BREEDING ECOLOGY OF TWO TIT SPECIES (PARIDAE) AT METU CAMPUS

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ABSTRACT

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Use of nest boxes is a common method to perform ecological research on hole nesting species. The family Paridae is the subject of longest running studies in the field of avian ecology. Despite the usefulness of such an approach, only a handful studies utilizing next boxes have been completed in Turkey. The aim of this study is to investigate the breeding ecology of Paridae species at METU campus , Ankara, which offers marginal habitat for most tree-dependent species. A total of 50 nest boxes were attached to tree trunks in three forested patches of the campus in early 2013. Data on breeding parameters (laying date, clutch size, breeding success, body measurements, predation rate) were collected with weekly visits during late March until July in 2013-2015. Two species have used the nest boxes placed: Great Tit (*Parus major*) and Coal Tit (*Parus ater*).

In total, 40 nest boxes were occupied by either species during the study, and 26 of those were used to calculate breeding parameters. The proportion of occupied next boxes was found to significantly increase further away from buildings or asphalt roads. Both species started nesting in the first week of April. Mean egg laying dates were 21^{st} of April and 4^{th} of May, and average clutch size were 7.5 and 6.8 for Coal Tits and Great Tits, respectively. The fate of nesting attempts pooled over three years were as follows: 42.5% predated, 40.0% successful, 15.0% deserted or predated, and 2.5% unknown. The number of fledglings per nest was 4.0 and 1.4 for Coal Tits and

Great Tits, respectively. The main identified predator was magpie (*Pica pica*) while the other predators were Caspian snake (*Dolichophis caspius*), fox (*Vulpes vulpes*) and domestic cat (*Felis catus*).

Although the findings on laying date and clutch size are comparable to other study sites at similar latitudes, predation rates, and hence the overall rate of breeding failure, are among the highest recorded. Very high densities of magpies at METU campus could be the reason. Our study indicates that the introduction of nest boxes might have created an ecological trap, particularly for Great Tits, leading to a sink population that can only persist with immigration from neighboring habitats. However further research, including some on success rates at nests in natural cavities, should be conducted in order to assess the full impact of nest boxes on tit populations at METU campus.

Keywords: Great Tit, Coal Tit, Phenology, Predation

ÖZ

ODTU KAMPÜSÜNDEKİ İKİ BAŞTANKARA TÜRÜNÜN (PARIDAE) ÜREME EKOLOJİSİ

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Yuva kutularının kullanımı, deliklerde yuva yapan türler üzerine yapılan ekolojik araştırmalarında kullanılan çok yaygın bir yöntemdir. Paridae ailesi ekoloji alanında kuşlarla ilgili en uzun sureli araştırmalara konu olmuştur. Bu yaklaşımın kullanışlı olmasına rağmen Türkiye'de çok az sayıda çalışma yuva kutularından faydalanarak tamamlanmıştır. Bu çalışmanın amacı, ağaca bağımlı yaşayan bir çok türe marjinal habitat sunan ODTÜ'de baştankara türlerinin üreme ekolojilerini araştırmaktır. 2013 yılının başında toplam 50 adet yuva kutusu kampüsün üç ormanlık arazi parçasında bulunan ağaçlara yerleştirilmiştir. Üreme parametreleri (yumurta bırakma tarihi, yumurta küme büyüklüğü, üreme başarısı, morfolojik ölçümler ve predasyon oranları) 2013-2015 yılları arasında, Mart ayından Temmuz ayına kadar her bir yuva kutusuna haftada en az bir kez olmak üzere yapılan ziyaretlerle toplanmıştır. Yuva kutularını Büyük Baştankara (*Parus major*) ve Çam Baştankarası (*Parus ater*) türleri kullanmıştır.

Çalışma boyunca toplam 40 yuva kutusuna yerleşilmiş olup, bunların içinden 26 tanesi üreme parametrelerinin hesaplanmasında kullanılmıştır. Yerleşilmiş yuva kutularının oranı binalardan ve asfalt yollardan uzaklaştıkça anlamlı düzeyde artmıştır. İki tür de Nisan ayının ilk haftasında üremeye başlamış olup sırasıyla Çam Baştankarası ve Büyük Baştankara için ortalama ilk yumurta bırakma tarihleri 21 Nisan ve 4 Mayıs, ortalama yumurta küme büyüklükleri 7.5 ve 6.8'dir. Üç yılın verileri birleştirildiğinde, yuvaların %42.5'i predasyona uğramış, %40'i başarılı, %15'i terk edilmiş veya predasyona uğramış olup %2.5'unun akıbeti bilinmemektedir. Yuvadan uçan yavru sayısı Çam Baştankarası ve Büyük Baştankara için sırasıyla 4.0 ve 1.4 olarak hesaplanmıştır. Başlıca yırtıcı saksağan (*Pica pica*) olup diğerleri bozyürük (*Dolichophis caspius*), tilki (*Vulpes vulpes*) ve evcil kedi(*Felis catus*) olarak belirlenmiştir.

Yumurta bırakma tarihleri ve yumurta küme büyüklükleri aynı enlem kuşağı üzerindeki diğer çalışmalarla karşılaştırılabilir olsa da kaydedilen predasyon oranları ve bunun sonucu olarak üreme başarısızlığı bilinen en yüksek değerler arasındadır. ODTÜ'de çok yüksek yoğunlukta bulunan saksağanlar bunun nedeni olarak gözükmektedir. Çalışmamız yuva kutuları yerleştirilmesinin, özellikle Büyük Baştankaralar için ekolojik tuzak oluşturmuş olabileceğine ve ancak komşu habitatlardan gelen göçle varlığını sürdürebilen bir yutak populasyona yol açtığına işaret etmektedir. Öte yandan, yuva kutularının ODTÜ'deki baştankara populasyonlarına olan etkilerinin tam değerlendirilmesi için başta doğal deliklerdeki üreme başarı oranlarını içeren çalışmalara gerek vardır.

