta botanica, 20: 17-36*

Blaker G.B. (Ed) 1934. The Barn owl in England and Wales. RSPB. 15 pp

Blanco J.C. (Ed) 1998a. Mamíferos de España I. Insectívoros, Quirópteros, Primates y Carnívoros de la Península Ibérica, Baleares y Canarias. Planeta S.A., Barcelona. 460 pp

Blanco J.C. (Ed) 1998b. Mamíferos de España II. Cetáceos, Artiodáctilos, Roedores y Lagomorphos de la Península Ibérica, Baleares y Canarias. Planeta S.A., Barcelona. 384 pp

Blondel J. & Aronson J. (Eds) 1999. Biology and wildlife of the mediterranean region. Oxford University Press, Oxford. 350 pp

Bohme W. 1978a. Micromys minutus - Zwergmaus (Pallas, 1771). Pp: 290-304, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas. Band 1/I, Rodentia I. Akademische Verlagsgesellschaft, Wiesbaden. 476 pp

Bohme W. 1978b. Apodemus agrarius - Brandmaus (Pallas, 1771). Pp: 368-381, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas. Band 1/I, Rodentia I. Akademische Verlagsgesellschaft, Wiesbaden. 476 pp

Bohr H.J. 1962. Zur kenntis der vogelwelt von Korfu. *Bonner Zoologische Beiträge, 13: 50-114*

Bond G., Burnside N.G., Metcalfe D.J., Scott D.M. & Blamire J. 2004. The effects of land use and landscape structure on Barn owl (*Tyto alba*) breeding success in southern England, UK. *Landscape Ecology, 20: 555-566*

Bonhomme F., Catalan J., Britton-Davidian J., Chapman V., Moriwaki K., Nevo E. & Thaler L. 1984. Biochemical diversity and evolution in the genus Mus. *Biochemical Genetics, 22: 275-303*

Bontzorlos A.V., Salvador J.P, Vlachos G.C., Bakaloudis E.D. 2005. The diet of Barn owl in the agricultural landscapes of central Greece. *Folia Zoologica, 54(1-2): 99-110*

Bontzorlos V., Peris S.J., Vlachos C.G., & Bakaloudis D.E. 2007a. The trophic ecology of Barn owl (*Tyto alba*, Scopoli 1769) in Greece: Review and comparisons. World Owl Conference, Groningen, Netherlands, 31 October - 4 November, 2007. (Oral presentation)

Bontzorlos V., Peris S.J., Vlachos C.G., & Bakaloudis D.E. 2007b. High Brown and Black rat (*Rattus norvegicus* & *R. rattus*) biomass contribution in the Barn owl diet during non-breeding season in Central Greece, Thessaly. *Hystrix, The Italian Journal of Mammalogy Vol II, Supp: 66*

Bontzorlos V., Peris S.J., Vlachos C.G., & Bakaloudis D.E. 2007c. Barn owl (*Tyto alba*, Scopoli 1769) winter energetics highly depend upon rat predation: The case of Thessaly, Central Greece. World Owl Conference, Groningen, Netherlands, 31 October - 4 November, 2007. (Oral presentation)

Bontzorlos V., Peris S.J., Vlachos C.G., & Bakaloudis D.E. 2007d. Is the Pygmy white-toothed shrew (*Suncus etruscus*) a common and abundant specie in Central Greece? *Hystrix, The Italian Journal of Mammalogy, Vol II, Supp: 193*

Bontzorlos V., Peris S.J., Vlachos C.G., & Bakaloudis D.E. 2007e. New data on the distribution of three Insectivora species in Thessaly, central Greece. In: "*VIII Jornadas de la SECEM, Huelva 2007 – (Congress of the Spanish Society of Mammalogists)*". Page 23. Huelva, Spain, 5-8 December, 2007. (Poster presentation)

Bontzorlos V., Peris S.J., Vlachos C.G., & Bakaloudis D.E. 2009a. The trophic ecology of Barn owl (*Tyto alba*, Scopoli 1769) in Greece: Review and comparisons. *Ardea (in press)*

Bontzorlos V., Peris S.J., Vlachos C.G., & Bakaloudis D.E. 2009b. Barn owl (*Tyto alba*, Scopoli 1769) winter energetics highly depend upon rat predation: The case of Thessaly, Central Greece. *Ardea (in press)*

Bonvicino C.R. & Bezerra M.R.A. 2003. Use of regurgitated pellets of Barn Owl (*Tyto alba*) for inventorying small mammals in the Cerrado of Central Brazil. *Studies on Neotropical Fauna and Environment, 38(1): 1-5*

Bousbouras D. 1999. Study of Apodemus sylvaticus and Apodemus flavicolis [flavicollis] habitat occupation at the Dadia Forest Reserve. Contribution to issues concerning the conservation of raptors. *Biologia Gallo Hellenica, 25(1): 3-14*

Bousbouras D. 2005. Report on the ornithological evaluation of the areas "GR056 Tirnavos area" and "GR062 Thessaly plain" and ""GR063 Farsala area" for their characterization as Areas of Special Protection. Appendix IV of the Ornithological Evaluation report of 10 important areas for bird species, for their characterization as Special Protection Areas. Hellenic Ministry for the Environment, Physical Planning and Public Works, and Hellenic Center of Wetlands. 62 pp

Braaksma S. & De Bruijn. 1976. De Kerkuilstand in Nederland (New data on Barn owls Tyto alba in the Nederlands). *Limosa, 49: 135-187*

Brown B.M. & Forsythe B.A. 1974. The Anova and multiple comparisons for data with heterogeneous variances. *Biometrics, 30(4): 719-724*

Brown D.J. 1981. Seasonal variations in the prey of some Barn owls in Gwynedd. *Bird Study, 28: 139-146*

Brunet-Lecompte P. & Delibes M. 1984. Alimentación de la Lechuza común *Tyto alba* en la cuenca del Duero, España. *Doñana Acta Vertebrata, 11: 213-229*

Buechner M. 1989. Are small-scale landscape features important factors for field studies of small mammal dispersal sinks? *Landscape Ecology, 2(3): 191-199*

Bunn D.S., Warburton A.B. & Wilson R.D.S. (Eds) 1982. The Barn owl. Buteo Books, Vermillion, SD. 264 pp

Burke J. & Taylor N. 2002. Small mammal survey on agricultural land during conversion and into full organic production. Pp: 253-254, in: UK Organic Research 2002, Proceedings of the COR Conference, 26-28th March 2002, Aberystwyth

Burton J.A. 1984. Owls of the world. Tanager Books, Dover, NH. 208 pp

Bury R.B. 1972. Small mammals and other prey in the diet of the pacific giant salamander (*Dicamptodon ensatus*). *American Midland Naturalist, 87(2): 524-526*

Campbell R.W., Manuwal D.A. & Harestad A.S. 1987. Food habits of the common Barn owl in British Columbia. *Canadian Journal of Zoology, 65: 578-586*

Capizzi D. & Luiselli L. 1995. Comparison of the trophic niche of four sympatric owls (*Asio otus*, *Athene noctua*, *Strix aluco* and *Tyto alba*) in Mediterranean central Italy. *Ecologia Mediterranea, 21: 13-20*

Capizzi D., Caroli L. & Varuzza P. 1998. Feeding habits of sympatric Long eared owl *Asio otus*, Tawny owl *Strix aluco* and Barn owl *Tyto alba* in a Mediterranean coastal woodland. *Acta Ornithologica, 33(3-4): 85-91*

Capula M. & Luiselli L. 1990. Analysis of the gut contents of *Vipera aspis* (Reptilia, Viperidae) from an area of central Italy (Tolfa mountains, Latium): A new method to study the terrestrial small mammals. *Hystrix, 2: 101-107*

Catalissano A. & Massa B. 1987. Considerations on the structure of the diet of the Barn owl (*Tyto alba*) in Sicily (Italy). *Bollettino di Zoologia, 54(1): 69-73*

Catzeflis F. 1983a. Relations genetiques entre trois especes de genre Crocidura (Soricidae, Mammalia) en Europe. *Mammalia, 47: 229-236*

Catzeflis F. 1983b. Analyse cytologique et biochimique des Crocidures de L' Ile de Chypre (Mammalia: Insectivora). *Revue Suisse de Zoologie, 90: 407-415*

Catzeflis F. 1984. Systematique biochimique, taxonomie et phylogynie des musaraignes d' Europe (Soricidae, Mammalia). These. Universite de Lausanne, Suisse

Catzeflis F., Graf J.D., Hausser J. & Vogel P. 1982. Comparison biochimique des musaraignes du genre Sorex en Europe occidentale (Soricidae, Mammalia). *Zeitschrift für Zoologische Systematik und Evolutionsforschung, 20: 223-233*

Catzeflis F., Maddalena T., Hellwing S. & Vogel P. 1985. Unexpected findings on the taxonomic status of east mediterranean Crocidura russula (Mammalia: Insectivora). *Zeitschrift für Säugetierkunde, 50: 185-201*

Cayford J. 1992. Barn Owl ecology on East Anglian farmland. *RSPB Conservation Review, 6: 45-50*

Chaline J. & Graf J.D. 1988. Phylogeny of the Arvicolidae (Rodentia): biochemical and paleontological evidence. *Journal of Mammalogy, 69: 22-33*

Chaline J., Baudvin H., Jammot D. & Saint-Girons M.C. 1974. Les proies des rapaces. Petits mammiferes et leur environnement. Doin, Paris. 141 pp

Chauveau L. 2005. Petit atlas des risques ecologiques. Larousse, Paris. 128 pp

Chaworth M.J. 1934. A contribution to our knowledge of the mammals of Macedonia and Thessaly. *Annals and Magazine of Natural History, 9: 166-171*

Cheylan G. 1976. La regime alimentaire de la Chouette effraie (*Tyto alba*) en Europe Mediterraneene. *Terre Vie (Revue Ecol), 4: 565-579*

Cheylan G. 1991. Patterns of Pleistocene turnover, current distribution and speciation among Mediterranean mammals. Pp: 227-262, in: Groves R.H. & Di Castri F. (Eds), Biogeography of Mediterranean Invasions. Cambridge University Press, Cambridge. 504 pp

Chinery M. 1993. Field guide to insects of Britain and Europe. Harper Collins Publishers. 320 pp

Chondropoulos B.P., Franguedakis-Tsolis S.E. & Giagia-Athanasopoulou E.B. 1994. The taxonomic status of the Cretan wild house mouse (genus Mus L.), a morphological and immunological approach. *Bios-(Thessaloniki), 2: 273-274*

Chondropoulos B.P., Franguedakis-Tsolis S.E., Markakis G. & Giagia-Athanasopoulou E.B. 1996. Morphometric variability in karyologically polymorphic populations of the wild Mus musculus domesticus in Greece. *Acta Theriologica, 41(4): 375-382*

Clark D.R. & Bunck C.M. 1991. Trends in North American small mammals found in common barn owl (*Tyto alba*) dietary studies. *Canadian Journal of Zoology, 69: 3093-4002*

Cohen-Shlagman L., Hellwing S. & Yom-Tov Y. 1984. The biology of the Levant mole, *Microtus guentheri* in Israel. II. The reproduction and growth in captivity. *Zeitschrift für Säugetierkunde, 49: 148-156*

Cohen-Shlagman L., Yom-Tov Y. & Hellwing S. 1984. The biology of the Levant mole, *Microtus guentheri* in Israel. I. Population dynamics in the field. *Zeitschrift für Säugetierkunde, 49: 135-147*

Colak E., Sozen M. & Yigit N. 1998. A Study on Ecology and Biology of *Microtus guentheri* Danford and Alston, 1880 (Mammalia: Rodentia) in Turkey. *Turkish Journal of Zoology, 22: 289-295*

Collado A., Gonzalez M. & Peris.J.S. 2004. Clave osteologica de las aves mas observadas en campo. Universidad de Salamanca. 72 pp

Collins R.J. & Barrett G.W. 1997. Effects of habitat fragmentation on meadow vole (*Microtus pennsylvanicus*) population dynamics in experiment landscape patches. *Landscape Ecology, 12(2): 63-76*

Colvin B.A. 1984. Barn owl foraging behavior and secondary poisoning hazard from rodenticide use on farms. PhD Thesis. Bowling Green State University

Colvin B.A. 1985. Common Barn owl population decline in Ohio and the relationship to agricultural trends. *Journal of Field Ornithology, 56: 224-235*

Colvin B.A. & McLean E.B. 1986. Food habits and prey specificity of the common Barn owl in Ohio. *Ohio Journal of Science, 86: 76-80*

Colwell R.K. & Futuyma D.J. 1971. On the measurement of niche breadth and overlap. *Ecology, 52: 567-576*

Contoli L., Agostini F., Aloise G. & Testa A. 1983. On the relationship between terrestrial small mammals and the Barn owl (*Tyto alba* Scopoli). *Accademia Nazionale dei Lincei Quaderni, 256: 182-288*

Cooke A.S., Bell A.A. & Haas M.B. 1982. Predatory birds, pesticides and pollution. Institute of Terrestrial Ecology, Cambridge. 74 pp

Cooke D., Nagle A.S., Fairley P. & Muircheartaigh J. 1996. The diet of the Barn owl (*Tyto alba*) in County Cork in relation to land use. *Proceedings of the Royal Irish Academy, 2: 97-111*

Costello A.B. & Osborne J.W. 2005. Best practices in exploratory Factor Analysis: Four recommendations for getting the most from your analysis. *Practical Assessment, Research & Evaluation, 10(7): 1-9*

Council of Europe. 1979. Convention on the conservation of European wildlife and natural habitats (Bern Convention)

Cramp S. & Simmons K.E.L. 1985. Handbook of the birds of Europe, the Middle East and North Africa: The birds of the western Palearctic. Volume IV: Terns to Woodpeckers. Oxford University Press, Oxford, UK. 960 pp

Cuisin J. & Cuisin M. 1979. Le regime alimentaire de la Chouette Effraie (*Tyto alba*) dans le canton de Riceys et ses environs immediats. *Orfo, 49: 81-89*

D'Andrea P.S., Gentile R., Maroja L.S., Fernandes F.A., Coura R. & Cerqueira R. 2007. Small mammal populations of an agroecosystem in the Atlantic Forest domain, southeastern Brazil. *Brazilian Journal of Biology, 67(1): 179-186*

Dawe N.K., Runyan C.S. & McKelvey R. 1978. Seasonal food habits of the Barn owl (*Tyto alba*) on the Alaskan National Wildlife Area, British Columbia. *Canadian Field Naturalist, 92: 151-155*

De Bruijn O. 1979. Feeding ecology of the Barn owl in the Netherlands. *Limosa, 52: 91-154*

De Bruijn O. 1994. Population ecology and conservation of the Barn owl in farmland habitats in Liemers and Achterhoek (the Netherlands). *Ardea, 82: 5-109*

De Jong J. 1983. De Kerkuil. Kosmos, Utrecht. 77 pp

De Wavrin H. 1977. Diminution des effectifs de Chouette Effraie (*Tyto alba*) en moyenne Belgique. *L' Homme et l' Oiseau, 15: 19-22*

DEFRA (Department for Environment, Food and Rural Affairs. Research and Development). 2004. Maximising the biodiversity value of farm woodlands to the agri-environment. Project Report. Central Science Laboratory, Sand Hutton, York. 22 pp

Del Hoyo J., Elliott A. & Sargatal J. 1998. Handbook of the Birds of the World, vol. 5: Barn owls to Hummingbirds. Lynx Editions, Barcelona. 760 pp

Delattre P., Giraudoux P., Baudry J., Quere J.P. & Fichet E. 1996. Effect of landscape structure on Common Vole (*Microtus arvalis*) distribution and abundance at several space scales. *Landscape Ecology, 11(5): 279-288*

Delibes J. 1985. Distribution and abundance of small mammals in a gradient of elevation. *Acta Zoologica Fennica, 173: 53-56*

Diaz, M., Asensio, B. y Telleria, J.L. 1996. Aves Ibericas. I. No paseriformes. J.M. Reyero (Ed). Madrid. 304 pp

Dickman C.R. 1987. Habitat fragmentation and vertebrate species richness in an urban environment. *Journal of Applied Ecology, 24: 337-351*

Dickman C.R., Daly S.E.J. & Connell G.W. 1991. Dietary relationships of the Barn Owl and Australian Kestrel on Islands of the coast of Western Australia. *Emu: Austral Ornithology, 91(2): 69-72*

Dieterlen F. 1963. Zur kenntnis der Kreta Stachelmaus, Acomys (cahirinus) minous Bate 1906. *Zeitschrift für Säugetierkunde. 28: 47-57*

Dieterlen F. 1978. Acomys minous - Kreta Stachelmaus (Bate, 1906). Pp: 452-461, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas. Band 1/I, Rodentia I. Akademische Verlagsgesellschaft, Wiesbaden. 476 pp

Diffendorfer J.E., Slade N.A., Gaines M.S. & Holt R.D. 1995. Population dynamics of small mammals in fragmented and continuous old-field habitat. Pp: 175-199, in: W.Z. Lidicker Jr (Ed), Landscape approaches in mammalian ecology and conservation. University of Minnesota Press, Minneapolis, Minnesota. 215 pp

Dimaki M. 1999. First record of the Edible dormouse Glis glis (Linnaeus, 1766), from the Greek island of Andros. *Annales Musei Goulandris, 10: 181-183*

Donazar J.A., Hiraldo F., Delibes M. & Estrella R.R. 1989. Comparative food habits of the Eagle Owl *Bubo bubo* and the Great Horned owl *Bubo virginianus* in six Palearctic and Nearctic biomes. *Ornis Scandinavica, 20: 298-306*

Duckett J.E. 1984. Barn owls (*Tyto alba*) and the "second generation" rat-baits utilized in oil palm plantations in Peninsular Malaysia. *Planter (Kuala Lumpur), 52: 4-15*

Emberger L. 1955. Une classification biogeographique des climat. *Rec. Trav. Lab. Bot., Geol. Zool., Fac. Sci., Montpellier, Ser. Bot. 7: 3-43*

Erico C.R. & Rivadeneira M.M. 2006. Food habits of the barn owl *Tyto alba* in the National Reserve Pampa del Tamarugal, Atacama Desert, North Chile. *Journal of Natural History, 40(7-8): 473-483*

Escribano E.M.A. & Martinez A.L. 2006. Relationship between landscape pattern and small mammal diversity in a traditional agricultural landscape in the Southeast of Madrid. Time-Geographical approaches to Emergence and Sustainable Societies (TiGrESS). Workpackage 5, Final Report. 20 pp

Everett M. 1977. A natural history of owls. Hamlyn London, New York. 156 pp

Fajardo I. 1990. Mortalidad de la Lechuza común (*Tyto alba*) en España central. *Ardeola, 37: 101-106*

Farias A.A. & Jaksic M.F. 2007. Effects of functional constraints and opportunism on the functional structure of a vertebrate predator assemblage. *Journal of Animal Ecology, 76: 246-257*

Feduccia A. 1999. The origin and evolution of birds. 2nd Edition. New Haven, Yale, University Press. 466 pp

Felten H. & Storch G. 1965. Insektenfresser und Nagetiere aus N-Griechenland und Jugoslawien (Mammalia: Insectivora und Rodentia). *Senckenbergiana Biologica, 46: 341-367*

Fernandez C.M. & Garcia R.M. 1971. Tyto alba alimentandose principalmente de Sturnus unicolor. *Ardeola, 15: 146*

Filippucci M.G. & Kotsakis T. 1995. Biochemical systematics and evolution of Myoxidae. *Hystrix, 6: 77-97*

Filippucci M.G. & Peshev D. 1999. Myomimus roachi (Bate, 1937). Pp: 302-303, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Filippucci M.G. & Simson S. 1996. Allozyme variation and divergence in Erinaceidae (Mammalia: Insectivora). *Israel Journal of Zoology, 42: 335-345*

Filippucci M.G., Fadda V., Krystufek B., Simson S. & Amori G. 1991. Allozyme variation and differentiation on Chionomys nivalis (Martins, 1842). *Acta Theriologica, 36: 47-62*

Filippucci M.G., Krystufek B., Simson S., Kurtonur C. & Ozkan B. 1995. Allozymic and biometric variation in Dryomys nitedula (Pallas, 1778). *Hystrix, 6: 127-140*

Filippucci M.G., Macholan M. & Michaux J.R. 2002. Genetic variation and evolution in the genus Apodemus (Muridae: Rodentia). *Biological Journal of the Linnean Society, 75: 395–419*

Filippucci M.G., Nascetti G., Capanna E. & Bullini L. 1987. Allozyme variation and systematics of European moles of the genus Talpa (Mammalia, Insectivora). *Journal of Mammalogy, 68: 487-499*

Flowerdew J.R., Gurnell J. & Gipps J.H.W. 1985. The ecology of woodland rodents: Bank voles and wood mice. Symposia of the Zoological Society of London, No 55. Academic Press, London. 418 pp

Franguedakis-Tsolis S.E. 1992. Contribution to the study of the wild house mouse, genus Mus L. (Mammalia, Rodentia, Muridae) in Greece. Study of three populations based on lymphocyte antigen analysis. *Zeitschrift für Säugetierkunde, 57(4): 225-230*

Franguedakis-Tsolis S.E. & Chondropoulos B.P. 1986. Electrophoretic patterns of serum proteins and lactate dehydrogenase (LDH) of three rodent species, Mus musculus, Apodemus flavicollis and Pitymys atticus (Mammalia, Rodentia). *Biologia Gallo Hellenica, 11(2): 249-257*

Franguedakis-Tsolis S.E. & Ondrias J.C. 1985. Geographic variation of the ground squirrel Citellus citellus (Mammalia: Rodentia) in Greece with a description of a new subspecies. *Saugetierkundliche Mitteilungen, 32(2): 185-198*

Franguedakis-Tsolis S.E., Chondropoulos B.P. & Giagia-Athanasopoulou E.B. 1986. Contribution to the study of the taxonomy and zoogeography of the wild house mouse, genus Mus L. (Mammalia, Rodentia, Muridae) in Greece. 1. Serological and immunological study of three populations from southern Greece. *Acta Veterinaria (Belgrade), 36(2): 95-106*

Franguedakis-Tsolis S.E., Chondropoulos B.P. & Giagia-Athanasopoulou E.B. 1987. Contribution to the study of the mouse Mus (Rodentia Muridae) from Peloponnese and Zakynthos Island. (Immunological study). *Biologia Gallo Hellenica, 12: 525-526*

Franguedakis-Tsolis S.E., Chondropoulos B.P. & Nikoletopoulos N.P. 1993. On the phylogeny of the genus Acomys (Mammalia: Rodentia). *Zeitschrift für Säugetierkunde, 58: 240-243*

Franguedakis-Tsolis S.E., Chondropoulos B.P., Lykakis J.J. & Ondrias J.C. 1983. Taxonomic problems of woodmice, Apodemus spp., of Greece approached by electrophoretic and immunological methods. *Mammalia, 47(3): 333-337*

Fuentes E.R & Campusano C. 1985. Pest outbreaks and rainfall in the semi arid region of Chile. *Journal of Arid Environment, 8: 67-72*

Galeotti P., Sacchi R. & Perani E. 1997. Cooperative defense and intrasexual aggression in Scops owl (*Otus scops*): responses to playback of male and female calls. *Journal of Raptor Research, 31: 353-357*

Gavish L. & Gurnell J. 1999. Sciurus anomalus (Guldenstaedt, 1785). Pp: 176-177, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Gerasimov S., Nikolov H., Mihailova V., Auffray J.C. & Bonhomme F. 1990. Morphometric stepwise discriminant analysis of the five genetically determined European taxa of the genus Mus. *Biological Journal of the Linnean Society, 41: 47-64*

Giagia-Athanasopoulou E.B. & Markakis G. 1996. Multivariate analysis of morphometric characters in the Eastern hedgehog *Erinaceus concolor* from Greece and adjacent areas. *Zeitschrift für Säugetierkunde, 61: 129-139*

Giagia-Athanasopoulou E.B. & Ondrias J.C. 1973. Karyological analysis of the vole Pitymys atticus (Rodentia, Mammalia) from Greece. *Biologia Gallo Hellenica, 4: 205-212*

Giagia-Athanasopoulou E.B. & Ondrias J.C. 1980. Karyological analysis of eastern European hedgehog *Erinaceus concolor* (Mammalia, Insectivora) in Greece. *Mammalia, 44: 59-71*

Giagia-Athanasopoulou E.B. & Searle J.B. 2003. Chiasma localization in male common shrews Sorex araneus, comparing Robertsonian trivalents and bivalents. *Mammalia, 67(2): 295-299*

Giagia-Athanasopoulou E.B. & Stamatopoulos C. 1997. Geographical distribution and interpopulation variation in the karyotypes of Microtus (Terricola) thomasi. *Caryologia, 50(3-4): 303-315*

Giagia-Athanasopoulou E.B., Chondropoulos B.P. & Franguedakis Tsolis S.E. 1987. Contribution to the study of the mouse Mus (Rodentia, Muridae) from Zakynthos Island (Karyological study). *Biologia Gallo Hellenica, 12: 527-528*

Giagia-Athanasopoulou E.B., Chondropoulos B.P. & Franguedakis-Tsolis S.E. 1995. Robertsonian chromosomal variation in subalpine voles Microtus (Terricola), Rodentia, Arvicolidae) from Greece. *Acta Theriologica, 40(2): 139-143*

Giagia-Athanasopoulou E.B., Franguedakis-Tsolis S.E. & Chondropoulos B.P. 1987. Contribution to the study of the taxonomy and zoogeography of wild house mouse, genus Mus L. (Mammalia, Rodentia, Muridae) in Greece. 2. Karyological study of two populations from southern Greece. *Mammalia, 51(1): 111-116*

Giagia-Athanasopoulou E.B., Franguedakis-Tsolis S.E. & Chondropoulos B.P. 1995. Chromosomal variation and geographical distribution of some wild mice populations of the genus Mus (Mammalia, Rodentia) in Greece. *Biologia Gallo Hellenica, 22: 193-202*

Giagia-Athanasopoulou E.B., Savic I. & Soldatovic B. 1982. Chromosomal forms of the Mole rat Microspalax from Greece and Turkey. Zeitshcrift für Säugetierkunde, 47: 231-236

Giagia-Athanasopoulou E.B., Soldatovic B., Savic I. & Zimonjic D. 1985. Karyotype study of the genus Apodemus (Kaup, 1829) populations from the Balkan Peninsula. *Acta Veterinaria (Belgrade), 35(5-6): 289-297*

Gill A., Petrov B., Zivkovic S. & Rimsa D. 1987. Biochemical comparison in Yugoslavian rodents of the families Arvicolidae and Muridae. *Zeitschrift für Säugetierkunde, 52: 247–256*

Glass G.E., Childs J.E., Korch G.W. & Leduc J.W. 1989. Comparative ecology and social interactions of Norway rat (*Rattus norvegicus*) populations in Baltimore, Maryland. *Museum of Natural History Annals, University of Kansas, 130: 1-33*

