THE SUMMER POPULATIONS OF CAVE-DWELLING BAT SPECIES OF ÇATALCA-KOCAELİ REGION AND ENVIRONMENTAL FACTORS THAT INFLUENCE THEIR DISTRIBUTION

by

İbrahim Raşit Bilgin

BS. In Civil Eng., Boğaziçi University, 1998

Submitted to the Institute of Environmental Sciences in partial fulfillment of

the requirements for the degree of

Master of Science

In Environmental Sciences

Boğaziçi University

2000

THE SUMMER POPULATIONS OF CAVE-DWELLING BAT SPECIES OF ÇATALCA-KOCAELİ REGION AND ENVIRONMENTAL FACTORS THAT INFLUENCE THEIR DISTRIBUTION

APPROVED BY:

Assist. Prof Dr. Andrzej Furman ....
(Thesis Supervisor)

Prof. Dr. Nilsun İnce ....

Prof. Dr. Nüzhet Dalfes ....

DATE OF APPROVAL ..19.06.2000..

THE SUMMER POPULATIONS OF CAVE-DWELLING BAT SPECIES OF ÇATALCA-KOCAELİ REGION AND ENVIRONMENTAL FACTORS THAT INFLUENCE THEIR DISTRIBUTION

İbrahim Raşit Bilgin

Environmental Sciençe M.S. Thesis, 2000

Thesis Supervisor: Andrzej Furman

Keywords: Chiroptera, Cave, Habitat, Temperature, Turkey

The summer population of cave dwelling-bat species in Çatalca-Kocaeli Region was surveyed between May-August 1999. The effects of geographical location, habitat, and temperature were studied as possible factors in determining the distribution patterns of the bat species in these caves. Nine out of the 11 caves were studied for the first time with regard to the assessment of bat populations inside. Three maternity colonies were identified for *Rhinolophus ferrumequinum*, *R. euryale* and *Miniopterus schreibersii* in three different caves.

The statistical analysis based on geographical coordinates, and species distribution hinted that Bosphorus might be acting as a natural barrier limiting migration and gene flow between Çatalca and Kocaeli regions. Hence it may be more correct to treat Çatalca and Kocaeli regions separately in terms of species occupancy.

The critical habitat types influencing species distribution were traditional arable land, pond, heathland, and maquis. River, riparian treeline, pasture, broadleaved woodland and broadleaved woodland/pasture edge were the common habitat types recorded for all of the bat species. Habitat surveys around the caves indicated that *M. schreibersii* might be able to utilize a greater number, and Large Myotis a lesser number of different habitat types, compared to the other species studied. Average temperature in the caves was the weakest contributing factor for explaining the distribution patterns of the species.

ÇATALCA-KOCAELİ BÖLÜMÜ 'NDE BULUNAN MAĞARA YARASASI POPULASYONU VE DAĞILIMLARINI ETKİLEYEN ÇEVRESEL ETMENLER

İbrahim Raşit Bilgin

ÇEVRE BİLİMİ M.S. TEZİ, 2000

TEZ DANIŞMANI: Andrzej Furman

Anahtar Kelimeler: Chiroptera, Mağara, Bitki Örtüsü, Sıcaklık, Türkiye

Çatalca-Kocaeli Bölgesi'nin, yaz mevsimindeki yarasa popülasyonu, Mayıs-Ağustos 1999 ayları arasında incelendi. Mağaraların coğrafi konumları, etraflarındaki bitki örtüsü ve sıcaklıkları yarasa türlerinin dağılımını etkileyen olası etmenler olarak incelendi. İncelenen 11 mağaradan 9'u içindeki yarasa popülasyonunun incelenmesi için ilk defa ele alındı. Üç ayrı mağarada *Rhinolophus ferrumequinum, R. euryale* ve *Miniopterus schreibersii*'a ait üç kreş kolonisine ratlandı.

Coğrafi koordinat ve yarasa dağılımı temel alınılarak yapılan statistiksel analizler, İstanbul Boğazı'nın Çatalca ve Kocaeli bölümleri arasında göç ve gen akımını etkileyen doğal bir engel olabileceği kanısını oluşturdu. Bu yüzden tür yerleşimi açısından Çatalca ve Kocaeli bölümlerini birbirlerinden ayrı olarak incelemenin daha doğru olacağı sonucuna varıldı.

Türlerin dağılımını etkileyen kritik bitki örtüsü tipleri olarak geleneksel tarım alanı, gölet, fundalık ve maki belirlendi. Dere, dere boyu sıralı ağaçlık, otlak, geniş yapraklı orman ve geniş yapraklı orman/otlak kenarı, tüm yarasaları türlerinin bulunduğu ortak bitki örtüsü tipleri olarak kaydedildi. Mağaraların etrafında yapılan bitki örtüsü çalışması, diğer türlere göre, *M. schreibersii*'nun en çok, Büyük Myotis'lerin ise en az farklı bitki örtüsü tipini kullanan türler olabileceklerini gösterdi. Mağara içi ortalama sıcaklıkları tür dağılımını en az etkileyen etmen olarak göze çarptı.

ACKNOWLEDGEMENTS

First of all, I would like to thank my family, for having supported and understood me when I told them that I don't want to work as a civil engineer, but that I wanted to study ecology. Without that understanding, my job would have been really much more difficult. Also I shouldn't forget my uncle I guess; as the roofs of the buildings that he had thrown my umbilical chord onto after I was born have perfectly matched the places that I had my highscool and university education in. But obviously more than that, I would like to thank him for all the support that he gave up to now.

I was at the 4th year of my undergraduate study, when I took Dr. Andrzej Furman's course 'Concepts and Models in Ecology'. At those days, my mind was pretty mixed up about what to do in my further life. And one of the readings That Dr. Furman gave in that ecology course about the selfish genes (from the book The River out of Eden by Richard Dawkins) actually cleared my mind. I definitely decided to study ecology. So I would like to thank him for the readings, advice, motor-rides, fun, recipes, and everything else.

Then there is Arpat. He is one of the people that made this thesis possible by his physical support (fieldtrips), as well as emotional support. Certainly without him, this thesis would be a totally different one.

Finally, I would like to thank my jury members, Prof. Dr. Nilsun İnce and Prof Dr. Nüzhet Dalfes, for the criticism they made and corrections they offered on my thesis.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

1.1. Foreword

Understanding the patterns of relationships of organisms with their environment is the main area of interest of the science of ecology. The knowledge of ecology is important *per se*, as it adds to the knowledge regarding the biology and behaviour of species. It is also crucial for coherent conservation planning of species today, characterized by very high rate of species extinctions. Bats constitute one of the important mammalian orders, which have key-roles in many ecosystems. Understanding their ecology is crucial for planning their conservation, as it is the case with any animal or plant species.

Turkish Bat Fauna studies have a history of about a century (Benda and Horacek 1999). These studies have almost exclusively focused on distribution of bat species (Özkan and Erman 1990, Benda and Horacek 1999). An understanding of the possible biotic and abiotic factors responsible for the distribution of the bat species has not ever been carried regarding Turkish Bat Fauna. Generally habitat has been one of the important environmental factors studied in this context, although there are differences in the scope of habitat studies, regarding bats in the world. In countries like Great Britain, nationwide habitat surveys have been carried out (Walsh 1995, Entwistle et al. 1997, Racey 1998). But for example for Australian habitat studies with regard to bats, Richards and Hall (1998) say that 'Virtually nothing is known about the habitat preferences of Australian bats'. Turkey is between these two poles, as although no habitat-related studies regarding bats have ever been conducted in Turkey, subjects of various European habitat-bat studies are in common. Temperature is another factor that has been studied to understand the distribution of bat species (Baudinett et al. 1994, Szatyor 1997). This study concentrates on habitats, and temperature as possible factors affecting summer distribution of cave dwelling bat species of Çatalca-Kocaeli Region (Figure 1.1).

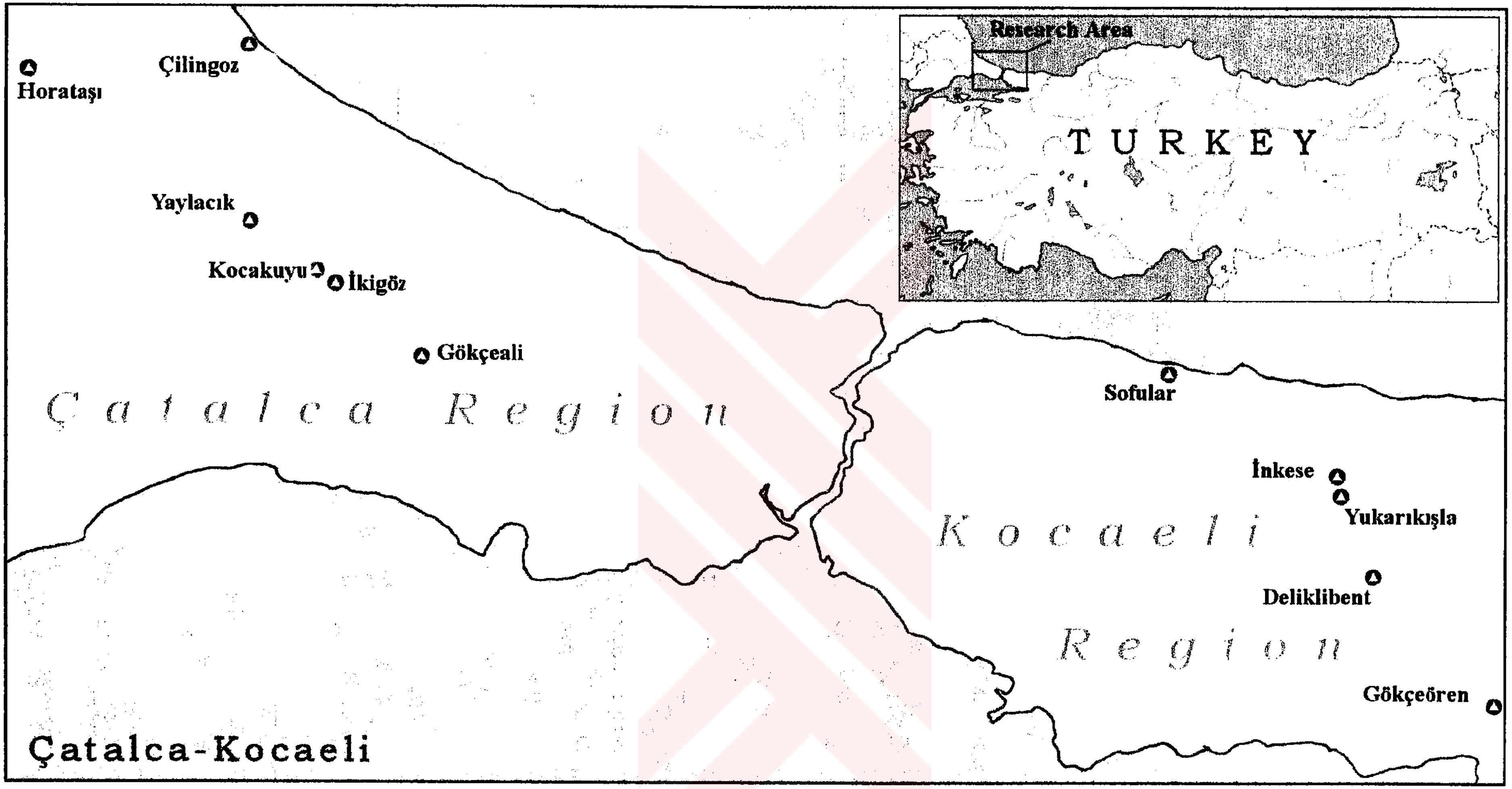


Figure 1.1. Map of Çatalca-Kocaeli Region

1.2. General Characteristics of Bats

Bats are taxonomically classified as order 'Chiroptera'. The order Chiroptera is composed of 17 families, 186 genera and 963 species, being distributed all over the world. Only the rodents, with approximately 1700 species, out of approximately 4000 species of mammals, outnumber bats in terms of specific diversity (Altringham 1996).

The order Chiroptera is believed to have evolved from arboreal insectivorous ancestors. This view is concordant with the fossil record which shows that bats were abundant and well developed at least as early as in the Eocene (approximately 50 million years ago) (Nowak 1994, Schoeber and Grimmberger 1997). The early fossils indicate that the earlier bats were similar to present day bats, even showing basic morphologic adaptations for echolocation. Consequently the bats are considered to have originated 70-100 million years ago (Altringham 1996). Based on morphological analysis, bats and especially flying lemurs (order Dermoptera) were believed to share a common ancestor (Simmons 1998). This view has been contradicted by the latest molecular studies, showing that a common ancestor for these two groups wasn't present (Teeling et al. 2000).

Chiroptera is divided into two suborders; the Microchiroptera (microbats) and the Megachiroptera (megabats). This distinction is based on the details of anatomical and morphological differences, biogeographical distribution, and evolutionary relationships.

The Megachiroptera is composed of fruit, flower, nectar and pollen eating bats, living exclusively in the Old World. It comprises one family, Pteropodidae, composed of 42 genera and 175 species (Altringham 1996). The Microchiroptera, on the other hand, shows a greater diversity both ecologically (in terms of inhabited niches) and in terms of number of species, comprising 16 families, 144 genera and 788 species. The Microchiroptera are present in both the Old World and the New World, and they can be found wherever Megachiroptera are present (except a few islands in the Indian ocean and central Pacific where only Megachiroptera are seen) (Altringham 1996, Nowak 1994).

The Megachiroptera are on average larger than the Microchiroptera in size, although a considerable overlap in size is seen. For the Megachiroptera, the range of weight is between 10 grams to 1500 grams, and the forearm range is between 36 mm and 228 mm. The Microchiropteran weight is 2-196 grams and forearm length is 22-115 mm. (Nowak 1994)

The largest megabat is the Indian large fruit bat, *Pteropus vampyrus*, with a wingspan of about 1700mm. The smallest microchiropteran is Kitti's hog-nosed bat, of Thailand, *Craseonycteris thonglongyai*. It weighs about 2 grams and is one of the smallest mammals of the world; only the Etruscan shrew (*Suncus etruscus*) is smaller. The largest microbat by forearm length is the false vampire bat of Central and South America, *Vampyrum spectrum*. The largest in terms of weight is the naked bat, *Cheriomeles torquatus*, of Indo-Malaysia and the Phillipines (Nowak 1994).

The bats have important characteristics that distinguish them from mammals of the other order. These characteristics of morphology, sensory mechanisms, life history and reproductive characteristics, roosts types inhabited, migration, feeding and foraging habits are the basis for the adaptive radiation of bats worldwide (Kunz and Racey 1998).

1.2.1. Morphology

Bats are the only truly flying mammals. The word Chiroptera is derived from the Greek roots *cheir* (hand) and *pteron* (wing). As their name suggests, bats' wings are actually highly modified hands (Nowak 1994). The other "flying" (e.g. flying lemurs or flying squirrels) are actually gliders and they are devoid of the characters, both morphological and physiological, that make actual flying possible. Flight involves both lift and thrust, created by the movements of the airfoil section of the wings and powerful pectoral and wing muscles. Lift helps the bat to stay in the air in the vertical direction and thrust propels the bat forward in the horizontal direction. The power for flight is generated by contraction of flight muscles located mainly in the upper arms and chest (Nowak 1994, Schoeber and Grimmberger 1997).

Their ability to rotate their hind limbs 180° makes bats capable of bending their knees backwards. This ability is important both for steering during flight and keeping their head-down roosting position. Hence they hang using their five toed and clawed feet without any expenditure of energy[1] (Nowak 1994, Schoeber and Grimmberger 1997, Schutt 1998).

The ears and faces are among the distinctive features of bats. Many taxa have fleshy ornaments on their faces which resemble leaves or horseshoes. This character of ornamented facial structures are greatly reduced or absent in megabats when compared with microbats. The pinnae (external ears) are crucial for bats, especially for the species that depend on echolocation for orientation and prey detection. The size and shape of the pinnae for different species are modified for amplifying echoes from prey or to detect their sounds. Again for aiding echolocation, Microchiropteran species have a tragus and/or antitragus as 'fleshy projections on the anterior edge of the ear opening' (Nowak 1994 p7) that are not present in Megachiroptera.

1.2.2. Evolutionary Relationships

The differences between Megachiroptera and Microchiroptera extend to fundamental characters of flight and sensory characteristics. Due to these differences, the question whether the Megachiroptera and Microchiroptera share a common ancestor or not is still not completely answered. Some researchers suggest that the Megachiroptera evolved independently of Microchiroptera and may be more closely related with Primates than the Microchiroptera (Alringham 1996, Findley 1993). This debate is still not settled since a monophyletic origin is supported also, especially by molecular studies. (Altringham 1996, Brum et al. 1994, Simmons 1998, Teeling et al. 2000).

The monophyly debate also includes Microchiroptera (Simmons 1998, Teeling et al. 2000). Various phylogenetic relationships have been proposed, based on skin and skeletal features, other general morphological characters, immunological distance data, and RNA

---

[1] During our field trips, we sometimes came along dead bats, hanging in a head down position.

restriction sites, resulting in dissimilar conclusions for higher levels of classification among Microchiroptera. The agreements were on the Rhinolophidae and Hipposideridae being sister taxa and Phyllostomidae, Mormoopidae, and Noctilionidae being closely related (Simmons 1998).

Molecular data is still incomplete for Chiroptera for making a complete phylogenetic analysis and coming up with a definitive conclusion regarding higher level taxonomic relationships of bats as the sampling has been restricted to fewer than half of the extant families (Simmons 1998).

Biogeographically the origin of Chiroptera and its two suborders is thought to be rooted in the old World; based on morphological, immunological and allozyme data (Simmons 1998).