Anahtar Kelimeler: Büyük Baştankara, Çam Baştankarası, Fenoloji, Predasyon

To my beloved family

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INTRODUCTION

1.1 Use of Nestboxes in Avian Studies

Many birds use some form of cavity for nesting or roosting (Gill, 2007). Those that are able to excavate their own nest holes in trees (e.g. woodpeckers) are called primary hole-nesters, while those that cannot drill large holes in hard wood but require such nest sites are called obligate secondary hole-nesters. Birds in this latter group are dependent upon natural tree cavities or unoccupied holes excavated by primary hole- nesters (Martin & Eadie, 1999), although some species may modify or enlarge existing cavities in dead or decaying trees (Newton, 1994).

Many secondary hole-nesting species readily use man-made artificial cavities, including nestboxes (Newton, 1994; Lesiński, 2000). The use of nestboxes in ornithological research has considerably enhanced our understanding of breeding behaviour in cavity-nesting birds. Researchers can perform routine monitoring and experimental manipulation of eggs or nestlings in nestboxes, as well as repeatedly capture, identify and manipulate the parents or the offspring (Lambrecht et al., 2010).

Nestbox design, placement and researcher manipulation may have considerable impacts on the survival and reproductive success of the nesting species, primarily through modifying natural rates of occupancy and predation (Lambrecht et al., 2010; Zingg et al., 2010). Nevertheless, studies using nestboxes, particularly on members of Paridae, are among the longest running ornithological research in the world.

The first such study was by Gerrit Wolda who, more than 80 years ago, monitored caterpillar consumption of tits and the consequent increase in tree growth in Wageningen, the Netherlands (Birkhead et al., 2014). H.N. Kluijver, who was working in that project with Wolda, developed the study further and later published his classical monograph about Great Tit (*Parus major*) ecology (Kluijver, 1951). David Lack wrote about Kluijver's study in his review as "This is far most comprehensive study yet made of a bird population, and probably of any animal population in the wild" (Lack, 1952).

Lack himself started research on *Parus* in 1947 in Wytham woods, Oxford, England. John Gibb, a student of Lack, studied breeding biology, feeding ecology and behavior during years 1950, 1954 and 1960 (e.g. Gibb, 1950). Chris Perrins continued the study by raising the number of nestboxes; he studied timing of breeding and reproductive parameters, including clutch size and how it changes (Perrins, 1965; 1970; Perrins & McCleery, 1989). This research programme continues until today and involves studies about hole-nesting birds, including tits (Lambrechts et al., 2010; Møller et al., 2014).

Breeding biology of many *Parus* spp. was studied also in other countries such as Finland, Norway, Portugal, and Korea (Solonen, 2001; Slagsvold, 1976; Pimentel & Nilsson 2007; Rhim et al. 2011). Overall, members of Paridae are among the best studied birds, from analysis of long-term data in breeding patterns of Great Tit (e.g. Sanz, 2002) to morphology differences among species, effect of brood size manipulation, and behavior (Moreno & Carrascal, 1993; Boyce & Perrins, 1987; Fitze et al., 2003; Van Duyse, 2002).

1.2 Life History of The Study Species

The relative ease to investigate their life traits and all this wealth of accumulated knowledge enables one to understand the life history of *Parus* spp. better than most other species of birds. The Paridae family belongs to Order Passeriformes and contains c. 55 species, which share similar morphological characters (Johansson et al., 2013). Traditionally the family is divided into 3 genera as *Parus, Melanochlora,* *Sylviparus*, whereas genus *Parus*, identified by a conical shaped, strong bill with nostrils hidden by bristles, and by characteristic feeding postures (Slikas et al., 1996). 18 species in the genus are distributed along the Palearctic Region, 15 in the Indomalayan and Afrotropical Regions, and 12 in the Nearctic Region (Johansson et al., 2013).

Almost all *Parus* species inhabit woodlands such as deciduous forests, mixed forests, conifer forests, tropical forests and also parks close to human settlements (Snow, 1954; Snow & Perrins, 1998). Coloration is similar with a black, brown or blue cap combined with white cheek and dark bib (Snow & Perrins, 1998). Width of dark colored breast stripe differs between males and females; for example it is wider in males of Great Tits (Norris, 1990). Rest of the underbody has pale colors.

Parus species have various preferences of breeding holes. Excavation of dead or well-decayed wood can be seen in some species such as Willow Tit (*Parus montanus*) (Mönkkönen & Orell, 1997). Natural holes or nestboxes are more attractive to Great Tits, Coal Tits (*P. ater*), Blue Tits (*P. caeruleus*) (Mönkkönen & Orell, 1997).

In this study, two species of *Parus* were investigated, Great Tit and Coal Tit.

1.2.1 Great Tit (*Parus major*)

Great Tit is probably the best-studied species in the Palearctic Region, starting in 1912 with Kluijver's pioneer work (Snow & Perrins, 1998). It prefers mixed deciduous forests but also can be seen in pine forests, gardens and urban parks. Basically it can inhabit any area with shrubs and trees. Even though it is more likely to be a lowland species, populations of Great Tit are known to be present at higher altitudes in Switzerland (Snow & Perrins,1998) and Northwest Africa (Snow, 1952).

Physical characteristics of Great Tit are easy to discriminate from other species by colorations of feathers. Head pattern consists of blue-black cap and black chins with a white triangular shape on cheeks. Downside of body is yellow with a black stripe from neck till down center. Upper side of body is green-blue and turns to blue-black towards tail and changes to grey-black at tail. Wings also have grey-black color with white tips and a white band close to upper part. Females have paler coloration compared to males (Snow & Perrins, 1998).