Glass G.V. & Hopkins K.D. 1996. Statistical Methods in Education & Psychology. Boston, Allyn & Bacon. 608 pp

Gliwicz J. & Krystufek B. 1999. Apodemus agrarius (Pallas, 1771). Pp: 266-267, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Glue D. 1974. Food of the Barn owl in Britain and Ireland. *Bird Study, 21:200-210*

Gotelli N.J. & Entsminger G.L. 2001. EcoSim: Null models software for ecology. Version 7.0. Acquired Intelligence Inc. & Kesey-Bear. http://homepages.together.net/~gentsmin/ecosim.html

Goutner V. & Alivizatos H. 2003. Diet of the Barn owl (*Tyto alba*) and Little owl (*Athene noctua*) in wetlands of north-eastern Greece. *Belgian Journal of Zoology, 133(1): 15-22*

Gryz J., Krayze D. & Goszczynski J. 2008. The small mammals of Warsaw as inferred from the Tawny owl (*Strix aluco*) pellet analyses. *Annales Zoologic Fennici, 45: 281 - 285*

Gurnell J. & Flowerdew J.R. 1990. Live trapping small mammals. A practical guide. *Occassional Publications of the Mammal Society of London, 3: 1-39*

Gurnell J. & Wauters L. 1999. Sciurus vulgaris (Linnaeus, 1758). Pp: 180-181, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Gutierrez J.R., Meserve P.L., Jaksic F.M., Contreras L.C., Herrera S. & Vasquez H. 1993. Structure and dynamics of vegetation in a Chilean arid thorn scrub community. *Acta Oecologica, 14: 271-285*

Guttinger, H.R. 1965. Gur Winterstblichkeit schweizerischer Schleiereulen (*Tyto alba*) mit besonder Berucksichtingung des Winters. *Ornithologische Beobachter, 62: 14-23*

Hagemeijer W.J.M. & Blair M.J. 1997. The EBCC Atlas of European Breeding Birds: Their distribution and abundance. T & A.D. Poyser, London, UK. 903 pp

Haitlinger R. 1993. Acari (Arachnida) and Anoplura (Insecta) collected on small mammals, reptiles and insects in Greece and Cyprus. *Biologia Gallo Hellenica, 20(1): 83-88*

Hammer O., Harper D.A.T. & Ryan P.D. 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontologia Electronica: http://palaeo-electronica.org/001_1/past/issue1_01.htm

Handrinos G. & Akriotis T. 1997. The birds of Greece. Christopher Helm, A & C Black, London. 336 pp

Harper S.J., Bollinger J.K. & Barrett G.W. 1993. Effects of habitat patch shape on meadow vole (Microtus pennsylvanicus) population dynamics. *Journal of Mammalogy, 74: 1045-1055*

Harrison D.L. 1972. The mammals of Arabia, Volume 3, Lagomorpha, Rodentia. London, Ernest Benn Limited. 670 pp

Hausser J., Hutterer R. & Vogel P. 1990. Sorex araneus (Linnaeus, 1758) - Waldspitzmaus. Pp: 237-277, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas. Band 3/I. Insectivora, Primates. Aula Verlag, Wiesbaden. 523 pp

Haverschmidt F. 1934. Het broeden van Kerkuilen (Tyto alba guttata Brehm) in boomholten. *Ardea, 23: 212*

Hecht-Markou P. 1995. Beschreibung, geographische Verbreitung, Biotope und Ortswechsel des Sciurus anomalus Gueldenstadt, 1785 auf der Insel Lesbos (Griechenland). *Annales Musei Goulandris, 9: 429-444*

Hecht-Markou P. 1999. Das Markieren des Lebensraumes von Sciurus anomalus auf der Insel Lesbos. *Annales Musei Goulandris, 10: 201-221*

Henderson M.T., Merriam G. & Wegner J. 1985. Patchy environments and species survival: chipmunks in an agricultural mosaic. *Biological Conservation, 31: 95-105*

Herrera C.M. 1974a. Trophic diversity of the Barn owl (*Tyto alba*) in continental Western Europe. *Ornis Scandinavica, 5: 181-191*

Herrera C.M. 1974b. Régimen alimenticio de Tyto alba en España sudoccidental. *Ardeola, 19: 359-394*

Herrera C.M. & Hiraldo F. 1976. Food niche and trophic relationships among European owls. *Ornis Scandinavica, 7: 29-41*

Herrera C.M. & Jaksic M.F. 1980. Feeding ecology of the barn owl in central Chile and southern Spain: A comparative study. *Auk, 97: 760-767*

Hille A. & Meinig H. 1996. The subspecific status of European populations of the striped mouse Apodemus agrarius (Pallas, 1771) based on morphological and biochemical characters. *Bonner Zoologische Beiträge, 46: 203-231*

Holmgren V.C. 1983. The Barn owl *Tyto alba* in Skane, south Sweden. *Anser, 22: 27-42*

Holt D.W. 1993. Trophic niche of nearctic Short-eared owls. *Wilson Bulletin, 105(3): 497-503*

Holz H. & Niethammer J. 1990. Erinaceus concolor - Weissbrustigel, Ostigel (Martin, 1838). Pp: 50-64, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas. Band 3/I. Insectivora, Primates. Aula Verlag, Wiesbaden. 523 pp

Honer M.R. 1963. Observations on the Barn owl (*Tyto alba guttata*) in the Netherlands in relation to its ecology and population fluctuations. *Ardea, 51: 158-195*

Hurlbert S.H. 1971. The non-concept of species diversity: A critique and alternative parameters. *Ecology, 52: 577-586*

Hurlbert S.H. 1978. The measurement of niche overlap and some relatives. *Ecology, 59: 67-77*

Hurley A.E., Scandura T.A., Schriesheim C.A., Brannick M.T., Seers A., Vandenberg R.J. & Williams L. 1997. Exploratory and Confirmatory Factor Analysis: Guidelines, Issues, and Alternatives. *Journal of Organizational Behavior, 18(6): 667-683*

Hutterer R. 1981. Der status von Crocidura ariadne, Pieper, 1979 (Mammalia: Soricidae). *Bonner Zoologische Beiträge, 32: 3-12*

Hutterer R. 1990. Sorex minutes - Zwergspitzmaus (Linnaeus, 1766). Pp: 183-206, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas. Band 3/I. Insectivora, Primates. Aula Verlag, Wiesbaden. 523 pp

Hutterer R. 1999. Sorex minutus (Linnaeus, 1766). Pp: 54-55, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Illner H. 1992. Road deaths of Westphalian owls: methodological problems, influence of road type and possible effects on population levels. In: Galbraith C.A., Taylor I.R. & Percival S. (Eds), The Ecology and Conservation of European Owls - Proceedings of a symposium held at Edinburgh University. UK Nature Conservation, No 5. 110 pp

IUCN. 1997. IUCN Red List of Threatened Animals. http://www.iucnredlist.org/

Jaarola M., Martinkova N., Gunduz I., Brunhoff C., Zima J., Nadachowskie A., Amori G., Bulatova N.S., Chondropoulos B. 2004. Molecular phylogeny of the speciose vole genus Microtus (Arvicolinae, Rodentia) inferred from mitochondrial DNA sequences. *Molecular Phylogenetics and Evolution, 33: 647–663*

Jaksic F.M. & Yanez J.L. 1979. The diet of the Barn Owl in central Chile and its relation to the availability of prey. *The Auk, 96(3): 619-621*

Jaksic F.M. & Marti D.C. 1981. Trophic ecology of Athene owls in Mediterranean-type ecosystems: a comparative analysis. *Canadian Journal of Zoology, 59: 2331-2340*

Jaksic F.M. & Marti D.C. 1984. Comparative food habits of Bubo owls in mediterranean-type ecosystems. *The Condor, 86: 288-296*

Jaksic F.M., Seib L.R. & Herrera M.C. 1982. Predation by the Barn owl (*Tyto alba*) in Mediterranean habitats of Chile, Spain and California: A comparative approach. *The American Midland Naturalist, 107(1): 151-162*

Jeffries D.J. & French M.C. 1976. Mercury, cadmium, zinc, copper and organochlorine insecticide levels in small mammals trapped in a wheat field. *Environmental pollution, 10: 175-182*

Johnson D. & Lewis L. 2006. Land degradation: Creation and destruction. Rowman and Littlefield Publishers, Lanham. 303 pp

Jones P.J. 2002. Understanding Owls: Biology, Management, Breeding, Training. Newton Abbot, Devon, David & Charles. 160 pp

Jubete F. 2002. Apodemus sylvaticus (Linnaeus, 1758). Pp: 404-407, in: Palomo J. & Gisbert J. (Eds), Atlas de los mamíferos terrestres de Espana. Ministerio de Medio Ambiente, Dirección General de la Conservación de la Naturaleza. 564 pp

Juillard M. & Beuret J. 1983. L' amenagement des sites de nidification et son influence sur une population de Chouettes Effraies, Tyto alba, dans le nord-ouest de la Suisse. *Nos Oiseaux, 37: 1-70*

Kahmann H. 1964. Contribution a l' etude des mammiferes du Peloponese. *Mammalia, 28: 109-136*

Kahmann H. & Vesmanis I. 1975. Morphometrische Untersuchungen an Wimperspitzmausen (Crocidura), (Mammalia: Soricidae). 2. Zur Weiteren Kenntnis von Crocidura gueldenstaedti (Pallas 1811) auf der Insel Kreta. *Opuscula Zoologica, 136: 1-12*

Kasprzykowski Z. & Golawski A. 2006. Habitat use of the Barn owl *Tyto alba* and the Little owl *Athene noctua* in central eastern Poland. *Biological Letters, 43(1): 33-39*

Kaus D. 1977. Zue populationsdynamik, okologie, und Brutbiologie der Schleiereule in Franken. *Anzeiger der Ornithologischen Gellsellschaft in Bayern, 16: 18-44*

Kelt D.S., Taper M.L. & Meserve P.L. 1995. Assessing the impact on community assembly: a case study using small mammals. *Ecology, 76: 1283-1296*

Klaas E.E., Wiemeyer S.N., Ohlendorf H.M. & Swineford D.M. 1978. Organochlorine residues, eggshell thickness, and nest success in barn owls from the Chesapeake Bay. *Estuaries, 1: 46-53*

Kock D. 1974. Zur Saugetierfauna der Insel Chios, Agais (Mammalia). *Senckenbergiana Biologica, 55: 1-19*

Konig C., Weick F. & Becking J.H. 1999. Owls, a Guide to the Owls of the World. Yale University Press, New Haven, Connecticut. 462 pp

Korpimaki E. 1992. Population dynamics of Fennoscandian owls in relation to wintering conditions and between-year fluctuations of food. Pp: 1-10, in: Galbraith C.A., Taylor I.R. & Percival S. (Eds), The Ecology and Conservation of European Owls - Proceedings of a symposium held at Edinburgh University. UK Nature Conservation, No 5. 110 pp

Korpimaki E. 1998. Experimental reduction of predators reverses the crash phase of small rodent cycles. *Ecology, 79: 2448-2455*

Korpimaki E. & Marti D.C. 1995. Geographical trends in trophic characteristics of mammal-eating and bird-eating raptors in Europe and North America. *The Auk, 112(4): 1004-1023*

Kragenow P. 1970. Die Schleiereule in den Nordbezirken der DDR. *Falke, 17: 256-259*

Krapp F. 1999. Crocidura leucodon (Hermann, 1780). Pp: 64-65, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Krapp F. 1982. Chionomys nivalis - Schneemaus (Martins, 1842). Pp: 261-283, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas, Band 2/I, Rodentia II. Akademische Verlagsgesellschaft, Wiesbaden. 649 pp

Krapp F. 1990. Crocidura leucodon - Feldspitzmaus (Herman, 1780). Pp: 465-484, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas. Band 3/I. Insectivora, Primates. Aula Verlag, Wiesbaden. 523 pp

Kratochvil J. 1971. Der status der populationen der gattung Pitymys aus Attika (Rodentia, Mamm.). *Zoologicke Listy, 20: 107-206*

Krebs C. 1994. Ecology. The experimental analysis of distribution and abundance. Benjamin-Cummings Publishing Company. 695 pp

Krebs C. 1999. Ecological Methodology. Addison Wesley Educational Publishers, Inc. 620 pp

Krebs C. 2002. Ecological Methodology. Statistics and Mathematical Software Package for Ecological Data Analysis, Software Program: http://www.exetersoftware.com/cat/update_ecometh.html

Krebs C. 2002. Beyond population regulation and limitation. *Wildlife Research, 29: 1-10*

Krebs C. 2006. Mammals, Chapter 10. Pp: 351-369, in: Sutherland W.J. (Ed), Ecological Census Techniques, a Handbook. Cambridge University Press, Cambridge. 448 pp

Krebs J.R. & Davies N.B. 1993. An introduction to behavioral ecology. Willey Blackwell Scientific Publications, Oxford. 432 pp

Krystufek B. 1994. The taxonomy of blind moles (*Talpa caeca* and *T. stankovici*, Insectivora, Mammalia) from south-eastern Europe. *Bonner Zoologische Beiträge, 45: 1-16*

Krystufek B. 1999a. Talpa caeca (Savi, 1822). Pp: 80-81, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Krystufek B. 1999b. Talpa europaea (Linnaeus, 1758). Pp: 82-83, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Krystufek B. 1999c. Talpa stankovici (Martino V. & Martino E., 1931). Pp: 88-89, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Krystufek B. 1999d. Dinaromys bogdanovi (Martino, 1922). Pp: 218-219, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders

P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Krystufek B. 1999e. Spermophilus citellus (Linnaeus, 1766). Pp: 190-191, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Krystufek B. 1999f. Glis glis (Linnaeus, 1766). Pp: 294-295, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Krystufek B. 1999g. Dryomys nitedula (Pallas, 1778). Pp: 300-301, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Krystufek B. 1999h. Nannospalax leucodon (Nordmann, 1840). Pp: 262-263, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Krystufek B. 1999i. Microtus felteni (Malec & Storch, 1963). Pp: 234-235, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Krystufek B. 1999j. Microtus guentheri (Danford & Alston, 1880). Pp: 238-239, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Krystufek B. 1999k. Microtus subterraneus (De Selys-Longchamps, 1836). Pp: 250-251, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Krystufek B. 1999l. Microtus thomasi (Barrett-Hamilton, 1903). Pp: 254-255, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Krystufek B. 2002. Identity of four Apodemus (Sylvaemus) types from the eastern Mediterranean and the Middle East. *Mammalia, 66: 43–51*

Krystufek B. & Francky B.M. 2005. Mt. Hermon field mouse Apodemus iconicus is a member of the European mammal fauna. *Folia Zoologica, 54(1-2): 69-74*

Krystufek B. & Griffiths H.I. 1999. Mediterranean vs. continental small mammal communities and the environmental degradation of the Dinaric Alps. *Journal of Biogeography, 26: 167-177*

Krystufek B. & Griffiths H.I. 2002. Species richness and rarity in European rodents. *Ecography, 25(1): 120-128*

Krystufek B. & Vohralik V. 1994. Distribution of the Forest Dormouse Dryomys nitedula (Pallas, 1778) (Rodentia, Myoxidae) in Europe. *Mammal Review, 24(4): 161-177*

Krystufek B. & Vohralik V. 1999. Meriones tristrami (Thomas, 1892). Pp: 258-259, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Krystufek B. & Vohralik V. 2005. Mammals of Turkey and Cyprus. Rodentia I: Sciuridae, Dipodidae, Gliridae, Arvicolinae. University of Primorskem. 292 pp

Krystufek B., Filipucci M.G., Macholan M., Zima J., Vujosevic M. & Simson S. 1994. Does Microtus majori occur in Europe? *Zeitschrift für Säugetierkunde, 59(6): 349-357*

Kunze B., Dieterlen F., Traut W. & Winking H. 2000. Karyotype relationship among four species of spiny mice (Acomys, Rodentia). *Zeitschrift für Säugetierkunde, 64(4): 220-229*

Kurtonur C. 1975. New records of Thracian mammals. *Säugetierkundliche Mitteilungen, 23: 14-16*

Kurtonur C. 1992. First specimens of Glis glis (Linnaeus, 1776) from Turkish Thrace (Mammalia:Rodentia: Gliridae). *Senckenbergiana Biologica, 72(1-3):1-6*

Kurtonur C. & Ozkan B. 1990. New records of Myomimus roachi (Bate, 1937) from Turkish Thrace (Mammalia: Rodentia: Gliridae). *Senckenbergiana Biologica, 71: 239-244*

Laan R. & Verboom B. 1990. Effects of pool size and isolation on amphibian communities. *Biological Conservation, 54: 251-262*

Lange H. 1948. Slorugens (*Tyto alba guttata*, Brehm) Fode, belyst gennem Undersogelser af Gulp. *Dansk Ornitologisk Forenings Tidsskrift, 42: 50-84*

Lapini L. 1999. Erinaceus concolor (Martin, 1838). Pp: 36-37, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

LaPolla V.N. & Barrett G.W. 1993. Effects of corridor width and presence on the population dynamics of the meadow vole (Microtus pennsylvanicus). *Landscape Ecology, 8: 25-37*

Lawrence M.J. & Brown R.W. 1974. Mammals of Britain. Their tracks, trails and signs. Blandford Press, Dorset. 296 pp

Leirs H., Verhagen R., Verheyen W., Mwanjabe P. & Mbise T. 1996. Forecasting rodent outbreaks in Africa: An ecological basis for Mastomys control in Tanzania. *Journal of Applied Ecology, 33: 937-943*

Leps J. & Smilauer P. 2003. Multivariate analysis of Ecological Data using CANOCO. Cambridge University Press. 269 pp

Lerg J.M. 1984. Status of the common Barn owl in Michigan. *Jack Pine Warbler, 62: 39-48*

Levan G., Szpirer J., Szpirer C., Klinga K., Hanson C. & Islam M.Q. 1991. The gene map of the Norway rat (*Rattus norvegicus*) and comparative mapping with mouse and man. *Genomics, 10(3): 699–718*

Levins R. 1968. Evolution in changing environments: Some theoretical explorations. Princeton University Press, New Jersey. 132 pp

Libois R. & Fons R. 1999. Suncus etruscus (Savi, 1822). Pp: 76-77, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Libois R., Ramalhinho M.G. & Fons R. 1999. Crocidura suaveolens (Pallas, 1811). Pp: 72-73, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Lima M. & Jacsik F.M. 1999. Population rate of change in the leaf-eared mouse: The role of density-dependence, seasonality and rainfall. *Australian Journal of Ecology, 24: 110-116*

Lima M., Juillard R., Stenseth N.C. & Jaksic F. 2001. Demographic dynamics of a neotropical small rodent (Phyllotis darwini): feedback structure, predation and climatic factors. *Journal of Animal Ecology, 70: 761-775*

Lindeman R.H., Merenda P.F. & Gold R. 1980. Introduction to bivariate and multivariate analysis. Longman Higher Education. 444 pp

Lippens L. & Wille H. 1972. Atlas des oiseaux de Belgique et d' Europe occidentale. Lannoo, Tielt. 846 pp

Lopez-Fuster M.J. 2002. Suncus etruscus (Savi, 1822). Pp: 118-121, in: Palomo L.J. & Gisbert J. (Eds) Atlas de los mamíferos terrestres de España. Ministerio de Medio Ambiente, Dirección General de la Conservación de la Naturaleza. 564 pp

Lovari S., Renzoni A. & Fondi R. 1976. The predatory habits of the Barn owl (*Tyto alba*) in relation to vegetation cover. *Bolletino di Zoologia, 43: 173-191*

Luiselli L. & Capizzi D. 1996. Composition of a small mammal community studied by three comparative methods. *Acta Theriologica, 41(4): 425-431*

MacArthur R.H. & Wilson E.O. The island biogeography theory. Princeton University Press, Princeton NJ. 224 pp

Macdonald D. & Barrett P. 1993. Mammals of Europe. Princeton University Press, Princeton & Oxford. 312 pp

Macdonald D.W. & Tattersall F.T. 2001. Britain's mammals. The challenge for conservation. The Wildlife Conservation research Unit, Oxford University. 295 pp

Macdonald D.W.,Tattersall F.H., Service K.M., Firbank L.G. & Feber R.E. 2007. Mammals, agri-environment schemes and set-aside – what are the putative benefits? *Mammal Review, 37(4): 259-277*

Macholan M. 1996. Morphometric analysis of European house mice. *Acta Theriologica, 41(3): 255-275*

Macholan M. 1999a. Mus domesticus (Schwarz & Schwarz, 1943). Pp: 282-283, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Macholan M. 1999b. Mus macedonicus (Petrov & Ruzic, 1983). Pp: 284-285, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Macholan M. 1999c. Mus spicilegus (Petenyi, 1882). Pp: 288-289, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Macholan M. & Vohralik V. 1997. Note on the distribution of Mus spicilegus (Mammalia: Rodentia) in the south-western Balkans. *Acta Societatis Zoologicae Bohemicae, 61(3): 219-226*

Macholan M., Krystufek B. & Vohralik V. 2003. The location of the Mus musculus/M. domesticus hybrid zone in the Balkans: Clues from morphology. *Acta Theriologica, 48(2): 177-188*

Malmquist M.G. 1985. Character displacement and biogeography of the Pygmy shrew in northern Europe. *Ecology, 66(2): 372-377*

Manning J.A. & Edge W.D. 2004. Small mammals' survival and downed wood at multiple scales in managed forests. *Journal of Mammalogy, 85: 87-96*

Markov G. 1957. Okologisch-faunistische Untersuchungnen der Insectivora und Rodentia in den Gebieten von Petric und Goce Delcev. *Izv. Zool. Inst. Mus. Sofia, 11: 5-30*

Marks J.S. & Marti C.D. 1984. Feeding ecology of sympatric Barn owls and Long eared owls in Idaho. *Ornis Scandinavica, 15: 135 – 143*

Marti C.D. 1973. Ten years of Barn owl prey data from a Colorado nest site. *Wilson Bulletin, 85: 85-86*

Marti C.D. 1974. Feeding ecology of four sympatric owls. *Condor, 76:45-61*

Marti C.D. 1987. Raptor food habit studies. Pp: 67-69, in: Pendleton B.A., Millsap B.A., Cleine K.W. & Bird D.M (Eds), Raptor management techniques manual. Natural Wildlife Federation of Science Techniques, Rep. 10. Washington DC. 420 pp

Marti C.D. 1988. A long term study of food niche dynamics in the common Barn owl: comparisons within and between populations. *Canadian Journal of Zoology, 66: 1803-1812*

Marti C.D. 1992. Barn owl (*Tyto alba*). In: Poole A., Stettenheim P. & Gill F. (Eds), The birds of North America No 1. Academy of Natural Sciences, Philadelphia, and American Ornithologists' Union, Washington, D.C.

Marti C.D. 1999. Natal and Breeding Dispersal in Barn Owls. *Journal of Raptor Research, 33: 181-189*

Marti C.D. & Wagner P.W. 1985. Winter mortality in common Barn owls and its effect on population density and reproduction. *Condor, 87: 111-115*

Martinez J.A. & Lopez G. 1995. Dispersal and causes of mortality of the Barn Owl (*Tyto alba*) in Spain. *Ardeola, 42: 29-37*

Martinez J.A. & Lopez G. 1999. Breeding ecology of the Barn owl (*Tyto alba*) in Valencia (East of Spain). *Journal für Ornithologie, 140:93-99*

Martinez J.A. & Zuberogoitia I. 2002. Factors affecting the vocal behavior of Eagle owls *Bubo bubo*: effects of sex and territorial status. *Ardeola, 49(1): 1-9*

Martinez J.A. & Zuberogoitia I. 2004. Habitat preferences and causes of population decline for Barn owls Tyto alba: A multi scale approach. *Ardeola, 51(2): 303-317*

Martinez J.A., Zuberogoitia I., Colas J. & Macia J. 2002. Use or recorded calls for detecting Long eared owls *Asio otus. Ardeola, 49(1): 97-101*

Masseti M. & Maurizio S. 2003. Non-volant terrestrial mammals on Mediterranean islands: Tilos (Dodecanese, Greece), a case study. *Bonner Zoologische Beiträge, 51(4): 261-268*

McAleece I., Lambshead P.J.D. & Paterson G.L.J. 1997. Biodiversity Pro Version 2. Statistical Package. The Natural History Museum of London & The Scottish Association for Marine Science, Oban, Scotland. Freely distributed in: http://www.sams.ac.uk/activities/downloads/downloads.html

Mendenhall V.M & Pank L.F. 1980. Secondary poisoning of owls by anticoagulant rodenticides. *Wildlife Society Bulletin, 8: 311-315*

Mendenhall V.M., Klaas E.E. & McLane M.A.R. 1983. Breeding success of Barn owls (*Tyto alba*) fed low levels of DDE and Dieldrin. *Archives in Environmental Contamination and Toxicology, 12: 235-240*

Merriam G. & Lanoue A. 1990. Corridor use by small mammals: field measurements for three experimental types of Peromyscus leucopus. *Landscape Ecology, 4: 123-131*

Meserve P.L. et al. 1995. Heterogeneous responses of small mammals to an El Nino southern oscillation event in Northcentral semiarid Chile and the importance of ecological scale. *Journal of Mammalogy, 76: 580-595*

Meserve P.L., Milstead B. & Gutierrez J.R. 2001. Results of a food addition experiment in a north-central Chile small mammal assemblage: evidence for the role of "bottom-up" factors. *Oikos, 94: 548-556*

Mezhzherin, S.V. 1997. Revision of mice genus Apodemus (Rodentia,Muridae) of Northern Eurasia. *Vestnik Zoologica, Kiev, 31(4): 29-41*

Michaux J.R., Chevret P., Filippucci M.G. & Macholan M. 2002. Phylogeny of the genus Apodemus with a special emphasis on the subgenus Sylvaemus using the nuclear IRBP gene and two mitochondrial markers: cytochrome b and 12S rRNA. *Molecular Phylogeny and Evolution, 23: 123-136*

Mikkola H. 1983. Owls of the world. T. & A.D. Poyser, Calton, Staffs. 397 pp

Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. 1999. The Atlas of European Mammals. T & A D Poyser Natural History. 484 pp

Mitsainas G.P. & Giagia-Athanasopoulou E.B. 2005. Studies on the Robertsonian chromosomal variation of Mus musculus domesticus (Rodentia, Muridae) in Greece. *Biological Journal of the Linnean Society, 84(3): 503-513*

Mittelbach G. 2001. What is the observed relationship between species richness and productivity? *Ecology, 82: 2381-2396*

Montgomery W.I. 1989a. Population regulation in the wood mouse, *Apodemus sylvaticus*. I. Density dependence in the annual cycle of abundance. *Journal of Animal Ecology, 58: 465-475*

Montgomery W.I. 1989b. Population regulation in the wood mouse, *Apodemus sylvaticus*. II. Density dependence in spatial distribution and reproduction. *Journal of Animal Ecology, 58: 477-494*