1.2.3. Sensory Mechanisms

One of the most fundamental sensory characteristics for bats (especially microbats) is echolocation. It is the adaptation that enables the microbats to essentially 'see' their surroundings by sound. Most of the echolocation calls used by bats are ultrasonic, ranging between 20 kHz to 215 kHz, above the upper limit of human hearing (Schoeber and Grimmberger 1997). More than half of the approximately 900 species of bats present in the world orient themselves and capture prey by echolocation. This ability present in the Microchiropterans and absent in the Megachiroptera (except for one genus), is one of the main characteristics distinguishing the two suborders (Nowak 1994).

Call patterns of different species are classified according to patterns of frequency change in time. The two main types are constant frequency (CF) and frequency modulated (FM) signals. The CF patterns refer to signals that are relatively constant, when compared to FM signals that sweep the frequency range mentioned above; with intensities ranging upwards from 50 dB to 120 dB (Nowak 1994).

Hutchen et al. (1995) had proposed that the bats of Microchiropteran superfamily Rhinolophoidea are more closely related to megabats than microbats. This work suggested that echolocation could have evolved independently in microbats and rhinolophoids or were lost during the Megachiropteran evolution. The recent molecular study of Teeling et al. (2000) also supports this view.

Although mostly echolocation is used for orientation, foraging and feeding, some Microchiroptera species use other sensory mechanisms for these purposes (Schoeber and Grimmberger 1997).

Vision plays an important role among these sensory perception mechanisms of bats. None of the bat species that are known today are blind. Many species (e.g. *Macrotus californius*) rely on vision as well as echolocation, especially for capturing of prey.

In addition to these, olfaction plays an important role. Using their highly developed sense of smell, bat species can distinguish different food sources. Olfaction is used for mother-offspring identification, during courtship and mating. It is also believed that bats might be able to identify roost sites by olfaction.

1.2.4. Social Structure

The mother and her young comprise the basic social unit of Chiroptera (Nowak 1994). Based on this unit; "solitary" species are defined as those species that raise their young alone, whereas the species whose females aggregate (ranging from a few individuals to millions) to nurse their young are said to form 'maternity colonies'. In general, the Megachiroptera are known to form smaller colonies than the Microchiroptera.

Males, on the other hand, occupy roosts singly, or in small numbers. Sometimes they stay in separate roosts, other than the one that the maternity colony is present.

1.2.5. Roosts

Roosts comprise the environment that bats spend more than half of their lives in. In accordance with the diversity of bat species, there exists a wide spectrum of roosts used by bats based on 'physiological demands of the adults or young, predation pressures, sociological considerations, or morphology' (Findley 1993, p 95). They are critical to bats as they influence 'ecology, social behaviour and survival of their populations' (O'Donnell and Sedgeley 1999, p 913).

The possible roosts include caves, mines, trees, crevices in rocks and trees, foliage (unmodified or modified as tents), and human made structures. Megachiroptera usually use trees as roosts, sometimes occupied by several thousands of individuals. The Microchiroptera, on the other hand, can utilize of all kinds of roost types. The Microchiropteran roost aggregations can reach numbers of 20 million individuals (Altringham 1996).

Different species show varying amounts of fidelity to roosts. Certain species are found only in a particular roost type. For instance, the neotropical disk-winged bat (*Thyroptera tricolor*) roosts in leaves of *Heliconia* plant, using the adhesive disks on their feet and wings to attach to them. This plants' distribution is thought to be the limiting factor for the distribution of this species, as they haven't been seen to be roosting in any other site. Certain species can take advantage of various type of roosts. A lot of species that hibernate in caves in winter (e.g. rhinolophoids and hipposiderids) change to human made structures for roosting in the summer (Altringham 1996, Findley 1993, Nowak 1994, Schoeber and Grimmberger 1997, Sedgeley and O'Donnell 1999).

The selection of roosts has a strong relationship with the season of the year, especially for the cave dwelling species of the temperate regions. Based on the roost microclimate, these species hibernate in winter, and form maternity colonies for giving birth to and raising their young in summer (Schoeber and Grimmberger 1997). Some species that form large aggregations in maternity colonies (e.g. *Miniopterus schreibersii*) can influence the roost microclimate (Baudinett et al. 1994).

1.2.6. Hibernation

In temperate zones, the abundance of insects drop in winter to levels not sufficient to sustain bat communities. Accordingly, Microchiropteran species (of the families Vepertilionidae and Rhinolophoidae) inhabiting the temperate regions in order to survive the winter months hibernate. Generally, hibernating bats store fat deposits in late summer, look for a hibernaculum, form aggregations and enter a torpid period lasting until spring (Findley 1993). In order to minimize the amount of energy loss, the hibernating bats drop their body temperature almost to the temperature of the roost. One of the most important factors determining the choice of hibernation roost is protection from the temperature fluctuations outside. Another factor is humidity inside the roost, in order to prevent desiccation during the months of torpidity. Hibernation is a very flexible strategy, performed by temperate-zone species even on a day to day basis when insect availability is low (Altringham 1996).

The tropical bat species do not hibernate in general, but many species show an ability to cope with varying thermal conditions, which is considered to be a preadaptation for the invasion of temperate zones by vespertilinoids and rhinolophoids (Findley 1993).

1.2.7. Migration

Some bat species are known to migrate to warmer climates during the winter. The migration, however, has a different character than the avian migration in which the birds move to warmer climates and stay active throughout winter. Although *Tadarida brasiliensis* (guano bat) shows such avian migration behaviour, more commonly, the migrating bats stay dormant in their wintering areas (Findley 1993, Nowak1994).

1.2.8. Life History

The lifespan of bat species is long when compared to other small mammals of similar size. The equation for life span in mammals in general, as a function of weight, given by Sacher's equation, is as follows (Findley 1993):

$$\text{Life span} = 11.6\ W^{0.20}$$

Consequently the life span of an eight gram small mammal like a temperate-zone bat of genus *Myotis* is expected to be approximately 4.5 years. But the temperate-zone bats that have been recaught after 20 years, and tropical bats with extended life spans show that bats live longer when compared to similar sized small mammals (Findley 1993).

The annual survival rates of bat species is high, both for temperate and tropical zone species, reaching up to 86%. The individuals that show the highest rate of mortality are those that are less than one year old, especially in the hibernating species. The greatest reason is not being able to build enough fat reserves to survive through winter by learning to capture prey quickly while under the pressure of predators. (Findley 1993)

1.2.9. Mating Systems

Although the conducted studies reflect the highly variable strategies, mating systems haven't been investigated thoroughly for bats. (Nowak 1994, Burland et al. 1999, Chesser 1991). Monogamy, a mating system rarely observed in mammals, is seen in a number of bat species. Lek mating in which the males perform courtship displays to attract females was observed in three species. Males of some species (e.g. *Artibeus jamaicensis*) actively defend their roosts sites (e.g. tree hollows) that are required by the females for raising their young, as a result of which they acquire reproductive access to females (Findley 1993). Promiscuous mating is found especially in the temperate-zone vespertilinoids. The most commonly observed mating system in Chiroptera is the so-called resource defense polygyny, where an individual male defends a harem (Nowak 1994).

1.2.10. Reproductive characteristics

Whereas most of the bat species living in the temperate zone and many tropical species produce one offspring per year (monestry), some tropical species give birth to two/three offspring per year (polyestry) (Findley 1993, Nowak 1994).

The bats have a smaller litter size compared to similar sized small mammals. The litter size, which is negatively correlated with body weight is given by Calder's equation (Findley 1993) as follows:

$$\text{Litter size} = 3.43\ W^{-0.16}$$

Based on this equation, the litter size of a 10-20 g bat should be 6.4 to 7.2. The mean annual litter size value that Gaisler estimated for bats is between 0.5 and 1.5, near large mammals (Findley 1993).

As hibernation is a strategy that has evolved to surpass the winter months that are scarce in food, there exist corresponding reproductive strategies in order to cope with this situation, as giving birth is a very energy consuming process. Because of the same reason of food scarcity, it is very difficult for the newly born litter to survive through winter. Consequently insectivorous and frugivorous species have birth cycles in which birth is given in the seasons when food is the most abundant. One of the strategies, in this context, is delayed fertilisation, seen in temperate zone vespertilinoids and rhinolophoids. The members of these genera mate in winter, and the females preserve the sperm in their uterus until spring (when sufficient number of insects are available), when ovulation and fertilization takes place. In some other species, the egg is fertilized by the sperm after copulation, but the fertilized egg stops growing in the blastocyst stage, continuing its growth in spring. Fertilized eggs of some other species continue their development until implantation (Findley 1993, Nowak 1994).

Bats also show other reproductive peculiarities. They have relatively long gestation periods (three to six months) when compared to other small mammals. The pregnancy period of even the smallest bats is about two months. Bats suckle and nurse their young for a longer period. They nurse their offspring until they reach the adult size whereas for most mammals, this size is approximately 40% of the adult's size. In comparison, only few similarly sized rodents have gestation and infant dependency periods longer than one month (Findley 1993, Nowak 1994). The average size of the offspring at birth is relatively large (Microchiroptera 25% and Megachiroptera 12-15% of the mother's weight). This characteristic is consistent with the fact that bats are unable to forage until they reach the adult size when their wings are fully developed (Nowak 1994).

Based on certain reproductive and life history characteristics, r and K selected species concepts have been proposed as a general classification scheme, the idea being coined by Dobzhanzky in 1950 and formalized by Macarthur and Wilson in 1967 (in Findley 1993). The r-selected species are those that have small size, many offspring, exhibiting population fluctuations, and inhabiting habitats characterized by unpredictability; whereas K-selected species are those that have bigger body size, small number of offspring, relatively constant population size, great competitive ability, and slower development (Begon et al. 1999, Findley 1993). Bats, as many small mammals, are expected to be r-selected due to their small size, but many of their characteristics are defined as K-selected. Gaisler (1987) notes that cave dwelling microbat species show more pronounced K-selective characteristics than the microbats that inhabit other kinds of roosts.

1.2.11. Activity, Foraging and Feeding Habits

The basic pattern of activity of Chiroptera involves resting at day and feeding at night, defining bats as nocturnal. When they forage, they cover on average a range of 4-15 km (Arlettaz 1999, McDonald and Barrett 1993, Nowak 1994, Racey 1998). Basically most of the Megachiropteran and Microchiropterans return to their day-roosts, during the daytime. Occasionally they stay at night roosts which they prefer to use due to their proximity to the foraging areas than the day-roosts (Nowak 1994, Walsh 1995). Some island dwelling Megachiroptera species, and in summer months some temperate–zone Microchiroptera exhibit diurnal activity (Nowak 1994, Schoeber and Grimmberger 1997).

The feeding habits of the order Chiroptera shows great diversity. The different modes of feeding include insectivory, frugivory, nectarivory, carnivory, folivory (feeding on leaves), piscivory (feeding on fish) and sanguinivory (feeding on blood of other animals). Most of the Microchiroptera (about 625 species) are insectivorous. Approximately 260 species are frugivorous or nectarivorous. (Findley 1993, Nowak 1994, Schoeber and Grimmberger 1997). The Megachiropterans feed on fruits, nectar, flowers and insects. Some species also feed on leaves, chewing and extracting the soluble juices from them.

Out of the approximately 900 species, three species that live in the New World tropics are sanguinivorous. These species make a small incision on the skin of their prey, onto which they mix a substance within their saliva to prevent blood from clotting. Out of these three, *Desmodus rotundus* specializes in mammals, whereas *Diphylla ecaudata* and *Diaemus youngi* are specialized on birds (Nowak 1994).

The diet of carnivorous species includes small vertebrates, birds, other bats, fish and frogs. The carnivorous species are represented primarily by the Neotropical phyllostomoids (Findley 1993).

The Microchiropteran insectivorous species show various foraging tactics, and are classified accordingly. There are sallying and gleaning insectivores, forest and clearing aerial insectivores, water-surface foragers, and open-air aerial insectivores. The insectivorous species feed on various insect species and arthropods that include spiders, scorpions and small crustaceans (Nowak 1994).

Different bat species forage on different sized insects. The echolocation frequency range and body weight of the bats are the primary determinants. In this context certain Microchiropterans are opportunistic, feeding on various habitat types, whereas some species are highly specialized, capable of acquiring food from only certain habitat types. In this manner some species of bats are characterized as specialists, some generalists and some are seen to shift between the two modes, depending on the prevalent conditions like habitat availability, seasonal food abundance, severity of interspecific or intraspecific competition (Arlettaz 1999). Different bat species have varying wing shapes and flight speeds which are highly related to their foraging behaviour. The main way to compare the wing shapes for bats, as well as birds, is via wing aspect ratios, given by wing area divided by wingspan squared (Schnitzler and Kalko 1998). Resource allocation is related to wing aspect ratios. In general species with high aspect ratios (long and narrow wings) are fast fliers that choose to forage in open and uncluttered habitats whereas the species with low aspect ratios (short and broad wings) choose to forage in cluttered habitats, using their slow and manerouvable flight (Findley 1993, Nowak 1994, Schnitzler and Kalko 1998).

One of the important consequences of feeding of bats is seed dispersal and pollination. The two taxa that play this “key role” for the forest communities are Old World pteropids and New World phyllostomids (Nowak 1994).

Insectivorous species are important for maintaining the balance of the ecosystems because of regulating nocturnal insect populations. By consuming insects almost equal to their body weight each night, they act as biological pest controllers, especially for the insects associated with crops like corn, cotton and potatoes (Nowak 1994).

1.3. Conservation

Hibernating bats are very sensitive to disturbance (as arousal from hibernation can cause depletion of fat reserves). Bats living in roosts like caves and mines are especially vulnerable to human disturbance (Richards and Halls 1998) and consequently many sites of hibernation in North America and Europe are under strict protection (Stebbings 1998, Nowak 1994).

The traditional method of bat conservation has focused on roost protection. Roost protection is important because such structural formations (e.g. rocks, caves) are usually more important than the floristic characteristics for a particular landscape, especially for bats that have specialized on particular types of roosts (Kunz and Racey 1998). A comprehensive protection should include both roost and habitat protection simultaneously, as roost protection, per se, is not adequate if a severe habitat alteration around the roosts is persevering (Entwistle et al. 1997). Until recently the importance of critical habitats focused mainly onto the tropical islands that have the highest diversity or oceanic islands that have very high endemism. But this trend is slowly changing, as it has been realized that habitat protection must also include temperate regions where some of the largest hibernating and maternity roosts that are known to exist in the world are present. Also, species centered protection based on density or rarity of species (Arita and Ortega 1998, Marinho-Filho and Sazima 1998, Pierson 1998) is recommended to be changed by the more productive and cost effective native area protection (Marinho-Filho and Sazima 1998).

1.4. Habitats

Habitats are important in any region as they constitute both the roosts and foraging areas for the animal species. Habitat destruction due to human intervention is one of the fundamental reasons for the loss of species ensuing worldwide, caused by the conflict between the need of the habitat as a resource for human use versus its survival value for the species of the zone (Fenton and Rautenbach 1998).

Like other organisms, bats are affected by habitat degradation, but their ability to fly makes them less vulnerable as they can switch to more suitable roosting and foraging areas (Richards and Hall 1998). Another important characteristic of some bat species is their vagility (the willingness to roost in anthropogenic structures) and generalism in terms of feeding habits, making them more resistant to changes in natural habitats (Altringham 1996, Richards and Hall 1998, Marinho and Filho 1998). Nevertheless, relatively few species can sustain stable populations under habitat alterations and species with limited distributions or restricted habitat requirements face the effects of human impact, resulting in a decrease of diversity and changes in composition of species abundance (Kunz and Racey 1998).

1.5. Turkish Bat Fauna Studies

An extensive review of Turkish Bat Fauna research over the last century has been made by Benda and Horacek (1999).

Until 1950s, the bat studies were undertaken mostly by non-Turkish researchers. Şadoğlu is the first Turkish author who has written an article on bats (Şadoğlu 1953). In 1960's Melahat Çağlar and Hermann Kahmann have been the most prominent figures in the Turkish Bat Fauna research. Between 60's and 70's various German and Austrian zoologists have also made research trips. Starting with the 80's the work of İrfan Albayrak stands out, including some research that yielded new species and location records (Albayrak 1988, 1990a, 1990b, 1993).

The Turkish Bat Fauna is composed of 32[2] species. One species is a Megachiropteran (*Rousettus aegyptiacus*); the remaining 30 species are Microchiropteran. Out of the 31 species comprising the European continental bat fauna, only *Myotis dascyneme* and *Eptesicus nilssonii* are absent in Turkey. On the other hand, the Turkish bat fauna includes *R. aegyptiacus* and *Otonycstris hemprichi* species that are not present in Europe.

Out of the 44 species that form the Middle Eastern bat fauna, 24 are also present in Turkey. Based on the percentage of similar species within the European and Middle Eastern Bat Faunas (94 % and 61 % respectively), Benda and Horacek (1999) concluded a maximum resemblance to the West Palearctic Arboreal for the Turkish bat fauna.

Turkey forms distribution borderlines for many species. It is the south and southeastern border for the temperate zone species that reach their maximum abundance in Europe and Siberia. *Myotis myotis* and *M. capacinni* reach their eastern borders in Turkey. *M. myotis* has the Rize-Erzurum-Diyarbakır-Antalya line and *M. capacinni* has Hatay as its eastern border. *R. aegyptiacus, E. bottae* and *O. hemprichi* reach their North and northwestern borders.

---

[2] 31 species (Benda and Horacek) + 1 species (*Taphozous nudiventeris*) (yet unpublished record of Benda)

Based on the bat fauna research regarding Turkey, Benda and Horacek divides Turkey into three zones.