Start of the breeding season for Great Tits depends on spring temperatures and geographic locations. For example in Israel, laying begins in mid February while in northern Europe it can begin as late as May (Shirihai et al., 1996; Silverin, 2008). Generally laying season starts in April in the Western Palearctic (Snow & Perrins, 1998). A second brood can also be laid after their first brood (Kluijver, 1971).

In England, larger broods are produced in oak woodlands whereas smaller broods are produced in open lands and gardens (Perrins, 1965). Clutch size decreases with increasing breeding density (Pimentel & Nilsson, 2007) and increases with increasing latitude (Perrins & Birkhead, 1983). Average clutch size is 9.0 in Denmark and England, between 7.84 -9.6 in Finland, 7.6 in Tunisia and Algeria, and varies between 5-7 in Israel (Frederiksen et al., 1972; Solonen, 2001; Lack, 1964; Shirihai et al.,1996; Snow & Perrins,1998).

Females complete incubation alone. After laying the third egg, females gradually increase the time spent incubating and eventually start spending the night in the nest-box (Haftorn & Reinertsen, 1982). During daytime, incubation time varies between 14 and 48 minutes before the clutch is complete (Haftorn & Reinertsen, 1982). While the female is incubating, she is normally fed by the male (Snow & Perrins, 1998). When females leave the nest for feeding, they cover the eggs with feathery material. Average incubation time range between 12 to 15 days (Snow & Perrins, 1998). After hatching of the eggs both parents feed the young.

Nestlings are able to leave the nest after 16-22 days. Number of the fledglings is mostly related with food scarcity and predation (Balen, 1973). On average, six fledglings out of nine eggs leave the nest (Krebs, 1971).

1.2.2 Coal Tit (*Parus ater*)

Coal Tit appears in most of the Palearctic Region and prefers to inhabit conifer forests, although they can also be found in broad-leaved woodlands (Snow, 1954; Partridge, 1976). Some researchers prefer to place the species into its own genus, *Periparus* (e.g. del Hoyo et al., 2007).

Coal Tit has smaller body size compared to Great Tit. Females and males have color patterns that are alike. Head is similarly colored as Great Tit. Black cap reaches to neck with a white patch in between. Chin is black, which is wider in males. Downside of body has lighter olive-grey color and upper side is dark olive-grey. Tail and wing are grey-black with white tips. Wings also have two white bands at upper part (Snow & Perrins, 1998).

According to Harrap & Quinn (1996) populations of Coal Tits increased with conifer plantations. A fine bill enables the species to remove small food items from cones compared to other *Parus* spp. (Partridge, 1975). During early winter, Coal Tit feeds on leaves and later they start feeding on living and dead branches (Gibb, 1954). At winter season they feed on conifers (Gibb, 1954). While season changes to summer, they switch their food to ash, catkin and insects (Gibb, 1954; Harrap & Quinn, 1996). Food of the nestling is similar to adults – however it mostly feeds on insects (Harrap & Quinn, 1996). Unlike Great Tit, Coal Tit also stores food, mostly seeds of pine but sometimes attaches insects to needles of conifers, during autumn for winter (Gibb, 1954; Haftorn, 1956).

Coal Tit generally starts breeding in mid-April and the length of the breeding season is related with 2^{nd} clutch occurrence (Snow & Perrins, 1998). Phenology shows variability with changing geographical location (Blondel, 1985). For example, breeding starts in late April in Finland and in early April in England (Blondel, 1985; Snow & Perrins,1998).

Coal Tit breeds in the nest boxes similar to Great Tit. It uses moss for nest building and covers the nest with feathers. Average clutch size is 9.5 in England, 8.6 in Finland, and 5.9 in Corsica (Lack, 1948; Blondel, 1985; Snow & Perrins, 1998). Female alone carries out incubation and it lasts 14-16 days on average (Snow & Perrins, 1998). Both parents feed nestlings until they fledge which is about after 19 days from hatching (Snow & Perrins, 1998). Breeding success of Coal Tit is 57% in Corsica and 84% in Turkey (Blondel, 1985; Kiziroğlu, 1984).

1.3 Major Parameters of Avian Breeding Biology

Breeding parameters of birds vary between and within species. Natural selection possibly plays a strong role in ensuring a high enough lifelong productivity for any population to sustain itself (Gill, 2007). Therefore, studying breeding parameters is important to understand the life cycle of bird species.

Variation in each breeding variable in the life history of a species has been well documented by ecologists. Reasons behind those variations can be explained with intensive data collection and interpretation of those large data sets. Of course none of these parameters can be explained as independent, since all these parameters are interact with each other to reach higher reproductive success and fitness.

1.3.1 Monogamy or Polygamy

Monogamy as a term refers to the social pair bond as a single couple. In contrast polygamy refers to mating with more than one mate for a breeding season or life. In birds both conditions are present, although monogamy is the most widespread breeding strategy (Gill, 2007).

Great Tit have monogamous pairing in Europe (Moller, 1989). A study showed that females tend to behave aggressive to other females in their territory, to avoid males mating with the intruder (Slagsvold, 1993). In this way, they can defend the resource of male care for themselves and increase survival of their nestlings. In a close relative of Great Tit, the Blue Tit is polygynous (where males mate with more than one female during the breeding season) and give paternal care for both broods, which results in either separation of care or no care for the secondary female by the male (Dhondt, 1987; Slagsvold & Lifjeld, 1994).

1.3.2 Laying Date

Laying date is mostly correlated with an increase in food abundance although other parameters such as photoperiod, temperature, etc., may also concurrently change

(Meijer et al., 1990; Van Noordwijk et al., 1995; Nilsson & Kallander, 2006). Therefore it is difficult to pinpoint the impact of any of those factors. As photoperiod affects all those traits, it determines and constraints the timing of reproduction (Meijer et al., 1990).