Montgomery W.I. 1999a. Apodemus flavicollis (Melchior, 1834). Pp: 270-271, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), The Atlas of European Mammals. Academic Press, London. 484 pp

Montgomery W.I. 1999b. Apodemus sylvaticus (Linnaeus, 1758). Pp: 274-275, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), The Atlas of European Mammals. Academic Press, London. 484 pp

Moreno E. 1985. Clave osteologica para la identificacion de los passeriformes ibericos. I: Aegithalidae, Remizidae, Paridae, Emberizidae, Passeridae, Fringillidae, Alaudidae. *Ardeola, 32(2): 295-377*

Moreno E. 1986. Clave osteologica para la identificacion de los passeriformes ibericos. II: Hirundinidae, Prunellidae, Sittidae, Certhiidae, Troglodytidae, Cinclidae, Laniidae, Oriolidae, Corvidae. *Ardeola, 33(1-2): 69-129*

Moreno E. 1987. Clave osteológica para la identificación de los paseriformes ibéricos. III: Muscicapidae. *Ardeola, 34(2): 243-273*

Moreno E. & Barbosa A. 1992. Distribution patterns of small mammal fauna along gradients of latitude and elevation in Northern Spain. *Zeitschrift für Säugetierkunde, 57: 169-175*

Moreno S. & Balbontin J. 1998. Los roedores. Pp: 166-273 & 353-365, in: Mamíferos de España II. Cetáceos, Artiodáctilos, Roedores y Lagomorphos de la Península Ibérica, Baleares y Canarias. Planeta S.A., Barcelona. 384 pp

Morris D.W. 1989. Habitat-dependent estimates of competitive interaction. *Oikos, 55: 111-120*

Morris P.A. 1999. Muscardinus avellanarius (Linnaeus, 1758). Pp: 296-297, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), The Atlas of European Mammals. Academic Press, London. 484 pp

Morton S.R. & Martin A.A. 1979. Feeding ecology of the Barn owl (*Tyto alba*) in arid southern Australia. *Australian Wildlife Research, 6: 191-204*

Morton S.R, Happold M., Lee A.K. & McMillen R.E. 1977. The diet of Barn owl *Tyto alba* in south-western Queensland. *Australian Wildlife Research, 4: 91-97*

Mumford R.E & Keller C.E. 1984. The birds of Indiana. Indiana University Press, Bloomington, IN. 376 pp

Munsell C. 1954. Munsell soil color charts

National Agricultural Research Foundation of Greece (N.Ag.Re.F.). 1999. Special Environmental Study of the Delta of Pineios river and Tempi valley. Code: GR1420002

National Agricultural Research Foundation of Greece (N.Ag.Re.F.). 2000. Special Environmental Study of the forest of Tempi valley. Code: GR1420005

National Agricultural Research Foundation of Greece (N.Ag.Re.F.). 2000. Special Environmental Study of Antixasia mountains and Meteora region. Code: GR1440003

National Agricultural Research Foundation of Greece (N.Ag.Re.F.). 2002. Special Environmental Study of Karla lake, Mavrovouni and Kefalovriso Velestinou. Code: GR1420004

Nahal I. 1972. Contribution a l' etude des bioclimats et de la vegetation naturelle de la Turquie. *Hannon, Rev. Liban. Geogr., 7: 115-129*

Nahal I. 1981. The Mediterranean climate from a biological viewpoint. Pp: 63-86, in: Di Castri F., Goodall D.W. & Sprech R.L. (Eds), Mediterranean-type Shrublands. Ecosystems of the World, 11. Elsevier, Amsterdam, North Holland. 644 pp

Nechay G. 2000. Status of Hamsters: Cricetus cricetus, Cricetulus migratorius, Mesocricetus Newtoni, and other hamster species in Europe. Convention on the conservation of European wildlife and natural habitats. Nature and Environment Series, No. 106. Council of Europe Publishing. 73 pp

Newton I. 1979. Population ecology of raptors. T & AD Poyser Ltd, London, UK . 399 pp

Newton I., Wyllie I. & Asher A. 1991. Mortality causes in British Barn owls *Tyto alb*a with a discussion of aldrin-dieldrin poisoning. *Ibis, 133: 162-169*

Newton I., Wyllie I. & Freestone P. 1990. Rodenticides in British Barn owls. *Environmental pollution, 68: 101-117*

Niethammer J. 1962a. Die Saugetiere von Korfu. *Bonner Zoologische Beiträge, 13(1): 1-49*

Niethammer J. 1962b. Zur verbreitung und taxonomie griechischer Saugetiere. *Bonner Zoologische Beiträge, 25: 28-55*

Niethammer J. 1963. Die einburgerung von Saugetieren und Vogeln in Europa. Paul Parey, Hamburg & Berlin. 319 pp

Niethammer J. 1969. Die Igel Neuseelands. *Zoologischer Anzeiger, 183: 151-155*

Niethammer J. 1971. Kleinsauger von Kithira, Griechenland. *Säugetierkundliche Mitteilungen, 19: 363-365*

Niethammer J. 1974. Zur verbreitung und taxonomie griechischer Saugetiere. *Bonner Zoologische Beiträge, 25: 28-55*

Niethammer J. 1978a. Apodemus flavicollis - Gelbhalsmaus (Melchior, 1834). Pp: 325-336, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas. Band 1/I, Rodentia I. Akademische Verlagsgesellschaft, Wiesbaden. 475 pp

Niethammer J. 1978b. Apodemus mystacinus - Felsenmaus (Danford & Alston, 1877). Pp: 306-324, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas. Band 1/I, Rodentia I. Akademische Verlagsgesellschaft, Wiesbaden. 476 pp

Niethammer J. 1978c. Apodemus sylvaticus - Waldmaus (Linnaeus, 1758). Pp: 337-358, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas. Band 1/I, Rodentia I. Akademische Verlagsgesellschaft, Wiesbaden. 476 pp

Niethammer J. 1982a. Cricetulus migratorius - Zwerghamster (Pallas, 1773). Pp: 39-50, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas, Band 2/I, Rodentia II. Akademische Verlagsgesellschaft, Wiesbaden. 649 pp

Niethammer J. 1982b. Microtus felteni (Malec & Storch, 1963). Pp: 438-441, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas, Band 2/I, Rodentia II. Akademische Verlagsgesellschaft, Wiesbaden. 649 pp

Niethammer J. 1982c. Microtus guentheri – Levante Wuhlmaus (Danford & Alston, 1880). Pp: 331-339, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas, Band 2/I, Rodentia II. Akademische Verlagsgesellschaft, Wiesbaden. 649 pp

Niethammer J. 1982d. Microtus subterraneus - Kurzohrmaus (De Selys-Longchamps, 1836). Pp: 397-418, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas, Band 2/I, Rodentia II. Akademische Verlagsgesellschaft, Wiesbaden. 649 pp

Niethammer J. 1982e. Microtus thomasi – Balkan Kurzohrmaus (Barrett-Hamilton, 1903). Pp: 485-490, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas, Band 2/I, Rodentia II. Akademische Verlagsgesellschaft, Wiesbaden. 649 pp

Niethammer J. 1989. Gewollinhalte der Schleiereule (*Tyto alba*) von Kos und aus Sudwestanatolien. *Bonner Zoologische Beiträge, 40: 1-9*

Niethammer J. 1990a. Talpa caeca - Blindmaulwurf (Savi, 1822). Pp: 145-156, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas, Band 3/I. Insectivora, Primates. Aula Verlag, Wiesbaden. 523 pp

Niethammer J. 1990b. Talpa europaea- Maulwurf (Linnaeus, 1758). Pp: 99-133, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas, Band 3/I. Insectivora, Primates. Aula Verlag, Wiesbaden. 523 pp

Niethammer J. 1990c. Talpa stankovici - Balkan Maulwurf (V. & E. Martino, 1931). Pp: 141-144, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas, Band 3/I. Insectivora, Primates. Aula Verlag, Wiesbaden. 523 pp

Niethammer J. & Krapp F. 1977. Handbuch der Saugetiere Europas – Band 1, Nagetiere 1. Akademische Verlagsgesellschaft, Wiesbaden. 476 pp

Niethammer J. & Krapp F. 1982a. Handbuch der Saugetiere Europas – Band 2/1, Nagetiere 2. Akademische Verlagsgesellschaft, Wiesbaden. 649 pp

Niethammer J. & Krapp F. 1982b. Microtus arvalis - Feldmaus (Pallas, 1779). Pp: 284-318, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas, Band 2/I, Rodentia II. Akademische Verlagsgesellschaft, Wiesbaden. 649 pp

Niethammer J. & Krapp F. 1990. Handbuch der Saugetiere Europas – Band 3/1, Insektenfresser – Herrentiere. AULA – Verlag Wiesbaden. 523 pp

O'Farrell M.J., Clark A.W., Emmerson F.H., Juarez M.S., Fenton R.K., O' Farrel M.T. & Goodlett Y.T. 1994. Use of a Mesh Live Trap for Small Mammals: Are Results from Sherman Live Traps Deceptive? *Journal of Mammalogy, 75(3): 692-699*

Obuch J. 2001. Dormice in the diet of owls in the Middle East. Trakya University, *Journal of Scientific Research, Edirne, 2(2): 145-150*

Ondrias J.C. 1964. Range extension of Microtus guentheri in Greece. *Zeitschrift für Säugetierkunde, 29: 378-380*

Ondrias J.C. 1965a. Die Saugetiere Griechenlands. *Säugetierkundliche Mitteilungen, 13(3): 109-127*

Ondrias J.C. 1965b. Contribution to the knowledge of Microtus guentheri hartingi from Thebes, Greece. *Mammalia, 29: 489-506*

Ondrias J.C. 1966. The taxonomy and geographical distribution of the rodents of Greece. *Säugetierkundliche Mitteilungen, 14(Suppl.): 136 pp*

Ondrias J.C. 1969a. Some observations on Crocidura leucodon, Hermann, 1780 (Insectivora, Mammalia) from the mainland of Greece. *Biologia Gallo Hellenica, 2:45-48*

Ondrias J.C. 1969b. Die Ussuri Gross Spitzmaus, Crocidura lasiura, Dobson, 1890, der Agaischen Insel Lesbos. *Zeitschrift für Säugetierkunde, 34: 353-358*

Ondrias J.C. 1970. Contribution to the knowledge of Crocidura suaveolens (Mammalia, Insectivora) from Greece, with a description of a new subspecies. *Zeitschrift für Säugetierkunde, 35: 371-381*

Opdam P. 1991. Metapopulation theory and habitat fragmentation: a review of Holarctic breeding bird studies. *Landscape Ecology, 5: 93-106*

Osborn D.J. 1966. Records of the Water vole, *Arvicola terrestris*, from Macedonia, Greece. *Senckenbergiana Biologica, 47: 223-224*

Ozkan B. & Krystufek B. 1999. Wood mice, Apodemus of two Turkish islands: Gokceada and Bozcaada. *Folia Zoologica, 48: 17-24*

Papa A., Nemirov K., Henttonen H., Niemimaa J., Antoniadis A., Vaheri A., Plyusnin A. & Vapalahti O. 2001. Isolation of Dobrava Virus from Apodemus flavicollis in Greece. *Journal of Clinical Microbiology, 39(6): 2291-2293*

Papageorgiou N., Vlachos C. & Bakaloudis D. 1993. Diet and nest site characteristics of Eagle owl (*Bubo bubo*) breeding in two different habitats in nort-eastern Greece. *Avocetta, 17: 49-54*

Papamichael G. 2007. Structure and function of a trophic network and the metapopulations of small mammals and their predators. Doctoral Thesis (PhD). Aegean University, Environmental Department, Laboratory of Ecosystems' Management

Parmley D. & Parmley A.P. 2001. Food Habits of the Canebrake Rattlesnake (Crotalus horridus atricaudatus) in Central Georgia. *Georgia Journal of Science, 59(4): 172-178*

Parslow J.L.F. 1967. Changes in status among breeding birds in Britain and Ireland: Part 3. *British Birds, 60: 177-202*

Pavlinov I.J., Dubrovsky Y.A., Rossolimo O.L. & Potapova E.G. 1990. Gerbils of the world. Nauka, Moscow. 368 pp

Payne S. 1986. Notes on the Soricidae (Insectivora, Mammalia) from Crete. II. The shrew remains from Minoan and classical Kommos. *Bonner Zoologische Beiträge, 37: 173-182*

Peet R.K. 1974. The measurement of species diversity. *Annual Review of Ecology and Systematics, 5: 285-307*

Peet R.K. 1975. Relative diversity indices. *Ecology, 56: 496-498*

Peles G.D. & Barrett G.W. 1996. Effects of vegetative cover on the population dynamics of meadow voles. *Journal of Mammalogy, 77: 857-869*

Perrins C.M. 1982. Prey specificity of the Barn owl, *Tyto alba*, in the Great Fish River valley of the Eastern Cape Province. *South African Journal of Wildlife Research, 12: 14-25*

Peshev D. 1983. On the Caryotypes in Some Populations of the Mole Rat (*Spalax leucodon Nordmann*) in Bulgaria. *Zoologischer Anzeiger, 206: 129-133*

Petrov B. & Ruzic A. 1982. Microtus epiroticus - Sudfeldmaus (Ognev, 1924). Pp: 319-330, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas, Band 2/I, Rodentia II. Akademische Verlagsgesellschaft, Wiesbaden. 649 pp

Petrov B. & Todorovic M. 1982. Dinaromys bogdanovi - Bergmaus (Martino, 1922). Pp: 192-208, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas, Band 2/I, Rodentia II. Akademische Verlagsgesellschaft, Wiesbaden. 649 pp

Peus F. 1954. Zur kenntnis der flohe Griechenlands. (Insecta, Siphonaptera). *Bonner Zoologische Beiträge, 8: 111-147*

Peus F. 1964. Flohe aus dem Mittelmeergebiet VI. Jugoslawien. VII. Griechenland: Pindus-Gebirge. *Bonner Zoologische Beiträge, 15: 256-265*

Pianka E.R. 1980. The structure of lizard communities. *Oikos, 35: 194-201*

Pielou N.C. 1969. An introduction to mathematical ecology. John Wiley & Sons Inc., New York. 292

Pieper H. 1966. Uber einige bemerkenswerte Kleinsauger-Funde auf den Inseln Rhodos und Kos. *Acta Biologica Hellenica, 1: 21-28*

Pieper H. 1976. Zur verbreitung einiger Kleinsauger auf Kreta. *Zeitschrift für Säugetierkunde, 41: 274-277*

Pieper H. 1977. Fledermause aus Schleiereulen-Gewollen von der Insel Kreta. *Zeitschrift für Säugetierkunde, 42: 7-12*

Pieper H. 1982. Zur Saugetiernahurng des Uhus (*Bubo bubo*) auf der griechishen Insel Lesbos. *Vogelwelt, 102: 55-56*

Pieper H. 1990. Crocidura zimmermanni - Kretaspitzmaus (Wettstein, 1953). Pp: 453-460, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas. Band 3/I. Insectivora, Primates. Aula Verlag, Wiesbaden. 523 pp

Pietch M. 1982. Ondatra zibethicus - Bisamratte, Bisam (Linnaeus, 1766). Pp: 177-192, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas. Band 2/I. Rodentia II. Akademische Verlagsgesellschaft, Wiesbaden. 649 pp

Pikula J., Beklova M. & Kubik V. 1984. The breeding bionomy of Tyto alba. *Acta Scientiarum Naturalium, Academiae Scientiarum Bohemoslovacae Brno, 18: 1-53*

Prestt I. 1965. An enquiry into the recent breeding status of some smaller birds of prey and crows in Britain. *Bird Study, 12: 196-221*

Promislow D.E.L & Harvey P.H. 1990. Living fast and dying young: A comparative analysis of life-history variation among mammals. *Journal of Zoology, 220: 417-437*

Raphael M.G. & White M. 1984. Use of snagsby cavity nesting birds in the Sierra Nevada. Wildlife Monograph, No 86

Read M., Allsop J. 1994. The Barn Owl. London, Blandford. 128 pp

Redpath S.M. 1994. Censusing Tawny owls (*Strix aluco*) by the use of imitation calls. *Bird Study, 41: 192-198*

Reichstein H. 1978. Mus musculus - Hausmaus (Linnaeus, 1758). Pp: 421-451, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas. Band 1/I, Rodentia I. Akademische Verlagsgesellschaft, Wiesbaden. 476 pp

Reichstein H. 1982. Arvicola terrestris - Schermaus (Linnaeus, 1758). Pp: 217-252, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas, Band 2/I, Rodentia II. Akademische Verlagsgesellschaft, Wiesbaden. 649 pp

Reumer J.W.F. 1986. Notes on the Soricidae (Insectivora, Mammalia) from Crete. I. The Pleistocene species Crocidura zimmermanni. *Bonner Zoologische Beiträge, 37: 161-171*

Rey J.M. 2002. Crocidura suaveolens (Pallas, 1811). Pp: 110-113, in: Palomo L.J. & Gisbert J. (Eds), Atlas de los mamíferos terrestres de España. Ministerio de Medio Ambiente, Dirección General de la Conservación de la Naturaleza. 564 pp

Ricther H. 1970. Zum taxonomischen Status der zwei Crociduren-Formen von Kreta (Mammalia, Insectivora, Soricidae). *Zoologische Abhandlungen, Staatliches Museum fur Tierkunde in Dresden, 31: 279-291*

Rifai L., Al Melhim W.N. & Amr Z.S. 1998. On the diet of the Barn Owl, *Tyto alba*, in Northern Jordan. *Zoology in the Middle East, Heidelberg, 16: 31-34*

Rob H. 2002. RSPB Birds of Britain and Europe. Dorling Kingsley Publications. 448 pp

Robinson G.R., Holt R.D., Gaines M.S., Hamburg S.T., Johnson M.J., Fitch S.S & Martinko E.A. 1992. Diverse and contrasting effects of habitat fragmentation. *Science, 257: 524-526*

Rodriguez C. & Peris S. 2007. Habitat associations of small mammals in farmed landscapes: implications for agri-environmental schemes. *Animal Biology, 57(3): 301-314*

Rojas A.B. & Palomo J.L. 2002. Rattus norvegicus (Berkenhout, 1769). Pp: 416-419, in: Palomo J. & Gisbert J. (Eds), Atlas de los mamíferos terrestres de España. Ministerio de Medio Ambiente, Dirección General de la Conservación de la Naturaleza. 564 pp

Rosenzweig M.L. 1995. Species diversity in space and time. Cambridge University Press. 458 pp

Rottmann R., Boye P. & Meinig H. 2003. Die Saugetierfauna am Nestos-Delta in Nordost-Griechenland. *Berichte aus dem Arbeitsgebiet Entwicklungsforschung am Institut fur Geographie in Munster, 33: 37*

Roulin A. 2004. Covariation between plumage colour polymorphism and diet in the Barn Owl (Tyto alba). *Ibis, 146(3): 509-517*

Routledge R.D. 1983. Evenness indices: Are any admissable? *Oikos, 40: 149-151*

Rovatsos M.T., Mitsainas G.P., Stamatopoulos E. & Giagia-Athanasopoulou E.B. 2008. First reports of XXY aneuploidy in natural populations of Thomas' pine vole *Microtus thomasi* (Rodentia: Arvicolidae) from Greece. *Mammalian Biology, 73(5): 342-349*

Royston P. 1982. An axtension of Shapiro and Wilk's W Test for normality to large samples. *Applied Statistics, 31: 115-124*

Ruprecht A.L. 1964. Analyse der Nahrungsbestandteile der Schlkeiereule, Tyto alba guttata vorkommend in Aleksandrow Koj. Ciechocinek und Raciazek in den Jahren 1960-1961. *Zeszyty Naukowe Uniwersytetu Mikolaja Kopernika w Toruniu, Biologia, 7: 45-66*

Ruprecht A.L. 1979. Food of the Barn owl, *Tyto alba guttata* from Kujawy. *Acta Ornithologica, 26: 493-511*

Ruzic A. 1978. Citellus citellus - Europaische Ziesel (Linnaeus, 1766). Pp: 123-144, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas. Band 1/I, Rodentia I. Akademische Verlagsgesellschaft, Wiesbaden. 476 pp

Ruzic A., Petrov B., Zivkovic S. & Rimsa D. 1975. On the species' independence of the 54 chromosome vole Microtus epiroticus Ondrias 1966 (Mammalia, Rodentia). Its distribution, ecology and importance as a pest in the West part of Balkan Peninsula. *Journal of Scientific Agricultural Research, Beograd, 104: 153-160*

Sage B.L. 1962. Barn owls catching sparrows at roost. *British Birds, 55: 237-238*

Sage R.D. 1981. Wild mice. Pp: 39-90, in: Foster H.L., Small J.D. & Fox J.G. (Eds), The mouse in biomedical research, Vol I. Academic Press, New York. 306 pp

Sage R.D., Atchley W.R. & Capanna E. 1993. House mice as models in systematic biology. *Systematic Biology, 42: 523-561*

Sanders H.L. 1968. Marine benthic diversity: a comparative study. *American Naturalist, 102: 243-282*

Sans A.M. 2002. Mus domesticus (Rutty, 1772). Pp: 420-423, in: Palomo J. & Gisbert J. (Eds), Atlas de los mamíferos terrestres de España. Ministerio de Medio Ambiente, Dirección General de la Conservación de la Naturaleza. 564 pp

Santucci F., Emmerson B.C. & Hewitt G.M. 1998. Mitochondrial DNA phylogeny of European hedgehogs. *Molecular Ecology, 7: 1163-1172*

Saucy F. 1999. Arvicola terrestris (Linnaeus, 1758). Pp: 222-223, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Savic I. 1982. Microspalax leucodon - Westblindmaus (Nordmann, 1840). Pp: 543-576, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas, Band 2/I, Rodentia II. Akademische Verlagsgesellschaft, Wiesbaden. 649 pp

Savic I. & Soldatovic B. 1979. Distribution Range and Evolution of the Chromosomal Forms in the Spalacidae of the Balkan Peninsula and Bordering Regions. *Journal of Biogeography, 6: 363-374*

Savic I. & Soldatovic B. 1978. Studies on the Karyotype and Distribution Range of the Mole Rat (*Spalax leucodon Nordmann*), in Greece. *Caryologia, 31: 63-73*

Savic I. & Soldatovic B. 1977. Contribution to the Study of Ecogeographic Distribution and Evolution of Chromosomal Forms of the Spalacidae from the Balkan Peninsula. *Arhiv Bioloskih Nauka, 29: 141-156*

Schaschil H., Lymberakis P. & Suchentrunk F. 2002. On allozyme and cyt-b gene characteristics of Cretan hedgehogs, *Erinaceus concolor nesiotes*, Bate 1906. *Mammalian Biology, 67: 257-267*

Seddon J.M., Santucci F., Reeve N. & Hewitt G.M. 2002. DNA footprints of *European hedgehogs, Erinaceus europaeus* and *Erinaceus concolor*. Pleistocene refugia, postglacial expansion and colonization routes. *Molecular Ecology, 10: 2187-2198*

Seel D.C., Thomson A.G. & Turner J.C.E. 1983. Distribution and breeding of the Barn owl Tyto alba on Anglesey, North Wales. Bangor Occasional Paper, No 16. Institute of Terrestrial Ecology, Bangor

Sfougaris A., Birtsas P. & Nastis A. 1998. Bird diversity and density in relation to different habitats and land uses in Portaicos-Pertouli area, Greece. Landscape, Livestock and Livelihoods in European less favoured areas. Proceedings of EU EQULFA Project

Shapiro S.S, Wilk M.B. & Chen H.J. 1968. A Comparative Study of Various Tests for Normality. *Journal of the American Statistical Association, 63: 1343-1372*

Sharrock J.T.R. 1976. The atlas of breeding birds in Britain and Ireland. T. & A.D. Poyser, Carlton, Staffordshire. 477 pp

Shawyer C.R. 1987. The Barn Owl in the British Isles: its past, present and future. The Hawk Trust, London. 112 pp

Shawyer C.R. 1998. Barn owl. Arlequin Publications. 208 pp

Shchipanov N.A. & Oleinichenko V.Y. 1993. The Bicolored white-toothed shrew. The behavior and spatial, ethological and functional structure of a population. Nauka, Moscow. 135 pp

Shehab H.A. 2005. Food of the Barn Owl Tyto alba in Southern Syria. *Acta Zoologica Cracoviensia. 48A(1-2): 35-42*

Shehab H.A. & Al Charabi M.S. 2006. Food of the Barn Owl Tyto alba in the Yahmool Area, Northern Syria. *Turkish Journal of Zoology, 30: 175-179*

Sheldon A.L. 1969. Equitability indices: dependence on the species count. *Ecology, 50:466-467*

Shenbrot G.I. & Krasnov B.R. 2005. An Atlas of the Geographic Distribution of the Arvicoline Rodents of the World (Rodentia, Muridae: Arvicolinae). Pensoft Publications, Sofia. 336 pp

Short H.L. & Burnham K.P. 1982. Technique for structuring wildlife guilds to evaluate impacts on wildlife communities. Special Scientific Report. Wildlife USDI, U.S., Fish and Wildlife Service. No 244

Sibley G.C. & Ahlquist E.J. 1990. Phylogeny & classification of birds: a study in molecular evolution. New Haven, Connecticut, Yale University Press. 976 pp

Simberloff D.S. 1972. Properties of the rarefaction diversity measurement. *The American Naturalist, 106: 414-418*

Smal C.M. 1987. The diet of Barn owl in southern Ireland with reference to a recently introduced prey species: The Bank vole (*Clethrionomys glareolus*). *Bird Study, 34: 113-125*

Smith B. & Wilson J.B. 1996. A consumer's guide to evenness indices. *Oikos, 76: 70-82*

Sofianidou T.S. & Vohralik V. 1991. Notes on the distribution of small mammals (Insectivora, Rodentia) in Epeirus, Greece. *Bonner Zoologische Beiträge, 42(2): 125-135*

Soldatovic B., Zimonjic D., Savic I. & Giagia-Athanasopoulou E.B. 1984. Comparative cytogenetic analysis of the populations of European ground squirrel (Citellus citellus L.) on the Balkan Peninsula. *Bulletin Academie Serbe des Sciences et des Arts, Classe des Sciences Mathematiques et Sciences Naturelles, 86(25): 47-56*

Spitzenberger F. 1970. Erstnachweise der Wimperspitzmaus Suncus etruscus für Kreta und Kleinasien und die Verbreitung der Art im Sudwestasiatischen Raum. *Zeitschrift für Säugetierkunde, 35: 107-113*

Spitzenberger F. 1986. Die Zwergmaus, Micromys minutus (Pallas, 1771). Mammalia Austriaca 12 (Mammalia, Rodentia, Muridae). *Mitteilungen der Abteilung für Zoologie am Landesmuseum Joanneum, 39: 23-40*