1) Northwestern Turkey
2) Southeastern Turkey
3) Central and Eatern Anatolia

Southeastern and Nortwestern Turkey show distinctive differences in terms of species, whereas Central and Eastern Anatolia is characterized as a zone of transition between the two other zones. Eastern Anatolia is especially rich in bats as 22 of 31 species comprising the Turkish bat fauna is found in it.

1.6. General Habitat Characteristics of the Çatalca and Kocaeli Peninsulas

1.6.1. Kocaeli Peninsula

In the Kocaeli Peninsula, the main vegetation types are forests (humid and dry), maquis, pseudomaquis and coastal vegetation. Based on these vegetation types, Dönmez (1979) identified two habitat zones in the peninsula: Humid forest zone, including pseudomaquis and dry forest zone, including maquis (composed mainly of *Arbutus unedo*, *Laurus nobilis*, and *Phillyrea latifolia*). In both regions, maquis are seen in coastal regions, composed of evergreen species where the native forest cover has been detoriated and Mediterranean climate is prevalent. The maquis change their character according to climatic and soil factors. For example in areas where summer draught is dominant; the diversity of maquis decreases, as only the most resistant species can survive (Dönmez 1979). These relatively poor formations, in terms of richness of species, are called garrigue. On the other hand, in coastal zones where the Mediterranean climate loses its effect, and summer rain rates increase (e.g. Black Sea coasts), the maquis that fill up the destroyed portions of the forests are mixed with species that shed their leaves in summer. These formations are called pseudomaquis.

are mixed with species that shed their leaves in summer. These formations are called pseudomaquis.

As the water boundary line passes nearer to the Marmara and İzmit Bays, the humid forest zone covers a greater area than the dry forest zone. Although these two forest zones have a different character based on the different species of trees present, the common feature of the zones is the replacement by maquis (composed mainly of *Arbutus unedo*, *Laurus nobilis*, and *Phillyrea latifolia*) in places where the forests are destroyed. The maquis are less specious within the humid forest zone where the Meditarenean influence is weaker when compared to the dry forest zone. On the other hand, the effect of Black Sea causes the humid forest maquis to be denser and greater in size (Dönmez 1979).

Within the Kocaeli Peninsula, the humid forest zone can be examined in two parts, taking Gökdere Valley that runs through north of Karakaya Hill, reaching the Black Sea near Ağva as a border. On the west of this line, two oak species (*Quercus pedunculiflora* and *Q. cerris*) and chestnut (*Castenae sativa*) are dominant; whereas on the east beech (*Fagus orientalis*) is dominant.

The main reasons for this division is the effect of climate, precipitation rate and soil types. The dominance of oak species on the western side is due to lower precipitation. The western zone's soil is exclusively composed of brown forest soil; whereas the eastern zone's soil is mainly brown soil that contains no lime, and the tree species' distribution are concordant with their soil preferences on each zone.

The reason for the existence of dry forests especially in the southern part of the peninsula (south of Alemdağ and Aydos mountains) is mainly due to the increase in average temperature compared to the northern parts (reflected by the greater frequency of days with temperature above 30°C), which results in an increase in the evaporation rate, and thus dry forests.

The dry forest zone is mainly composed of oak forests which are tolerant to dry climates. The most dominant species is *Q. infectoria* whose water requirement is the least among the deciduous oak species present in the region. *Q. frainetto* is also very abundant. The effect of maquis in the Kocaeli Peninsula is much more pronounced (maquis at some places is more dominant than the oak) than the Çatalca Peninsula where maquis is almost totally absent.

As the dry forest zone exists between two of the biggest urban areas of Turkey (İstanbul and Kocaeli), it has been subject to a great deal of habitat alterations. Consequently the dry forest has lost its original character, and has been displaced by Medittarenean type maquis. In contrast to to the pseudomaquis of humid dry forests which is mainly composed of 4-5 species, the dry forest maquis formation is more speciose, composed of about 15 species; lacking only the two species *Pistacia lentiscus* and *Ceratonia siliqua* of the Medittarenean maquis-type flora.

1.6.2. Çatalca Peninsula

In general Çatalca Peninsula shows habitat morphology similar to that of Kocaeli Peninsula (Dönmez 1990).

The humid forest zone is mainly seen in the Istıranca Mountains especially on the Northern faces which comprise the highest topography of the region. The Istıranca Mountains, both due to their altitude and their proneness to the effects of Black Sea's humid climate, is one of the regions of Turkey with the highest precipitation rates. The dominant species of the humid forest zone of the Çatalca peninsula is beech (*Fagus orientalis*). Various oak species (*Quercus dschorochensis*, *Q. frainetto* and *Q. cerris*) disrupt the homogeneity of beech forests, sometimes surrounding and sometimes staying in between the beech aggregations.

The precipitation rates decrease as one moves southwards, resulting in the dry forest zone at the southern facing slopes of Istıranca Mountains which are not open to the effects of the Black Sea. The dry forest formation continues southwards until about 10 km from the coast of the Marmara Sea. Although the dry forest zone has a lower precipitation rate than the humid forest zone, the rate is much higher than the anthropogenic steppe zone to the west.

The dry forest zone is composed of deciduous oak forests composed of a rich variety of eight oak species that shed their leaves in summer. The other abundant elements are two horn beech species (*Carpinus orientalis* and *C. Orientalis*).

1.7. Species Descriptions

In this section, the general characteristics and preferences of the 10 cave dwelling species within three genera that inhabit Çatalca-Kocaeli region will be described (Benda and Horacek 1999, Schoeber and Grimmberger 1997).

1.7.1. Genus *Rhinolophus* (Lacépéde, 1799) – Horseshoe Bats

Out of 69 existing species, five are found in Europe. They inhabit both caves and human-made structures. Their wings have low aspect ratios allowing them to exploit cluttered environments while exhibiting maneuvering flight (Schoeber and Grimmberger 1997, Schnitzler and Kalko 1998). The females of this genus have two false teats that develop after reaching maturity to which the newly born offspring can cling to with their mouths. The juveniles stay within the wing membranes of their mothers which can be partially or completely wrapped around their body The ears, which lack a tragus, can move independently of each other in order to receive the emitted echolocation signals (Schoeber and Grimmberger 1997).

Four horseshoe bat species that were recorded in the survey area are *Rhinolophus hipposideros, R. ferrumequinum, R. euryale and R. meheyli.*

***Rhinolophus hipposideros* (Bechstein, 1800) – The Lesser Horseshoe Bat**

R. hipposideros inhabits relatively warmer regions in mountains, forests, limestone formations and sometimes houses. It can be classified as a house bat at the northern latitudes and a cave bat at the southern latitudes. In winter, *R. hipposideros* hibernates at 6-9°C without forming clusters and at high relative humidity (up to 100%). In summer females form nursery colonies of 10-500 individuals.

R. hipposideros is a non-migratory species and does not move more than 5-10 km between the winter and summer roosts. Due to its small size, it is a relatively fast flier hunting in open forests, preying on small moths, mosquitoes, crane flies, beetles and spiders. Although its dominant strategy is gleaning; it can also hunt by aerial hawking and by pouncing on ground.

***Rhinolophus ferrumequinum* (Schreber, 1774)– Greater Horseshoe Bat**

R. ferrumequinum inhabits warmer regions with trees and shrubs (where running or standing water is available), karst formations and houses. Similar to *R. hipposideros,* it is a house bat in the north, and a cave bat in the south. It rarely forms clusters, preferring temperatures between 7-10°C. It is a permanent resident, migrating at most 20-30 km between summer and winter roosts. The young are born between June to mid-July in the summer roosts.

R. ferrumequinum is a relatively slow flier, foraging and hunting around open tree stands, rock faces, and gardens, preying on June beetles, carrion beetles, grasshoppers, and moths by gleaning or perching.

***Rhinolophus euryale* (Blasius, 1853) – The Mediterranean Horseshoe Bat**

R. euryale is a cave bat which forms maternity roosts of 50-400 females in summer. Winter roosts are caves or tunnels in which the temperature is around 10°C. While hibernating it is sometimes seen to be maintaining body contact with con-specifics, as well as hibernating singly. It is a sedentary species.

R. euryale forages on hillsides, within relatively dense tree or shrub cover that have a fresh water supply nearby. Using its slow, fluttering flight, it can hover and feed on moths and other insects.

***Rhinolophus meheyli* (Matschie, 1901) – Mehely's Horseshoe Bat**

R. meheyli is a cave bat which roosts in karst formations that have access to water. It forms maternity colonies of up to 500 females. It hunts on warm mountain slopes, among shrubs and trees, using a similar flight style to the Mediterranean Horseshoe Bat. *R. meheyli* feeds on insects and moths.

1.7.2. Genus *Myotis* (Kaup, 1829) – Little Brown Bats

This genera comprises 90 species, 10 of which inhabit Europe. They use FM frequency signals for echolocation and on average they have a low wing aspect ratio that makes it possible for them to exploit cluttered environments. They use forests as well as caves and human-made structures as roosts.

***Myotis daubentoni* (Kuhl, 1817) - Daubenton's Bat**

M. daubentoni is mainly a forest bat that spends the winter in caves or human made structures. Its temperature preferences for hibernation in winter is 0-6°C, but it is occasionally found in temperatures below 0°C. It likes high humidity. Some winter roosts contain up to 1000 individuals. Maternity roosts have been recorded to contain 200 individuals. *M. daubentoni* is a partial migrant that can travel around 100 km between summer and winter roosts.

M. daubentoni is a fast and agile flier; hunting 5-20 cm above water and around trees, feeding mainly on mosquitos, craneflies and moths.

Myotis capaccinii **(Bonaparte, 1837)– Long fingered Bat**

M. capaccinii's nursery colonies are within caves, consisting of up to 500 females. In winter it is usually found in crevices in caves. It prefers forested and shrubby landscapes near water, feeding especially on flying insects caught over water.

Myotis emarginatus **(Geoffrey, 1806)– Geoffrey's Bat**

M. emarginatus' nursery roosts are attics of houses in the northern latitudes of the temperate zone, and caves and mine galleries in the southern latitudes. Its winter roost temperature preference is 6-9°C, the number of the roosting individuals changing between 20-2000 individuals. Most hang singly, and they are rarely seen in clusters or crevices. *M. emarginatus* is mainly sedentary, its movements between summer and winter roosts being less than 40 km.

M. emarginatus feeds mainly on brown lacewings, diptera, hymnoptera, moths and caterpillars taken from branches, leaves or ground.

Myotis myotis **(Borkhausen, 1797) - Greater Mouse Eared Bat**

M. myotis is a warmth loving species. In summer it chooses roosts with temperatures near 45°C, in winter the temperature range is 3-12°C. It can be found both hanging singly or in clusters (100-4500 individuals), inhabiting holes in the walls, ceilings of caves and although rarely, narrow cracks. It is a partial migrant with a range of about 50 km.

M. myotis prefers light wooded areas, meadows, open stands of trees, forested habitat, parks, fields and towns. It has a slow, fluttering flight about 5 to 10 m from the ground. *M. myotis* feeds on carabid beetles, cockhafers, dung beetles, moths caught in flight, and non-flying beetles, spiders, grasshoppers and crickets taken from the ground.

Myotis blythii (Tomes, 1857) - Lesser Mouse Eared Bat

Maternity colonies of *M. blythii* (composed of up to 5000 individuals) are located in caves (usually with *Miniopterus schreibersii, Myotis myotis* and other horseshoe bats). In winter, it usually hangs singly, preferring temperatures between 6-12°C. It is a partial migrant similar to *M. myotis.*

M. blythii prefers to forage in open stands of trees and shrubs that are not too dense, parks and sometimes urban areas. It feeds on moths and beetles taken from ground or air.

1.7.3. Genus *Miniopterus* (Bonaparte, 1837)

This genus, which has 10 species in the world, is represented by one species in the temperate zone Europe. They are fast fliers with high wing aspect ratios that forage in uncluttered environments. They are mainly cave dwellers.

Miniopterus Screibersii (Kuhl, 1817) – The Bentwinged Bat

M. schreibersii is a cave bat which forms big clusters (between 1000-4000 individuals), especially in the summer roosts. In the winter, it hangs freely or forms clusters, preferring temperatures between 7-12°C.

M. schreibersii is a very fast flyer; its flight speed is 50-55 km/hr. Due to its wings that have high aspect ratios, it is a migratory species that can migrate around 100 km. It hunts in open and rocky landscapes, feeding on moths, gnats, and beetles.

2. METHODOLOGY

This section consists of two parts. The first part consists of the details of the fieldwork done in order to record bat species composition, make habitat assessment, measure temperatures, and mark geographical coordinates for each cave. The second part consists of the details of statistical analysis.

2.1. Fieldwork

2.1.1. Species Surveys

The cave visits were made once to each cave between May and August 1999. The main species identification scheme was based on morphological characters. Bats were captured from the cave wall either by hand while it was sleeping or by a hand-net if it was flying. Forearm length was the dominant diagnostic measurement. The measurements were made by a Vernier scale with a precision of 0.1 mm. A heterodyne bat detector (Batbox 3) was used for identification of flying horseshoe bats.

The counts of single individuals and clusters less than approximately 100 individuals were made by counting one by one. The counts of bats in clusters were made indirectly by using a torch. The number of individuals of bats in an area that the torch illuminated in a cluster was counted and the number of those areas that form that particular cluster were counted to infer the total number of bats.

The diagnostic details for each genera and species are as follows:

2.1.1.1. *Rhinolophus*

The most striking feature of this genus is the leaf-like skin process surrounding the nasal region through which echolocation calls are emitted. Their echolocation calls are composed of a constant frequency component that ends with a terminal FM buzz. The different constant echolocation frequencies emitted by different species make identification using a heterodyne detector possible.

Rhinolophus ferrumequinum

It is the largest European horseshoe bat. The forearm length is 54-61mm. The dorsal hair is gray brown to smoky gray with a reddish tinge, the ventral hair is gray-white to yellowish white. The upper connecting process of the nose (ucp) is short and rounded, the lower connecting process (lcp) is pointed. It emits a relatively low frequency call when compared to other rhinolophids, between 77-81 kHz.

Rhinolophus hipposideros

This is the smallest horseshoe bat. The forearm length changes between 32-42.5 mm. The color of the dorsal side is brownish smoky gray (without a reddish tinge); the ventral side is gray to gray white. The upc is short and round, the lcp is short and pointed. The echolocation frequency changes between 105 to 111 kHz.

Rhinolophus euryale

This is one of the three medium sized horseshoe species. The forearm length is 43-51mm. Another measurement that is made for identification of the medium sized horseshoe bats is the measurement of the first and second phalanx of the fourth finger. The 1st phalanx is 6.6-8.5 mm, the 2nd phalanx is 17.9-19.2 mm. The ventral side is gray-white to yellowish white, the dorsal side is gray-brown with a pinkish tinge. The boundary between the two sides is indistinct. The upc is pointed and it slightly curves downwards and protrudes more than the rounded lcp. The lancet tapers off to a blunt point evenly.

Rhinolophus meheyli

It is the other medium sized cave-dwelling horseshoe bat that was recorded within the caves of the region. Its forearm is 50-55 mm. The 1st pahalanx of the fourth finger is 7.7 mm, the 2nd phalanx is 19 mm. The dorsal side is gray-brown, the ventral side is almost white. The border between the two sides is distinct. The ucp is blunt and slightly longer than the lcp. The lancet gets thinner in a convex curving manner towards its tip, in contrast to *R. euryale*. Its echolocation frequency changes between 105-112 kHz.

2.1.1.2. *Myotis*

The ears that pass the height of the head and absence of nasal ornamentation are the most distinguishing features of this genus, used for distinguishing it from *Miniopterus* and *Rhinolophus* genera. Other than the forearm length, the length of spur on the tail membrane, and the presence/absence of bristles on the free (spurless) end of the tail membrane are used for identification.

Myotis daubentoni

It is a medium to small sized mouse-eared bat. Its forearm is 33-42 mm. Its spur attains 1/3rd the length of the tail membrane. At 3/4th of the spur there is a distinct break. No hair exists on the free end of the tail membrane. The dorsal hair is brown-gray to dark bronze, ventral side is silver gray with a brownish tinge. The border between the dorsal and ventral fur is distinct. It muzzle is rufous. It hunts using FM signals, sweeping a range between 78-25 kHz, with a peak at 45 kHz.

Myotis capaccinii

It is another medium sized mouse-eared bat. Its forearm length is 38-44 mm. The spur attains 1/3rd the length of the tail membrane. At 2/3rd to 3/4th of the tail membrane, there is a break acting as a spur tip. The tail membrane has dense, dark hair both above and below that reaches the spur region. The dorsal fur is light smoky gray with a slight yellowish tinge. The ventral fur is light gray. The border between the dorsal and ventral sides is indistinct. It has a reddish brown muzzle. Its feet are bigger than the other medium-sized myotis. The tail membrane is covered with dense and dark hair above and below which is absent in the other myotis species.

Myotis emarginatus

It is a medium sized mouse-eared bat. Its forearm length is 36-42 mm. Its spur attains one half the length of the tail membrane. The free margin of the tail membrane has sparse bristles. It has a tricolored dorsal fur whose base is gray, middle is straw-yellow and top is rufous brown. The ventral side is yellowish gray. Its muzzle is brown. On its ear there is a notch almost perpendicular to the ear, at a distance of about two thirds from the base.

Myotis myotis

It is one of the largest species belonging to the genus *Myotis,* and the largest one in Europe. Its ears are long and broad; the brown-gray muzzle is short and wide. The tragus reaches one half of the length of the ear. The dorsal fur is light gray-brown with a rusty tinge, the ventral fur is whitish gray.