Perrins (1970) theoretically demonstrated that the differences in food supply increase rate changes the quality of the period for raising hatchlings. If food supply increase rate is slow, there is sufficient time and resource for the female to form eggs, lay eggs, incubate and feed the hatchlings. In contrast, when food supply increases rapidly and then decrease at the same rate, resources become insufficient by the time of feeding hatchlings (Perrins, 1970).

Studies on abundance of food supply showed that species have different arrangements for breeding stages. Start date of laying in Great Tits correlate with an increase in food abundance, which later affects the survival of chicks (Perrins, 1965; Verboven & Visser, 1998; Visser et al., 2006). Experimental designs with artificial food inclusion pairs resulted in earlier laying dates compared to normal food condition pairs (Nager et al., 1997).

Laying date of the first egg also varies according to the age of female, the length of pair bond and the habitat quality. Older females tend to lay eggs earlier than young females (Kuijver, 1951; Mills, 1973). Differences in laying date can vary between a few days to five weeks depending on species (Dhondht, 1989; Potts et al., 1980). Similarly pairs that were mated in previous year(s) have earlier laying dates than newly mated pairs in some species (Coulson, 1966; Cooke et al., 1981). However, age of individuals has slightly larger effect on laying date than age of a pair (Fowler, 1995).

Lack (1955) showed that Great Tit and Blue Tit have different egg laying dates according to the habitat, earlier in gardens than in woodlands (Perrins, 1965). Dhondt et al. (1984) obtained similar results in Belgium while no difference was detected in the Mediterranean region (Beldal et al., 1998).

1.3.3 Clutch Size

The term 'clutch size' refers to total number of laid eggs in one nest during one breeding cycle. Many ecologists have studied variation of clutch size, between species and within species, which is also a best-studied trait among animals.

Even though clutch size vary among species, most bird species lay 2-3 eggs in a breeding cycle (Jetz et al., 2008). However three northern members of Paridae (Blue Tit, Great Tit, Coal Tit) have very high number of eggs in a clutch – for example, up to 18 eggs in Blue tit (Gibb, 1950).

Production of eggs has high cost for female and consumes energy. With decreased temperature, a female spends more energy to lay eggs (te Marvelde et al., 2012). With increased temperature, food abundance usually also increased, which gives enough energy for female to increase clutch size. According to the spent cost for development of eggs, strategies of being precocial or altricial also have influence on clutch size. Daily energy expenditure for egg production increases in order of altricial, semi-altricial, semi-precocial and precocial chicks (Martin, 1987). Clutch size of precocial species is higher than altricial species, which can be explained by reduced parental care after hatching (Jetz et al., 2008; Martin, 1987).

A similar relation is present for nest type strategies. Species that use natural or artificial holes to build nests have larger clutch sizes than open-nesters (Lima, 1987). Varying predation rates on different types of nest may indirectly have an influence on clutch size (Slagsvold, 1982). Hole-nesters encounter predation risk at lower rates compared to open nesters (Jetz et al., 2008), which might explain observed high clutch size.

1.4 Aims of The Thesis

This study has several aims. The first aim is to document breeding parameters (such as start of laying, clutch size, breeding success, etc.) for *Parus* populations at METU, Ankara. Except for the study by Kiziroğlu (1982, 1983) in Beynam which took place at a considerably higher altitude and almost 40 years ago and a recent in study in Antalya (Kabasakal & Albayrak,2013), there is no systematic or long-term research on the breeding biology of those species in Turkey. Therefore, the findings of my study will provide an addition to our scarce knowledge on the ecology of Paridae in Turkey.

A second aim of this study is to investigate whether limited resources at METU impact phenology, clutch size, number of broods or breeding success of the species. Compared to other sites in the world where those parameters have been studied, METU is a marginal habitat with colder winters and drier summers, creating conditions with less productivity and more climatic constraints. Such marginal habitats are known to shape breeding parameters (e.g. Sanz, 1995). I expect to find a later laying date, and lower clutch sizes and number of fledglings (i.e. overall lower success) compared to natural habitats.

A third aim is to test the hypothesis that nest predation rates are higher at METU than elsewhere. Antropogenic environments are known to have higher rates due to increased densities of such predators or due to opportunites created by human activities (Thorington & Bowman, 2003). Therefore I expect to record lower survival rate of nestlings due to predation, which can also give information about the food resources available for predators.

Finally, this study can provide the baseline data on breeding phenology and other reproductive parameters that can be used in climate change monitoring in the future as well as provide a model field study setup for student training.

CHAPTER 2

MATERIALS & METHODS

2.1 Study Area

This research was conducted in METU Campus, Ankara (Figure 2.1). The study area is located approximately at 39.89 N, 32.78 E. Climate of the region is considered as semiarid (Erinç, 1984). Average temperature varies between 16 and 23°C during breeding season. Detailed climate data can be seen in Table 2.1.

Table 2.1: Mean, maximum, minimum temperatures and Mean rainfall values for Ankara (from Turkish State of Meteorological Service, for years between 1954 and 2013)

Months/Parameters	1	2	3	4	5	6	7	8	9	10	11	12
Mean temp. (°C)	0.4	1.9	6.1	11.3	16.2	20.2	23.6	23.3	18.7	13.1	7.0	2.6
Max. temp. (°C)	16.6	20.4	26.4	30.6	33.0	37.0	41.0	40.4	36.0	32.2	24.4	20.4
Min. temp. (°C)	-21.0	-22.0	-19.0	-6.7	-1.6	3.8	4.5	6.3	2.5	-4.1	-11.0	-17.2
Mean precipitation (kg/m2)	42.2	37.0	38.8	47.7	49.7	35.0	14.5	10.5	19.2	29.4	32.6	45.4

Although the original dominant vegetation type in Ankara is steppe, some areas were converted into forest by afforestation since late 1950s. Parts of METU Campus also have semi-natural stands of conifer trees, with black or Austrian pine (*Pinus nigra*) as the dominant species. Pure or mixed stands of Scots pine (*Pinus sylvestris*), *Cedrus* spp., *Populus nigra, Ailanthus* spp., *Tilia* spp., *Fraxinus* spp. are also present in the area. Shrubs such as *Rosa canina, Mahonia aquifolium, Crataegus* spp. are dispersed in the gaps between tall trees. Open landscapes are covered with various herbaceous plants.