Spitzenberger F. 1990a. Neomys anomalus - Sumpfspitzmaus (Cabrera, 1907). Pp: 317-333, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas. Band 3/I. Insectivora, Primates. Aula Verlag, Wiesbaden. 523 pp

Spitzenberger F. 1990b. Neomys fodiens - Wasserspitzmaus (Pennant, 1771). Pp: 334-374, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas. Band 3/I. Insectivora, Primates. Aula Verlag, Wiesbaden. 523 pp

Spitzenberger F. 1990c. Suncus etruscus - Etruskerspitzmaus (Savi, 1822). Pp: 375-392, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas. Band 3/I. Insectivora, Primates. Aula Verlag, Wiesbaden. 523 pp

Spitzenberger F. 1999a. Neomys anomalus (Cabrera, 1907). Pp: 58-59, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London, 484 pp

Spitzenberger F. 1999b. Neomys fodiens (Cabrera, 1907). Pp: 60-61, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas of European Mammals. Academic Press, London. 484 pp

Spitzenberger F. 1999c. Micromys minutus (Pallas, 1771). Pp: 264-265, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas or European Mammals. Academic Press, London. 484 pp

Spitzenberger F. 1999d. Clethrionomys glareolus (Schreber, 1780). Pp: 212-213, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas or European Mammals. Academic Press, London. 484 pp

Springhorn R. & Kachel G. 1981. Erster Lebendnachweis der Etruskerspitzmaus (Insectivora, Soricidae) auf Kreta. *Zeitschrift für Säugetierkunde, 46(1): 55-56*

Stamatopoulos C. & Ondrias J.C. 1995. First record of the levant vole *Microtus guentheri* Danfor and Alston, 1880 in Lesbos island, Greece. *Säugetierkundliche Mitteilungen, 36(2): 53-59*

Stein G.H.W. 1963. Unterartengliederung und nacheiszeitliche ausbreitung des Maulwurfs, *Talpa europaea*. *Mitteilungen Zoologische Museum, Berlin, 39: 379-402*

Stenseth N.C & Ims R.A. 1993. The biology of lemmings. (Linnean Society Symposium Series, No 15). Academic Press, London. 704 pp

Stevens J. 2001. Applied multivariate statistics for the social sciences. Hillsdale, NJ: Lawrence Erlbaum. 720 pp

Stewart P.A. 1980. Population trends of barn owls in North America. *American Birds, 34: 698-700*

Storch G. 1977. Die ausbreitung der Felsenmaus (*Apodemus mystacinus*): Zur problematic der insel besiedlung und tiergeographie der Agais. *Natur und Museum, 107: 174-182*

Storch G. 1978a. Glis glis - Siebenschlafer (Linnaeus, 1766). Pp: 243-258, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas. Band 1/I, Rodentia I. Akademische Verlagsgesellschaft, Wiesbaden. 476 pp

Storch G. 1978b. Muscardinus avellanarius - Haselmaus (Linnaeus, 1758). Pp: 259-280, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas. Band 1/I, Rodentia I. Akademische Verlagsgesellschaft, Wiesbaden. 476 pp

Storch G. 1978c. Dryomys nitedula - Baumschlafer (Pallas, 1779). Pp: 227-237, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas. Band 1/I, Rodentia I. Akademische Verlagsgesellschaft, Wiesbaden. 476 pp

Storch G. 1978d. Myomimus roachi - Mausschlafer (Bate, 1937). Pp: 238-242, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas. Band 1/I, Rodentia I. Akademische Verlagsgesellschaft, Wiesbaden. 476 pp

Storch G. 1999. Apodemus mystacinus (Danford & Alston, 1877). Pp: 272-273, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas or European Mammals. Academic Press, London. 484 pp

Straeten E. & Asselberg R. 1973. Het voedsel van de kerkuill in Belgie. *Giervalk, 63: 149-159*

Sultana J. & Gauci C. 1982. A new guide to the birds of Malta. The Ornithological Society, Valletta. 207 pp

Taylor I.R. 1991. Effects of nest inspections and radiotagging on Barn owl breeding success. *Journal of Wildlife Management, 55: 312-315*

Taylor I.R. 1992. An assessment of the significance of annual fluctuations in snow cover in determining short-term population changes in field vole *Microtus agrestis* and Barn owl *Tyto alba* populations. Pp: 32-38, in: Galbraith C.A., Taylor I.R. & Percival C.M. (Eds), The Ecology and Conservation of European Owls. Joint Nature Conservation Committee, Peterborough

Taylor I.R. 1994. Barn owls. Predator-prey relationships and conservation. Cambridge University Press, Cambridge, UK. 304 pp

Taylor K.D. & Quy R.J. 1978. Long distance movements of common rat (*Rattus norvegicus*) revealed by radio tracking. *Mammalia, 42: 63-71*

Tea A., Alexiou D.S., Papoutsi A., Papa A. & Antoniadis A. 2004. Bartonella species isolated from Rodents, Greece. *Emerging Infectious Diseases, 10(5): 963-964*

Ter Braak C.J.F. 1994. Canonical community ordination. Part I: basic theory and linear methods. *Ecoscience, 1: 127-140*

Ter Braak C.J.F. & Prentice I.C. 1988. A theory of gradient analysis. *Advances in Ecological Research, 18: 93-138*

Ter Braak C.J.F. & Smilauer P. 2002. Canoco reference manual and CanoDraw for Windows user's guide: software for canonical community ordination (version 4.5). Microcomputer Power, Ithaca, New York, USA.

Terradas J. 1996. Introduccio als ecosistemes mediterranis: clima i condicions de la vida. Pp: 21-40, in: Ecologia del Foc. Edicions Proa, S.A.

Tichy H. & Vucak I. 1987. Chromosomal polymorphism in the house mouse (*Mus musculus*) of Greece and Yugoslavia. *Chromosoma (Berlin), 95(1): 31-36*

Toms M.P., Crick, H.Q.P. & Shawyer, C.R. 2000. Project Barn Owl Final Report | BTO Research Report 197/ HOT Research Report 98/1. BTO/Hawk & Owl Trust, Thetford

Toms M.P., Crick, H.Q.P. & Shawyer, C.R. 2001. The status of breeding Barn Owls *Tyto alba* in the United Kingdom 1995-97. *Bird Study, 48: 23-37*

Torre I. 2001. Tendencias geograficas en la dieta de la Lechuza comun (*Tyto alba*, Scopoli 1769) e interpretacion de los patrones de riqueza de las comunidades de micromamiferos. Una nueva aproximación. *Galemys, 13(2): 55-66*

Torre I. 2004. Distribution, population dynamics and habitat selection of small mammals in Mediterranean environments: the role of climate, vegetation structure, and predation risk. Phd Thesis. Department of Biology, University of Barcelona. 178 pp

Torre I., Arrizabalaga A. & Flaquer C. 2004. Three methods for assessing richness and composition of small mammal communities. *Journal of Mammalogy, 85: 524-530*

Torre I., Tella J.L. & Arrizabalaga A. 1996. Environmental and geographic factors affecting the distribution of small mammals in an isolated mediterranean mountain. *Zeitschrift für Säugetierkunde, 61: 365-375*

Torre I., Tella J.L. & Ballesteros T. 1997. Tendencias troficas de la Lechuza Comun (*Tyto alba*) en la Depresion Media del Ebro. *Historia animalium, 3: 34-44*

Toschi A. 1965. Mammalia. Lagomorpha, Rodentia, Carnivora, Artiodactyla, Cetacea. Edizioni Calderini Bologna. 647 pp

Toschi A. & Lanza B. 1959. Mammalia. Generalita, Insectivora, Chiroptera. Edizioni Calderini Bologna. 485 pp

Travaini A., Donazar J.A., Ceballos O., Rodriguez A., Hiraldo F. & Delibes M. 1997. Food habits of common Barn-owls along an elevational gradient in Andean Argentine Patagonia. *Journal of Raptor Research, 31(1): 59-64*

Tryfonopoulos G., Chondropoulos B. & Fraguedakis T.S. 2005. Allozymic polymorphism among 14 populations of the House mouse, *Mus musculus domesticus*, from Greece. *Biochemical Genetics, 43(1-2):11-24*

Tsekoura N., Franguedakis-Tsolis S., Chondropoulos B. & Markakis G. 2002. Mophometric and allozyme variation in central and southern Greek populations of the vole Microtus (Terricola) thomasi (Rodentia, Arvicolidae). *Acta Theriologica, 47: 137-149*

Tsounis G. & Dimitropoulos A. 1992. Seasonal variation of the feeding of Barn owl, Tyto alba (Scopoli, 1769) in mount Hymetus, Attica, Greece. *Biologia Gallo Hellenica, 19: 29-36*

Tucker G.M. & Heath M.F. 1994. Birds in Europe: their conservation status. Cambridge UK, Birdlife International. 600 pp

Tucker K., Ruston S.P., Sanderson S.A., Martin E.B. & Blaiklock J. 1997. Modelling bird distributions: A combined GIS and Bayesioan based approach. *Landscape Ecology, 12: 77-93*

U.S. Dept. of Agriculture. 1975. Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys. Agriculture Handbook No 436. 754 pp

Van W.Z. & Bottema S. 1982. Vegetational history of the eastern Mediterranean and the Near East during the last 20.000 years. Pp: 277-321, in: Bintliff J.L. & Zeist W.V. (Eds), Paleoclimates, Paleoenvironments and Human communities in the Eastern Mediterranean region in the later Prehistory. BAR International Series, Oxford.

Varuzza P., Capizzi D., Santini L. & Apollonio M. 2001. Barn owl *Tyto alba* predation on small mammals in relation to the Mediterranean environment (Pisa Province, Italy). *Acta Ornithologica, 36(2): 153-159*

Vernon C.J. 1972. An analysis of owl pellets collected in southern Africa. *Ostrich, 43: 109-124*

Vesmanis I. & Kahmann H. 1978. Morphometrische Untersuchungen an Wimperspitzmausen (Crocidura). 4. Bemerkungen uber die Typusreihe der kretaischen Crocidura russula zimmermanni Wettstein, 1953 im Vergleich mit Crocidura gueldenstaedti caneae (Miller, 1909). *Säugetierkundliche Mitteilungen, 26: 214-222*

Viro P. & Niethammer J. 1982. Clethrionomys glareolus - Rotelmaus (Schreber, 1780). Pp: 109-146, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas, Band 2/I, Rodentia II. Akademische Verlagsgesellschaft, Wiesbaden. 649 pp

Vlachos C., Bakaloudis D. & Chatzinikos E. 2004. Unusual nesting of the Lesser Kestrel (*Falco naumanni*) in Thessaly, Greece. *Journal of Raptor Research, 38(2): 161-163*

Vlachos C., Bakaloudis D., Chatzinikos E., Papadopoulos T. & Dimitrios T. 2003. Aerial hunting behaviour of the Lesser Kestrel *Falco naumanni* during the breeding season in Thessaly (Greece). *Acta Ornithologica, 38(1): 47-52*

Vlasak P. & Niethammer J. 1990. Crocidura suaveolens - Gartenspitzmaus (Pallas, 1811). Pp: 397-428, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas, Band 3/I. Insectivora, Primates. Aula Verlag, Wiesbaden. 523 pp

Vogel P. 1986. Der karyotyp der Kretaspitzmaus, *Crocidura zimmermanni* Wettstein, 1953 (Mammalia, Insectivora). *Bonner Zoologische Beiträge, 37: 35-38*

Vogel P. 1999. Crocidura zimmermanni (Wettstein, 1953). Pp: 74-75, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas or European Mammals. Academic Press, London. 484 pp

Vogel P. & Sofianidou T.S. 1996. The shrews of the genus Crocidura on Lesbos, an eastern Mediterranean Island. *Bonner Zoologische Beiträge, 46(1-4): 339-347*

Vogel P., Maddalena T. & Catzeflis F. 1986. A contribution to the taxonomy and ecology of shrews (*Crocidura zimmermanni* and *Crocidura suaveolens*) from Crete and Turkey. *Acta Theriologica, 31: 537-545*

Vohralik V. 1991. A record of the mole Talpa levantis (Mammalia: Insectivora) in Bulgaria and the distribution of the species in the Balkans. *Acta Universitatis Carolinae-Biologia, 23: 119-127*

Vohralik V. 1999. Cricetulus migratorius (Pallas, 1773). Pp: 204-205, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas or European Mammals. Academic Press, London. 484 pp

Vohralik V. & Jitka L. 2002. Small mammals (Insectivora, Rodentia) of the Jicinska pahorkatina and Vychodolabska tabule regions (Chech Republic) in the food of the Barn owl (Tyto alba). *Lynx (Praha), 33: 249-264*

Vohralik V. & Sofianidou T.S. 1987. Small mammals (Insectivora, Rodentia) of Macedonia, Greece. *Acta Universitatis Carolinae Biologia, 14: 319-354*

Vohralik V. & Sofianidou T.S. 1992. Small mammals of (Insectivora, Rodentia) of Thrace, Greece. *Acta Universitatis Carolinae Biologia, 36: 341-369*

Vohralik V. & Sofianidou T.S. 1993. New records of *Apodemus agrarius* (Mammalia: Rodentia) in Greece and the distribution of the species in the south of the Balkans. Pp: 217-220, in: Horacek I. & Vohralik V. (Eds), Prague Studies in Mammalogy. Charles University Press, Prague. 245 pp

Vohralik V. & Sofianidou T.S. 2000. New records of *Suncus etruscus* (Mammalia: Insectivora) in Bulgaria and Greece and distribution of the species in the Balkans. *Lynx (Praha), 31: 143-148*

Vohralik V., Sofianidou T.S. & Frynta D. 1996. Population structure in *Mus macedonicus* (Mammalia: Rodentia) in the Balkans. *Folia Zoologica, 45(2): 97-103*

Vohralik V., Sofianidou T.S. & Frynta D. 1998. Reproduction in *Mus macedonicus* (Mammalia: Rodentia) in the Balkans. *Bonner Zoologische Beiträge, 47(3-4): 283-292*

Vohralik V., Frynta D., Mikulova P., Benda P. & Nova P. 2002. Multivariate morphometrics of *Apodemus mystacinus* in the near east and its divergence from European *A. m. epimelas* (Mammalia: Rodentia). *Israel Journal of Zoology, 48(2): 135-148*

Voous K.H. 1950. On the distributional and genetic origin of the intermediate populations of the Barn owl (*Tyto alba*) in Europe. Pp: 429-443, in: Kleinschmidt L.O. (Ed), Syllegomena Biologica. 471 pp

Voous K.H. 1989. Owls of the Northern Hemisphere. M.I.T. Press, Cambridge, MA. 320 pp

Vos C.C. & Stumpel A.H.P. 1996. Comparison of habitat isolation parameters in relation to fragmented distribution patterns in the tree frog (*Hyla arborea*). *Landscape Ecology, 11: 203-214*

Ward J.H. 1963. Hierarchical grouping to optimize an objective function. *Journal of the American Statistical Association, 58: 236-244*

Webster J.A. 1973. Seasonal variation of mammal contents of Barn owl castings. *Bird Study, 20: 185-196*

Wettstein O. 1941. Die Saugetierwelt der Agais nebst einer Revision des Rassenkreises von Erinaceus europaeus. *Annalen des Naturhistorischen Museums in Wien, 52: 245-278*

Whashington H.G. 1984. Diversity, biotic and similarity indices: a review with special relevance to aquatic ecosystems. *Water Research, 18: 653-694*

Wiens J.A. 1995. Habitat fragmentation: island versus landscape perspectives on bird conservation. *Ibis, 137: 97-104*

Williams C.K., Witmer V.A., Casey M. & Barret G.W. 1994. Effects of strip-cropping on small mammal population dynamics in soybean agroecosystems. *Ohio Journal of Sciences, 94(4): 94-98*

Wilson D.E. & Reeder D.M. 2005. Mammal Species of the World. Johns Hopkins University Press, Baltimore. 2000 pp

Wiltafsky H. 1978. Sciurus vulgaris - Eichlornchen (Linnaeus, 1758). Pp: 86-105, in: Niethammer J. & Krapp F. (Eds), Handbuch der Saugetiere Europas. Band 1/I, Rodentia I. Akademische Verlagsgesellschaft, Wiesbaden. 476 pp

Winking H., Dulic B. & Bulfield G. 1988. Robertsonian karyotype variation in the European house mouse, *Mus musculus*. Survey of present knowledge and new observations. *Zeitschrift für Säugetierkunde, 53(3): 148-161*

Xirouchakis S. 2005. The avifauna of the western Rodopi forests (N. Greece). *Belgian Journal of Zoology, 135(2): 261-269*

Yalden D. 2003. The analysis of owl pellets. Mammal Society, London. 28 pp

Yassoglou N., Henrard K. & Apostolakis K. 1964. Second progress report of pedological studies in the Peloponnesus. Nuclear Research Centre “Democritus”, Athens

Yom Tom Y. & Wool D. 1997. Do the contents of Barn owl pellets accurately represent the proportion of prey species in the field? *The Condor, 99: 972-976*

Yosida T.H. 1980. Cytogenetics of the black rat: karyotype evolution and species differentiation. University of Tokyo Press, Tokyo. 256 pp

Yu H.T. 1994. Distribution and abundance of small mammals along a subtropical elevational gradient in central Taiwan. *Journal of Zoology, 234: 577-600*

Yuksel E. & Gulkac M.D. 2001. The cytogenetical comparisons of Spalax (Rodentia: Spalacidae) populations from middle Kizilirmak Basin, Turkey. *Turkish Journal of Biology, 25: 17-24*

Zamorano E. & Palomo J.L. 2002. Rattus rattus (Linnaeus, 1758). Pp: 412-415, in: Palomo J. & Gisbert J. (Eds), Atlas de los mamíferos terrestres de España.

Ministerio de Medio Ambiente, Dirección General de la Conservación de la Naturaleza. 564 pp

Zelenka G. & Pricam R. 1964. Variations d' effectifs des population de petits mammiferes revelees par le regime alimentaire d' un rapace nocturne. *Terre et Vie, 18: 178-184*

Zima J. 1999a. Ondatra zibethicus (Linnaeus, 1766). Pp: 224-225, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas or European Mammals. Academic Press, London. 484 pp

Zima J. 1999b. Acomys minous (Bate, 1906). Pp: 292-293, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas or European Mammals. Academic Press, London. 484 pp

Zima J. 1999c. Microtus rossiaemeridionalis (Ognev, 1924). Pp: 246-247, in: Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (Eds), Atlas or European Mammals. Academic Press, London. 484 pp

Zima J. & Kral B. 1984. Karyotypes of European mammals II. *Acta Scientarum Naturalium Academiae Scientiarum Bohemicae Brno, 18: 1-62*

Zima J., Lukaeova L. & Macholan M. 1998. Chromosomal evolution in shrews. Pp: 173-218, in: Wojcik J.M. & Wolsan M. (Eds), Evolution of shrews. Bialowieza: Mammalian Research Institute, Polish Academy of Sciences. 458 pp

Zima J., Zagorodniuk I.V., Gaichenko V.A. & Zhezherina T.O. 1991. Polymorphism and chromosomal variability in *Microtus rossiaemeridionalis* (Rodentiformes). *Vestnik Zoologii, (4): 48-53*

Zima J., Gaichenko V.A., Macholan M., Radjabli S.I., Sablina O.V. & Wojcik J.M. 1990. Are robertsonian variations a frequent phenomenon in mouse populations in Eurasia? *Biological Journal of the Linnean Society, 41: 229-233*

Zima J., Fedyk S., Fredga K., Hausser J., Mishta A., Searle J., Volobuev V.T. & Wojcik J.M. 1996. The list of the chromosome races of the Common shrew (*Sorex araneus*). *Hereditas, 125: 97-107*

Zimmermann K., Wettstein O., Siewert O.V.H. & Pohle H. 1953. Die wildsauger von Kreta. *Zeitschrift für Säugetierkunde, 17: 1-71*

APPENDICES

APPENDIX A

Agricultural Cultivations in Each Sampling Site, for Each Year from 2003 to 2005

(Sampling sites abbreviations are demonstrated analytically in Chapter 3)

2003	AGBIS		AGGEL		AMPEK		AMIGD		ANBUN		ARMEN		ASPRO	
	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%
Cereals	5716	45.5	8515	67.8	1925	15.3	7813	62.2	6336	50.4	3220	25.6	6211	49.5
Industrial crops	6100	48.6	3600	28.7	10217	81.3	4515	35.9	1275	10.2	7347	58.5	3941	31.4
Pasture crops	572	4.6	0	0.0	51	0.4	26	0.2	0	0.0	0	0.0	1247	9.9
Mpostanika	0	0.0	0	0.0	9	0.1	33	0.3	167	1.3	0	0.0	0	0.0
Arable Land	12388	98.6	12116	96.5	12203	97.2	12387	98.6	7778	61.9	10568	84.1	11464	91.3
Vegetables	132	1.1	121	1.0	102	0.8	19	0.2	27	0.2	209	1.7	1055	8.4
Trees	0	0.0	14	0.1	0	0.0	47	0.4	618	4.9	104	0.8	34	0.3
Vineyards	0	0.0	3	0.0	0	0.0	0	0.0	62	0.5	0	0.0	0	0.0
Non Arable Land	132	1.1	138	1.1	102	0.8	66	0.5	707	5.6	313	2.5	1089	8.7
Irrigated Land	6923	55.1	3739	29.8	10414	82.9	6584	52.4	1656	13.2	7843	62.4	5178	41.2
Fallow land	0	0.0	0	0.0	0	0.0	0	0.0	115	0.9	0	0.0	0	0.0
Mountainous area	0	0.0	0	0.0	0	0.0	0	0.0	2080	16.6	0	0.0	0	0.0
Grassland	0	0.0	0	0.0	0	0.0	0	0.0	1820	14.5	0	0.0	0	0.0
Urban area	40	0.3	306	2.4	255	2.0	107	0.9	60	0.5	1679	13.4	72	0.6
Other Land Uses	40	0.3	306	2.4	255	2.0	107	0.9	4075	32.4	1679	13.4	72	0.6
Cultivated area	12520	99.7	12254	97.6	12305	98	12453	99.1	8485	67.6	10881	86.6	12488	99.4
TOTAL AREA	12560	100.0	12560	100.0	12560	100	12560	100	12560	100	12560	100	12560	100

Table I. Crop types and land uses (in acres & percentages %) for the year 2003, in all the breeding sites where samplings were realized. Villages are used with their codenames

Table I (continued)

2003	ASTRI		AURA		GIRTO		DASOK		DELER		DOXAR		ELEFT	
	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%
Cereals	1275	10.1	5665	45.1	2772	22.1	2483	19.8	8127	64.7	6918	55.1	3219	25.6
Industrial crops	10101	80.4	5184	41.3	3004	23.9	8089	64.4	41	0.3	3261	26.0	8473	67.5
Pasture crops	444	3.5	557	4.4	813	6.5	117	0.9	1650	13.1	0	0.0	423	3.4
Mpostanika	30	0.2	1	0.0	1823	14.5	142	1.1	480	3.8	0	0.0	23	0.2
Arable Land	11849	94.3	11451	91.2	8411	67.0	10831	86.2	10298	82	10178	81.0	12138	96.6
Vegetables	41	0.3	87	0.7	301	2.4	537	4.3	286	2.3	147	1.2	11	0.1
Trees	0	0.0	97	0.8	2860	22.8	0	0.0	789	6.3	0	0.0	65	0.5
Vineyards	0	0.0	0	0.0	6	0.0	7	0.1	815	6.5	0	0.0	33	0.3
Non Arable Land	41	0.3	184	1.5	3168	25.2	544	4.3	1890	15	147	1.2	109	0.9
Irrigated Land	10772	85.8	5472	43.6	8297	66.1	9483	75.5	7646	60.9	3438	27.4	10263	81.7
Fallow land	0	0.0	0	0.0	291	2.3	0	0.0	0	0.0	0	0.0	45	0.4
Mountainous area	0	0.0	936	7.5	600	4.8	0	0.0	0	0.0	0	0.0	0	0.0
Grassland	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1640	13.1	0	0.0
Urban area	670	5.3	33	0.3	90	0.7	1185	9.4	372	3.0	595	4.7	268	2.1
Other Land Uses	670	5.3	969	7.7	981	7.8	1185	9.4	372	3.0	2235	17.8	313	2.5
Cultivated area	11890	94.7	11591	92.3	11579	92.2	11375	90.6	12188	97	10325	82.2	12247	97.5
TOTAL AREA	12560	100	12560	100	12560	100	12560	100	12560	100	12560	100	12560	100

Table I (continued)

2003	ZOODP		KALAM		KILER		KRANN		KIPAR		LOUTR		MAGEL	
	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%
Cereals	7252	57.7	1097	8.7	2579	20.5	5503	43.8	7700	61.3	4006	31.9	6848	54.5
Industrial crops	3831	30.5	3547	28.2	8755	69.7	6225	49.6	3649	29.0	1599	12.7	25	0.2
Pasture crops	579	4.6	141	1.1	162	1.3	111	0.9	545	4.3	68	0.5	3735	29.7
Mpostanika	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	4	0.0	224	1.8
Arable Land	11855	94.4	4785	38.1	11495	91.5	11839	94.3	11893	94.7	5678	45.2	10833	86.2
Vegetables	574	4.6	67	0.5	464	3.7	531	4.2	64	0.5	16	0.1	747	5.9
Trees	0	0.0	1441	11.5	0	0.0	0	0.0	0	0.0	56	0.4	760	6.0
Vineyards	33	0.3	7	0.1	0	0.0	0	0.0	0	0.0	2	0.0	75	0.6
Non Arable Land	607	4.8	1515	12.1	464	3.7	531	4.2	64	0.5	74	0.6	1581	12.6
Irrigated Land	4442	35.4	4754	37.9	11819	94.1	7486	59.6	3734	29.7	1722	13.7	6562	52.2
Fallow land	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	126	1.0	50	0.4
Mountainous area	0	0.0	5940	47.3	440	3.5	0	0.0	345	2.7	6620	52.7	0	0.0
Grassland	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Urban area	291	2.3	320	2.5	161	1.3	190	1.5	258	2.1	62	0.5	96	0.8
Other Land Uses	291	2.3	6260	49.8	601	4.8	190	1.5	603	4.8	6808	54.2	146	1.2
Cultivated area	12269	97.7	6300	50.2	11959	95.2	12370	98.5	11957	95.2	5752	45.8	12414	98.8
TOTAL AREA	12560	100	12560	100	12560	100	12560	100	12560	100	12560	100	12560	100

Table I (continued)