Myotis blythii

It is slightly smaller than *M. myotis.* Its ears are narrow and smaller. Its light gray muzzle is also narrower and pointed. The tragus is one half the length of the ear. Its dorsal fur is gray with a brownish tinge, its ventral fur is grayish white.

2.1.1.3. *Miniopterus*

Miniopterus schreibersii

Its most distinguishing feature from the mouse eared bats is the ears that do not exceed the height of the head. Its tragus is bent at the tip. Its dorsal fur is gray-brown to ash-gray, sometimes with a lilac tinge. Its underside is lighter gray. Its muzzle is gray-brown.

2.1.2. Methodology for Habitat Assessment

The habitat assessment was made in a three km diameter region around each cave. The habitat types that were especially important for bat species were noted based on the work of Fenton and Bell (1979), Gaisler and Kolibac (1991), Rachwald (1992), Ekman and Dejong (1994), Entwistle et al (1997), Carmel and Safriel (1998), and Racey (1998) (Table 2.1.). For the classification, the work of Entwistle et al(1997), Gaisler and Kolibac (1991) and Donmez(1979a, 1979b) and Carmel and Safriel (1998) have been used as basis for the identification of habitat types. DAFOR scale (Fowler and Cohen 1996) has been used for defining relative amounts of land coverage by the habitat types present. The scale was defined as follows:

1... The habitat type is rarely present
2... The habitat type is occasionally present
3... The habitat type is frequently present
4... The habitat type is abundant
5... The habitat type is dominant

Table 2.1. Important Habitat Types for Bats

Woodland (Coniferous): Forest composed of tree species that do not shed their leaves in winter.

Woodland (Deciduous): Forest composed of tree species that shed their leaves in winter.

Woodland (Mixed): Forest composed of both coniferous and deciduous tree species.

Wet Woodland: Forest composed of deciduous trees which are rooted in soil covered with water.

Coastal Area: Area that has an open sea interface and/or a beach (including rocky, sand and shingle beaches and sand dunes) .

Woodland Ecotone-Clearing: Openings within broad-leaved deciduous trees which are uncluttered enough for bats to forage in.

Woodland Ecotone-Edge: The interface between grassland/moorland and tall scrub/woodlands.

Urban: Areas of human settlement.

Ditches: Open linear drainage features.

Single Trees: Plantations of single trees.

Treeline: a line of at least 3 single trees less than 2 canopy widths apart and greater than 4m high.

Hedgerow: linear woody vegetation less than 4m high and 5m wide.
Lake and Reservoir: Standing water greater than 0.25 ha (artificial or natural)
Pond: Standing water less than 0.25 ha (artificial or natural)
Bog: An area of wet and soft land, improper for agriculture of any kind
River: Running water bodies greater than 2.5 m wide
Stream: Running water bodies less than 2.5 m wide
Moorland: Land which is covered with rough grass or low bushes and is not proper for grazing or agriculture
Pasture: Grassland used solely for grazing; improved or unimproved
Meadow: Grassland used for hay or silage production, improved or unimpoved
Arable Land (Traditional): Land used for agriculture, less than 0.25 ha in area
Arable Land (Intensive): Land used for agriculture, greater than 0.25 ha in area
Tall scrub: underdeveloped broadleaved tree formations 3-12m high.
Maquis: low bushes typical of Mediterranean climate
Riparian treeline: Treeline located at the fringe of a river or stream
Riparian hedgerow: Hedgerow located at the fringe of a river or stream

2.1.3. Temperature Measurement

Temperature measurements were taken at shoulder height (~1.50 m), under the areas within the cave where bats were seen to be present using a thermometer.

2.1.4. Methodology for Geological Coordinate Estimation

The GPS device Garmin XL 12 was used for obtaining X and Y coordinates for each cave during the field trips.

2.2. Statistical Analysis

Although the data collected by any ecological study has descriptive meaning by itself, in order to understand the patterns inherent in communities, descriptive ecological data should be analyzed statistically.

In the analysis, count data were treated as untransformed, double transformed (row and column standardization), and logarithmically transformed. The count data were further simplified by treating big *Myotis* species (*Myotis myotis*, and *M. blythii*) as large myotis, and the remaining *Myotis* spp. as small myotis. *R. meheyli* was taken out of the analysis as only three individuals were found in the entire survey.

The three main diversity indices (N0, N1 and N2) and evenness index E5[3] were calculated for each of the sampling units (caves). N0, N1 and N2 represent the number of species, the number abundant species and number of very abundant species respectively. E5 was used as it is unaffected by the population size. Green's index (G) was calculated for understanding the clumping patterns of species.

The relative abundance of the species was plotted for making the distribution model diagram which was used to understand if any association, and hence niche overlap exists between the species.

Association analysis was used for grouping caves based on their homogeneity in terms of the presence or absence of species. A group was considered homogeneous if no statistically significant association was seen to be present between species in the caves after interspecific pairwise association Chi-square values were computed. The basic program 'Nassoc.bas'[4] was used for the association analysis.

---

[3] E5=((N2-1)/(N1-1))

[4] This and basic(.bas) and quickbasic(.qba) programs mentioned later are from the statistical package accompanying the book of Ludwig and Reynolds (1998).

Cluster analysis was applied for grouping of similar caves together. The method involves hierarchical arrangement of sampling units into similar clusters in a 'treelike structure called a dendrogram' (Ludwig and Reynolds 1988), based on distances between sampling units. The clusters formed may represent different biotic communities. The distance coefficients are resemblance functions that describe the similarity (or dissimilarity) of sampling units based on species abundance data. For computing the distances, chord distance[5] method was used as recommended by Ludwig and Reynolds (1988). During cluster analysis, the most similar sampling units are grouped together in clustering cycles. At each step of the cycle, one pair of entities are joined to form a new cluster. The pair of entities that group together can be a sampling unit (SU) and another SU, a SU and a cluster, or a cluster and a cluster. Four different clustering methods (centroid (weighted), centroid (unweighted), group average, and flexible strategy) were used to see if any different patterns emerged by different clustering techniques. The different methods differ in the coefficients used for determining the distances between newly formed clusters. The basic program 'Cluster.qba' was used for computing distances and cluster analysis.

Various community ordination methods were used to understand the effects of environmental factors on distribution of species in caves. By ordination, the SUs are arranged with respect to one or more axis, so that their positions indicate their similarities or dissimilarities. The identification of similar (or dissimilar) SUs may help in determining biological or environmental factors that cause the patterns (if any) observed in species distribution. There exist a wide array of possible ordination methods that can be used for ecological data interpretation based on the linearity and nonlinearity of relationships. Non-linear techniques are especially useful when SUs that have few species in common are at opposite ends of wide environmental gradients, whereas linear methods are effective for showing the relationships across narrow gradients.

Principle Component Analysis (PCA), a linear ordination method, was used to see if the environmental factors have a narrow environmental gradient. In this method, 'the coordinates of a SU in the space of the PCA axis system are determined by a linear combination of weighted species abundances' (Ludwig and Reynolds 1998). In PCA, the

---

[5] $CRD_{jk} = (2(1\text{-}ccos_{jk}))^{0.5}$; where j and k are two sampling units whose distance to each other is being computed.

abundance data for each species is standardized by the mean of that particular species' abundance. If the PCA indicates that the underlying environmental gradient is not narrow and relationships are not linear, other ordination methods are used.

Correspondence analysis (COA), a nearly-linear ordination method, is one of the alternatives to PCA. The main difference between the two methods is that in COA, the abundance data is double standardized, in contrast to center-normalization of PCA, and hence variance of the data is decreased prior to analysis. Another difference is that the 'corresponding' component values for axis are obtained for SUs and species at the same time. The COA generally gives accurate results for one axis and usually an arching is seen for the second axis, which makes interpretation difficult. When arching is apparent after COA, a non-linear ordination technique, Detrended Principle Component Analysis (DPC), is applied in order to remove the arching and reflect the underlying environmental gradient. The detrended curve is plotted by a second-order polynomial regression of components of one of the axis onto the other one. Nonlinear Multidimensional Scaling (NMDS) is another nonlinear ordination method. This method rank-orders the SUs and places them on the component axis based on their distances to each other. NMDS is more appropriate than DPC when strong species nonlinearities cause spiralling or looping patterns on the component axis. Ludwig and Reynolds (1998) recommend to test the results of different methods in terms of their consistency, therefore both NMDS and DPC were used for nonlinear ordination. The basic programs 'PCA.BAS, COA.BAS, DPC.AS, and NMDS.BAS' were used for the computations of the ordination analysis.

The habitat data was recorded in two formats. The binary format indicates the presence/absence of habitat types. The DAFOR scale format, indicates the relative cover of habitat types. The data in DAFOR format for the habitat types was standardized for each cave by summing the values for habitat types for that cave, and dividing each habitat type's value by this sum. The standardized data was used for cluster analysis and ordination of habitat types around caves.

The temperature data was used for calculating average temperature for each cave and weighted average temperature for each species.

Nestedness analysis was done for understanding the randomness of species distribution in caves, using temperatures as indicators of randomness, with 0° representing maximum order and 100° representing maximum disorder (Atmar and Patterson 1993). The randomness patterns of both regions (Kocaeli and Çatalca) was investigated together and separately for each region.

In the final stage of data analysis, the multi-linear regression of component values of various ordination methods, based on species, were used for computing the effects of geographic location, habitat and temperature on species distribution. DPC which gave the most explanatory pattern among the ordination of caves on species was used for calculation of regression values used in the discussion section. The basic program 'PCREG.BAS' was used for regression analysis.

3. RESULTS

3.1. Distribution of Bats in Caves

Çilingoz

In this cave a maternity colony of *Rhinolophus euryale* was present (approximately 2500 individuals with juveniles). Also a 2000 individual colony of *Miniopterus schreibersii* and 350 individual colony of *Myotis emarginatus* were counted in one of the saloons of the cave.

Deliklibent

The species identified in the cave were *R. ferrumequinum* (10 individuals), and *R. euryale* (1 individual). Two bats of genus *Rhinolophus* and three bats of genus *Myotis* were seen, but not identified to the species level.

Gökçeali

The entrance into the cave is in a military zone, therefore not many people can enter it. In this cave, colonies of large myotis (2200), *M. schreibersii* (1530 individuals), *M. cappaccini* (60 individuals), and *R. euryale* (40 individuals) were recorded. One free hanging individual was identified as *R. meheyli*. A 50 individual myotis group, and one rhinolophus individual couldn't be identified to species level.

Horataşı

In this cave, *M. schreibersii* (700 individuals), large myotis (440 individuals), *R. ferrumequinum* (two individuals), *R. euryale* (two individuals) and *M. cappacini* (one individual) were encountered.

Kocakuyu

In this cave, three species were seen, namely *M. schreibersii*, large myotis and *M. blythii*. All of the large myotis species that were caught and examined were males which implies that the cave was a male roost for the summer. A colony of 400 inidividuals of large myotis, 50 *M. schreibersii*, 3 male *M. blythii* were recorded in total.

Yaylacık

The cave hosts a maternity colony for *M. schreibersii*. The counts were 1400 individuals for *M. shreibersii*, and 200 for large myotis. At the entrance to the cave one *M. emarginatus* was recorded.

İnkese

A large colony of approximately 500 individuals of *R. euryale* was seen during the counts.

Sofular

The cave hosted a nursery colony of 510 *R. ferrumequinum*, and 200 individuals of the same genus that couldn't be identified. There were 300 individuals of *M. schreibersii*, 300 *R. euryale*, and 3 individuals of *R. meheyli*.

Gökçeören

There were *R. ferrumequinum* (50 individuals), *R. euryale* (21 individuals), and *M. cappaccini* (17 individuals) present.

İkigöz

In this cave, the only record of *M. daubentoni* in the entire survey was made. The cave being an active one, with a stream flowing through, might be the reason for the bat's presence in the cave as this species forages on streams. Also 15 individuals of *R. euryale* were recorded.

Yukarıkışla

In this cave 25 individuals of *R. euryale* were noted.

3.2. Habitat Assessment

Kocakuyu and İkigöz

These two caves constitute the two ends of one bigger cave formation which is cut at intervals by siphons. Therefore the habitat around them is treated as the same in terms of its possible utilization by bats. The tall scrub constitute the most abundant vegetation type within the area. Next, deciduous woodland, meadow, and arable land on which intensive agriculture is done are the most frequent habitat types. Woodland clearing, and riparian treeline along a stream are the other habitat types that are also present though not as dominantly as the previous ones. Edge, sub-urban areas in which traditional agriculture is done, and single fruit trees are also present.

Horataşı

The deciduous woodland, tall scrub and meadow are the most abundant habitat types. The deciduous woodland has several clearings, and edges are caused by the presence of meadow next to the deciduous woodland and tall scrub formations. A stream is present that has treelines on its fringe. A treeline aggregation is also notable away from the stream. A bog situated about 50 m from the mouth of the cave exhibits very high insect activity very near to the cave. There are a few small ponds in vicinity. Fields where traditional agriculture is done are occasionally present.

Yaylacık

Tall scrub comprise the most dominant vegetation around the cave. Meadow is the next most abundant habitat type. There is a riparian treeline along a stream. Treelines are also present away from the stream. Edges are present along the tall scrub/meadow interface. A small village is present whose inhabitants practice traditional agriculture. Single fruit trees are seen within the village.

Çilingoz

The habitat around the cave, which is located within a valley, shows a heterogeneous forest composition. In 1990, Dönmez recorded that *Quercus* was the most dominant tree genus. *Carpinus*, *Fagus* and *Pinus* were the three abundant genera. The forests around the cave composed of these species were deciduous, coniferous or mixed. Wet deciduous woodlands were also present. The pseudomaquis elements cover the regions in which oaks, beech and pines have been removed.

In the survey, it was found that the forest composition is similar to that described by Dönmez (1990). The most dominant forest type is deciduous woodland, followed by coniferous woodland which form mixed woodlands where they coexist with the deciduous forests. Wet woodlands were not present within the Çilingoz valley area, in contrast to Dönmez (1979). The maquis are the most dominant type of habitat within the extensive coastal zones. Tall scrub are seen less frequently in this area compared to the areas around other caves in the Çatalca region. Moorland, meadow, woodland clearings and edges can also be seen. Riparian hedgerow and riparian treeline are present along a stream. A small water reservoir is formed as a result of presence of a concrete water dike on the flowpath of the stream. An artificial sub-urban area is created as the area is used as a recreational site in summer.

Gökçeali

The most frequent types of habitat are deciduous woodland, tall scrub, and intensive arable land. Traditional arable lands, coniferous woodland (artificial), maquis, pasture, single trees and extensive tree lines are also present. Riparian vegetation around a stream is composed of hedgerow and treelines. An artificial pond which is formed by a dike built into the flowpath of the stream is present. A village in which there are street lamps is nearby. Edges exist at the tall scrub/deciduous woodland and pasture interfaces.

Sofular

The habitat around this cave is the richest in Kocaeli region. Both coniferous and deciduous woodlands are present. Maquis are abundantly present in places that the woodland has been destroyed. The mouth of the cave faces a coastal zone. Pasture and heathland are occasionally present. A stream that runs through the coastal zone which reaches the sea has treeline and hedgerow on its banks. Edges and woodland clearings are also formed by woodlands and pasture.

Gökçeören

Tall scrub comprise the most abundant habitat type of the region. Pasture, maquis and the reservoir nearby cover the next largest area after tall scrub. A stream that has riparian treeline and hedgerow is also present. Treelines and single trees are seen frequently. There are two villages nearby the cave whose inhabitants practice both traditional and intensive agriculture. Edges are formed between tall scrub and pasture.

İnkese and Yukarıkışla

Tall scrub is the dominant habitat type around these caves. Single trees, heathland and pasture cover a large area. Deciduous woodlands are also occasionally present. Riparian vegetation is present as hedgerows and treelines around a stream that flows into the cave. Edge exists mainly between pasture and tall scrub.

Deliklibent

Tall scrub and agricultural land (intensive) cover the largest area around the cave. Maquis and pasture are abundant. An urban area is present nearby. Riparian hedgerows and treelines are present by a stream. Extensive edge is notable at the tall scrub-pasture interface.

3.3. Statistical Analysis

In this section, analysis of count data in untransformed format is presented only, as the analysis using untransformed and transformed data gave very similar results.

The corresponding species counts for each cave are given in Table 3.1. The names of the species are abbreviated as follows:

Rhinolophus euryale – Rhieu
Rhinolophus ferrumequinum- Rhife
Miniopterus schreibersii – Minsc
Large Myotis- Myola
Small Myotis- Myosm

Table 3.1. Cave Counts

	Rhieu	Rhife	Minsc	Myola	Myosm
Horataşı	42	2	660	440	1
Cilingoz	2500	0	2000	0	350
Yaylacık	0	0	1400	200	0
Kocakuyu	0	0	50	400	0
İkigöz	14	0	0	0	0
Gökçeali	40	0	1530	2200	60
Sofular	500	520	300	0	0
İnkese	500	0	0	0	0
Yukarıkısla	25	0	0	0	0
Deliklibent	1	11	0	0	0
Gökçeören	21	50	4	0	17

The abundance of species is plotted in Figure 3.1.,where the most abundant species in the region was found as *M. screibersii,* and the least abundant as Large Myotis.