Three different sites were chosen for this study according to their distance to roads, buildings and nesting availability for tits. Species assemblages of areas are also showing some differences. However, at every site the dominating species is black pine and almost all nest boxes were placed on this common tree.

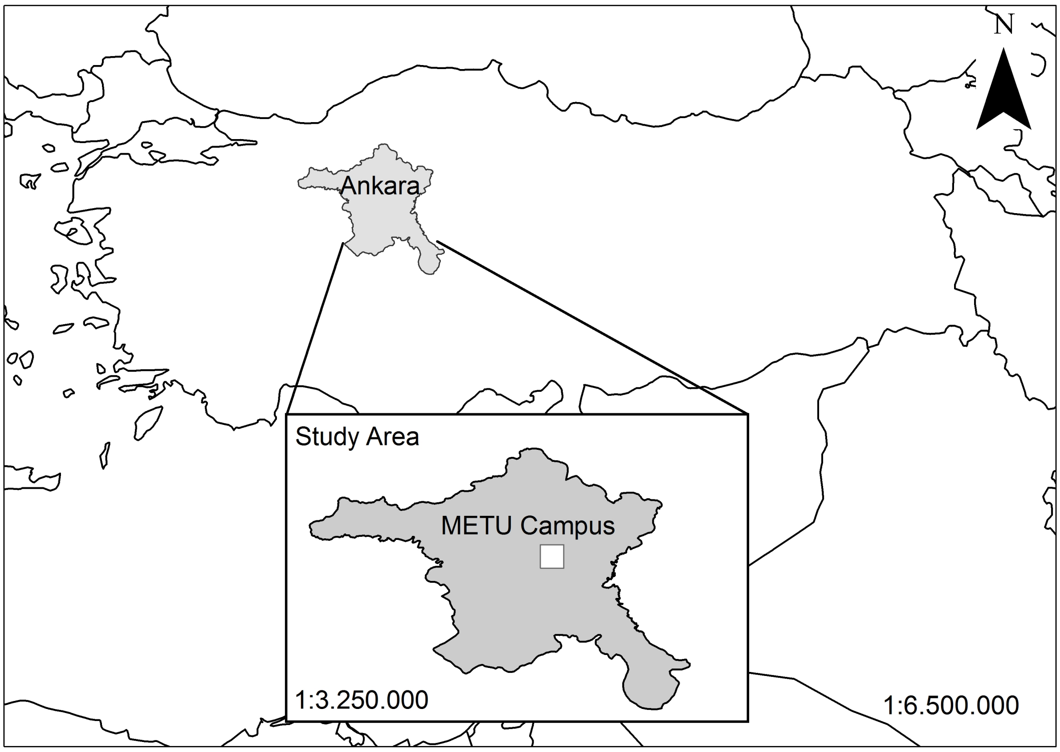

Figure 2.1: Location of the METU Campus, Ankara.

Total area for this study covers approximately 26 ha. Site A (Figure 2.2, yellow points) is located behind Department of Foreign Language and it is larger compared to other sites of the study, with 33 nest boxes. This area consists of mixed vegetation of pines and oaks and has some paths for people to walk.

Site B (Figure 2.2, blue points) is the closest location to roads and buildings. In the beginning of the study, 7 nest boxes were present. However during second year fieldwork, 2 nest boxes were missing. In the third year of the study, next boxes in this area were removed.

In the third site, C (Figure 2.2, red points), 20 nest boxes were placed behind the dormitory buildings. This area is covered with black pines. Similar to Area B, one nest box was missing in the second year.

Figure 2.2: Distribution of nest boxes (Photo from Google Earth).

2.2 Nest Boxes

One of the most common and widely used methods to study the breeding ecology of cavity-nesting birds and to construct model systems for breeding parameters is to utilize artificial nest boxes (Pickett et al., 2013; Møller et al., 2014). Nest box studies have been used to investigate brood size manipulation, phenology and conservation for various species (Bowers et al., 2014; Mitrus, 2003; Libois et al., 2012).

For this study, 50 nest boxes were obtained from the General Directorate of Forestry. 2 cm thick wood was used to construct the nest boxes. External dimensions of each nest box is 13.5 cm (width) x 22.5 cm (height) x 12 cm (depth). The topside of the box is hinged, which allowed checking the nest status in the field. The nest boxes had entrance diameters of 40 mm, which allows tits to accommodate and prevents most other species to enter. Even though most tits use nest boxes with this diameter, they are mostly preferred by Great Tits (Rhim et al., 2011).

In March 2013 the nest boxes were distributed throughout the study area at a minimum distance of 50 m from one another. This distance between nest boxes is usually sufficient to avoid territorial overlap between pairs (Krebs, 1971). The nest boxes were tied or hung to trunks of trees with large enough diameters at 2-2.5 m height above ground level (Figure 2.3) and exact coordinates of each nest box were recorded with GPS unit.

Figure 2.3: Nest box placed on tree trunk in the study area.

There are already a number of nest boxes at some of our study sites that were previously placed by the university forest manager. However, none have been observed to be occupied by any birds.