2003	**MELIS**		**MIRIN**		**NIAMA**		**NEKAR**		**ORFAN**		**PAGRA**		**PEDIN**	
	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%
Cereals	5277	42.0	4266	34.0	3318	26.4	9007	71.7	1910	15.2	2945	23.4	921	7.3
Industrial crops	6282	50.0	6905	55.0	8616	68.6	2630	20.9	9768	77.8	7393	58.9	10300	82.0
Pasture crops	251	2.0	508	4.0	237	1.9	530	4.2	263	2.1	749	6.0	857	6.8
Mpostanika	25	0.2	13	0.1	0	0.0	0	0.0	5	0.0	17	0.1	181	1.4
Arable Land	11835	94.2	11692	93.1	12171	96.9	12167	96.9	11947	95.1	11110	88.5	12259	97.6
Vegetables	138	1.1	107	0.9	237	1.9	43	0.3	226	1.8	125	1.0	103	0.8
Trees	0	0.0	0	0.0	0	0.0	11	0.1	0	0.0	25	0.2	18	0.1
Vineyards	113	0.9	67	0.5	0	0.0	22	0.2	0	0.0	4	0.0	2	0.0
Non Arable Land	251	2.0	174	1.4	237	1.9	76	0.6	226	1.8	154	1.2	123	1.0
Irrigated Land	9460	75.3	10766	85.7	9090	72.4	2701	21.5	10361	82.5	8392	66.8	12371	98.5
Fallow land	100	0.8	200	1.6	0	0.0	0	0.0	0	0.0	1200	9.6	38	0.3
Mountainous area	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Grassland	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Urban area	374	3.0	494	3.9	152	1.2	317	2.5	387	3.1	102	0.8	140	1.1
Other Land Uses	474	3.8	694	5.5	152	1.2	317	2.5	387	3.1	1302	10.4	178	1.4
Cultivated area	12086	96.2	11866	94.5	12408	98.8	12243	97.5	12173	96.9	11258	89.6	12382	98.6
TOTAL AREA	12560	100	12560	100	12560	100	12560	100	12560	100	12560	100	12560	100

Table I (continued)

2003	**STAVR**		**STEFN**		**XAIDE**	
	acres	%	acres	%	acres	%
Cereals	1670	13.3	3098	24.7	6103	48.6
Industrial crops	10033	79.9	5602	44.6	3247	25.9
Pasture crops	24	0.2	1035	8.2	186	1.5
Mpostanika	0	0.0	0	0.0	266	2.1
Arable Land	11727	93.4	9735	77.5	9803	78.1
Vegetables	201	1.6	586	4.7	311	2.5
Trees	0	0.0	676	5.4	616	4.9
Vineyards	0	0.0	8	0.1	136	1.1
Non Arable Land	201	1.6	1270	10.1	1063	8.5
Irrigated Land	10306	82.1	7505	59.8	9189	73.2
Fallow land	0	0.0	347	2.8	1214	9.7
Mountainous area	0	0.0	180	1.4	360	2.9
Grassland	0	0.0	0	0.0	0	0.0
Urban area	632	5.0	1028	8.2	120	1.0
Other Land Uses	632	5.0	1555	12.4	1694	13.5
Cultivated area	11928	95.0	11005	87.6	10866	86.5
TOTAL AREA	12560	100	12560	100	12560	100

2004	AGBIS		AGGEL		AMPEK		AMIGD		ANBUN		ARMEN		ASPRO	
	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%
Cereals	5511	43.9	7331	58.4	1950	15.5	7265	57.8	6055	48.2	3220	25.6	6401	51.0
Industrial crops	5950	47.4	4096	32.6	10072	80.2	5061	40.3	1497	11.9	7347	58.5	3802	30.3
Pasture crops	784	6.2	723	5.8	62	0.5	29	0.2	71	0.6	0	0.0	1017	8.1
Mpostanika	0	0.0	0	0.0	9	0.1	42	0.3	275	2.2	0	0.0	0	0.0
Arable Land	12244	97.5	12150	96.7	12093	96.3	12397	98.7	7899	62.9	10568	84.1	11265	89.7
Vegetables	130	1.0	87	0.7	212	1.7	8	0.1	71	0.6	209	1.7	1234	9.8
Trees	0	0.0	14	0.1	0	0.0	47	0.4	536	4.3	104	0.8	34	0.3
Vineyards	0	0.0	3	0.0	0	0.0	0	0.0	94	0.7	0	0.0	0	0.0
Non Arable Land	130	1.0	104	0.8	212	1.7	56	0.4	701	5.6	313	2.5	1268	10.1
Irrigated Land	6974	55.5	4264	33.9	10370	82.6	6709	53.4	2111	16.8	7843	62.4	5302	42.2
Fallow land	146	1.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Mountainous area	0	0.0	0	0.0	0	0.0	0	0.0	2080	16.6	0	0.0	0	0.0
Grassland	0	0.0	0	0.0	0	0.0	0	0.0	1820	14.5	0	0.0	0	0.0
Urban area	40	0.3	306	2.4	255	2.0	107	0.9	60	0.5	1679	13.4	72	0.6
Other Land Uses	186	1.5	306	2.4	255	2.0	107	0.9	3960	31.5	1679	13.4	72	0.6
Cultivated area	12374	98.5	12254	97.6	12305	98.0	12453	99.1	8600	68.5	10881	86.6	12488	99.4
TOTAL AREA	12560	100	12560	100	12560	100	12560	100	12560	100	12560	100	12560	100

Table II. Crop types and land uses (in acres & percentages %) for the year 2004, in all the breeding sites where samplings were realized. Villages are used with their codenames

Table II (continued)

2004	**ASTRI**		**AURA**		**GIRTO**		**DASOK**		**DELER**		**DOXAR**		**ELEFT**	
	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%
Cereals	707	5.6	5376	42.8	2095	16.7	2378	18.9	7954	63.3	6735	53.6	2289	18.2
Industrial crops	10285	81.9	5223	41.6	2760	22.0	7899	62.9	47	0.4	3296	26.2	9720	77.4
Pasture crops	657	5.2	546	4.3	974	7.8	104	0.8	1629	13.0	61	0.5	123	1.0
Mpostanika	30	0.2	1	0.0	1845	14.7	144	1.1	383	3.1	0	0.0	16	0.1
Arable Land	11679	93.0	11146	88.7	7680	61.1	10524	83.8	10014	79.7	10093	80.4	12147	96.7
Vegetables	211	1.7	348	2.8	312	2.5	543	4.3	286	2.3	171	1.4	26	0.2
Trees	0	0.0	96	0.8	2981	23.7	0	0.0	788	6.3	61	0.5	48	0.4
Vineyards	0	0.0	0	0.0	6	0.0	7	0.1	815	6.5	0	0.0	33	0.3
Non Arable Land	211	1.7	445	3.5	3298	26.3	551	4.4	1888	15.0	232	1.9	107	0.9
Irrigated Land	11275	89.8	5741	45.7	8234	65.6	9771	77.8	8597	68.4	3431	27.3	11466	91.3
Fallow land	0	0.0	0	0.0	898	7.1	300	2.4	286	2.3	0	0.0	38	0.3
Mountainous area	0	0.0	936	7.5	600	4.8	0	0.0	0	0.0	0	0.0	0	0.0
Grassland	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1640	13.1	0	0.0
Urban area	670	5.3	33	0.3	90	0.7	1185	9.4	372	3.0	595	4.7	268	2.1
Other Land Uses	670	5.3	969	7.7	1588	12.6	1485	11.8	658	5.2	2235	17.8	306	2.4
Cultivated area	11890	94.7	11591	92.3	10972	87.4	11075	88.2	11902	94.8	10325	82.2	12254	97.6
TOTAL AREA	12560	100	12560	100	12560	100	12560	100	12560	100	12560	100	12560	100

Table II (continued)

2004	**ZOODP**		**KALAM**		**KILER**		**KRANN**		**KIPAR**		**LOUTR**		**MAGEL**	
	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%
Cereals	7490	59.6	1125	9.0	2688	21.4	5466	43.5	7420	59.1	4055	32.3	7200	57.3
Industrial crops	3632	28.9	3612	28.8	8573	68.3	6230	49.6	3812	30.3	1551	12.3	0	0.0
Pasture crops	470	3.7	110	0.9	109	0.9	65	0.5	606	4.8	108	0.9	3228	25.7
Mpostanika	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	20	0.2	0	0.0
Arable Land	12047	95.9	4848	38.6	11370	90.5	11761	93.6	11837	94.2	5733	45.6	10428	83.0
Vegetables	648	5.2	48	0.4	589	4.7	609	4.8	120	1.0	0	0.0	993	7.9
Trees	7	0.1	1402	11.2	0	0.0	0	0.0	0	0.0	60	0.5	968	7.7
Vineyards	22	0.2	2	0.0	0	0.0	0	0.0	0	0.0	2	0.0	74	0.6
Non Arable Land	678	5.4	1452	11.6	589	4.7	609	4.8	120	1.0	62	0.5	2036	16.2
Irrigated Land	4575	36.4	4816	38.3	9998	79.6	7612	60.6	3978	31.7	2104	16.7	6753	53.8
Fallow land	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	83	0.7	0	0.0
Mountainous area	0	0.0	5940	47.3	440	3.5	0	0.0	345	2.7	6620	52.7	0	0.0
Grassland	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Urban area	291	2.3	320	2.5	161	1.3	190	1.5	258	2.1	62	0.5	96	0.8
Other Land Uses	291	2.3	6260	49.8	601	4.8	190	1.5	603	4.8	6765	53.9	96	0.8
Cultivated area	12269	97.7	6300	50.2	11959	95.2	12370	98.5	11957	95.2	5795	46.1	12464	99.2
TOTAL AREA	12560	100	12560	100	12560	100	12560	100	12560	100	12560	100	12560	100

Table II (continued)

2004	MELIS		MIRIN		NIAMA		NEKAR		ORFAN		PAGRA		PEDIN	
	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%
Cereals	5057	40.3	4171	33.2	2726	21.7	9013	71.8	2196	17.5	2797	22.3	901	7.2
Industrial crops	6574	52.3	6840	54.5	8888	70.8	2632	21.0	9302	74.1	7283	58.0	10618	84.5
Pasture crops	152	1.2	556	4.4	166	1.3	523	4.2	216	1.7	832	6.6	505	4.0
Mpostanika	0	0.0	13	0.1	0	0.0	0	0.0	5	0.0	7	0.1	181	1.4
Arable Land	11783	93.8	11581	92.2	11780	93.8	12177	97.0	11719	93.3	10922	87.0	12214	97.2
Vegetables	139	1.1	81	0.6	628	5.0	43	0.3	454	3.6	153	1.2	112	0.9
Trees	0	0.0	0	0.0	0	0.0	11	0.1	0	0.0	25	0.2	18	0.1
Vineyards	114	0.9	67	0.5	0	0.0	22	0.2	0	0.0	10	0.1	2	0.0
Non Arable Land	253	2.0	148	1.2	628	5.0	76	0.6	454	3.6	188	1.5	132	1.1
Irrigated Land	9899	78.8	10630	84.6	9682	77.1	2710	21.6	10071	80.2	8086	64.4	12335	98.2
Fallow land	150	1.2	337	2.7	0	0.0	0	0.0	0	0.0	1350	10.7	83	0.7
Mountainous area	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Grassland	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Urban area	374	3.0	494	3.9	152	1.2	317	2.5	387	3.1	102	0.8	140	1.1
Other Land Uses	524	4.2	831	6.6	152	1.2	317	2.5	387	3.1	1452	11.6	223	1.8
Cultivated area	12036	95.8	11729	93.4	12408	98.8	12243	97.5	12173	96.9	11108	88.4	12337	98.2
TOTAL AREA	12560	100	12560	100	12560	100	12560	100	12560	100	12560	100	12560	100

Table II (continued)

2004	**STAVR**		**STEFN**		**XAIDE**	
	acres	%	acres	%	acres	%
Cereals	1401	11.2	2818	22.4	5782	46.0
Industrial crops	9821	78.2	5749	45.8	3503	27.9
Pasture crops	24	0.2	1059	8.4	364	2.9
Mpostanika	0	0.0	0	0.0	120	1.0
Arable Land	11246	89.5	9625	76.6	9770	77.8
Vegetables	682	5.4	447	3.6	297	2.4
Trees	0	0.0	653	5.2	625	5.0
Vineyards	0	0.0	8	0.1	158	1.3
Non Arable Land	682	5.4	1109	8.8	1079	8.6
Irrigated Land	10565	84.1	7462	59.4	9651	76.8
Fallow land	0	0.0	618	4.9	1231	9.8
Mountainous area	0	0.0	180	1.4	360	2.9
Grassland	0	0.0	0	0.0	0	0.0
Urban area	632	5.0	1028	8.2	120	1.0
Other Land Uses	632	5.0	1826	14.5	1711	13.6
Cultivated area	11928	95.0	10734	85.5	10849	86.4
TOTAL AREA	12560	100	12560	100	12560	100

2005	AGBIS		AGGEL		AMPEK		AMIGD		ANBUN		ARMEN		ASPRO	
	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%
Cereals	5359	42.7	6480	51.6	1974	15.7	6792	54.1	6042	48.1	3151	25.1	6079	48.4
Industrial crops	6112	48.7	5469	43.5	9970	79.4	5513	43.9	1604	12.8	7415	59.0	4656	37.1
Pasture crops	903	7.2	222	1.8	100	0.8	15	0.1	18	0.1	0	0.0	536	4.3
Mpostanika	0	0.0	7	0.1	9	0.1	0	0.0	217	1.7	0	0.0	0	0.0
Arable Land	12373	98.5	12178	97.0	12053	96.0	12320	98.1	7881	62.7	10566	84.1	11320	90.1
Vegetables	12	0.1	59	0.5	197	1.6	34	0.3	89	0.7	200	1.6	1183	9.4
Trees	0	0.0	14	0.1	0	0.0	69	0.6	536	4.3	16	0.1	34	0.3
Vineyards	0	0.0	3	0.0	0	0.0	0	0.0	94	0.7	0	0.0	0	0.0
Non Arable Land	12	0.1	76	0.6	197	1.6	103	0.8	719	5.7	215	1.7	1217	9.7
Irrigated Land	7203	57.3	5608	44.6	10416	82.9	7012	55.8	2591	20.6	9684	77.1	6196	49.3
Fallow land	135	1.1	0	0.0	55	0.4	30	0.2	0	0.0	100	0.8	0	0.0
Mountainous area	0	0.0	0	0.0	0	0.0	0	0.0	2080	16.6	0	0.0	0	0.0
Grassland	0	0.0	0	0.0	0	0.0	0	0.0	1820	14.5	0	0.0	0	0.0
Urban area	40	0.3	306	2.4	255	2.0	107	0.9	60	0.5	1679	13.4	72	0.6
Other Land Uses	175	1.4	306	2.4	310	2.5	137	1.1	3960	31.5	1779	14.2	72	0.6
Cultivated area	12385	98.6	12254	97.6	12250	97.5	12423	98.9	8600	68.5	10781	85.8	12488	99.4
TOTAL AREA	12560	100	12560	100	12560	100	12560	100	12560	100	12560	100	12560	100

Table III. Crop types and land uses (in acres & percentages %) for the year 2005, in all the breeding sites where samplings were realized. Villages are used with their codenames

Table III (continued)

2005	**ASTRI**		**AURA**		**GIRTO**		**DASOK**		**DELER**		**DOXAR**		**ELEFT**	
	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%
Cereals	873	6.9	5089	40.5	2001	15.9	2066	16.4	7191	57.3	6757	53.8	1975	15.7
Industrial crops	10256	81.7	5441	43.3	3199	25.5	7835	62.4	207	1.7	3150	25.1	9884	78.7
Pasture crops	691	5.5	495	3.9	1008	8.0	360	2.9	1938	15.4	161	1.3	286	2.3
Mpostanika	30	0.2	0	0.0	1654	13.2	285	2.3	456	3.6	0	0.0	16	0.1
Arable Land	11849	94.3	11038	87.9	7862	62.6	10546	84.0	9792	78.0	10068	80.2	12161	96.8
Vegetables	41	0.3	219	1.7	323	2.6	822	6.5	433	3.4	196	1.6	5	0.0
Trees	0	0.0	303	2.4	3081	24.5	0	0.0	946	7.5	61	0.5	50	0.4
Vineyards	0	0.0	3	0.0	6	0.0	7	0.1	969	7.7	0	0.0	74	0.6
Non Arable Land	41	0.3	524	4.2	3410	27.1	829	6.6	2349	18.7	257	2.0	129	1.0
Irrigated Land	11128	88.6	5922	47.1	8883	70.7	10371	82.6	11469	91.3	3386	27.0	11108	88.4
Fallow land	0	0.0	43	0.3	598	4.8	0	0.0	47	0.4	0	0.0	2	0.0
Mountainous area	0	0.0	936	7.5	600	4.8	0	0.0	0	0.0	0	0.0	0	0.0
Grassland	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1640	13.1	0	0.0
Urban area	670	5.3	33	0.3	90	0.7	1185	9.4	372	3.0	595	4.7	268	2.1
Other Land Uses	670	5.3	1012	8.1	1288	10.3	1185	9.4	419	3.3	2235	17.8	270	2.1
Cultivated area	11890	94.7	11548	91.9	11272	89.7	11375	90.6	12141	96.7	10325	82.2	12290	97.9
TOTAL AREA	12560	100	12560	100	12560	100	12560	100	12560	100	12560	100.0	12560	100

Table III (continued)

2005	**ZOODP**		**KALAM**		**KILER**		**KRANN**		**KIPAR**		**LOUTR**		**MAGEL**	
	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%
Cereals	7316	58.2	1063	8.5	2688	21.4	5849	46.6	7529	59.9	3663	29.2	7217	57.5
Industrial crops	3829	30.5	3878	30.9	8573	68.3	6111	48.7	3730	29.7	1403	11.2	26	0.2
Pasture crops	486	3.9	73	0.6	142	1.1	0	0.0	595	4.7	385	3.1	3093	24.6
Mpostanika	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	8	0.1	0	0.0
Arable Land	12036	95.8	5013	39.9	11403	90.8	11961	95.2	11854	94.4	5460	43.5	10335	82.3
Vegetables	538	4.3	12	0.1	556	4.4	409	3.3	103	0.8	15	0.1	902	7.2
Trees	7	0.1	1270	10.1	0	0.0	0	0.0	0	0.0	84	0.7	979	7.8
Vineyards	23	0.2	5	0.0	0	0.0	0	0.0	0	0.0	3	0.0	77	0.6
Non Arable Land	567	4.5	1287	10.2	556	4.4	409	3.3	103	0.8	102	0.8	1959	15.6
Irrigated Land	4598	36.6	5014	39.9	10012	79.7	7415	59.0	3864	30.8	2060	16.4	7010	55.8
Fallow land	71	0.6	0	0.0	0	0.0	0	0.0	0	0.0	317	2.5	170	1.4
Mountainous area	0	0.0	5940	47.3	440	3.5	0	0.0	345	2.7	6620	52.7	0	0.0
Grassland	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Urban area	291	2.3	320	2.5	161	1.3	190	1.5	258	2.1	62	0.5	96	0.8
Other Land Uses	362	2.9	6260	49.8	601	4.8	190	1.5	603	4.8	6999	55.7	266	2.1
Cultivated area	12198	97.1	6300	50.2	11959	95.2	12370	98.5	11957	95.2	5561	44.3	12294	97.9
TOTAL AREA	12560	100	12560	100	12560	100	12560	100	12560	100	12560	100	12560	100

Table III (continued)

2005	**MELIS**		**MIRIN**		**NIAMA**		**NEKAR**		**ORFAN**		**PAGRA**		**PEDIN**	
	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%
Cereals	5093	40.6	4074	32.4	2192	17.5	9010	71.7	1927	15.3	3787	30.2	887	7.1
Industrial crops	5993	47.7	6660	53.0	9481	75.5	2631	20.9	9403	74.9	6558	52.2	10604	84.4
Pasture crops	283	2.3	280	2.2	261	2.1	523	4.2	269	2.1	934	7.4	505	4.0
Mpostanika	0	0.0	0	0.0	0	0.0	0	0.0	12	0.1	0	0.0	180	1.4
Arable Land	11369	90.5	11015	87.7	11934	95.0	12168	96.9	11611	92.4	11319	90.1	12177	96.9
Vegetables	75	0.6	56	0.4	474	3.8	43	0.3	562	4.5	88	0.7	144	1.1
Trees	0	0.0	0	0.0	0	0.0	15	0.1	0	0.0	35	0.3	0	0.0
Vineyards	141	1.1	70	0.6	0	0.0	22	0.2	0	0.0	14	0.1	2	0.0
Non Arable Land	217	1.7	126	1.0	474	3.8	80	0.6	562	4.5	137	1.1	146	1.2
Irrigated Land	9401	74.8	10267	81.7	11223	89.4	2704	21.5	10354	82.4	7948	63.3	11760	93.6
Fallow land	600	4.8	925	7.4	0	0.0	0	0.0	0	0.0	1042	8.3	97	0.8
Mountainous area	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Grassland	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Urban area	374	3.0	494	3.9	152	1.2	317	2.5	387	3.1	102	0.8	140	1.1
Other Land Uses	974	7.8	1419	11.3	152	1.2	317	2.5	387	3.1	1144	9.1	237	1.9
Cultivated area	11586	92.2	11141	88.7	12408	98.8	12243	97.5	12173	96.9	11416	90.9	12323	98.1
TOTAL AREA	12560	100	12560	100	12560	100	12560	100	12560	100	12560	100	12560	100

Table III (continued)

2005	STAVR		STEFN		XAIDE	
	acres	%	acres	%	acres	%
Cereals	824	6.6	2592	20.6	6103	48.6
Industrial crops	10598	84.4	6150	49.0	3247	25.9
Pasture crops	26	0.2	1069	8.5	186	1.5
Mpostanika	1	0.0	0	0.0	266	2.1
Arable Land	11449	91.2	9811	78.1	9803	78.1
Vegetables	421	3.4	469	3.7	311	2.5
Trees	0	0.0	571	4.5	616	4.9
Vineyards	0	0.0	8	0.1	136	1.1
Non Arable Land	421	3.4	1048	8.3	1063	8.5
Irrigated Land	11131	88.6	8218	65.4	9189	73.2
Fallow land	58	0.5	493	3.9	1214	9.7
Mountainous area	0	0.0	180	1.4	360	2.9
Grassland	0	0.0	0	0.0	0	0.0
Urban area	632	5.0	1028	8.2	120	1.0
Other Land Uses	690	5.5	1701	13.5	1694	13.5
Cultivated area	11870	94.5	10859	86.5	10866	86.5
TOTAL AREA	12560	100	12560	100	12560	100

APPENDIX B

Amphibians, Reptiles, Mammals, Raptors and Non-Raptorial Birds Which Are Present in Thessaly Plain

Table I. Amphibians and reptiles recorded in the Thessaly plain, their conservation status and population trend.

Species		IUCN Red List Status	European Threat Status	BERN Convention	Population Trend
Latin name	Common name				
Newts					
Triturus cristatus	Northern crested newt	LC	V	II	D
Triturus vulgaris	Common newt			III	S
Toads					
Bufo bufo spinosus	Common toad	LC		III	
Bufo viridis	Green toad	LC	R	II	S
Bombina variegata	Yellow bellied toad	LC	V	III	
Pelobates syriacus	Eastern spadefoot	LC		II	D
Frogs					
Hyla arborea	Common tree frog	NT	R	II	D
Rana dalmatina	Agile frog	LC		III	D
Rana graeca	Balkan stream frog	LC		III	S
Rana balcanica	Greek march frog			III	
Terrapins					
Emys orbicularis	European pond terrapin	LC	V	II	
Mauremys caspica	Spanish terrapin			II	
Tortoises					
Testudo hermanni	Hermann’s tortoise	LC	V	II	S
Testudo graeca ibera	Spur thighed tortoise	LC	R	II	
Testudo marginata	Marginated tortoise	LC	R	II	
Lizards					
Cyrtodactylus kotschyi	Kotschy’s gecko	LC		II	
Hemidactylus turcicus	Turkish gecko			III	
Anguis fragilis	Slow worm	LC		III	S
Ophisaurus apodus	European glass lizard			III	
Ablepharus kitabeillii	Snake-eyed skink	LC		II	S
Ophiomorus punctatissimus	Limbless skink			III	
Lacerta agilis	Sand lizard	LC		II	D
Lacerta trilineata	Balkan green lizard	LC		II	D
Lacerta viridis	Green lizard	LC		II	D
Podarcis erhardii	Erhard’s wall lizard			III	
Podarcis muralis	Common wall lizard	LC		II	S
Podarcis taurica	Balkan wall lizard	LC		II	D
Snakes					
Coluber caspius	Large whip snake			III	
Coluber gemonensis	Balkan whip snake	LC		II	
Coluber najadum	Dahl’s whip snake			III	
Coronella austriaca	Smooth snake		V	II	
Elaphe longissima	Aesculapian snake		R	II	
Elaphe quatuorlineata	Four-lined snake		V	II	
Elaphe situla	Leopard snake		V	II	

Table I (continued)

Species		IUCN Red List Status	European Threat Status	BERN Convention	Population Trends
Latin name	Common name				
Snakes					
Eryx jaculus	Sand boa				
Malpolon monspessulanus	Montpellier snake			III	
Natrix natrix	Grass snake			III	
Natrix tessellata	Dice snake		R	III	
Telescopus fallax	Cat snake			III	
Typhlops vermicularis	Worm snake			III	
Vipera ammodytes	Nose-horned viper			II	

II: Strictly protected species

III: Protected species

V: Vulnerable

R: Rare

D: Decreasing

S: Stable

LC: Least Concern

NT: Near Threatened

Table II. List of birds of prey recorded in the Thessaly plain, their conservation status, SPEC categories and seasonal movements.

Species							
Latin name	Common name	**1**	**2**	**3**	**4**	**5**	**6**
	Harriers						
Circus aeroginosus	Marsh Harrier	I	n	S	II		R/b
Circus cyaneus	Hen Harrier	I	III	V	II	II	W/v
Circus macrourus	Pallid Harrier	I	IV	S	II	II	P/v
Circus pygargus	Montagu’s Harrier	I	IV	S	II	II	P/v
	Buzzards						
Buteo buteo	Common Buzzard		n	S	II		R/b
Buteo rufinus	Long-legged Buzzard	I	III	(E)	II	II	S/b
	Hawks						
Accipiter brevipes	Levant Sparrowhawk	I	II	R	II	II	S/b
Accipiter gentilis	Goshawk		n	S	II		R/b
	Falcons						
Falco cherrug	Saker Falcon		III	E	II		P/v
Falco columbarius	Merlin	I	n	S	II		W/v
Falco naummanni	Lesser Kestrel	I	I	(V)	II	II	S/b
Falco tinnunculus	Common Kestrel		III	D	II	II	R/b
	Owls						
Bubo bubo	Eagle owl	I	III	V	II		R/b
Athene noctua	Little owl		III	D	II		R/b
Strix aluco	Tawny owl		IV	S	II		R/b
Asio otus	Long-eared owl		n	S	II		W/v – R/b
Asio flammeus	Short-eared owl	I	III	V	II		P/v – W/v
Tyto alba	Barn owl		III	D	II		R/b
Otus scops	Scop’s owl		III	D	II		S/b

1. European Wildbird Directive 79/409 on the conservation of Wild Birds.

Annex I: Species which are subject of special conservation measures concerning their habitat in order to ensure their survival and reproduction in their area of distribution.