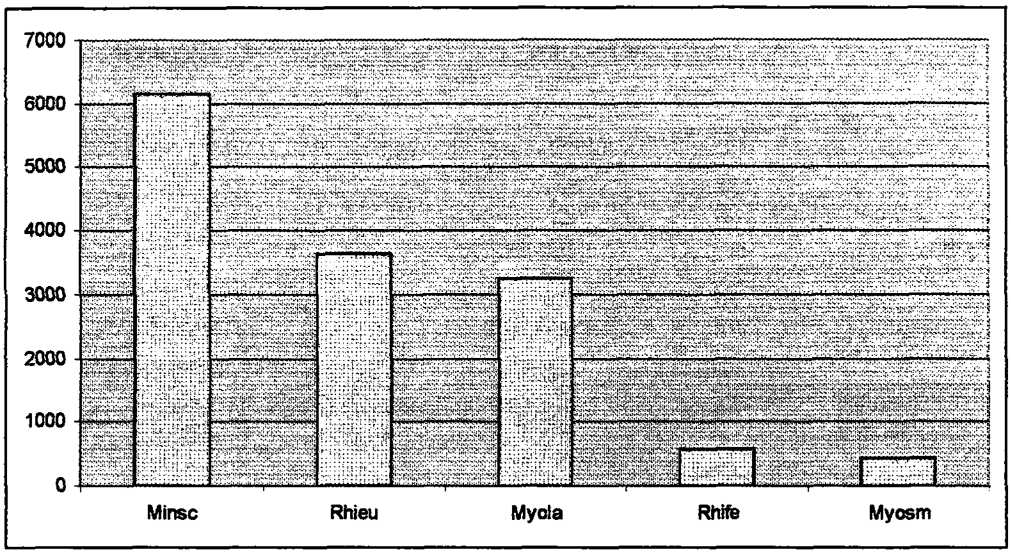


Figure 3.1. Abundance Pattern for Species

In order to understand the species interactions, the relative abundance of species were plotted (Figure 3.2). The consequent species distribution model indicates a 'broken-stick distribution' (Ludwig and Reynolds 1998), hinting that species are not associated directly, and patterns of association are mainly due to environmental factors.

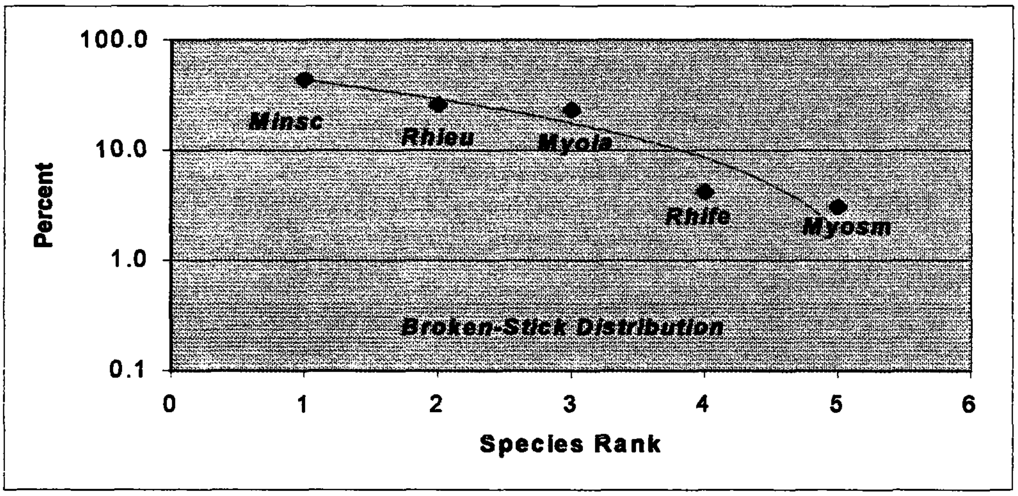


Figure 3.2. Species Distribution Model

Green's index(G) was calculated as a measure of the distribution pattern for species. A value of one for G indicates maximum clumping for that species in a certain sampling unit, and a value of zero indicates minimum clumping (maximum randomness) for the distribution of species. *Miniopterus schreibersii* showed the least amount of clumping and *Rhinolophus ferrumequinum* showed the greatest clumping among the species encountered (Table 3.2).

Table 3.2. Green's Index

	Minsc	Rhieu	Myola	Rhife	Myos
G's Index	0.17	0.46	0.45	0.78	0.65

When diversity indices were examined (Table 3.3), it was generally seen that the number of very abundant species (N2) was around 2. In Çatalca Region, *Miniopterus schreibersii* was always one of the very abundant species, except in Kocakuyu where the N2 value was 1.25 and the very abundant species was Large Myotis. Correspondingly *M. schreibersii* was the divider species in the grouping of caves by association analysis (Figure 3.3). In this figure, the caves whose names are given on the left side of the figure formed two separate groups (on the right side of the figure), based on the presence (+) or absence (-) of *M. schreibersii*. Large Myotis was the second most abundant species in Çatalca Region, and it was not encountered in the Kocaeli Region. *R. ferrumequinum* was the most abundant species in the caves it was present in Kocaeli Region. It was found only in Horataşı cave in the Çatalca Region and was represented by two individuals. Generally evenness of species distribution (given by E5) was relatively high, and Sofular cave showed the highest evenness. As only *R. euryale* was found in İkigöz, İnkese and Yukarıkışla caves, the diversity indices were one and evenness indices could not be computed for these caves (Table 3.3).

Table 3.3. Diversity and Evenness Indices

	N0	N1	N2	E5
Horataşı	5	2.28	2.08	0.84
Gökçeali	4	2.22	2.04	0.85
Gökceören	4	3.06	2.65	0.80
Çilingoz	3	2.45	2.27	0.82
Yaylacık	3	1.46	1.28	0.61
Sofular	3	2.92	2.86	0.97
Kocakuyu	2	1.42	1.25	0.50
Deliklibent	2	1.33	1.2	0.60
İkigöz	1	1	1	NC*
İnkese	1	1	1	NC
Yukarıkışla	1	1	1	NC

Figure 3.3. Species Associations for Caves

The cluster analysis, using different clustering techniques, gave similar results for the untransformed data. The dendrogram obtained by the centroid (weighted) technique is given in Figure 3.4. İkigöz, İnkese and Yukarıkışla caves grouped together as *R. euryale* was the only species present in them. Other than these, the caves of Çatalca region clustered together except Çilingoz, and caves of Kocaeli region clustered together.

---

* Not computable

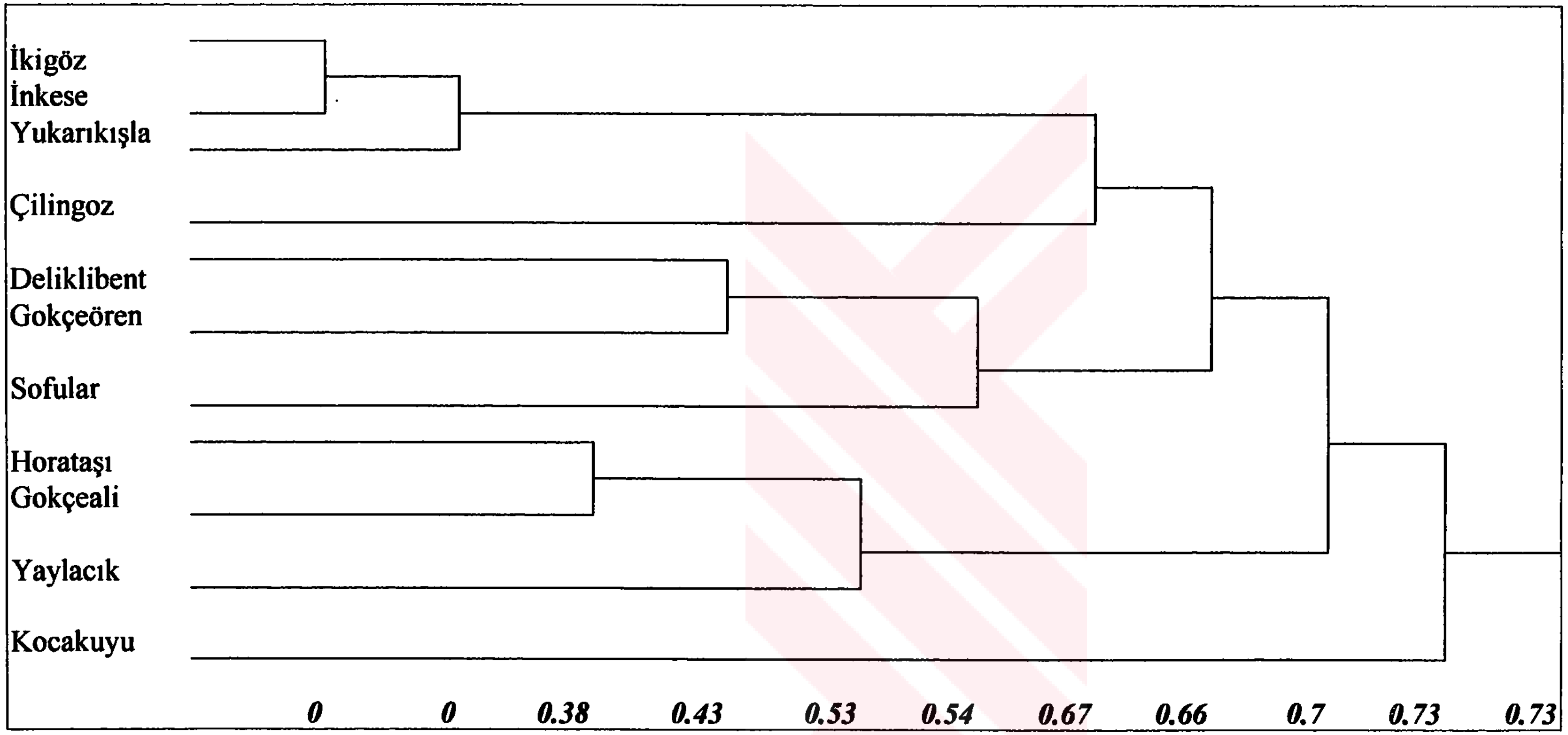


Figure 3.4. Cluster Analysis for Untransformed Data

3.3.1. Sampling Unit Ordination

PCA was done in order to decrease the number of dimensions describing the sampling units and to simplify the interpretation of species distribution.(Table 3.4, figures 3.5, 3.6 and 3.7[5]) Caves grouped together except for Gökçeali, Çilingoz and Sofular.

The detached position of Çilingoz cave handicapped the analysis, therefore COA was applied. As the components of COA showed an arching (Figure 3.8), DPC was applied to remove this effect by projecting the points onto the detrended curve (Figure 3.9). This curve was projected onto R^1 (Figure 3.10) by computing the distances between points, and standardizing the distances between 0 and 100 (Table 3.6). The caves grouped in a similar fashion to cluster analysis. Kocakuyu, Gökçeali, Yaylacık and Horataşı grouped together as caves of Çatalca Region; Sofular, Deliklibent and Gökçeören grouped together as caves of Kocaeli region. İkigöz, Yukarıkışla, İnkese formed another group, and Çilingoz stayed separately from these groups. NMDS showed the same groupings; the Çatalca caves (except Çilingoz) stayed on the left side of the axis for component I; the Kocaeli caves were at the fourth quadrant; İkigöz, İnkese, and Yukarıkışla were in the second quadrant with Çilingoz although Çilingoz stayed singly (Figure 3.11)

---

[5] The caves leabeled as red and yellow are in Çatalca and Kocaeli regions respectively

Table 3.4. PCA Results for Components for Raw Data (Caves)

	I	II	III
Accumulated trace percentages	50.6	77.9	95.9
Horataşı	0.515	-0.084	-0.019
Cilingoz	-0.026	0.182	0.676
Yaylacık	0.555	-0.043	0.156
Kocakuyu	0.551	-0.149	-0.361
İkigoz	-0.417	-0.455	0.007
Gökçeali	0.478	-0.01	0.021
Sofular	-0.231	0.324	-0.317
İnkese	-0.417	-0.455	0.007
Yukarıkısla	-0.417	-0.455	0.007
Deliklibent	-0.314	0.514	-0.455
Gökçeören	-0.277	0.629	0.278

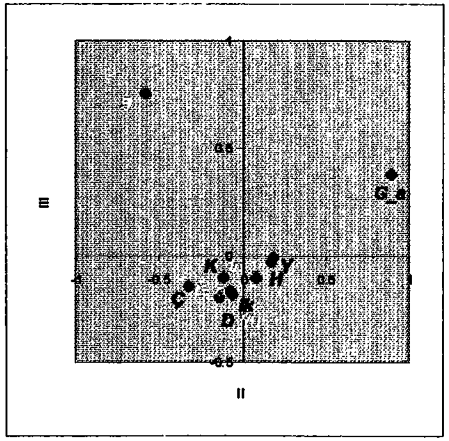


Figure 3.5 PCA Diagram for Components I and II

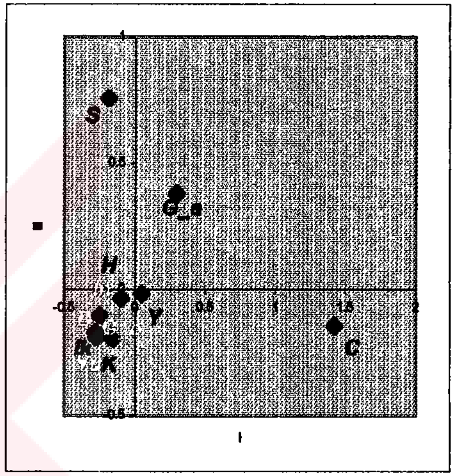


Figure 3.6. PCA Diagram for Components I and III

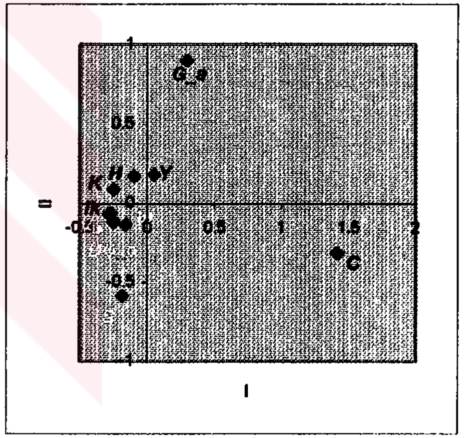


Figure 3.7. PCA Diagram for Components II and III

Table 3.5. COA Results for Components II and III (Caves)

	II	III
Horataşı	-0.772	-0.08
Cilingoz	0.722	0.845
Yaylacık	-0.459	0.204
Kocakuyu	-1.59	-0.683
İkigoz	1.503	1.153
Gökçeali	-1.089	-0.293
Sofular	1.509	-2.374
İnkese	1.503	1.153
Yukarıkısla	1.503	1.153
Deliklibent	2.458	-6.628
Gökçeören	1.868	-3.435

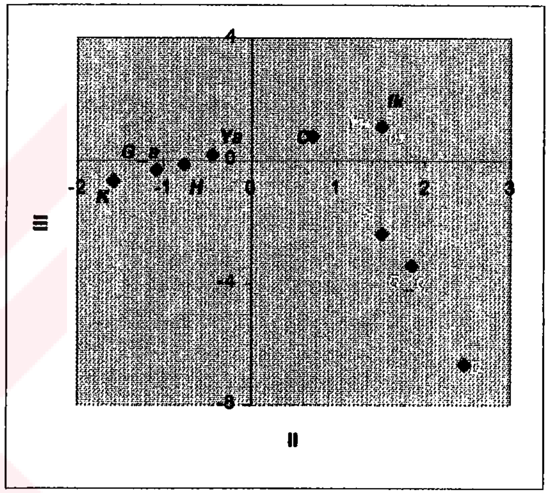


Figure 3.8. COA Components II and III (Caves)

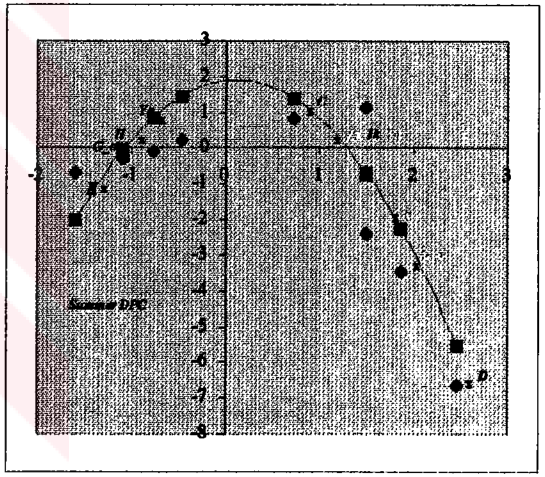


Figure 3.9. DPC Components II and III (Caves)

Table 3.6. DPC Values for Projection onto R^1 (Caves)

	Distance	Standardized
Kocakuyu	0	0.0
Gökçeali	3	6.3
Horataşı	5	10.4
Yaylacık	7.5	15.6
Çilingoz	21	43.8
İkigoz	24.5	51.0
İnkese	24.5	51.0
Yukarıkışla	24.5	51.0
Sofular	32.5	67.7
Gökceören	37	77.1
Deliklibent	48	100.0