2.3 Field Methods

2.3.1 Collection of Breeding Biology Data

Breeding biology of tits has been studied for a long time in different countries around the world. One of the longest such study is at Wytham Woods, Oxford, England (Gibb, 1950; Evans & Sheldon, 2012). Field protocol was adapted from that study by Edward Grey Institute of Field Ornithology with minor changes, similar to other studies.

Breeding season was divided into 4 stages: (i) initiation, when the pairs start to select the nest location and collect the material that are necessary for nesting, (ii) egg laying, which covers the time interval from the date of first egg laid until clutch completion, (iii) incubation, the period of incubating, which lasts on average 14 days for either study species and (iv) nestlings, comprises the duration from hatching until the age of fledging (approximately 14 days for both species). The duration of the first stage was approximated due to difficulties in differentiating the exact date of the start and pauses during nest building.

Breeding was monitored for three years, between 2013 and 2015. Starting from the mid- March until the end of July each nest box was visited at least once a week to record the progress of nest development. Related with the nesting status (Figure 2.4), certain nest boxes were monitored more frequently, once every two-three days, to record laying date of first egg, clutch size and the approximate start date for incubation. Throughout the study, there were nests that did not develop their status for a week and remain at the same state of nest building (Figure 2.4 b). Those nests were accepted as nest attempts and evaluated under the stage of 'Initiation'.

During the period of monitoring, if a nest included more than one egg, laying date was calculated with the assumption of one egg is laid per day (Perrins, 1965). After completion of the clutch, which can be determined by observation of an incubating bird, the nest box was not disturbed until the estimated day of hatching (14^{th} day). On the expected day of hatching, nest boxes were controlled carefully and quietly to minimize disturbance. Following visits to record fledging date and predation status were made with intervals of 2-3 days, to avoid premature desertion of the nest.

During or just after incubation, a number of camera traps (Bushnell Natureview or Bushnell Trophy) were placed to monitor the nest boxes. From captured photographs or videos, predators, if any, were identified and dates of predation were recorded to assess the ages of nestlings at the predation event. Once nesting was over, nest material were removed from nest boxes to prepare them for another nesting attempt.

Nests with at least one laid egg were evaluated under either of three categories: (i) deserted or predated, (ii) predated or (iii) succeeded, according to their states and continuity. The nests with nestling(s) reaching fledging age and leaving the nest were considered to have "Succeeded". The decision to categorize a nest to any of the other

Figure 2.4: Process of nest building. (a: empty nest box; b: collection of nest materials; c: laid eggs are covered with light material before incubation; d: complete clutch)

two categories, which explain the reasons for failure, were determined with camera traps, if it was not possible to document the event, then several indicators (such as broken egg shells or nest material on the ground) were used to assess the status. "Deserted or predated" nests were identified according to the stage of nest process. Starting from the egg laying process until fledging time, the nest boxes without any progress and a sign for predation, were accepted as deserted or predated nests. During egg laying process, if clutch size did not increase for a week and status of the nest remained stable, nests were also categorized as "Deserted or predated". For predated nest boxes, scattered nest material on the ground was accepted as a first indicator. In cases that lack this indicator, observed changes in the total number of the eggs or nestlings were used for this decision. If there was a decrease in those numbers, nest fate was accepted as predated, even though some nestlings or eggs had survived.

2.4 Capturing and Species Identification

Two methods were used for capturing the breeding pairs before fledging. The first method was the placement of a swinging door trap over the nest box entrance. The mechanism is very simple but requires constant monitoring of the parents and quick reflexes. A metal plate is attached to the entrance of the nest box, and lifted with the help of a thin stick, which in turn is tied to a nylon fishing line. When a parent enters the nest, the line is pulled by an observer $>$20 m away, and the plate swings down to prevent the captured parent to leave the nest. Since the parent birds quickly got wary of the mechanism, it was often not possible to capture the parents with this method. A second method is placing mist nets near the nest boxes, a widely used and accepted method for bird captures. This caused parents to get entangled while they enter or leave the nest box after feeding the nestlings.

In 2013, parents were tried to be captured when the nestlings were 10-14 days old. On the 15^{th} day measurements of nestlings were completed. In 2014, due to difficulties in capturing parents and to avoid premature fledging, start date for capture was moved earlier to 8^{th} day (since hatching) for adults and 13^{th} day for nestlings. In the last year of the study, parents were not captured due to logistical difficulties.

The capturing process and time spent in field was designed to minimize disturbance for the parents or the nestlings. Scheduled capture days with traps were divided into two sessions, one in the early morning and one in the afternoon before sunset. Each occasion lasted at most 90 minutes with traps. If parents became wary of the traps, trapping was stopped and tried again in the afternoon. Captures using mist nets were tried more than twice in a day. First try usually took place at sunrise and last one at sunset. Mist nest did not appear to cause any disturbance for parents, as they were observed to be not deterred by the nets and continued to visit the nest to provide for the nestlings.

Both parents and nestlings were ringed with metal rings with 2.8 mm diameter and a unique number for identification. As the rings enables individual identification, it is possible to investigate second broods or nest selection of individuals in the future. During ringing, species identification and preliminary sex determination for adults were made according to presence of a brood patch (Figure 2.5) or the plumage pattern underneath (Figure 2.6 and 2.7). Great Tit males have broader black band on their throat and chest. In Coal Tit black coloration is present only at the throat, and similar to Great Tit, males have wider black plumage on the throat.

Heat transfer from an incubating female to her eggs is necessary to develop chicks. Brood patch is an adaptation to make the transfer of the heat more efficiently. Females lose feathers at midline on their belly and the resulting bare skin thickens before incubation (Redfern, 2010). In both species, only females incubate (Haftorn & Slagsvold, 1995), therefore brood patch was used as another indicator for sex identification. In addition, blood samples for sex identification and morphological measurements were collected during ringing (Appendix A and B).