2. SPEC. Species of European Conservation Concern.

I = SPEC 1 category, II = SPEC 2 category, III = SPEC 3 category, IV = SPEC 4 category, n = Non-SPEC category

3. European Threat Status.

E = Endangered, V = Vulnerable, R = Rare, D = Declining, S = Secure, () = Insufficiently known

4. Bern Convention.

Convention on the conservation of European wildlife and natural habitats.

Annex II: Strictly protected fauna species.

5. Bonn Convention.

Convention on the Conservation of Migratory species of Wild Animals.

Annex II: Migratory species conserved through agreements

6. Seasonal Movements

W/v: Winter visitor, P/v: Passage visitor, S/b: Summer breeder, R/b: Resident all year long & breeder

Table III. List of non-raptorial birds recorded in the Thessaly plain, their conservation status, SPEC categories and seasonal movements.

Species							
Latin name	Common name	**1**	**2**	**3**	**4**	**5**	**6**
Waders							
Actitis hypoleucos	Common Sandpiper			S	III		S/b
Arenaria interpres	Ruddy Turnstone			S	III		P/v
Burhinus oedicnemus	Stone Curlew	I	3	V	II	II	S/b
Calidris alpina	Dunlin		3	V	II	II	W/v
Calidris ferruginea	Curlew Sandpiper				II		P/v
Calidris minuta	Little Stint			(S)	II		P/v
Calidris temminckii	Temminck's Stint			(S)	II		W/v
Charadrius dubius	Little Ringed Plover			(S)	II		S/b
Charadrius hiaticula	Common Ringed Plover			S	II		W/v
Gallinago gallinago	Common Snipe			(S)	III		W/v
Glareola pratincola	Collared Pratincole	I	3	E	II	II	S/b
Himantopus himantopus	Black-winged Stilt	I		S	II		S/b
Limosa limosa	Black-tailed Godwit	II/2	2	V	III	II	P/v
Numenius arquata	Eurasian Curlew	II/2	3	D	III	II	W/v
Phalaropus lobatus	Red-necked Phalarope	I		(S)	II		P/v
Philomachus pugnax	Ruff	I	4	(S)	III	II	W/v
Pluvialis apricaria	Golden Plover	II/2	4	S	III	II	W/v
Recurvirostra avosetta	Avocet	I	3	L	II	II	R/b
Scolopax rusticola	Woodcock	II/1	3	V	III		W/v
Tringa erythropus	Spotted Redshank			S	III		W/v
Tringa glareola	Wood Sandpiper	I	3	D	II	II	P/v
Tringa nebularia	Common Greenshank			S	III		P/v
Tringa ochropus	Green Sandpiper			(S)	II		W/v
Tringa stagnatilis	Marsh Sandpiper			(S)	II		P/v
Tringa totanus	Common Redshank	II/2	2	D	III	II	R/b
Vanellus vanellus	Northern Lapwing			(S)	III		S/b
Wildfowl							
Anas acuta	Northern Pintail	II/1	3	V	III	II	P/v
Anas clypeata	Northern Shoveler			S	III		W/v
Anas crecca	Common Teal			S	III		W/v
Anas penelope	Wigeon			S	II		P/v
Anas platyrhynchos	Mallard			S	III		R/b
Anas querquedula	Garganey	II/1	3	V	II	II	P/v
Anas strepera	Gadwall	II/1	3	V	III	II	R/b
Anser albifrons	White-fronted Goose			S	II		W/v
Anser anser	Greylag Goose			S	II		W/v
Aythya ferina	Common Pochard	II/1	4	S	III	II	W/v
Aythya fuligula	Tufted Duck			S	III		W/v
Aythya nyroca	Ferruginous Duck	I	1	V	III	II	W/v
Bucephala clangula	Common Goldeneye			S	III		W/v
Cygnus cygnus	Whooper Swan	I	4	S	II	II	W/v

Table III (continued)

Species							
Latin name	Common name	**1**	**2**	**3**	**4**	**5**	**6**
Cygnus olor	Mute Swan			S	III		S/b
Mergellus albellus	Smew	I	3	V	II	II	W/v
Mergus merganser	Goosander			S	III		S/b
Netta rufina	Red-crested Pochard	II/1	3	D	III	II	W/v
Tadorna tadorna	Common Shelduck			S	II		W/v
Herons, Storks & Ibises							
Ardea cinerea	Grey Heron			S	II		W/v
Ardea purpurea	Purple Heron	I	3	V	II	II	W/v
Ardeola ralloides	Squacco Heron	I	3	V	II		S/b
Botaurus stellaris	Great Bittern	I	3	(V)	II	II	W/v
Egretta alba	Great Egret	I		S	II		S/b
Egretta garzetta	Little Egret	I		S	II		S/b
Ixobrychus minutus	Little Bittern	I	3	(V)	II	II	S/b
Nycticorax nycticorax	Night Heron	I	3	D	II		S/b
Terns & Gulls							
Chlidonias hybridus	Whiskered Tern	I	3	D	II		S/b
Chlidonias leucopterus	White-winged Tern			S	II		P/v
Chlidonias niger	Black Tern	I	3	D	II	II	P/v
Gelochelidon nilotica	Gull-billed Tern	I	3	(E)	II		P/v
Larus cachinnans	Yellow-legged Gull			(S)			R/b
Larus canus	Common Gull	II/2	2	D	III		W/v
Larus melanocephalus	Mediterranean Gull	I	4	S	II	II	R/b
Larus minutus	Little Gull		3	D	II		W/v
Larus ridibundus	Black-headed Gull			S	III		W/v
Sterna caspia	Caspian Tern	I	4	(E)	II		W/v
Sterna hirundo	Common Tern			S	II		S/b
Sterna sandvicensis	Sándwich Tern	I	2	D	II	II	W/v
Rails & Crakes							
Fulica atra	Eurasian Coot			S	III		R/b
Gallinula chloropus	Common Moorhen			S	III		R/b
Porzana parva	Little Crake		4	(S)	II	II	P/v
Porzana pusilla	Baillon’s Crake	I	3	R	II	II	P/v
Rallus aquaticus	Water Rail			(S)	III		R/b
Grebes							
Podiceps cristatus	Great Crested Grebe			S	III		S/b
Podiceps grisegena	Red-necked Grebe			S	III		W/v
Podiceps nigricollis	Black-necked Grebe			S	III		W/v
Tachybaptus ruficolis	Little Grebe			S	III		R/b
Cormorants							
Phalacrocorax carbo	Great Cormorant			S	III		W/v
Phalacrocorax pygmeus	Pygmy Cormorant	I	2	V	III	II	S/b
Flamingos							
Phoenicopterus ruber	Greater Flamingo	I	3	L	II	II	W/v
Sparrows							
Passer domesticus	House Sparrow			S			R/b

Table III (continued)

Species Latin name	Common name	**1**	**2**	**3**	**4**	**5**	**6**
Passer hispanoliensis	Spanish Sparrow			(S)	III		R/b
Passer montanus	Tree Sparrow			S	III		R/b
Larks							
Alauda arvensis	Skylark	II/2	3	V	II		R/b
Calandrella brachydactyla	Short-toed Lark	I	3	V	II		W/v
Galerida cristata	Crested Lark		3	(D)	III		R/b
Lullula arborea	Woodlark	I	2	(V)	III		R/b
Melanocorypha calandra	Calandra Lark	I	3	(D)	II		R/b
Warblers							
Acrocephalus arundinaceus	Great Reed Warbler			(S)	II		S/b
Acrocephalus melanopogon	Moustached Warbler	I		(S)	II		R/b
Acrocephalus schoenobaenus	Sedge Warbler		4	S	II	II	S/b
Acrocephalus scirpaceus	Reed Warbler		4	S	II	II	S/b
Cisticola juncidis	Zitting Cisticola			(S)	II		R/b
Sylvia communis	Whitethroat		4	S	II	II	S/b
Pipits & Wagtails							
Anthus campestris	Tawny Pipit	I	3	V	II		S/b
Anthus cervinus	Red-throated Pipit			(S)	II		P/v
Anthus pratensis	Meadow Pipit		4	S	II		W/v
Anthus spinoletta	Water Pipit			S	II		W/v
Motacilla alba	White-pied Wagtail			S	II		R/b
Motacilla cinerea	Grey Wagtail			(S)	II		R/b
Motacilla flava	Yellow Wagtail			S	II		S/b
Finches							
Carduelis carduelis	Goldfinch			(S)	II		R/b
Carduelis chloris	Greenfinch		4	S	II		R/b
Fringilla coelebs	Chaffinch		4	S	III		R/b
Serinus serinus	Serin		4	S	II		R/b
Pigeons & Doves							
Columba oenas	Stock dove	II/2	4	S	III		R/b
Columba palumbus	Wood pigeon	II/1	4	S			R/b
Streptopelia decaocto	Collares dove			S	III		R/b
Streptopelia turtur	Turtle dove	II/2	3	D	III		S/b
Crows							
Corvus corax	Raven			(S)	III		R/b
Corvus monedula	Jackdaw			S	III		R/b
Garrulus glandarius	Jay			(S)			R/b
Pica pica	Magpie			S			R/b
Woodpeckers							
Dendrocopos medius	Middle Spotted Woodpecke	I	4	(S)	II		R/b
Dendrocopos syriacus	Syrian Woodpecker	I	4	(S)	II		R/b
Dendrocopos minor	Lesser Spotted Woodpecke			S	II		R/b
Dryocopus martius	Black Woodpecker	I		S	II		R/b
Picus viridis	Green Woodpecker		2	D	II		R/b

Table III (continued)

Species							
Latin name	Common name	**1**	**2**	**3**	**4**	**5**	**6**
Swallows & Martins							
Delichon urbica	House martin			S	II		S/b
Hirundo rustica	Barn swallow		3	D	II		S/b
Hoopes & Bee-eaters							
Coracias garrulus	Soller	I	2	(D)	II	II	S/b
Merops apiaster	Bee-eater		3	D	II		S/b
Upupa epops	Hoopoe			S	II		S/b
Buntings							
Emberiza cirlus	Cirl bunting		4	(S)	II		R/b
Emberiza hortulana	Ortolan bunting	I	2	(V)	III		S/b
Emberiza schoeniclus	Reed bunting			S	II		R/b
Miliaria calandra	Corn bunting		4	(S)	III		R/b
Thrushes							
Erithacus rubecula	Robin		4	S	II		R/b
Luscinia megarhynchos	Nightingale		4	(S)	II		S/b
Saxicola rubetra	Whinchat		4	S	II	II	S/b
Turdus merula	Blackbird	II/2	4	S	III	II	R/b
Turdus philomelos	Song thrush	II/2	4	S	III	II	W/v
Tits							
Panurus biarmicus	Bearded reedling			(S)	II		R/b
Parus caeruleus	Blue tit		4	S	II		R/b
Parus lugubris	Sombre tit		4	(S)	II		R/b
Parus major	Great tit			S	II		R/b
Storks							
Ciconia ciconia	White stork	I	2	V	II	II	S/b
Ciconia nigra	Black stork	I	3	R	II	II	S/b
Starlings & Orioles							
Lanius collurio	Red-backed shrike	I	3	(D)	II		S/b
Oriolus oriolus	Golden Oriole			S	II		S/b
Swifts							
Apus apus	Swift			S	III		S/b
Nightjars							
Caprimulgus europaeus	Nightjar	I	2	(D)	II		S/b
Cuckoos							
Cuculus canorus	Cuckoo			S	III		S/b
Partridges & Pheasants							
Coturnix coturnix	Quail	II/2	3	V	III	II	S/b
Starlings							
Sturnus vulgaris	Starling			S			R/b
Wrens							
Troglodytes troglodytes	Wren			S	II		S/b

1. European Wildbird Directive 79/409 on the conservation of Wild Birds.

Annex I: Species which are subject of special conservation measures concerning their habitat in order to ensure their survival and reproduction in their area of distribution.

2. SPEC. Species of European Conservation Concern.

I = SPEC 1 category, II = SPEC 2 category, III = SPEC 3 category, IV = SPEC 4 category, n = Non-SPEC category

3. European Threat Status.

E = Endangered, V = Vulnerable, R = Rare, D = Declining, S = Secure, () = Insufficiently known

4. Bern Convention.

Convention on the conservation of European wildlife and natural habitats.

Annex II: Strictly protected fauna species.

5. Bonn Convention.

Convention on the Conservation of Migratory species of Wild Animals.

Annex II: Migratory species conserved through agreements

6. Seasonal Movements

W/v: Winter visitor, P/v: Passage visitor, S/b: Summer breeder, R/b: Resident all year long & breeder

APPENDIX C

Absolute and Relative Frequency of Species Which Comprise the Barn owl Diet, in Each Sampling Site, and for Each Sampling Season

(Species and sampling sites abbreviations are demonstrated analytically in Chapter 3)

	Croleu		**Crosua**		**Crouni**		**Sunetr**		**Micgue**		**Miclev**		**Mictho**		**Micuni**		**Crimig**		**Apofla**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
AGBIS	14	2.99	166	35.39	0	0.00	5	1.07	141	30.06	13	2.77	0	0.00	0	0.00	0	0.00	18	3.84
AGGEL	7	2.33	63	20.93	7	2.33	13	4.32	64	21.26	38	12.62	0	0.00	0	0.00	23	7.64	9	2.99
AMPEK	13	3.92	93	28.01	0	0.00	13	3.92	94	28.31	28	8.43	0	0.00	0	0.00	0	0.00	16	2.99
AMGID	0	0.00	38	19.29	0	0.00	0	0.00	90	45.69	46	23.35	0	0.00	0	0.00	0	0.00	4	2.03
ANBUN	0	0.00	31	19.75	0	0.00	0	0.00	103	65.61	2	1.27	0	0.00	0	0.00	0	0.00	2	1.27
ARMEN	15	5.91	32	12.60	1	0.39	7	2.76	107	42.13	72	28.35	0	0.00	0	0.00	0	0.00	3	1.18
ASPRO	0	0.00	50	22.03	0	0.00	0	0.00	142	62.56	8	3.52	0	0.00	0	0.00	0	0.00	2	0.88
ASTRI	2	1.45	10	7.25	0	0.00	0	0.00	109	78.99	5	3.62	2	1.45	0	0.00	0	0.00	4	2.90
AURA	3	1.17	74	28.79	0	0.00	4	1.56	112	43.58	10	3.89	0	0.00	0	0.00	3	1.17	10	3.89
GIRTO	5	2.53	27	13.64	0	0.00	5	2.53	56	28.28	20	10.10	0	0.00	0	0.00	0	0.00	13	6.57
DASOK	5	2.70	27	14.59	0	0.00	2	1.08	47	25.41	9	4.86	8	4.32	0	0.00	0	0.00	7	3.78
DELER	2	0.97	4	1.94	0	0.00	0	0.00	118	57.28	27	13.11	40	19.42	0	0.00	0	0.00	0	0.00
DOXAR	1	0.53	37	19.68	0	0.00	2	1.06	131	69.68	7	3.72	0	0.00	0	0.00	0	0.00	2	1.06
ELEFT	0	0.00	14	7.00	0	0.00	1	0.50	127	63.5	28	14.00	0	0.00	0	0.00	0	0.00	1	0.50
ZOODP	5	1.98	101	40.08	0	0.00	0	0.00	92	36.51	15	5.95	0	0.00	0	0.00	1	0.40	5	1.98
KALAM	0	0.00	2	1.12	0	0.00	0	0.00	166	92.74	6	3.35	0	0.00	0	0.00	0	0.00	0	0.00
KILER	0	0.00	24	17.78	0	0.00	0	0.00	61	45.19	13	9.63	0	0.00	0	0.00	0	0.00	0	0.00
KRANN	1	0.33	69	23.00	0	0.00	1	0.33	124	41.33	24	8.00	0	0.00	0	0.00	0	0.00	14	4.67
KIPAR	2	1.01	103	52.02	0	0.00	0	0.00	61	30.81	2	1.01	0	0.00	0	0.00	2	0.00	0	0.00
LOUTR	7	3.85	14	7.69	0	0.00	0	0.00	86	47.25	44	24.18	10	5.49	0	0.00	0	1.01	6	3.30
MAGEL	4	2.44	15	9.15	0	0.00	5	3.05	77	46.95	37	22.56	8	4.88	0	0.00	0	0.00	5	3.05
MELIS	10	2.07	81	16.74	0	0.00	0	0.00	87	17.98	14	2.89	157	32.44	0	0.00	0	0.00	10	2.07
MIRIN	3	2.14	13	9.29	0	0.00	2	1.43.	4	2.86	7	5.00	18	12.86	0	0.00	0	0.00	7	5.00
NIAMA	0	0.00	11	6.21	0	0.00	1	0.56	136	76.84	5	2.82	0	0.00	0	0.00	0	0.00	1	0.56
NEKAR	2	1.03	57	29.38	0	0.00	0	0.00	73	37.63	4	2.06	3	1.55.	0	0.00	5	2.58	13	6.70
ORFAN	2	0.50	136	34.17	0	0.00	4	1.01	119	29.90	42	10.55	0	0.00	0	0.00	0	0.00	10	2.51
PAGRA	12	5.66	75	35.38	0	0.00	0	0.00	56	26.42	20	9.43	0	0.00	0	0.00	0	0.00	6	2.83
PEDIN	0	0.00	19	11.18	0	0.00	0	0.00	0	0.00	0	0.0	90	52.94	0	0.00	0	0.00	4	2.35
STAVR	3	2.33	36	27.91	0	0.00	1	0.78	51	39.53	7	5.43	0	0.00	0	0.00	0	0.00	8	6.20
STEFN	1	0.76	11	8.33	0	0.00	0	0.00	91	68.94	18	13.64	0	0.00	0	0.00	0	0.00	2	1.52
XAIDE	10	5.15	3	1.55	0	0.00	0	0.00	37	19.07	16	8.25	39	20.10	0	0.00	0	0.00	4	2.06

Table I: Absolute frequency (n) and percentage of frequency (%) of prey items from the 1st sampling which was realized in September 2003

Table I: (continued)

	Apoepi		**Aposyl**		**Apouni**		**Ratnor**		**Ratrat**		**Ratuni**		**Musmus**		**Musmac**		**Musuni**		**Musave**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
AGBIS	0	0.00	13	2.77	0	0.00	0	0.00	2	0.43	0	0.00	64	13.65	24	5.12	0	0.00	0	0.00
AGGEL	0	0.00	11	3.65	2	0.66	3	1.00	0	0.00	1	0.33	35	11.63	12	3.99	2	0.66	0	0.00
AMPEK	5	1.51	9	2.71	0	0.00	0	0.00	0	0.00	0	0.00	39	11.75	16	4.82	0	0.00	0	0.00
AMGID	4	2.03	5	2.54	0	0.00	0	0.00	0	0.00	0	0.00	6	3.05	4	2.03	0	0.00	0	0.00
ANBUN	0	0.00	4	2.55	0	0.00	0	0.00	0	0.00	0	0.00	6	3.82	2	1.27	0	0.00	0	0.00
ARMEN	0	0.00	7	2.76	0	0.00	0	0.00	0	0.00	0	0.00	6	2.36	4	1.57	0	0.00	0	0.00
ASPRO	0	0.00	4	1.76	0	0.00	0	0.00	0	0.00	0	0.00	6	2.64	8	3.52	0	0.00	0	0.00
ASTRI	0	0.00	2	1.45	0	0.00	0	0.00	0	0.00	0	0.00	2	1.45	2	1.45	0	0.00	0	0.00
AURA	0	0.00	9	3.50	0	0.00	0	0.00	0	0.00	0	0.00	20	7.78	12	4.67	0	0.00	0	0.00
GIRTO	4	2.02	17	8.59	0	0.00	5	2.53	0	0.00	0	0.00	18	9.09	26	13.13	0	0.00	0	0.00
DASOK	2	1.08	14	7.57	0	0.00	0	0.00	0	0.00	0	0.00	24	12.97	33	17.84	0	0.00	0	0.00
DELER	4	1.94	2	0.97	0	0.00	2	0.97	0	0.00	0	0.00	4	1.94	2	0.97	0	0.00	0	0.00
DOXAR	0	0.00	2	1.06	0	0.00	0	0.00	0	0.00	0	0.00	2	1.06	4	2.13	0	0.00	0	0.00
ELEFT	0	0.00	2	1.00	0	0.00	2	1.00	0	0.00	6	3.00	13	6.50	6	3.00	0	0.00	0	0.00
ZOODP	0	0.00	13	5.16	0	0.00	0	0.00	0	0.00	0	0.00	11	4.37	9	3.57	0	0.00	0	0.00
KALAM	0	0.00	0	0.00	0	0.00	2	1.12	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
KILER	0	0.00	16	11.85	0	0.00	5	3.70	3	2.22	0	0.00	8	5.93	5	3.70	0	0.00	0	0.00
KRANN	1	0.33	11	3.67	2	0.67	7	2.33	0	0.00	1	0.33	30	10.00	9	3.00	0	0.00	0	0.00
KIPAR	0	0.00	2	1.01	0	0.00	2	1.01	0	0.00	4	2.02	6	3.03	9	4.55	0	0.00	0	0.00
LOUTR	0	0.00	4	2.20	0	0.00	0	0.00	0	0.00	0	0.00	3	1.65	8	4.40	0	0.00	0	0.00
MAGEL	0	0.00	4	2.44	0	0.00	0	0.00	0	0.00	0	0.00	2	1.22	0	0.00	0	0.00	0	0.00
MELIS	4	0.83	10	2.07	0	0.00	5	1.03	0	0.00	0	0.00	31	6.40	46	9.50	0	0.00	0	0.00
MIRIN	0	0.00	7	5.00	0	0.00	1	0.71	14	10.00.	0	0.00	42	30.00	13	9.29	0	0.00	3	2.14
NIAMA	5	2.82	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	16	9.04	2	1.13	0	0.00	0	0.00
NEKAR	0	0.00	10	5.15	0	0.00	0	0.00	0	0.00	0	0.00	22	11.34	5	2.58	0	0.00	0	0.00
ORFAN	0	0.00	24	6.03	0	0.00	0	0.00	2	0.50	0	0.00	45	11.31	14	3.52	0	0.00	0	0.00
PAGRA	0	0.00	15	7.08	0	0.00	2	0.94	2	0.94	0	0.00	14	6.60	5	2.36	0	0.00	0	0.00
PEDIN	0	0.00	9	5.29	0	0.00	0	0.00	0	0.00	0	0.00	27	15.88	17	10.00	0	0.00	0	0.00
STAVR	0	0.00	11	8.53	0	0.00	0	0.00	0	0.00	0	0.00	11	8.53	1	0.78	0	0.00	0	0.00
STEFN	0	0.00	6	4.55	0	0.00	1	0.76	0	0.00	0	0.00	2	1.52	0	0.00	0	0.00	0	0.00
XAIDE	0	0.00	9	4.64	0	0.00	0	0.00	0	0.00	0	0.00	48	24.74	27	13.92	0	0.00	0	0.00

Table I: (continued)

	Pippip		**Tadten**		**Rhifer**		**Pasdom**		**Pasmon**		**Carchl**		**Serser**		**Fricoe**		**Milcal**		**Turmer**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
AGBIS	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
AGGEL	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.33	1	0.33	0	0.00	0	0.00	0	0.00
AMPEK	0	0.00	0	0.00	0	0.00	2	0.60	0	0.00	1	0.30	0	0.00	0	0.00	0	0.00	0	0.00
AMGID	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ANBUN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ARMEN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ASPRO	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.44	0	0.00	1	0.44	0	0.00
ASTRI	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
AURA	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
GIRTO	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.51	0	0.00	0	0.00	0	0.00
DASOK	0	0.00	0	0.00	0	0.00	1	0.54	1	0.54	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
DELER	0	0.00	0	0.00	0	0.00	1	0.49	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
DOXAR	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ELEFT	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ZOODP	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
KALAM	0	0.00	0	0.00	0	0.00	0	0.00	1	0.56	0	0.00	0	0.00	0	0.00	0	0.00	2	1.12
KILER	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
KRANN	0	0.00	0	0.00	0	0.00	2	0.67	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
KIPAR	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
LOUTR	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
MAGEL	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
MELIS	0	0.00	0	0.00	0	0.00	5	1.03	1	0.21	0	0.00	2	0.41	6	1.24	1	0.21	0	0.00
MIRIN	0	0.00	0	0.00	0	0.00	1	0.71	0	0.00	1	0.71	0	0.00	0	0.00	0	0.00	0	0.00
NIAMA	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
NEKAR	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ORFAN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
PAGRA	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
PEDIN	0	0.00	0	0.00	2	1.18	1	0.59	1	0.59	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
STAVR	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
STEFN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
XAIDE	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.52	0	0.00	0	0.00	0	0.00

Table I: (continued)

	Erirub		**Parmaj**		**Parcae**		**Stuvul**		**Picpic**		**Strdec**		**Chopar**		**Locmig**		**Grygry**		**Tetvir**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
AGBIS	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	5	1.07	4	0.85	0	0.00	0	0.00
AGGEL	0	0.00	1	0.33	0	0.00	0	0.00	0	0.00	0	0.00	5	1.66	2	0.66	0	0.00	0	0.00
AMPEK	0	0.00	1	0.30	0	0.00	0	0.00	0	0.00	0	0.00	2	0.60	0	0.00	0	0.00	0	0.00
AMGID	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ANBUN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	1.27	3	1.91	0	0.00	0	0.00
ARMEN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ASPRO	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	0.88	1	0.44	0	0.00	1	0.44
ASTRI	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
AURA	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
GIRTO	0	0.00	0	0.00	0	0.00	1	0.51	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
DASOK	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	3	1.62	2	1.08	0	0.00	0	0.00
DELER	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
DOXAR	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ELEFT	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ZOODP	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
KALAM	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
KILER	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
KRANN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	3	1.00	1	0.33	0	0.00	0	0.00
KIPAR	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	4	2.02	1	0.51	0	0.00	0	0.00
LOUTR	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
MAGEL	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	3	1.83	1	0.61	0	0.00	0	0.00
MELIS	7	1.45	0	0.00	3	0.62	0	0.00	0	0.00	0	0.00	3	0.62	1	0.21	0	0.00	0	0.00
MIRIN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	1.43
NIAMA	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
NEKAR	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ORFAN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
PAGRA	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	4	1.89	1	0.47	0	0.00	0	0.00
PEDIN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
STAVR	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
STEFN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
XAIDE	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00

Table I: (continued)