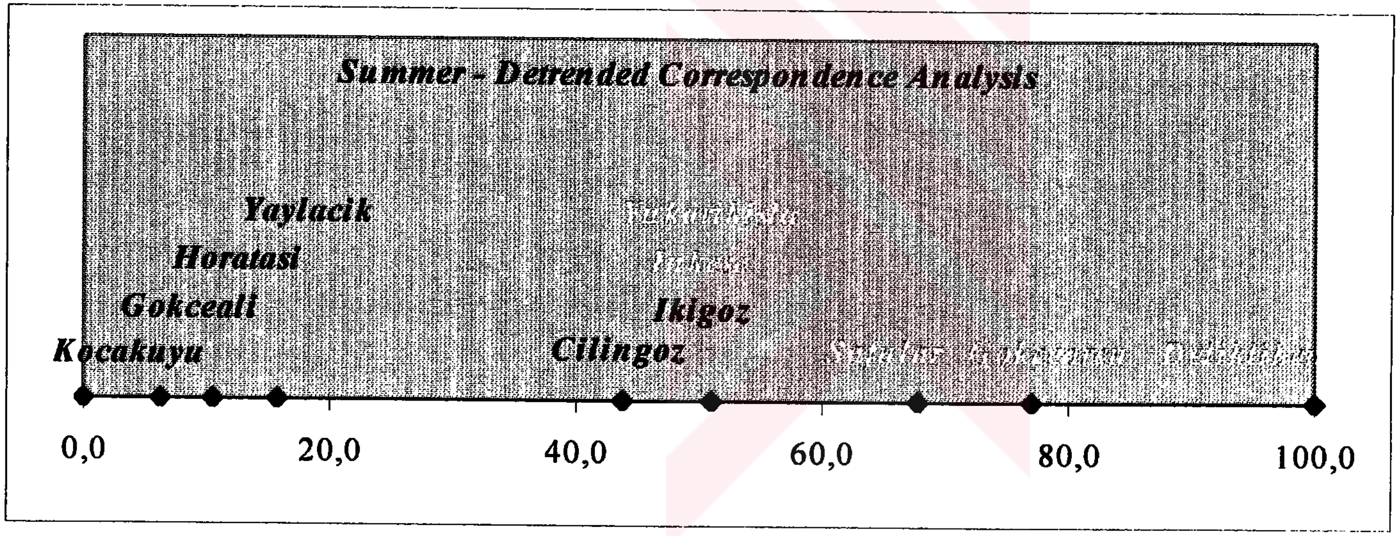


Figure 3.10. DPC Projection onto R^1 (Caves)

Table 3.7. NMDS Results for Components I and II (Caves)

	I	II
Kocakuyu	-0.3725	-0.1551
Gokceali	-0.3384	-0.0414
Horatasi	-0.2819	0.0612
Yaylacik	-0.3031	0.1596
Cilingoz	0.0272	0.1742
Ikigoz	0.262	0.1298
Inkese	0.262	0.1298
Yukarikisla	0.262	0.1298
Sofular	0.1068	-0.05
Gokceoren	0.1686	-0.2302
Deliklibent	0.2071	-0.3077

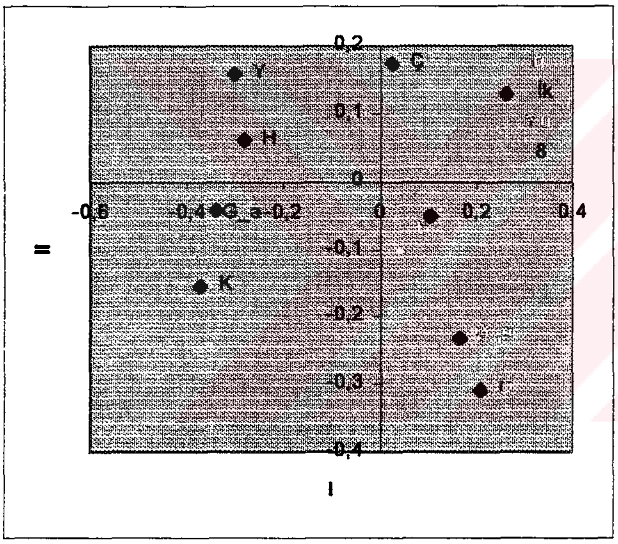


Figure 3.11 NMDS Diagram for Components I and II (Caves)

3.3.2. Species Ordination

The PCA analysis of species ordination did not show a linear relationship. Factors did not group any species together consistently for the different components (Figures 3.12, 3.13, and 3.14). COA was applied and detrending was done as the arching was seen (Figure 3.15). Figure 3.17 shows the projection of the detrended curve (Figure 3.16) onto one dimension. In terms of the separation of species based on the underlying environmental factor, Large Myotis and *R. ferrumequinum* were at the two ends and Small Myotis and *R. euryale* were in between, with *R. euryale* being the nearest species to *R. ferrumequinum*. *M. schreibersii* was nearest to Large Myotis,.

Table 3.8. PCA Results for Components I, II and III (Species)

	I	II	III
Accumulated Trace Percentages	50.6	77.9	95.9
Rhieu	0.9	-0.403	-0.033
Rhife	-0.143	-0.539	0.83
Minsc	0.857	0.342	0.208
Myola	0.157	0.88	0.396
Myosm	0.97	-0.15	-0.094

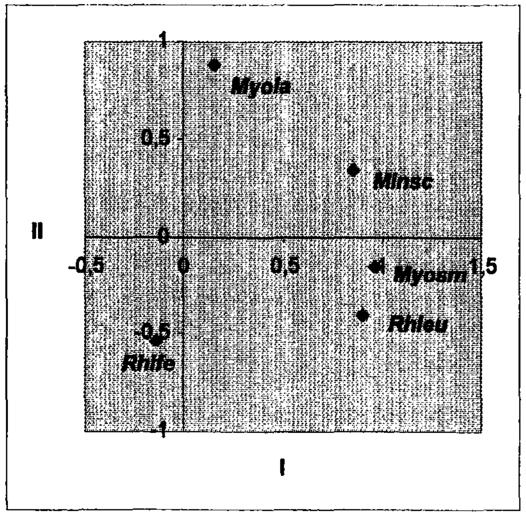


Figure 3.12. PCA Components I and II

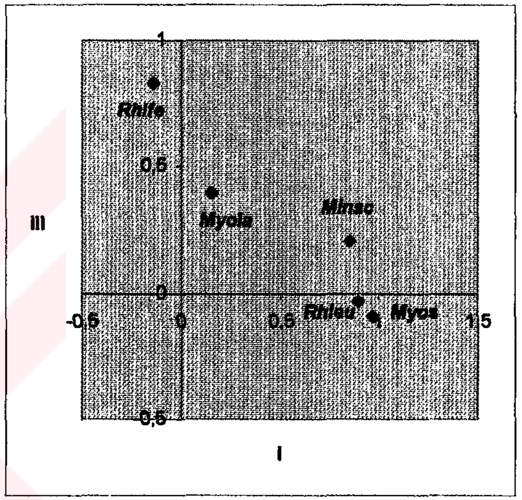


Figure 3.13. PCA Components I and III

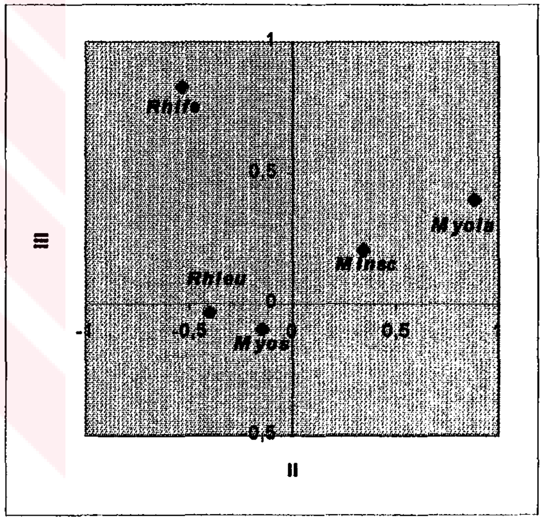


Figure 3.14. PCA Components II and III

Table 3.9. COA Results for Components II and III (Species)

	II	III
Rhieu	1.173	-0.678
Rhife	1.986	4.314
Minsc	-0.214	-0.205
Myola	-1.369	0.477
Myos	0.65	-0.872

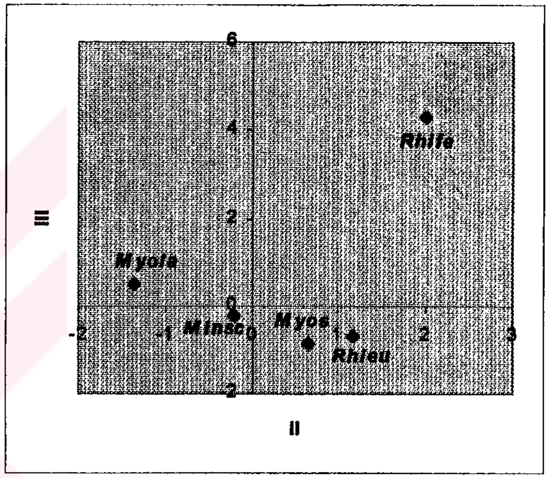


Figure 3.15. COA Components II and III (Species)

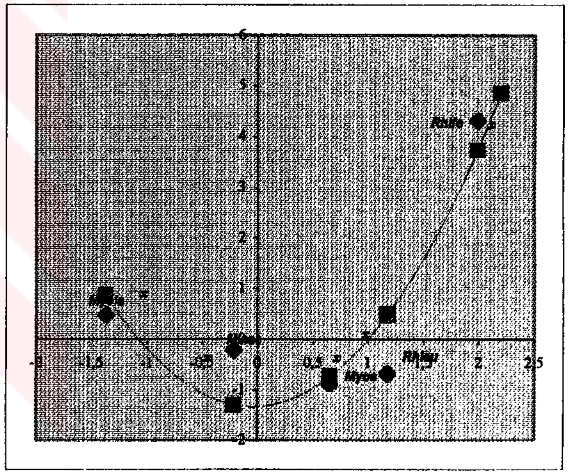


Figure 3.16. DPC Components II and III (Species)

Table 3.10. Values for Projection onto R^1 (Species)

	Distance	Standardized
Myola	0	0.0
Minsc	5.5	17.2
Myos	13.5	42.2
Rhieu	16	50.0
Rhife	32	100.0

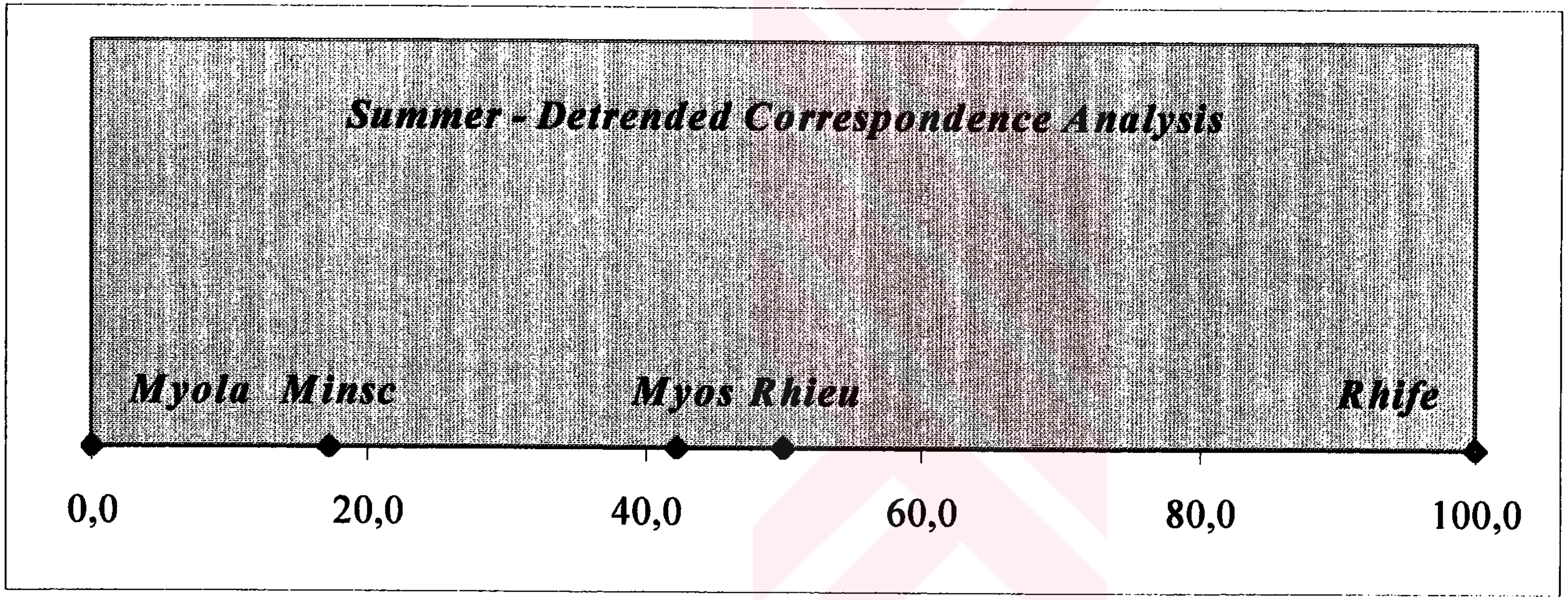


Figure 3.17. DPC Projection onto R^1 (Species)

3.3.3. Habitat Analysis

The relative coverage of habitat types that bat species can forage upon are given in Table 3.11. The standardized data are given in table 3.12. This data was used for cluster analysis in order to see if any difference existed in terms of the habitat types between the two sides of Bosphorus. There was not distinction in the habitat coverage between Çatalca and Kocaeli regions separately (Figure 3.18). COA was applied to check for interpretable patterns, but none was observed (Figure 3.19). NMDS did not yield any clear patterns either (Figure 3.20). The only prominent associations were Çilingoz-Sofular and Deliklibent-Gökçeören.

The habitat data in binary form (Table 3.15) that indicated the presence/absence of habitat types was used to infer the habitat types that bat species were ever found in, and always found in (Table 3.16). *R. euryale* and *M. schreibersii* were present in all the habitat types, and Large Myotis species were found in the least number of habitat types. The number of habitat types always found around caves that a particular species was recorded in was biggest for Large Myotis (7 types) and least for *M. schreibersii* (4 types). Woodland-scrub/pasture edge, river, pasture, broadleaved ecidous woodland (tall scrub and deciduous woodland) and riparian treeline were the habitat types always present for all the species.

Table 3.11 Two Dimensional Habitat Coverage Values based on DAFOR Scale

	Gökçeali	Cilingoz	Gökçeören	Horataşı	Kocakuyu+İkigöz	Deliklibent	Sofular	Inkese+Yukarıkışla	Yaylacık
Woodland (Coniferous)	2	3	0	0	0	0	4	0	0
Woodland (Deciduous)	3	4	0	4	3	0	4	2	0
Woodland(Mixed)	0	3	0	0	0	0	0	0	0
Lake and Reservoir	0	0	3	0	0	0	0	0	0
Bog	0	0	0	1	0	0	0	0	0
Pond	1	1	0	1	0	0	0	0	0
Heathland	0	0	0	0	0	0	1	3	0
Pasture	2	1	3	3	3	3	2	3	3
Arable Land (Trad)	2	1	1	2	2	0	0	0	2
Arable Land (Intensive)	3	0	2	0	3	4	0	0	2
Tall scrub	2	1	4	4	5	4	0	5	4
Maquis	2	3	3	0	0	3	4	0	0

Table 3.12. Column Standardized Habitat Data

	Gökçeali	Cilingoz	Gökçeören	Horataşı	Kocakuyu+İkigöz	Deliklibent	Sofular	Inkese+Yukarıkışla	Yaylacık
Woodland (Coniferous)	12	18	0	0	0	0	27	0	0
Woodland (Deciduous)	18	24	0	27	19	0	27	15	0
Woodland(Mixed)	0	18	0	0	0	0	0	0	0
Lake and Reservoir	0	0	19	0	0	0	0	0	0
Bog	0	0	0	7	0	0	0	0	0
Pond	6	6	0	7	0	0	0	0	0
Heathland	0	0	0	0	0	0	7	23	0
Pasture	12	6	19	20	19	21	13	23	27
Arable Land (Trad)	12	6	6	13	13	0	0	0	18
Arable Land (Intensive)	18	0	13	0	19	29	0	0	18
Tall scrub	12	6	25	27	31	29	0	38	36
Maquis	12	18	19	0	0	21	27	0	0

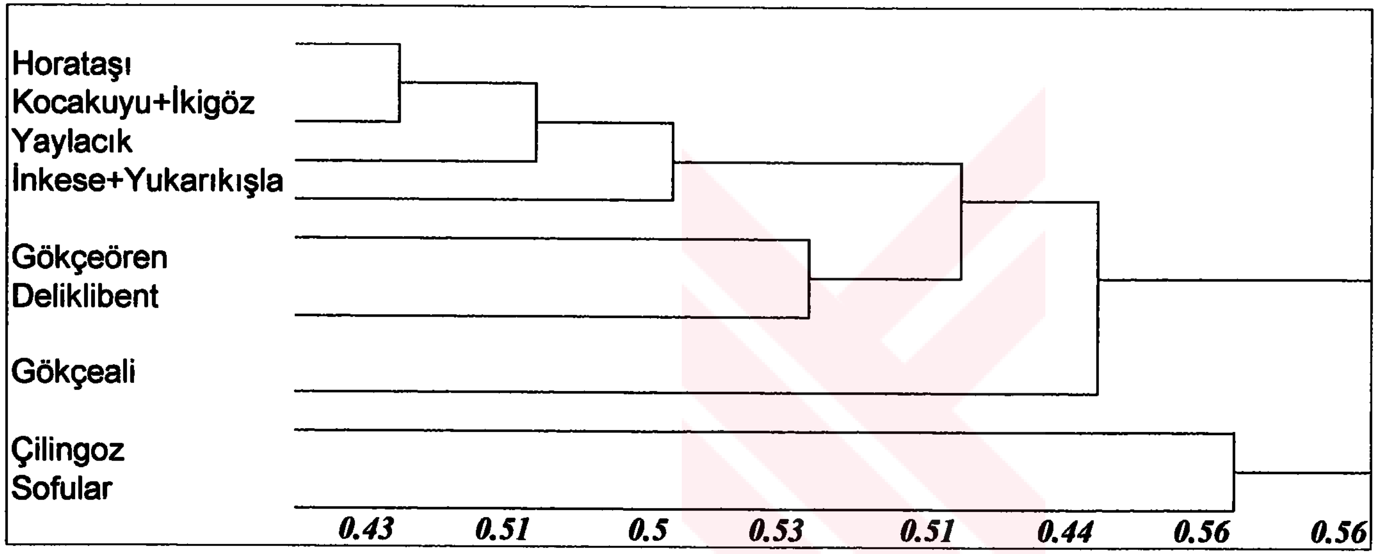


Figure 3.18. Cluster Analysis for Standardized Habitat Data

Table 3.13. COA for Standardized Habitat Data

	II	III
Cilingoz	-1.916	0.408
Horataşı	0.14	-0.979
Kocakuyu+İkigöz	0.647	-0.23
Yaylacık	1.067	-0.052
Gökçeali	-0.274	0.234
Gökçeören	0.834	1.802
Deliklibent	0.668	0.77
Sofular	-1.525	0.003
Inkese+Yukarıkışla	0.416	-1.994