Figure 2.5: Brood patch of Great Tit. (Photo credit: Josie Hewitt)

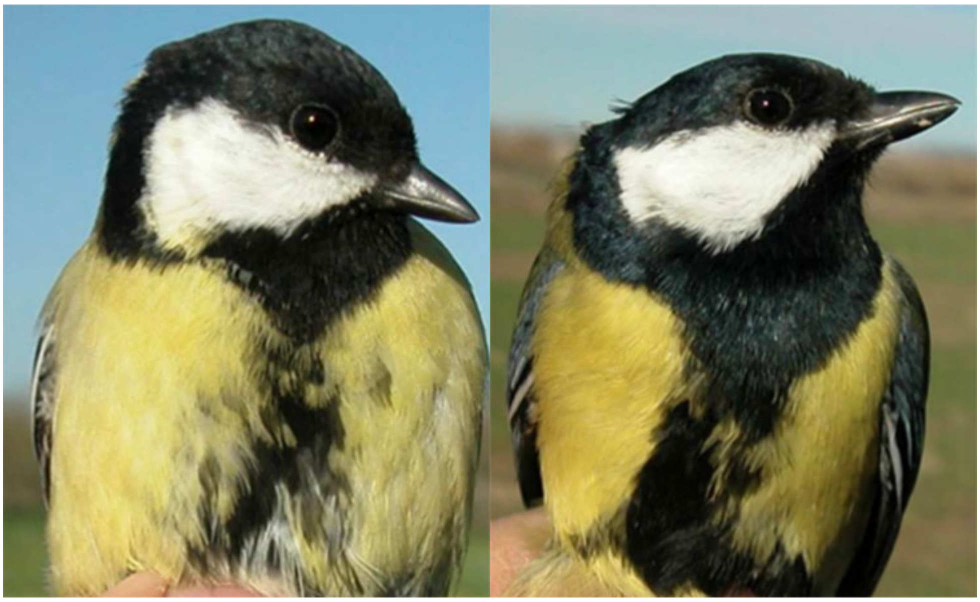

Figure 2.6: Plumage color differences between sexes in Great Tit (left: female, right:male). (Photo credit: Javier Blasco-Zumeta & Gerd-Michael Heinze)

Figure 2.7: Plumage color differences between sexes in Coal Tit (left: female, right:male). (Photo credit: Stephen Menzie)

2.5 Assessment of Success

In this study, as mentioned in the previous section, only nests that fledged young without any disturbance were considered successful. However, partial success was used for an assessment of overall reproductive success of the sampled pairs. Partial success was defined for nests with some hatching failure (i.e. not all eggs hatched) or partially predated nests. Two separate measures were calculated following Murray (2000): hatching failure in Equation 2.1, and breeding success in Equation 2.2.

Hatching failure represents the ratio of unhatched laid eggs in any one nest and is calculated as follows:

$$HatchingFailure = 1 - \frac{Total \quad number \quad of \quad Nestlings}{Total \quad number \quad of \quad Laid \quad Eggs} \tag{2.1}$$

Breeding success was calculated in order to allow comparisons between different study populations. It represents the ratio of the fledglings with respect to laid eggs.

$$BreedingSuccess = \frac{Total \quad number \quad of \quad Fledglings}{Total \quad number \quad of \quad Laid \quad Eggs} \tag{2.2}$$

Breeding success was calculated both individually for each nest, and as overall success in a particular year for each species. Since observations on the survival of the nestlings after fledging was not possible, breeding success only indicates the raised proportion of fledglings.

2.6 Data Analysis

All analysis and graphs were carried out with R Statistics Software (R Core Team, 2015). To calculate descriptive parameters, dates in data set were converted into continuous numeric values, starting with "1" for March 20^{th} which is the first date of collected data for this study. For assessing of the start of the breeding season, pentads (5-day periods) were used, as it was difficult to find the exact day of nest building process. Pentad numeration started from 1^{st} of January, and each five day was categorized in continuous values starting from "1" (01/01-05/01). Mean and standard deviation of the "First egg date" and clutch size were calculated for an assessment of changes through the season and of differences from other populations. For this assessment data from 2013 and 2014 were used. Collected data from 2015 was only used for the overall assessment of success and predation rate.

To understand the relation between clutch size and laying date, Spearman's Rank Correlation Coefficient, a non-parametric test, was used, since the collected data did not have normal distribution. Laying date was used as explanatory and clutch size as response variable.

Distances between nest boxes and man-made structures were calculated using ArcGIS 10.x Euclidian Distance analysis (ESRI, 2011). Calculated distances were used to investigate their relation with nest selection and predation occurrence. In order to explore those relations, a generalized linear model with binomial response (0-1, Yes-No) with continuous dependent variable was constructed. This analysis is also known as "Logistic Regression", which allows to create a regression equation combining the response variable and predictors.

CHAPTER 3

RESULTS

3.1 Breeding Phenology

The breeding phenology, with process and fate of each nest, for Coal Tit and Great Tit are shown in Figure 3.1 for 2014. It can be seen that breeding season starts in late March for Coal Tit and early April for Great Tit and continues until the end of June. Approximate nest building process is 5-10 days long. Egg laying duration depends on the total number laid eggs and on average it lasts a week. Incubation lasts 10-14 days for both species. Nestlings leave their nest after they reach the age of 13-17 days.