	Ptenig		**Carnem**		**Coplun**		**Melmel**	
	n	%	n	%	n	%	n	%
AGBIS	0	0.00	0	0.00	0	0.00	0	0.00
AGGEL	0	0.00	1	0.33	0	0.00	0	0.00
AMPEK	0	0.00	0	0.00	0	0.00	0	0.00
AMGID	0	0.00	0	0.00	0	0.00	0	0.00
ANBUN	0	0.00	0	0.00	2	1.27	0	0.00
ARMEN	0	0.00	0	0.00	0	0.00	0	0.00
ASPRO	1	0.44	0	0.00	0	0.00	0	0.00
ASTRI	0	0.00	0	0.00	0	0.00	0	0.00
AURA	0	0.00	0	0.00	0	0.00	0	0.00
GIRTO	0	0.00	0	0.00	0	0.00	0	0.00
DASOK	0	0.00	0	0.00	0	0.00	0	0.00
DELER	0	0.00	0	0.00	0	0.00	0	0.00
DOXAR	0	0.00	0	0.00	0	0.00	0	0.00
ELEFT	0	0.00	0	0.00	0	0.00	0	0.00
ZOODP	0	0.00	0	0.00	0	0.00	0	0.00
KALAM	0	0.00	0	0.00	0	0.00	0	0.00
KILER	0	0.00	0	0.00	0	0.00	0	0.00
KRANN	0	0.00	0	0.00	0	0.00	0	0.00
KIPAR	0	0.00	0	0.00	0	0.00	0	0.00
LOUTR	0	0.00	0	0.00	0	0.00	0	0.00
MAGEL	1	0.61	0	0.00	0	0.00	2	1.22
MELIS	0	0.00	0	0.00	0	0.00	0	0.00
MIRIN	2	1.43	0	0.00	0	0.00	0	0.00
NIAMA	0	0.00	0	0.00	0	0.00	0	0.00
NEKAR	0	0.00	0	0.00	0	0.00	0	0.00
ORFAN	0	0.00	0	0.00	0	0.00	0	0.00
PAGRA	0	0.00	0	0.00	0	0.00	0	0.00
PEDIN	0	0.00	0	0.00	0	0.00	0	0.00
STAVR	0	0.00	0	0.00	0	0.00	0	0.00
STEFN	0	0.00	0	0.00	0	0.00	0	0.00
XAIDE	0	0.00	0	0.00	0	0.00	0	0.00

	Croleu		**Crosua**		**Crouni**		**Sunetr**		**Micgue**		**Miclev**		**Mictho**		**Micuni**		**Crimig**		**Apofla**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
AGBIS	6	2.70	47	21.17	0	0.00	5	2.25	63	28.38	8	3,60	0	0.00	0	0.00	0	0.00	9	4.05
AGGEL	4	1.66	39	16.18	2	0.83	6	2.49	32	13.28	13	5.39	0	0.00	0	0.00	19	7.88	11	4.56
AMPEK	3	1.24	61	25.31	0	0.00	13	5.39	54	22.41	23	9.54	0	0.00	0	0.00	0	0.00	16	6.64
AMGID	0	0.00	11	7.01	0	0.00	0	0.00	22	14.01	8	5.10	0	0.00	0	0.00	0	0.00	5	3.18
ANBUN	0	0.00	31	14.03	0	0.00	10	4.52	55	24.89	23	10.41	0	0.00	0	0.00	0	0.00	25	11.31
ARMEN	2	1.30	28	18.18	0	0.00	2	1.30	92	59.74	7	4.55	0	0.00	0	0.00	0	0.00	0	0.00
ASPRO	5	2.30	87	40.09	0	0.00	2	0.92	64	29.49	3	1.38	0	0.00	0	0.00	1	0.46	4	1.84
ASTRI	0	0.00	12	7.19	0	0.00	0	0.00	86	51.50	44	26.35	0	0.00	0	0.00	0	0.00	8	4.79
AURA	2	1.29	54	34.84	0	0.00	6	3.87	53	34.19	4	2.58	0	0.00	0	0.00	0	0.00	3	1.94
GIRTO	2	1.50	18	13.53	0	0.00	2	1.50	88	66.17	10	7.52	0	0.00	0	0.00	0	0.00	5	3.76
DASOK	2	0.73	39	14.29	0	0.00	1	0.37	45	16.48	14	5.13	2	0.73	0	0.00	0	0.00	6	2.20
DELER	0	0.00	27	8.85	0	0.00	0	0.00	160	52.46	47	15.41	6	1.97	0	0.00	0	0.00	0	0.00
DOXAR	0	0.00	67	31.75	0	0.00	9	4..27	58	27.49	28	13.27	0	0.00	0	0.00	0	0.00	8	3.79
ELEFT	0	0.00	21	11.80	0	0.00	0	0.00	74	41.57	23	12.92	0	0.00	0	0.00	0	0.00	6	3.37
ZOODP	2	0.48	119	28.54	0	0.00	12	2.88	96	23.02	10	2.40	0	0.00	0	0.00	16	3.84	2	0.48
KALAM	0	0.00	33	16.42	5	2.49	0	0.00	71	35.32	25	12.44	0	0.00	0	0.00	0	0.00	10	4.98
KILER	0	0.00	53	12.30	0	0.00	3	0.70	222	51.51	34	7.89	0	0.00	0	0.00	8	1.86	11	2.55
KRANN	2	1.10	39	21.55	0	0.00	7	3.87	71	39.23	19	10.50	0	0.00	0	0.00	2	1.10	5	2.76
KIPAR	0	0.00	92	39.83	0	0.00	4	1.73	31	13.42	19	8.23	0	0.00	0	0.00	0	0.00	17	7.36
LOUTR	0	0.00	40	34.19	0	0.00	2	1.71	36	30.77	2	1.71	1	0.85	0	0.00	0	0.00	9	7.69
MAGEL	7	4.61	10	6.58	0	0.00	2	1.32	46	30.26	13	8.55	10	6.58	0	0.00	0	0.00	8	5.26
MELIS	6	3.08	17	8.72	0	0.00	0	0.00	13	6.67	2	1.03	50	25.64	0	0.00	0	0.00	10	5.13
MIRIN	5	1.95	13	5.06	1	0.39	3	1.17	8	3.11	10	3.89	25	9.73	0	0.00	0	0.00	17	6.61
NIAMA	0	0.00	23	12.30	0	0.00	1	0.53	97	51.87	17	9.09	0	0.00	0	0.00	0	0.00	4	2.14
NEKAR	0	0.00	39	28.68	0	0.00	1	0.74	40	29.41	10	7.35	0	0.00	0	0.00	2	1.47	7	5.15
ORFAN	0	0.00	53	37.06	0	0.00	5	3.50	27	18.88	9	6.29	0	0.00	0	0.00	0	0.00	4	2.80
PAGRA	0	0.00	87	40.85	0	0.00	7	3.29	42	19.72	6	2.82	0	0.00	0	0.00	0	0.00	1	0.47
PEDIN	0	0.00	33	16.84	0	0.00	0	0.00	0	0.00	0	0.00	75	38.27	0	0.00	0	0.00	6	3.06
STAVR	0	0.00	41	28.87	0	0.00	6	4.23	18	12.68	9	6.34	0	0.00	0	0.00	0	0.00	6	4.23
STEFN	0	0.00	40	11.53	0	0.00	2	0.58	186	53.60	20	5.76	0	0.00	0	0.00	0	0.00	3	0.86
XAIDE	20	8.47	8	3.39	0	0.00	0	0.00	23	9.75	14	5.93	46	19.49	0	0.00	0	0.00	10	4.24

Table II: Absolute frequency (n) and percentage of frequency (%) of prey items from the 2nd sampling which was realized in March 2004

Table II: (continued)

	Apoepi		Aposyl		Apouni		Ratnor		Ratrat		Ratuni		Musmus		Musmac		Musuni		Musave	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
AGBIS	0	0.00	19	8.56	0	0.00	6	2.70	5	2.25	4	1.80	38	17.12	7	3.15	2	0.90	0	0.00
AGGEL	3	1.24	18	7.47	1	0.41	6	2.49	3	1.24	3	1.24	51	21.16	19	7.88	3	1.24	0	0.00
AMPEK	0	0.00	22	9.13	0	0.00	0	0.00	0	0.00	0	0.00	38	15.77	8	3.32	1	0.41	0	0.00
AMGID	0	0.00	8	5.10	0	0.00	49	31.21	14	8.92	11	7.01	20	12.74	9	5.73	0	0.00	0	0.00
ANBUN	0	0.00	20	9.05	0	0.00	19	8.60	0	0.00	1	0.45	25	11.31	9	4.07	0	0.00	0	0.00
ARMEN	0	0.00	4	2.60	0	0.00	0	0.00	0	0.00	0	0.00	13	8.44	6	3.90	0	0.00	0	0.00
ASPRO	1	0.46	14	6.45	0	0.00	0	0.00	0	0.00	0	0.00	30	13.82	3	1.38	0	0.00	0	0.00
ASTRI	0	0.00	7	4.19	0	0.00	0	0.00	0	0.00	0	0.00	8	4.79	0	0.00	0	0.00	0	0.00
AURA	0	0.00	9	5.81	0	0.00	0	0.00	0	0.00	0	0.00	20	12.90	2	1.29	0	0.00	0	0.00
GIRTO	0	0.00	1	0.75	0	0.00	0	0.00	0	0.00	0	0.00	5	3.76	2	1.50	0	0.00	0	0.00
DASOK	0	0.00	26	9.52	0	0.00	4	1.47.	4	1.47	0	0.00	90	32.97	23	8.42	0	0.00	10	3.66
DELER	0	0.00	15	4.92	0	0.00	12	3.93	6	1.97	0	0.00	15	4.92	4	1.31	0	0.00	0	0.00
DOXAR	0	0.00	17	8.06	0	0.00	0	0.00	0	0.00	0	0.00	17	8.06	7	3.32	0	0.00	0	0.00
ELEFT	0	0.00	12	6.74	0	0.00	20	11.24	7	3.93	7	3.93	6	3.37	2	1.12	0	0.00	0	0.00
ZOODP	0	0.00	22	5.28	0	0.00	20	4.80	0	0.00	2	0.48	91	21.82	22	5.28	0	0.00	0	0.00
KALAM	4	1.99	15	7.46	0	0.00	3	1.49	6	2.99	0	0.00	20	9.95	5	2.49	0	0.00	0	0.00
KILER	0	0.00	26	6.03	0	0.00	2	0.46	0	0.00	0	0.00	60	13.92	8	1.86	0	0.00	0	0.00
KRANN	2	1.10	12	6.63	0	0.00	1	0.55	0	0.00	0	0.00	17	9.39	4	2.21	0	0.00	0	0.00
KIPAR	0	0.00	17	7.36	0	0.00	12	5.19	11	4.76	7	3.03	7	3.03	11	4.76	0	0.00	0	0.00
LOUTR	2	1.71	4	3.42	0	0.00	0	0.00	0	0.00	4	3.42	5	4.27	8	6.84	2	1.71	0	0.00
MAGEL	0	0.00	27	17.76	0	0.00	0	0.00	0	0.00	0	0.00	17	11.18	10	6.58	0	0.00	0	0.00
MELIS	2	1.03	18	9.23	0	0.00	6	3.08	18	9.23	14	7.18	20	10.26	8	4.10	0	0.00	4	2.05
MIRIN	3	1.17	31	12.06	0	0.00	4	1.56	23	8.95	3	1.17	71	27.63	27	10.51	0	0.00	9	3.50
NIAMA	5	2.67	8	4.28	0	0.00	0	0.00	0	0.00	0	0.00	27	14.44	5	2.67	0	0.00	0	0.00
NEKAR	0	0.00	8	5.88	0	0.00	1	0.74	0	0.00	0	0.00	16	11.76	10	7.35	0	0.00	0	0.00
ORFAN	0	0.00	16	11.19	0	0.00	3	2.10	0	0.00	0	0.00	23	16.08	0	0.00	0	0.00	0	0.00
PAGRA	0	0.00	23	10.80	0	0.00	0	0.00	0	0.00	0	0.00	40	18.78	7	3.29	0	0.00	0	0.00
PEDIN	0	0.00	16	8.16	0	0.00	0	0.00	0	0.00	0	0.00	39	19.90	16	8.16	0	0.00	0	0.00
STAVR	0	0.00	12	8.45	0	0.00	0	0.00	0	0.00	0	0.00	41	28.87	5	3.52	0	0.00	0	0.00
STEFN	0	0.00	7	2.02	0	0.00	68	19.60	0	0.00	0	0.00	13	3.75	2	0.58	0	0.00	0	0.00
XAIDE	0	0.00	23	9.75	0	0.00	0	0.00	0	0.00	0	0.00	62	26.27	27	11.44	0	0.00	0	0.00

Table II: (continued)

	Pippip		**Tadten**		**Rhifer**		**Pasdom**		**Pasmon**		**Carchl**		**Serser**		**Fricoe**		**Milcal**		**Turmer**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
AGBIS	0	0.00	0	0.00	0	0.00	2	0.90	0	0.00	0	0.00	0	0.00	1	0.45	0	0.00	0	0.00
AGGEL	0	0.00	0	0.00	0	0.00	2	0.83	1	0.41	0	0.00	0	0.00	1	0.41	0	0.00	0	0.00
AMPEK	0	0.00	0	0.00	0	0.00	1	0.41	0	0.00	0	0.00	0	0.00	1	0.41	0	0.00	0	0.00
AMGID	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.45	0	0.00	0	0.00	0	0.00
ANBUN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	0.90	1	0.00	0	0.00	0	0.00	0	0.00
ARMEN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.46	0	0.00	0	0.00	0	0.00
ASPRO	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.46	1	0.00	0	0.00	1	0.46	0	0.00
ASTRI	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
AURA	0	0.00	0	0.00	0	0.00	2	1.29	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
GIRTO	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
DASOK	0	0.00	0	0.00	0	0.00	2	0.73	1	0.37	1	0.37	0	0.00	0	0.00	0	0.00	2	0.73
DELER	0	0.00	0	0.00	0	0.00	4	1.31	1	0.33	0	0.00	2	0.66	4	1.31	0	0.00	0	0.00
DOXAR	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ELEFT	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ZOODP	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	0.48	1	0.24	0	0.00	0	0.00	0	0.00
KALAM	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	1.00	0	0.00	0	0.00	2	1.00
KILER	0	0.00	0	0.00	0	0.00	3	0.70	0	0.00	1	0.23	0	0.00	0	0.00	0	0.00	0	0.00
KRANN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
KIPAR	0	0.00	0	0.00	0	0.00	1	0.43	1	0.43	0	0.00	0	0.00	0	0.00	1	0.43	0	0.00
LOUTR	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.85
MAGEL	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.66	0	0.00	1	0.66	0	0.00	0	0.00
MELIS	0	0.00	0	0.00	0	0.00	3	1.54	1	0.51	0	0.00	1	0.51	1	0.51	0	0.00	0	0.00
MIRIN	0	0.00	0	0.00	0	0.00	2	0.78	0	0.00	1	0.39	1	0.39	0	0.00	0	0.00	0	0.00
NIAMA	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
NEKAR	0	0.00	0	0.00	0	0.00	2	1.47	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ORFAN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
PAGRA	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
PEDIN	1	0.51	0	0.00	1	0.51	2	1.02	1	0.51	1	0.51	2	1.02	0	0.00	0	0.00	0	0.00
STAVR	0	0.00	0	0.00	0	0.00	2	1.41	0	0.00	2	1.41	0	0.00	0	0.00	0	0.00	0	0.00
STEFN	0	0.00	0	0.00	0	0.00	0	0.00	1	0.29	0	0.00	2	0.58	1	0.29	2	0.58	0	0.00
XAIDE	0	0.00	0	0.00	0	0.00	2	0.85	0	0.00	0	0.00	1	0.42	0	0.00	0	0.00	0	0.00

Table II: (continued)

	Erirub		Parmaj		Parcae		Stuvul		Picpic		Strdec		Chopar		Locmig		Grygry		Tetvir	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
AGBIS	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
AGGEL	1	0.41	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	0.83	0	0.00
AMPEK	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
AMGID	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ANBUN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ARMEN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ASPRO	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ASTRI	0	0.00	0	0.00	1	0.60	0	0.00	1	0.60	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
AURA	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
GIRTO	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
DASOK	1	0.37	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
DELER	2	0.66	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
DOXAR	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ELEFT	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ZOODP	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
KALAM	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
KILER	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
KRANN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
KIPAR	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
LOUTR	0	0.00	0	0.00	0	0.00	1	0.85	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
MAGEL	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
MELIS	0	0.00	0	0.00	1	0.51	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
MIRIN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
NIAMA	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
NEKAR	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ORFAN	0	0.00	1	0.70	2	1.40	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
PAGRA	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
PEDIN	3	1.53	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
STAVR	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
STEFN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
XAIDE	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00

Table II: (continued)

	Ptenig		**Carnem**		**Coplun**		**Melmel**	
	n	%	n	%	n	%	n	%
AGBIS	0	0.00	0	0.00	0	0.00	0	0.00
AGGEL	0	0.00	1	0.41	0	0.00	0	0.00
AMPEK	0	0.00	0	0.00	0	0.00	0	0.00
AMGID	0	0.00	0	0.00	0	0.00	0	0.00
ANBUN	0	0.00	0	0.00	0	0.00	0	0.00
ARMEN	0	0.00	0	0.00	0	0.00	0	0.00
ASPRO	0	0.00	0	0.00	0	0.00	0	0.00
ASTRI	0	0.00	0	0.00	0	0.00	0	0.00
AURA	0	0.00	0	0.00	0	0.00	0	0.00
GIRTO	0	0.00	0	0.00	0	0.00	0	0.00
DASOK	0	0.00	0	0.00	0	0.00	0	0.00
DELER	0	0.00	0	0.00	0	0.00	0	0.00
DOXAR	0	0.00	0	0.00	0	0.00	0	0.00
ELEFT	0	0.00	0	0.00	0	0.00	0	0.00
ZOODP	0	0.00	0	0.00	0	0.00	0	0.00
KALAM	0	0.00	0	0.00	0	0.00	0	0.00
KILER	0	0.00	0	0.00	0	0.00	0	0.00
KRANN	0	0.00	0	0.00	0	0.00	0	0.00
KIPAR	0	0.00	0	0.00	0	0.00	0	0.00
LOUTR	0	0.00	0	0.00	0	0.00	0	0.00
MAGEL	0	0.00	0	0.00	0	0.00	0	0.00
MELIS	0	0.00	0	0.00	0	0.00	0	0.00
MIRIN	0	0.00	0	0.00	0	0.00	0	0.00
NIAMA	0	0.00	0	0.00	0	0.00	0	0.00
NEKAR	0	0.00	0	0.00	0	0.00	0	0.00
ORFAN	0	0.00	0	0.00	0	0.00	0	0.00
PAGRA	0	0.00	0	0.00	0	0.00	0	0.00
PEDIN	0	0.00	0	0.00	0	0.00	0	0.00
STAVR	0	0.00	0	0.00	0	0.00	0	0.00
STEFN	0	0.00	0	0.00	0	0.00	0	0.00
XAIDE	0	0.00	0	0.00	0	0.00	0	0.00

	Croleu		**Crosua**		**Crouni**		**Sunetr**		**Micgue**		**Miclev**		**Mictho**		**Micuni**		**Crimig**		**Apofla**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
AGBIS	20	5.60	157	43.98	0	0.00	6	1.68	90	25.21	15	4.20	0	0.00	0	0.00	0	0.00	6	1.68
AGGEL	0	0.00	103	37.05	0	0.00	10	3.60	57	20.50	8	2.88	0	0.00	0	0.00	17	6.12	9	3.24
AMPEK	2	0.88	93	40.97	0	0.00	5	2.20	59	25.99	9	3.96	0	0.00	0	0.00	0	0.00	9	3.96
AMGID	0	0.00	31	17.03	1	0.55	0	0.00	50	27.47	27	14.84	0	0.00	1	0.55	0	0.00	8	4.40
ANBUN	6	1.79	35	10.45	0	0.00	0	0.00	236	70.45	21	6.27	2	0.60	0	0.00	0	0.00	5	1.49
ARMEN	15	6.52	54	23.48	1	0.43	5	2.17	44	19.13	27	11.74	0	0.00	0	0.00	0	0.00	8	3.48
ASPRO	11	5.95	100	54.05	0	0.00	4	2.16	32	17.30	6	3.24	0	0.00	0	0.00	1	0.54	1	0.54
ASTRI	2	1.60	25	20.00	0	0.00	4	3.20	61	48.80	5	4.00	1	0.80	0	0.00	0	0.00	6	4.80
AURA	1	0.43	59	25.54	0	0.00	2	0.87	84	36.36	10	4.33	0	0.00	0	0.00	0	0.00	18	7.79
GIRTO	8	3.35	34	14.23	0	0.00	1	0.42	164	68.62	9	3.77	0	0.00	0	0.00	1	0.42	1	0.42
DASOK	5	2.45	31	15.20	0	0.00	0	0.00	34	16.67	16	7.84	19	9.31	0	0.00	0	0.00	7	3.43
DELER	1	0.43	5	2.16	0	0.00	0	0.00	149	64.22	42	18.10	7	3.02	0	0.00	0	0.00	3	1.29
DOXAR	4	2.41	80	48.19	0	0.00	4	2.41	30	18.07	2	1.20	3	1.81	0	0.00	1	0.60	0	0.00
ELEFT	0	0.00	41	12.31	2	0.60	0	0.00	183	54.95	20	6.01	0	0.00	0	0.00	0	0.00	2	0.60
ZOODP	6	1.33	284	62.97	0	0.00	11	2.44	66	14.63	9	2.00	0	0.00	0	0.00	9	2.00	0	0.00
KALAM	7	2.06	59	17.40	0	0.00	0	0.00	204	60.18	16	4.72	0	0.00	0	0.00	0	0.00	22	6.49
KILER	6	1.24	133	27.48	1	0.21	8	1.65	169	34.92	8	1.65	0	0.00	0	0.00	2	0.41	18	3.72
KRANN	10	2.79	110	30.64	0	0.00	1	0.28	138	38.44	25	6.96	0	0.00	0	0.00	3	0.84	8	2.23
KIPAR	8	3.52	62	27.31	0	0.00	4	1.76	33	14.54	15	6.61	0	0.00	0	0.00	8	3.52	13	5.73
LOUTR	3	1.82	36	21.82	0	0.00	2	1.21	105	63.64	3	1.82	3	1.82	0	0.00	0	0.00	1	0.61
MAGEL	3	2.48	8	6.61	0	0.00	3	2.48	65	53.72	10	8.26	14	11.57	0	0.00	0	0.00	1	0.83
MELIS	8	2.44	39	11.89	0	0.00	0	0.00	38	11.59	8	2.44	158	48.17	0	0.00	0	0.00	4	1.22
MIRIN	10	4.31	21	9.05	0	0.00	9	3.88	16	6.90	16	6.90	31	13.36	0	0.00	0	0.00	6	2.59
NIAMA	0	0.00	25	17.12	0	0.00	0	0.00	49	33.56	18	12.33	0	0.00	0	0.00	0	0.00	9	6.16
NEKAR	3	0.88	82	24.19	0	0.00	4	1.18	93	27.43	10	2.95	0	0.00	0	0.00	6	1.77	14	4.13
ORFAN	11	4.78	77	33.48	0	0.00	11	4.78	42	18.26	19	8.26	0	0.00	0	0.00	0	0.00	8	3.48
PAGRA	11	5.50	60	30.00	0	0.00	9	4.50	20	10.00	9	4.50	0	0.00	0	0.00	0	0.00	11	5.50
PEDIN	0	0.00	37	17.54	0	0.00	0	0.00	0	0.00	0	0.00	89	42.18	0	0.00	0	0.00	8	3.79
STAVR	6	3.24	52	28.11	0	0.00	0	0.00	65	35.14	18	9.73	0	0.00	0	0.00	0	0.00	8	4.32
STEFN	30	6.25	154	32.08	0	0.00	2	0.42	220	45.83	31	6.46	0	0.00	0	0.00	0	0.00	3	0.63
XAIDE	17	9.44	26	14.44	0	0.00	0	0.00	19	10.56	19	10.56	38	21.11	0	0.00	0	0.00	5	2.78

Table III: Absolute frequency (n) and percentage of frequency (%) of prey items from the 3rd sampling which was realized in September 2004

Table III: (continued)

	Apoepi		Aposyl		Apouni		Ratnor		Ratrat		Ratuni		Musmus		Musmac		Musuni		Musave	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
AGBIS	0	0.00	10	2.80	0	0.00	0	0.00	0	0.00	0	0.00	16	4.48	16	4.48	3	0.84	0	0.00
AGGEL	0	0.00	10	3.60	0	0.00	0	0.00	0	0.00	1	0.36	40	14.39	16	5.76	0	0.00	0	0.00
AMPEK	0	0.00	15	6.61	0	0.00	0	0.00	0	0.00	0	0.00	20	8.81	11	4.85	0	0.00	0	0.00
AMGID	2	1.10	13	7.14	0	0.00	16	8.79	12	6.59	3	1.65	9	4.95	6	3.30	3	1.65	0	0.00
ANBUN	2	0.60	9	2.69	0	0.00	0	0.00	0	0.00	2	0.60	5	1.49	4	1.19	0	0.00	0	0.00
ARMEN	4	1.74	18	7.83	0	0.00	4	1.74	1	0.43	0	0.00	37	16.09	12	5.22	0	0.00	0	0.00
ASPRO	2	1.08	15	8.11	0	0.00	0	0.00	0	0.00	0	0.00	8	4.32	0	0.00	0	0.00	0	0.00
ASTRI	0	0.00	9	7.20	0	0.00	0	0.00	0	0.00	0	0.00	6	4.80	2	1.60	0	0.00	0	0.00
AURA	0	0.00	24	10.39	0	0.00	0	0.00	0	0.00	0	0.00	26	11.26	4	1.73	0	0.00	0	0.00
GIRTO	6	2.51	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	11	4.60	2	0.84	0	0.00	0	0.00
DASOK	0	0.00	23	11.27	0	0.00	1	0.49	1	0.49	1	0.49	36	17.65	25	12.25	0	0.00	1	0.49
DELER	0	0.00	6	2.59	0	0.00	0	0.00	0	0.00	0	0.00	16	6.90	3	1.29	0	0.00	0	0.00
DOXAR	0	0.00	3	1.81	0	0.00	0	0.00	0	0.00	1	0.60	18	10.84	15	9.04	0	0.00	0	0.00
ELEFT	0	0.00	15	4.50	0	0.00	5	1.50	2	0.60	0	0.00	34	10.21	15	4.50	3	0.90	0	0.00
ZOODP	0	0.00	4	0.89	0	0.00	0	0.00	2	0.44	2	0.44	12	2.66	28	6.21	0	0.00	0	0.00
KALAM	0	0.00	19	5.60	0	0.00	0	0.00	0	0.00	0	0.00	5	1.47	3	0.88	0	0.00	0	0.00
KILER	0	0.00	24	4.96	1	0.21	0	0.00	0	0.00	0	0.00	48	9.92	34	7.02	11	2.27	0	0.00
KRANN	0	0.00	10	2.79	1	0.28	0	0.00	0	0.00	0	0.00	27	7.52	19	5.29	3	0.84	0	0.00
KIPAR	6	2.64	26	11.45	0	0.00	10	4.41	4	1.76	1	0.44	22	9.69	7	3.08	0	0.00	0	0.00
LOUTR	0	0.00	2	1.21	0	0.00	1	0.61	0	0.00	0	0.00	4	2.42	5	3.03	0	0.00	0	0.00
MAGEL	0	0.00	8	6.61	0	0.00	0	0.00	0	0.00	0	0.00	6	4.96	0	0.00	0	0.00	0	0.00
MELIS	0	0.00	10	3.05	0	0.00	0	0.00	0	0.00	2	0.61	18	5.49	32	9.76	4	1.22	0	0.00
MIRIN	2	0.00	16	6.90	0	0.00	4	1.72	9	3.88	1	0.43	49	21.12	30	12.93	0	0.00	8	3.45
NIAMA	0	0.00	17	11.64	0	0.00	7	4.79	1	0.68	0	0.00	12	8.22	8	5.48	0	0.00	0	0.00
NEKAR	0	0.00	26	7.67	0	0.00	3	0.88	0	0.00	0	0.00	59	17.40	29	8.55	7	2.06	0	0.00
ORFAN	0	0.00	11	4.78	0	0.00	9	3.91	0	0.00	0	0.00	19	8.26	6	2.61	3	1.30	0	0.00
PAGRA	0	0.00	24	12.00	0	0.00	0	0.00	0	0.00	0	0.00	32	16.00	11	5.50	1	0.50	0	0.00
PEDIN	0	0.00	19	9.00	0	0.00	0	0.00	0	0.00	0	0.00	34	16.11	16	7.58	0	0.00	0	0.00
STAVR	0	0.00	16	8.65	0	0.00	0	0.00	0	0.00	0	0.00	14	7.57	4	2.16	0	0.00	0	0.00
STEFN	0	0.00	8	1.67	0	0.00	4	0.83	2	0.42	0	0.00	10	2.08	8	1.67	0	0.00	0	0.00
XAIDE	0	0.00	13	7.22	0	0.00	0	0.00	0	0.00	0	0.00	23	12.78	17	9.44	0	0.00	0	0.00