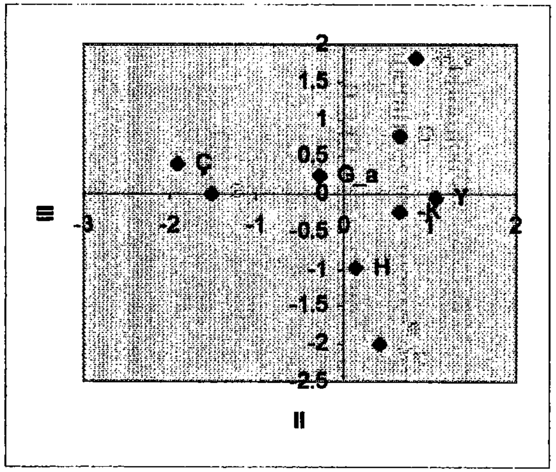


Figure 3.19. COA diagram for Standardized Habitat Data

Table 3.14. NMDS for Standardized Habitat Data

	II	III
Cilingoz	-0.4421	0.1245
Horataşı	-0.0251	-0.2137
Kocakuyu+İkigöz	0.1508	-0.0715
Yaylacık	0.2883	0.0014
Gökçeali	-0.0581	0.0553
Gökçeören	0.1659	0.2762
Deliklibent	0.2558	0.1889
Sofular	-0.5257	-0.0363
Inkese+Yukarıkışla	0.1902	-0.3257

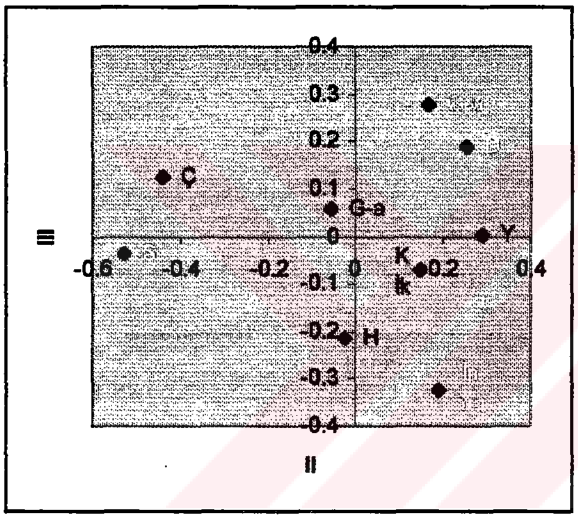


Figure 3.20. NMDS Diagram for Standardized Habitat Data

Table 3.15. Binary Habitat Data

	Cilingoz	Gökçeören	Horataşı	Kocakuyu+İki	Sofular	Yaylacık	Deliklibent	Inkese+Yuk	Gökçeali
Edge	1	1	1	1	1	1	1	1	1
River	1	1	1	1	1	1	1	1	1
Pasture	1	1	1	1	1	1	1	1	1
Riparian Treeline	1	1	1	1	1	1	1	1	1
Tall scrub	1	1	1	1	0	1	1	1	1
Riparian Hedgerow	1	1	1	1	1	0	1	1	1
Woodland (Deciduous)	1	0	1	1	1	0	0	1	0
Arable Land (Trad)	1	1	1	1	0	1	0	0	1
Single Trees	0	1	1	1	0	1	0	1	1
Urban	1	1	0	0	0	1	1	0	1
Treeline	0	1	1	0	0	1	1	0	1
Arable Land (Intensive)	0	1	0	1	0	1	1	0	1
Maquis	1	1	0	0	1	0	1	0	1
Woodland Clearing	1	0	1	1	1	0	0	0	0
Woodland (Coniferous)	1	0	0	0	1	0	0	0	1
Coastal zone	1	0	0	0	1	0	0	0	0
Heathland	0	0	0	0	1	0	0	1	0
Street Lamp	0	0	0	1	0	1	0	0	1
Pond	1	0	1	0	0	0	0	0	1
Woodland(Mixed)	1	0	0	0	0	0	0	0	0
Lake and Reservoir	0	1	0	0	0	0	0	0	0
Bog	0	0	1	0	0	0	0	0	0
Hedgerow	0	0	0	0	0	0	0	0	1

Table 3.16. Union (Gray) and Intersection (Blue) of Habitat Types for Species

	Minsc	Rhieu	Myosm	Rhife	Myola
Edge	1	1	1	1	1
River	1	1	1	1	1
Pasture	1	1	1	1	1
Riparian Treeline	1	1	1	1	1
Tall scrub	1	1	1	1	1
Riparian Hedgerow	1	1	1	1	1
Arable Land (Trad)	1	1	1	1	1
Single Trees	1	1	1	1	1
Woodland (Deciduous)	1	1	1	1	1
Urban	1	1	1	1	1
Treeline	1	1	1	1	1
Arable Land (Intensive)	1	1	1	1	1
Maquis	1	1	1	1	1
Woodland Clearing	1	1	1	1	1
Woodland (Coniferous)	1	1	1	1	1
Pond	1	1	1	1	1
Bog	1	1	1	1	1
Coastal zone	1	1	1	1	0
Hedgerow	1	1	1	0	1
(Street Lamp)	1	1	1	0	1
Heathland	1	1	0	1	0
Lake and Reservoir	1	1	0	1	0
Woodland(Mixed)	1	1	1	0	0

3.3.4. Multilinear Regression

The component values that were obtained from DPC of caves based on species distribution were used for regression analysis with geographical location of caves (Table 3.17), habitat around caves (Table 3.12), and average temperature within caves (Table 3.18). DPC values were used as they gave the most distinct grouping of caves based on species.

Table 3.17. GPS Coordinates of Caves (UTM)

	X	Y
Çilingoz	601922	4597626
Deliklibend	734768	4537584
Gökçeali	621552	4564047
Gökçeören	752515	4526380
Horataşı	576626	4594573
İkigöz	610606	4569865
İnkese	730637	4548646
Kocakuyu	610359	4571618
Sofular	710664	4562395
Yaylacık	601792	4579252
Yukarıkışla	730508	4548563

Table 3.18. Average Temperature in Caves

	T(°C)
Çilingoz	16.4
Horataşı	14.2
Kocakuyu	9.8
İkigöz	15.1
Yaylacık	13.7
Gökçeali	16.2
Gökçeören	16.1
Deliklibent	18.1
Sofular	18.5
İnkese	13.8

The regression of geographical location and DPC components yielded a coefficient of determination (R^2) value of 0.631. (F (2,8) = 6.855, $p<0.05$). The longitude accounted for 82.8 percent of the explanation of geographical coordinates on the distribution of the species (Table 3.19).

Table 3.19. Percentage Contribution of Latitude and Longitude on Distribution of Species

	%
Longitude	82.8
Latitude	17.2
R^2	0.631
F-Ratio	6.855
Degrees of Freedom	(2,8)
Standard Error	0.000

The regression of habitat types was done using component values of different ordination methods (PCA, COA, DPC, NMDS) with untransformed and transformed species count data. The habitat types that comprised less than five percent of the explanation of the environmental factor examined (habitat) were eliminated. The habitat types that were not eliminated as a result of this analysis, affecting the distribution of species were pond, heathland, traditional arable land and maquis, $R^2 = 0.821$, $F\,(4,6) = 6.878$, $p < 0.05$ (Table 3.20).

Table 3.20. Percentage Contribution of Habitat Types to Distribution of Species

	%	Standard Error
Pond	13.5	3.170
Heathland	10.3	1.136
Arable Land (Trad)	69.7	1.050
Maquis	6.5	0.792
R^2	0.821	
F-Ratio	6.878	
Degrees of Freedom	(4,6)	

Regression value for average cave temperature and distribution of species was found as $R^2 = 0.496$, $t\,(8) = 2.807$, $p < 0.05$, S.E. =.3.352.

COA values obtained by the ordination of habitat types and caves were used for regression analysis of habitats on geographic location. The relationship between habitats and geographical coordinates of caves was not significant ($R^2 = 0.549$, F (2,8) = 4.873, S.E. = 0.000) (Table 3.21).

Table 3.21. Percentage Contribution of Latitude and Longitude on Habitat Distribution

	%
Longitude	20.5
Latitude	79.5
R^2	0.549
F-Ratio	4.873
Degrees of Freedom	(2,8)
Standard Error	0.000

The nestedness temperatures for the two sides of Bosphorus and the entire Çatalca-Kocaeli Region in terms of bat species distribution are given in Table 3.22. Çatalca and Kocaeli regions gave lower temperatures by themselves than both sides taken together, showing that the two regions have different levels of randomness than the regions taken as a whole.

Table 3.22. Nestedness Temperatures

	T(°)
Both Sides	27.87
Çatalca	12.84
Kocaeli	0.3

Species ordination values that were obtained by DPC (Table 3.10) were used for regression analysis with weighted average temperatures that species were found in (Table 3.23). The relationship was not significant ($R^2 = 0.243$, t (3) = 2.807, S.E. =.3.352).

.

Table 3.23. Weighted Average Temperatures for Species

	T(°C)
Minsc	15.0
Myosm	15.0
Myola	14.9
Rhieu	17.7
Rhife	17.6

4. DISCUSSION

The data interpretation was made both using the descriptive data, and the results of statistical analysis. Hence, the conclusions drawn are both descriptive, as well as explaining patterns of distribution of species in relation to geographical location of caves, effects of habitat, and temperature. The relevant conservation measures that can be taken in these perspectives are also stressed.

Out of the 11 caves studied, 9 have provided the first known descriptions of bat communities in them, thus adding to the bat fauna record of North-western Turkey. Only Sofular and Gökçeali have been previously studied with regard to the presence of bats (Benda and Horacek 1999).

The most important conservation implication of bat species count data concerns the roosts where maternity colonies are present. Sofular, Yaylacık and Çilingoz caves that have maternity colonies of *R. ferrumequinum*, *M. schreibersii*, and *R. euryale* respectively are crucial caves for these species. Especially the high value of Green's index indicates that Sofular cave is a critical cave for *R. ferrumequinum* as it shows a high degree of clumping in this cave. In Great Britain, all the maternity roosts of *R. ferrumequinum* are under protection. Sofular cave and Çilingoz cave are being used as recreational sites in summer, and therefore maternity colonies in these caves are prone to human disturbance. As a measure of decreasing human disturbance, fencing of the entrance of these roosts is recommended.

The distribution model curve indicates that the species show broken-stick distribution (Ludwig and Reynolds 1988), implying that no niche overlap exists between species. Hence they utilize the resources independent of each other, and species associations are caused by external environmental factors, but not by the species themselves.

The cluster analysis showed grouping of Çatalca and Kocaeli caves separately, after cutting the dendrogram at a cumulative distance of 0.67 (Figure 3.4). İkigöz, Yukarıkışla and İnkese caves grouped separately as only one species, *R. euryale,* was present in them. Çilingoz stayed aside from these groupings.

PCA showed that the relationships between sampling units in terms of species did not show a linear pattern. The plotting of the three components taken two at a time (Figure 3.5, 3.6, 3.7) did not show any interpretable patterns, with detached positions of Çilingoz, Gökçeali, and Sofular caves for different graphs.

Due to the observed nonlinearities, and detached positions of the caves, COA was made (Figure3.8). COA showed arching, and DPC was applied to remove it (Figure 3.9). Projecting of the detrended curve onto one dimension gave a similar grouping to cluster analysis; the caves on the Çatalca Peninsula grouped together on the left part of the graph, and the caves in Kocaeli Peninsula on the right (Figure 3.10). NMDS gave very similar results to DPC over two axis, the caves of Çatalca peninsula being on the left of the axis for component 1, and Kocaeli caves being on the right of the axis. This distinction of the two peninsulas from the species point of view will be more pronounced if İkigöz and Kocakuyu caves which are a part of a bigger cave formation (Erdem and Akbükrek 1994) are treated as a single cave. The detached position of Çilingoz cave after NMDS was similar to that of cluster analysis.

Cluster analysis and various ordination analysis made consistently show a grouping of Çatalca and Kocaeli caves separately. This distinct grouping of Çatalca and Kocaeli regions suggests that Bosphorus might be acting as a natural barrier limiting species migration and gene flow between the two sides. This idea is also supported by nestedness analysis that gives lower temperatures for the order of species by regions separately than together; indicating that the two regions show different levels of randomness. Hence it might be more correct to treat Çatalca and Kocaeli regions as two different regions than treating them as Çatalca-Kocaeli Region in terms of species occupancy. The longitude component being dominant (82.8%), $R^2 = 0.631$, (F (2,8) = 6.855, $p<0.05$), in the regression of the distribution of species and geographical location of caves is another support for this view.

The regression analysis made on standardized habitat data and geographical locations of the caves was not significant. Using various ordination methods and transformations, and eliminating the habitat types with relatively low contributions, the obtained R^2 value of 0.821, F (4,6) = 6.878, $p < 0.05$, from DPC regression strongly suggests that certain habitat types can be important limiting factors for the distribution of the species. The outstanding habitat types that were significant for the distribution were traditional arable land, pond, heathland and maquis, from the greatest to the least. Traditional arable land is seen around all of the caves in Çatalca Region, whereas it is seen only around one cave (Gökçeören) in Kocaeli region; suggesting that the presence of traditional arable land might be an important reason for the dichotomy of Çatalca and Kocaeli regions in terms of distribution of bat species. The importance of traditional arable land contradicts Carmel and Safriel (1998), and Walsh et al.(1995), who suggested that arable lands were actually avoided by the bats. Ponds were found near all the caves that small myotis were found in, which are mainly in the European side except one (Horataşı, Gökçeali, Çilingoz (Çatalca) and Gökçeören (Kocaeli)). The reservoir near the Gökçeören cave is a stationary, pond-like water source. Mcdonald (1993) mentions the association of small myotis species with water bodies which was also the case for the small myotis species in this study. Although weaker, heathland and maquis elements also show a significant contribution for the distribution of the species.

The habitat types found around all caves any species was ever found in were river, pasture, riparian treeline, broadleaved woodland (union of deciduous woodland and tall scrub) and edge (broadleaved woodland/pasture interface) (Table 3.16). This might indirectly suggest that these habitat types are critical for all the species.

The importance of river and riparian vegetation for bats have been mentioned by various authors, and the consensus over their utilization is reflected also by this study (Carmel and Safriel 1998, Walsh et al. 1995, Racey 1998). The importance of treelines as linear landscape elements providing connectivity between different habitat types has been mentioned by Ekman and De Jong (1996), and Beier and Noss (1998). Pasture is generally avoided by *Myotis spp.* according to Walsh et al. (1995), and actively selected by large myotis and *R. ferrumequinum* according to Arlettaz (1999) and Racey (1998). An important notion regarding pasture is that it creates the important ecotone of edge (Rachwald 1992) that was also found to be associated with all of the species in this study. The other element of the edge, broadleaved decidous woodland is generally another point of agreement between different researchers for habitat preferences of bats (Walsh and

Harris 1995, Racey 1998, Carmel and Safriel 1998), although some authors (Rachwald 1992) noted negligible activity within the deciduous forests.

In this context, it is important to note that near Sofular cave, coniferous trees are planted. Considering the existence of a large maternity colony of *R. ferrumequinum* being present in this cave, and the preference of pasture of this species, it is important to preserve areas of pasture while tree plantations are being done.

The total number of habitat types associated with all of the caves that a species is recorded in differed for different species. This number was greatest for *R. ferrumequinum*, and *M. schreibersii* (all of the 23 habitat types), and lowest for Large Myotis (19 habitat types) (Table 3.16). The number of habitat types associated with caves that a species is ever found is was greatest for Large Myotis (7 habitat types) and smallest for *M. schreibersii* (4 habitat types). This might imply that *M. schreibersii* might be able to utilize a greater variety of habitat types, and Large Myotis a lesser variety of habitat types compared to the other species studied.

Average temperature within the caves for summer was the weakest contributor to the explanation of the distribution of the species among the factors that were studied ($R^2 = 0.496$, $t(8) = 2.807$, $p < 0.05$). The temperature is expected as to be a dominant factor for explaining the distribution of species in winter.

Field studies using bat detectors in traditional arable lands and pasture near the caves to see their actual usage of these two habitat types would help in clearing of the controversies in the usage of these habitat types by the species studied. Genetic analysis comparing the populations on the two sides of Bosphorus, in a similar manner to Burland et al.'s (1999) who compared populations of *Plecotus auritus* in different caves genetically, will be very useful for understanding if Bosphorus is actually a barrier limiting the migration of the species.

5. CITED REFERENCES

Albayrak, I., "The presence of *Myotis daubentoni* (Kuhl, 1819) in Turkey", *Mammalia*, Vol. 52, No. 3, pp 415-418, 1988.

Albayrak, İ., "The Long-fingered Bat (*Myotis capaccinii)* from Turkey", *Doğa – Tr. J. of Zoology*, No. 14, pp 150-155, 1990a.

Albayrak, İ, "Doğu Anadolu Yarasaları ve Yayılışları (Mammalia: Chiroptera)", *Doğa – Tr. J. of Zoology*, No. 14, pp 214-228, 1990b.

Albayrak, İ, "Batı Anadolu Yarasaları ve Yayılışları (Mammalia: Chiroptera)", *Doğa – Tr. J. of Zoology*, No. 17, pp 237-257, 1993.

Altringham, J.D., Bats Biology and Behaviour, Oxford University Press Inc., New York, 1998.

Arita, H.T., and Ortega, J., "The Middle American Bat Fauna: Conservation in the Neotropical-Nearctic Border", in Thomas H. Kunz and Paul A. Racey (eds), *Bat Biology and Conservation*, pp 295-308, United States of America, Smithsonian Institution Press, 1998.

Arlettaz, A., "Habitat Selection as a Major Resource Partitioning Mechanism Between Two Sympatric Sibling Bat Species *Myotis myotis* and *Myotis blythii*", Journal of Animal Ecology, No. 68, pp. 460-471, 1999.

Atmar, W., and Patterson, B.D., "The Measure of Order and Disorder in The Distribution of Species in Fragmened Habitat", *Oecologica*, No.96, pp. 373-382, 1993.

Baudinett, R.V., Wells, R.T., Sanderson, K.J., Clark, B.,, "Micro-climatic Conditions in Maternity Caves of the Bent-wing Bat, *Miniopterus Schreibersii*: an Attempted restoration of a Former Maternity Site", *Wildl. Res*, No. 21, pp. 607-619, 1994.

Begon, M., Harper, J.L., Townsend, C.R., *Ecology Individuals, Populations and Communuties*, Great Britain, Blackwell Science Ltd., 1999.

Beier P., and Noss, R.F., "Do Habitat Corridors Provide Connectivity?", *Conservation Biology*, Vol. 12, No.12, pp. 1241-1252, December 1998.

Benda, P., and Horacek, I., "Bats (Mammalia: Chiroptera) of the Eastern Mediterranean. Part 1. Review and Taxonomy of Bats in Turkey", *Acta Soc. Zool. Bohem.*, No. 62, pp. 255-313, 1998.

Burland, T.M., Barratt, E.M., Beaumont, M.A., Racey, P.A:, "Population Genetic Structure and Gene Flow in a Gleaning Bat, *Plecotus auritus*", *Proc. R. Soc. Lond. B*, No.266, pp. 975-980, January 1999.

Carmel, Y, and Safriel U., "Habitat Use by Bats in a Mediterranean Ecosystem in Israel-Conservation Implications", *Biological Conservation,* Vol. 84, No.3, pp. 245-250, 1998.

Catto, C.M.C., A. M. Hutson, P.A. Racey and Stephenson P.J., "Foraging behaviour and habitat use of the serotine bat (*Eptesicus serotinus*) in Southern England", *J. Zool., London* Vol. 238, pp 623-633, 1996.

Chesser, R.K., "Gene Diversity and Female Philopatry", *Genetics,* No. 127, pp. 437-447, 1991.

Dönmez,Y., *Kocaeli Yarımadasının Bitki Coğrafyası,* İstanbul, Edebiyat Fakültesi Matbaası, 1979.

Dönmez, Y., *Traya'nın Bitki Coğrafyası,* İstanbul, Edebiyat Fakültesi Basımevi, 1990.

Ekman, M., and De Jong J., "Local Patterns of Distrubution and resource utilisation of four bat species (*Myotis brandti, Eptesicus nilssoni, Plecotus auritus and Pipistirellus pipistirellus*)", *J. Zool., London* Vol. 238, pp 771-580, 1996.

Entwistle, A., Gibson, S., Harris, S., Hutson, T., Racey, P., Walsh, A., *Habitat Management for Bats*, Great Britain, 1997.

Erdem, B. and Akbükrek, M., İhsaniye ve Gümüşpınar Köyü Mağaraları, İstanbul, 1994.

Fenton, M.B., and Bell G.P., "Echolocation andfeeding behaviour in four species of *Myotis* (Chiroptera)", *Canadian Journal of Zoology,* Vol. 57, pp 1271-1277, 1979.

Fenton, M.B., and Rautenbach, I.L., "Impacts of Ignorance and Human and Elephant Populations on the Conservation of Bats in African Woodlands", in Thomas H. Kunz and Paul A. Racey (eds), *Bat Biology and Conservation*, pp 261-270, United States of America, Smithsonian Institution Press, 1998.

Findley, J.S., *Bats A Community Perspective,* Great Britain, Cambridge University Press, 1995.

Fowler and Cohen, *Practical Statistics for Field Biology,* Great Britain, Redwood Books, 1996.

Gaisler, J., and Kolibac, J., "Summer Occurrence of Bats in Agrocoenoses", *Folia Zool. BRNO,* Vol. 41, No.1, pp 19-27, 1992.

Gaisler, J., "The r-K selection Model and Life-History Strategies in Bats", in Hannak V., Horacek I., Gaisler J.(Eds), pp. 117-124, Praha, Charles University Press, 1989.

Hutcheon, J.M., Kirsch, J.A., Pettigrew, J.D., "Base-compositional biases and the bat problem. The questions of microchiropteran monophyly", *Philos Trans R Soc. Lond. B. Biol Sci,* Vol. 29, No. 353, pp. 607-617, 1998

Kunz, T.H., and Racey, P.A., *Bat Biology and Conservation,* United States of America, Smithsonian Institute Press, 1998.

Ludwig, J.A., Reynolds, J.F., *Statistical Ecology,* United States of America, John Wiley&Sons, Inc., 1988.

Macdonald, D., and Barrett, P., *Mammals of Britain and Europe,* Great Britain, Butler&Tanner, Frome, Somerset, 1995.

Marinho-Filho, J., and Sazima, I., "Brazilian Bats and Conservation Biology: A First Survey", in Thomas H. Kunz and Paul A. Racey (eds), *Bat Biology and Conservation*, pp 282-294, United States of America, Smithsonian Institution Press, 1998.

Nowak, R.M., *Walker's Bats of the World*, London, The Johns Hopkins Press Ltd., 1994.

O'Donnell, C.F.J., and Sedgeley, J.A., "Use of Roosts by the Long-Tailed Bat, *Chalinolobus tuberculatus*, in Temperate Rainforest in New Zealand", *Journal of Mammalogy*, Vol. 80, No. 3, pp. 913-923, 1999.

Özkan, M., Erman, O., "Türkiye'den Yeni bir *RHINOPHORACARUS* (ACARI, HYDRACHNELLAE, ARRENURIDAE) Türü", *Doğa – Tr. J. of Zoology,* No. 14, pp 229-236, 1990.

Pierson, E.D., "Tall Trees, Deep Holes, and Scarred Landscapes: Conservation Biology of North American Bats", in Thomaş H. Kunz and Paul A. Racey (eds), *Bat Biology and Conservation*, pp 309-325, United States of America, Smithsonian Institution Press, 1998.

Racey, P.A., "Ecology of European Bats in Relationship to Their Conservation", in Thomas H. Kunz and Paul A. Racey (eds), *Bat Biology and Conservation*, pp 249-260, United States of America, Smithsonian Institution Press, 1998.

Rachwald, A., "Habitat Preference and activity of the noctule bat Nyctalus Noctula in the Bialowieza Primeval Forest", *Acta Theriol,* Vol. 37, pp 413-422, 1992.

Richards, G.C., and Hall, L.S., "Conservation Biology of Australian Bats: Are Recent Advances Solving Our Problems?", in Thomas H. Kunz and Paul A. Racey (eds), *Bat Biology and Conservation*, pp 271-281, United States of America, Smithsonian Institution Press, 1998.

Schnitzler, H.U., and Kalko, E.K.V., "How Echolocating Bats Search and Find Food", in Thomas H. Kunz and Paul A. Racey (eds), *Bat Biology and Conservation*, pp 183-196, United States of America, Smithsonian Institution Press, 1998.

Schober, W., and Grimmberger, E., *The Bats of Europe and North America,* United States of America, T.F.H. Publications, Inc., 1997.

Schutt, W.A:Jr., "Chiropteran Hindlimb Morphology and the Origin of Blood Feeding in Bats", in Thomas H. Kunz and Paul A. Racey (eds), *Bat Biology and Conservation*, pp 157-168, United States of America, Smithsonian Institution Press, 1998.

Sedgeley, J.A., and O'Donnell, C.F.J., "Roost Selection by the long-tailed bat, *Chalinolobus tuberculatus,* in Temperate New Zealand Rainforest and its Implications for the Conservation of Bats in Managed Forests", *Biological Conservation,* No. 88, pp. 261-276, 1999.

Simmons, N.B., "A Reappraisal of Interfamilial Relationships of Bats", in Thomas H. Kunz and Paul A. Racey (eds), *Bat Biology and Conservation*, pp 3-26, United States of America, Smithsonian Institution Press, 1998.

Şadoğlu, P., "Meyva Yiyen Yarasaların Beslemesi", *Biologi*, Vol. 3, No.1, pp. 12-17, 1953.

Teeling, E.C., Scally, M., Kao, D.J., Romagnoli, M.L., Springer, M.S., Stanhope, M.J., "Molecular Evidence Regarding the Origin of Echolocation and Flight in Bats", *Nature,* Vol. 403, No. 6766, pp 188-192, 2000.

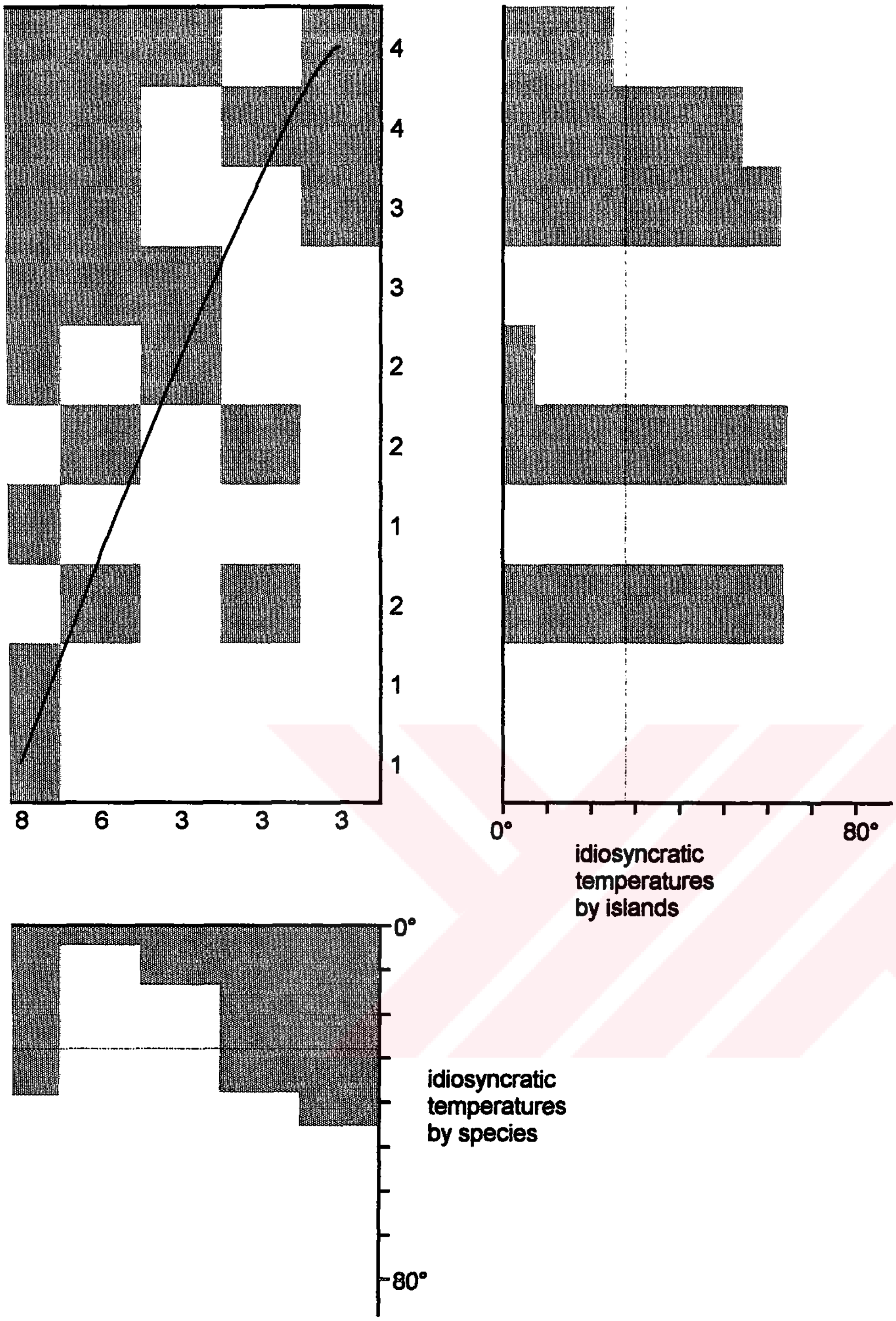
Walsh, A.L., Harris, S., Hutson, A.M., "Abundance and Habitat Selection of Foraging Vespertilinoid Bats in Britain: A Ladnscape-Scale Approach", *Symp. zool. Soc. Lond.,* No. 67, pp. 325-344, 1995.

APPENDIX

111
: 46%

NESTEDNESS ANALYSIS:
1. Çatalca-Kocaeli Region

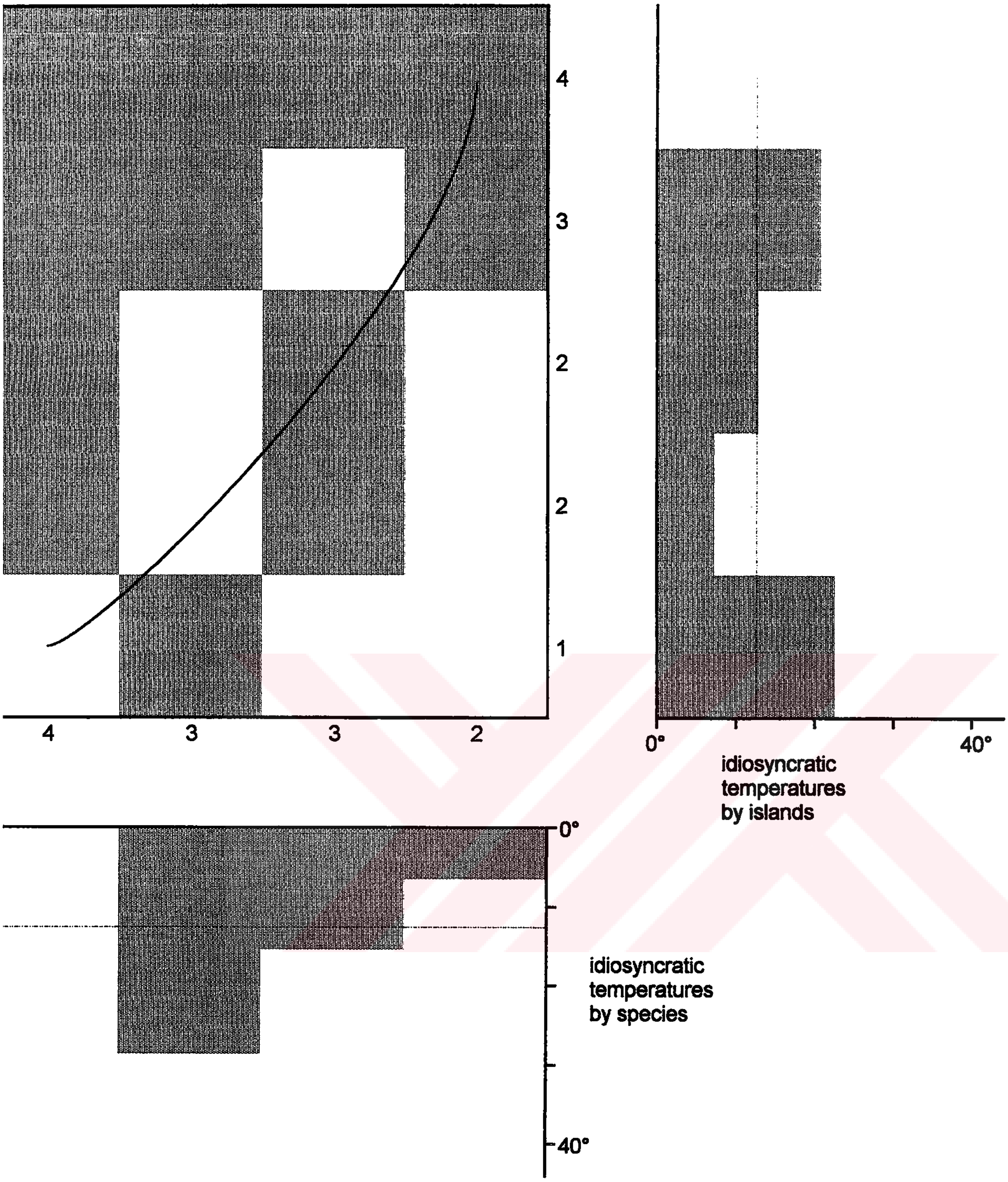
run: 01:35 PM, June 22, 2000
matrix temperature: 27.87°



111
60%

2. Çatalca Region

run: 01:36 PM, June 22, 2000
matrix temperature: 12.64°



2. Kocaeli Region

10
50%

run: 01:35 PM, June 22, 2000
matrix temperature: 0.3°