Table III: (continued)

	Pippip		**Tadten**		**Rhifer**		**Pasdom**		**Pasmon**		**Carchl**		**Serser**		**Fricoe**		**Milcal**		**Turmer**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
AGBIS	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
AGGEL	0	0.00	0	0.00	0	0.00	1	0.36	0	0.00	0	0.00	0	0.00	1	0.36	0	0.00	0	0.00
AMPEK	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
AMGID	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ANBUN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ARMEN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ASPRO	0	0.00	0	0.00	0	0.00	1	0.54	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ASTRI	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
AURA	0	0.00	0	0.00	0	0.00	1	0.43	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
GIRTO	0	0.00	2	0.84	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
DASOK	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.49	0	0.00	1	0.49	0	0.00	0	0.00
DELER	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
DOXAR	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ELEFT	0	0.00	0	0.00	0	0.00	1	0.30	2	0.60	1	0.30	1	0.30	0	0.00	0	0.00	0	0.00
ZOODP	0	0.00	0	0.00	0	0.00	2	0.44	0	0.00	1	0.22	1	0.22	0	0.00	0	0.00	0	0.00
KALAM	0	0.00	0	0.00	0	0.00	3	0.88	0	0.00	0	0.00	0	0.00	1	0.29	0	0.00	0	0.00
KILER	0	0.00	0	0.00	0	0.00	2	0.41	1	0.21	0	0.00	0	0.00	0	0.00	1	0.21	0	0.00
KRANN	0	0.00	0	0.00	0	0.00	1	0.28	0	0.00	1	0.28	0	0.00	0	0.00	0	0.00	0	0.00
KIPAR	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
LOUTR	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
MAGEL	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
MELIS	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
MIRIN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
NIAMA	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
NEKAR	0	0.00	0	0.00	0	0.00	2	0.59	1	0.29	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ORFAN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
PAGRA	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
PEDIN	0	0.00	0	0.00	0	0.00	1	0.47	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
STAVR	0	0.00	0	0.00	0	0.00	1	0.54	0	0.00	1	0.54	0	0.00	0	0.00	0	0.00	0	0.00
STEFN	0	0.00	0	0.00	0	0.00	2	0.42	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
XAIDE	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00

Table III: (continued)

	Erirub		**Parmaj**		**Parcae**		**Stuvul**		**Picpic**		**Strdec**		**Chopar**		**Locmig**		**Grygry**		**Tetvir**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
AGBIS	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	8	2.24	6	1.68	0	0.00	0	0.00
AGGEL	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	4	1.44	1	0.36	0	0.00	0	0.00
AMPEK	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	3	1.32	1	0.44	0	0.00	0	0.00
AMGID	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ANBUN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	4	1.19	3	0.90	0	0.00	0	0.00
ARMEN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ASPRO	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	3	1.62	1	0.54	0	0.00	0	0.00
ASTRI	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	3	2.40	1	0.80	0	0.00	0	0.00
AURA	0	0.00	1	0.43	1	0.43	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
GIRTO	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
DASOK	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	0.98	0	0.00	0	0.00	0	0.00
DELER	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
DOXAR	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	4	2.41	1	0.60	0	0.00	0	0.00
ELEFT	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	0.60	1	0.30
ZOODP	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	9	2.00	5	1.11	0	0.00	0	0.00
KALAM	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
KILER	0	0.00	0	0.00	2	0.41	0	0.00	0	0.00	0	0.00	5	1.03	4	0.83	0	0.00	1	0.21
KRANN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.28	1	0.28	0	0.00	0	0.00
KIPAR	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	5	2.20	3	1.32	0	0.00	0	0.00
LOUTR	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
MAGEL	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	1.65	1	0.83	0	0.00	0	0.00
MELIS	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	3	0.91	4	1.22	0	0.00	0	0.00
MIRIN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	3	1.29	1	0.43	0	0.00	0	0.00
NIAMA	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
NEKAR	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ORFAN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	4	1.74	2	0.87	2	0.87	2	0.87
PAGRA	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	7	3.50	5	2.50	0	0.00	0	0.00
PEDIN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	3	1.42	0	0.00	0	0.00	0	0.00
STAVR	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
STEFN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	4	0.83	2	0.42	0	0.00	0	0.00
XAIDE	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	1.11	1	0.56	0	0.00	0	0.00

Table III: (continued)

	Ptenig		**Carnem**		**Coplun**		**Melmel**	
	n	%	n	%	n	%	n	%
AGBIS	1	0.28	0	0.00	1	0.28	2	0.56
AGGEL	0	0.00	0	0.00	0	0.00	0	0.00
AMPEK	0	0.00	0	0.00	0	0.00	0	0.00
AMGID	0	0.00	0	0.00	0	0.00	0	0.00
ANBUN	0	0.00	0	0.00	1	0.30	0	0.00
ARMEN	0	0.00	0	0.00	0	0.00	0	0.00
ASPRO	0	0.00	0	0.00	0	0.00	0	0.00
ASTRI	0	0.00	0	0.00	0	0.00	0	0.00
AURA	0	0.00	0	0.00	0	0.00	0	0.00
GIRTO	0	0.00	0	0.00	0	0.00	0	0.00
DASOK	0	0.00	0	0.00	0	0.00	0	0.00
DELER	0	0.00	0	0.00	0	0.00	0	0.00
DOXAR	0	0.00	0	0.00	0	0.00	0	0.00
ELEFT	0	0.00	0	0.00	0	0.00	3	0.90
ZOODP	0	0.00	0	0.00	0	0.00	0	0.00
KALAM	0	0.00	0	0.00	0	0.00	0	0.00
KILER	3	0.62	0	0.00	2	0.41	0	0.00
KRANN	0	0.00	0	0.00	0	0.00	0	0.00
KIPAR	0	0.00	0	0.00	0	0.00	0	0.00
LOUTR	0	0.00	0	0.00	0	0.00	0	0.00
MAGEL	0	0.00	0	0.00	0	0.00	0	0.00
MELIS	0	0.00	0	0.00	0	0.00	0	0.00
MIRIN	0	0.00	0	0.00	0	0.00	0	0.00
NIAMA	0	0.00	0	0.00	0	0.00	0	0.00
NEKAR	0	0.00	0	0.00	0	0.00	0	0.00
ORFAN	3	1.30	1	0.43	0	0.00	0	0.00
PAGRA	0	0.00	0	0.00	0	0.00	0	0.00
PEDIN	2	0.95	0	0.00	1	0.47	1	0.47
STAVR	0	0.00	0	0.00	0	0.00	0	0.00
STEFN	0	0.00	0	0.00	0	0.00	0	0.00
XAIDE	0	0.00	0	0.00	0	0.00	0	0.00

	Croleu		**Crosua**		**Crouni**		**Sunetr**		**Micgue**		**Miclev**		**Mictho**		**Micuni**		**Crimig**		**Apofla**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
AGBIS	24	6.96	60	17.39	4	1.16	11	3.19	34	9.86	35	10.14	0	0.00	0	0.00	0	0.00	15	4.35
AGGEL	9	4.74	32	16.84	0	0.00	3	1.58	26	13.68	16	8.42	0	0.00	0	0.00	9	4.74	7	3.68
AMPEK	1	0.33	82	26.97	0	0.00	18	5.92	38	12.50	16	5.26	0	0.00	0	0.00	0	0.00	10	3.29
AMGID	0	0.00	26	12.75	2	0.98	0	0.00	28	13.73	19	9.31	0	0.00	0	0.00	0	0.00	6	2.94
ANBUN	4	2.74	18	12.33	0	0.00	0	0.00	62	42.47	11	7.53	0	0.00	0	0.00	0	0.00	2	1.37
ARMEN	8	4.49	25	14.04	0	0.00	6	3.37	38	21.35	8	4.49	0	0.00	0	0.00	0	0.00	9	5.06
ASPRO	35	15.98	60	27.40	0	0.00	6	2.74	12	5.48	15	6.85	0	0.00	0	0.00	4	1.83	14	6.39
ASTRI	4	1.65	36	14.88	0	0.00	6	2.48	35	14.46	21	8.68	0	0.00	1	0.41	0	0.00	11	4.55
AURA	19	8.02	71	29.96	0	0.00	1	0.42	27	11.39	17	7.17	0	0.00	0	0.00	0	0.00	10	4.22
GIRTO	34	11.00	54	17.48	7	2.27	2	0.65	78	25.24	26	8.41	0	0.00	0	0.00	0	0.00	26	8.41
DASOK	5	2.16	17	7.33	1	0.43	0	0.00	12	5.17	17	7.33	13	5.60	0	0.00	0	0.00	15	6.47
DELER	8	3.60	25	11.26	0	0.00	0	0.00	41	18.47	16	7.21	12	5.41	0	0.00	0	0.00	11	4.95
DOXAR	29	10.21	65	22.89	0	0.00	5	1.76	34	11.97	30	10.56	1	0.35	0	0.00	0	0.00	9	3.17
ELEFT	7	3.23	43	19.82	0	0.00	7	3.23	44	20.28	27	12.44	0	0.00	0	0.00	0	0.00	9	4.15
ZOODP	0	0.00	85	27.33	0	0.00	10	3.22	37	11.90	10	3.22	0	0.00	0	0.00	10	3.22	13	4.18
KALAM	27	10.84	33	13.25	0	0.00	6	2.41	29	11.65	10	4.02	0	0.00	0	0.00	0	0.00	23	9.24
KILER	11	3.89	96	33.92	0	0.00	3	1.06	21	7.42	24	8.48	0	0.00	0	0.00	1	0.35	4	1.41
KRANN	10	6.67	30	20.00	0	0.00	4	2.67	37	24.67	19	12.67	0	0.00	0	0.00	1	0.67	6	4.00
KIPAR	15	6.85	48	21.92	0	0.00	7	3.20	13	5.94	17	7.76	0	0.00	0	0.00	7	3.20	0	0.00
LOUTR	4	2.88	25	17.99	1	0.72	0	0.00	47	33.81	25	17.99	2	1.44	0	0.00	0	0.00	0	0.00
MAGEL	3	2.22	5	3.70	0	0.00	3	2.22	23	17.04	9	6.67	11	8.15	0	0.00	0	0.00	14	10.37
MELIS	1	0.35	40	13.99	0	0.00	2	0.70	21	7.34	12	4.20	101	35.31	0	0.00	0	0.00	3	1.05
MIRIN	5	2.23	16	7.14	0	0.00	5	2.23	8	3.57	12	5.36	17	7.59	0	0.00	0	0.00	12	5.36
NIAMA	0	0.00	39	17.18	0	0.00	0	0.00	26	11.45	10	4.41	0	0.00	0	0.00	0	0.00	15	6.61
NEKAR	0	0.00	42	18.50	0	0.00	5	2.20	37	16.30	20	8.81	0	0.00	0	0.00	0	0.00	4	1.76
ORFAN	19	4.47	114	26.82	0	0.00	50	11.76	45	10.59	35	8.24	0	0.00	0	0.00	0	0.00	19	4.47
PAGRA	0	0.00	76	25.25	0	0.00	19	6.31	17	5.65	11	3.65	0	0.00	0	0.00	0	0.00	13	4.32
PEDIN	0	0.00	29	10.14	0	0.00	0	0.00	0	0.00	0	0.00	90	31.47	0	0.00	0	0.00	20	6.99
STAVR	1	0.43	53	22.55	0	0.00	13	5.53	25	10.64	14	5.96	0	0.00	0	0.00	0	0.00	15	6.38
STEFN	0	0.00	30	14.63	1	0.49	4	1.95	48	23.41	33	16.10	0	0.00	0	0.00	0	0.00	7	3.41
XAIDE	14	6.28	23	10.31	0	0.00	0	0.00	20	8.97	13	5.83	31	13.90	0	0.00	0	0.00	7	3.14

Table IV: Absolute frequency (n) and percentage of frequency (%) of prey items from the 4th sampling which was realized in March 2005

Table IV: (continued)

	Apoepi		Aposyl		Apouni		Ratnor		Ratrat		Ratuni		Musmus		Musmac		Musuni		Musave	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
AGBIS	7	2.03	38	11.01	5	1.45	0	0.00	17	4.93	7	2.03	62	17.97	22	6.38	0	0.00	0	0.00
AGGEL	4	2.11	12	6.32	1	0.53	6	3.16	1	0.53	1	0.53	51	26.84	5	2.63	0	0.00	0	0.00
AMPEK	25	8.22	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	77	25.33	22	7.24	3	0.99	0	0.00
AMGID	5	2.45	10	4.90	1	0.49	34	16.67	15	7.35	2	0.98	39	19.12	15	7.35	2	0.98	0	0.00
ANBUN	8	5.48	8	5.48	4	2.74	0	0.00	0	0.00	0	0.00	19	13.01	4	2.74	2	1.37	0	0.00
ARMEN	4	2.25	17	9.55	0	0.00	5	2.81	0	0.00	4	2.25	33	18.54	13	7.30	8	4.49	0	0.00
ASPRO	1	0.46	36	16.44	0	0.00	0	0.00	0	0.00	0	0.00	21	9.59	3	1.37	0	0.00	0	0.00
ASTRI	0	0.00	34	14.05	1	0.41	5	2.07	1	0.41	2	0.83	63	26.03	17	7.02	0	0.00	0	0.00
AURA	0	0.00	44	18.57	0	0.00	0	0.00	1	0.42	0	0.00	41	17.30	6	2.53	0	0.00	0	0.00
GIRTO	6	1.94	21	6.80	0	0.00	0	0.00	0	0.00	0	0.00	46	14.89	5	1.62	0	0.00	0	0.00
DASOK	0	0.00	22	9.48	0	0.00	0	0.00	0	0.00	0	0.00	77	33.19	29	12.50	13	5.60	6	2.59
DELER	0	0.00	28	12.61	0	0.00	36	16.22	0	0.00	6	2.70	17	7.66	6	2.70	4	1.80	0	0.00
DOXAR	1	0.35	39	13.73	1	0.35	9	3.17	7	2.46	0	0.00	39	13.73	7	2.46	0	0.00	0	0.00
ELEFT	0	0.00	19	8.76	0	0.00	3	1.38	2	0.92	0	0.00	29	13.36	6	2.76	7	3.23	0	0.00
ZOODP	2	0.64	25	8.04	0	0.00	23	7.40	2	0.64	1	0.32	78	25.08	5	1.61	2	0.64	0	0.00
KALAM	34	13.65	37	14.86	0	0.00	0	0.00	3	1.20	5	2.01	25	10.04	0	0.00	0	0.00	0	0.00
KILER	7	2.47	35	12.37	0	0.00	1	0.35	0	0.00	4	1.41	61	21.55	11	3.89	0	0.00	0	0.00
KRANN	1	0.67	12	8.00	0	0.00	0	0.00	1	0.67	0	0.00	26	17.33	3	2.00	0	0.00	0	0.00
KIPAR	7	3.20	33	15.07	5	2.28	0	0.00	0	0.00	6	2.74	37	16.89	15	6.85	5	2.28	0	0.00
LOUTR	0	0.00	15	10.79	0	0.00	0	0.00	1	0.72	0	0.00	16	11.51	0	0.00	0	0.00	0	0.00
MAGEL	0	0.00	28	20.74	0	0.00	0	0.00	0	0.00	0	0.00	30	22.22	5	3.70	0	0.00	0	0.00
MELIS	2	0.70	18	6.29	1	0.35	13	4.55	3	1.05	4	1.40	38	13.29	8	2.80	4	1.40	3	1.05
MIRIN	4	1.79	39	17.41	0	0.00	7	3.13	15	6.70	4	1.79	46	20.54	25	11.16	0	0.00	5	2.23
NIAMA	5	2.20	37	16.30	0	0.00	16	7.05	0	0.00	0	0.00	63	27.75	16	7.05	0	0.00	0	0.00
NEKAR	0	0.00	25	11.01	0	0.00	0	0.00	0	0.00	0	0.00	73	32.16	21	9.25	0	0.00	0	0.00
ORFAN	2	0.47	40	9.41	0	0.00	0	0.00	0	0.00	0	0.00	84	19.76	14	3.29	0	0.00	0	0.00
PAGRA	0	0.00	48	15.95	0	0.00	1	0.33	0	0.00	0	0.00	80	26.58	27	8.97	0	0.00	1	0.33
PEDIN	0	0.00	53	18.53	0	0.00	0	0.00	0	0.00	0	0.00	58	20.28	29	10.14	0	0.00	0	0.00
STAVR	0	0.00	50	21.28	0	0.00	0	0.00	0	0.00	0	0.00	41	17.45	16	6.81	0	0.00	0	0.00
STEFN	1	0.49	29	14.15	0	0.00	4	1.95	0	0.00	1	0.49	31	15.12	3	1.46	1	0.49	0	0.00
XAIDE	0	0.00	20	8.97	0	0.00	0	0.00	0	0.00	0	0.00	59	26.46	28	12.56	0	0.00	0	0.00

Table IV: (continued)

	Pippip		**Tadten**		**Rhifer**		**Pasdom**		**Pasmon**		**Carchl**		**Serser**		**Fricoe**		**Milcal**		**Turmer**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
AGBIS	0	0.00	0	0.00	0	0.00	1	0.29	2	0.58	0	0.00	0	0.00	1	0.29	0	0.00	0	0.00
AGGEL	0	0.00	0	0.00	0	0.00	1	0.53	0	0.00	0	0.00	0	0.00	1	0.53	0	0.00	0	0.00
AMPEK	0	0.00	0	0.00	0	0.00	2	0.66	1	0.33	1	0.33	0	0.00	2	0.66	0	0.00	0	0.00
AMGID	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ANBUN	0	0.00	0	0.00	0	0.00	1	0.68	0	0.00	2	1.37	0	0.00	0	0.00	0	0.00	0	0.00
ARMEN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ASPRO	0	0.00	0	0.00	0	0.00	1	0.46	0	0.00	2	0.91	1	0.46	0	0.00	2	0.91	0	0.00
ASTRI	0	0.00	0	0.00	0	0.00	0	0.00	2	0.83	1	0.41	1	0.41	0	0.00	0	0.00	1	0.41
AURA	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
GIRTO	0	0.00	0	0.00	0	0.00	2	0.65	0	0.00	0	0.00	1	0.32	0	0.00	0	0.00	0	0.00
DASOK	0	0.00	0	0.00	0	0.00	2	0.86	0	0.00	1	0.43	0	0.00	1	0.43	0	0.00	1	0.43
DELER	0	0.00	0	0.00	0	0.00	3	1.35	0	0.00	0	0.00	1	0.45	1	0.45	0	0.00	2	0.90
DOXAR	0	0.00	0	0.00	0	0.00	2	0.70	1	0.35	1	0.35	0	0.00	2	0.70	1	0.35	0	0.00
ELEFT	0	0.00	0	0.00	0	0.00	2	0.92	1	0.46	0	0.00	3	1.38	2	0.92	0	0.00	0	0.00
ZOODP	0	0.00	0	0.00	0	0.00	3	0.96	0	0.00	0	0.00	1	0.32	3	0.96	0	0.00	0	0.00
KALAM	1	0.40	0	0.00	1	0.40	2	0.80	1	0.40	1	0.40	0	0.00	3	1.20	4	1.61	1	0.40
KILER	0	0.00	0	0.00	0	0.00	2	0.71	0	0.00	0	0.00	1	0.35	0	0.00	1	0.35	0	0.00
KRANN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
KIPAR	0	0.00	0	0.00	0	0.00	2	0.91	0	0.00	0	0.00	0	0.00	1	0.46	0	0.00	0	0.00
LOUTR	0	0.00	0	0.00	0	0.00	0	0.00	1	0.72	0	0.00	1	0.72	0	0.00	0	0.00	1	0.72
MAGEL	0	0.00	0	0.00	0	0.00	0	0.00	1	0.74	2	1.48	0	0.00	1	0.74	0	0.00	0	0.00
MELIS	0	0.00	0	0.00	0	0.00	2	0.70	0	0.00	0	0.00	0	0.00	1	0.35	1	0.35	0	0.00
MIRIN	0	0.00	0	0.00	0	0.00	1	0.45	0	0.00	0	0.00	2	0.89	1	0.45	0	0.00	0	0.00
NIAMA	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
NEKAR	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ORFAN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
PAGRA	0	0.00	0	0.00	0	0.00	2	0.66	0	0.00	0	0.00	1	0.33	0	0.00	0	0.00	1	0.33
PEDIN	0	0.00	0	0.00	1	0.35	2	0.70	0	0.00	0	0.00	1	0.35	1	0.35	0	0.00	0	0.00
STAVR	0	0.00	0	0.00	0	0.00	1	0.43	0	0.00	0	0.00	0	0.00	1	0.43	0	0.00	0	0.00
STEFN	0	0.00	0	0.00	0	0.00	3	1.46	0	0.00	0	0.00	0	0.00	2	0.98	0	0.00	0	0.00
XAIDE	0	0.00	0	0.00	0	0.00	2	0.90	0	0.00	0	0.00	3	1.35	1	0.45	0	0.00	0	0.00

Table IV: (continued)

	Erirub		**Parmaj**		**Parcae**		**Stuvul**		**Picpic**		**Strdec**		**Chopar**		**Locmig**		**Grygry**		**Tetvir**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
AGBIS	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
AGGEL	1	0.53	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	1.05	0	0.00
AMPEK	1	0.33	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
AMGID	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ANBUN	1	0.68	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ARMEN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ASPRO	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.46	0	0.00
ASTRI	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
AURA	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
GIRTO	0	0.00	0	0.00	1	0.32	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
DASOK	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
DELER	0	0.00	0	0.00	0	0.00	1	0.45	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	0.90
DOXAR	0	0.00	0	0.00	1	0.35	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ELEFT	4	1.84	0	0.00	0	0.00	0	0.00	0	0.00	2	0.92	0	0.00	0	0.00	0	0.00	0	0.00
ZOODP	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.32	0	0.00	0	0.00	0	0.00	0	0.00
KALAM	0	0.00	0	0.00	0	0.00	2	0.80	1	0.40	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
KILER	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
KRANN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
KIPAR	0	0.00	1	0.46	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
LOUTR	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
MAGEL	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
MELIS	0	0.00	0	0.00	2	0.70	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
MIRIN	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
NIAMA	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
NEKAR	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ORFAN	1	0.24	2	0.47	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
PAGRA	0	0.00	3	1.00	1	0.33	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
PEDIN	2	0.70	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
STAVR	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
STEFN	0	0.00	0	0.00	0	0.00	1	0.49	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
XAIDE	2	0.90	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00

Table IV: (continued)

	Ptenig		Carnem		Coplun		Melmel	
	n	%	n	%	n	%	n	%
AGBIS	0	0.00	0	0.00	0	0.00	0	0.00
AGGEL	0	0.00	0	0.00	1	0.53	1	0.53
AMPEK	1	0.33	2	0.66	2	0.66	0	0.00
AMGID	0	0.00	0	0.00	0	0.00	0	0.00
ANBUN	0	0.00	0	0.00	0	0.00	0	0.00
ARMEN	0	0.00	0	0.00	0	0.00	0	0.00
ASPRO	2	0.91	0	0.00	3	1.37	0	0.00
ASTRI	0	0.00	0	0.00	0	0.00	0	0.00
AURA	0	0.00	0	0.00	0	0.00	0	0.00
GIRTO	0	0.00	0	0.00	0	0.00	0	0.00
DASOK	0	0.00	0	0.00	0	0.00	0	0.00
DELER	2	0.90	0	0.00	0	0.00	0	0.00
DOXAR	0	0.00	0	0.00	0	0.00	0	0.00
ELEFT	0	0.00	0	0.00	0	0.00	0	0.00
ZOODP	0	0.00	0	0.00	0	0.00	0	0.00
KALAM	0	0.00	0	0.00	0	0.00	0	0.00
KILER	0	0.00	0	0.00	0	0.00	0	0.00
KRANN	0	0.00	0	0.00	0	0.00	0	0.00
KIPAR	0	0.00	0	0.00	0	0.00	0	0.00
LOUTR	0	0.00	0	0.00	0	0.00	0	0.00
MAGEL	0	0.00	0	0.00	0	0.00	0	0.00
MELIS	3	1.05	2	0.70	0	0.00	1	0.35
MIRIN	0	0.00	0	0.00	0	0.00	0	0.00
NIAMA	0	0.00	0	0.00	0	0.00	0	0.00
NEKAR	0	0.00	0	0.00	0	0.00	0	0.00
ORFAN	0	0.00	0	0.00	0	0.00	0	0.00
PAGRA	0	0.00	0	0.00	0	0.00	0	0.00
PEDIN	0	0.00	0	0.00	0	0.00	0	0.00
STAVR	0	0.00	2	0.85	3	1.28	0	0.00
STEFN	0	0.00	2	0.98	4	1.95	0	0.00
XAIDE	0	0.00	0	0.00	0	0.00	0	0.00