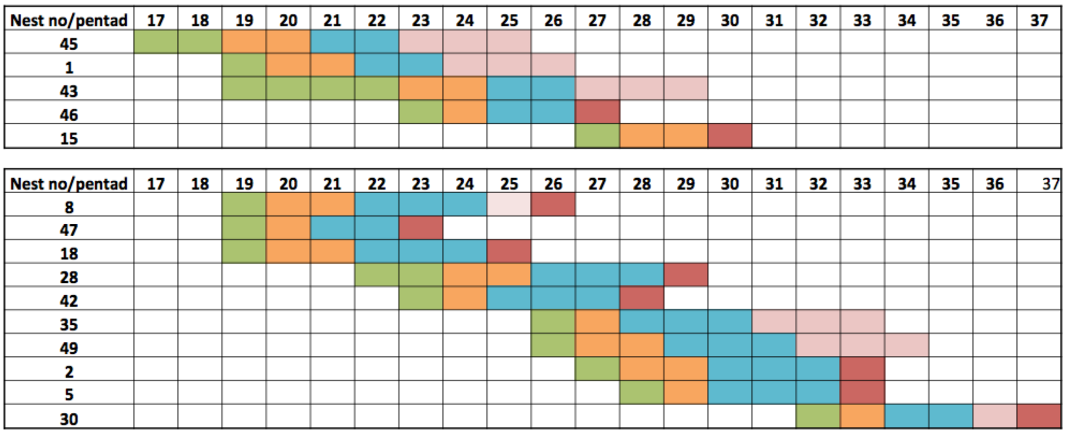

Figure 3.1: Presentation of phenology for both species in 2014 (Pentad 17: 22-26 March). Top: Coal Tit and Bottom: Great Tit. “Nest Initiation” (Green) refers to the stage of nest building, “Egg laying” (Orange) shows duration of the process, “Incubation” (Blue) duration of incubation and “Nestling” (Pink) duration after the hatching. Red color represents the occurrence of predation at egg stage and after hatching.

3.1.1 Nest Building

Start of nest building (nest initiation) timing for both species and total number of nests for each pentad is shown in Figure 3.2 for 2014. For Great Tit it can be seen that number of nest initiations are higher at 19^{th} and 26^{th} pentad, which is 30 days apart.

Pentad	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
# of nests	1				2				1				1								

Pentad	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
# of nests					3			1	1			2	1	1				1			

Figure 3.2: Total number of nest initiations versus time in 2014. Top: Coal Tit, Bottom: Great Tit (Pentad 17: 22-26 March).

In 2013, a total 9 nest boxes were occupied out of 50 nest boxes placed around the campus. Earliest nest building stage was recorded in late March by to a Coal Tit pair. That year the only pair of Great Tit started to build their nest in the third week of May.

In the second year of the study (2014) a total 15 nest boxes were occupied by *Parus* spp. The first nest building started in late March for Coal Tits, and the first week of April for Great Tits. In both years nests were mainly made with moss and lichens, while at some nests pine needles were observed.

The last nest by a Coal Tit in 2013 was built in last week of May. Similarly, in 2014, a Coal Tit pair built the last nest in the mid-May, and a Great Tit pair in the first week of June.

3.1.2 Egg Laying and Clutch Size

The average period between nest initiation and first egg laying is 8 and 5 days, respectively for Coal Tit and Great Tit. These values are approximate, due to uncertainties in determining the exact day of nest initiation. One pair of Coal Tit had an unusually long interval of 36 days in 2013, which was excluded while calculating the mean difference.

Among two years, start of egg laying dates for Coal Tit are 7 days apart. Coal Tits laid the first egg on April 7^{th} in 2013, and on April 1^{st} in 2014. For Great Tit only data in 2014 is available and the start date is April 1^{st} .

The clutch size of Coal Tits varied between 6-9 eggs. Great Tits had a wider range compared to Coal Tit and it is between 6-10 eggs. Mean values for both years are given in Table 3.1, including the date of laying.

Table 3.1: Date of laying (1=20 March) and clutch size of both species. Values are Mean±SE, with sample size in parentheses. (NA= not available)

Year	2013		2014	
Variable/Species	Great tit	Coal tit(4)	Great tit(10)	Coal tit(5)
Date of laying	NA	54.25±11.96	46.40±6.92	33.80±8.29
Clutch size	NA	7.00±0.70	7.50±0.40	6.80±0.37

The relation between laying date and clutch size was analyzed with correlation analysis. Great Tits appeared to have a negative correlation between clutch size and laying date (rho=-0.86, p-value=0.006), i.e. they had smaller clutches as the season progressed (Figure 3.3).

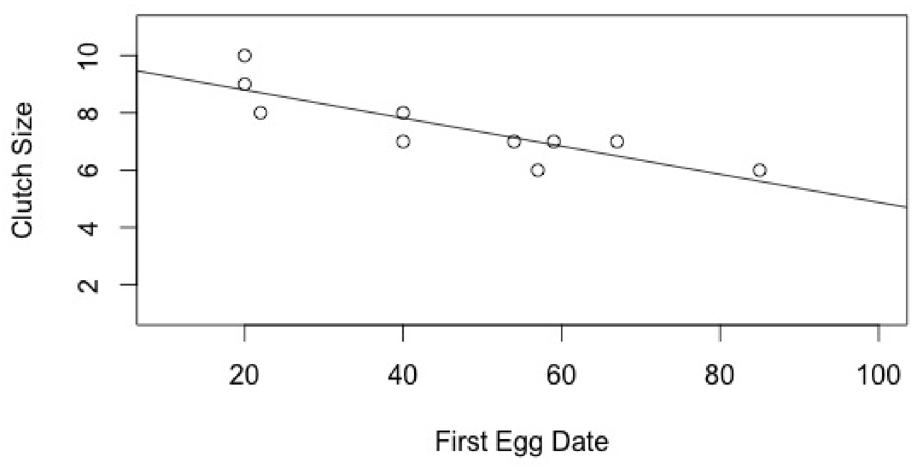

Figure 3.3: Relation between clutch size and first egg laying date for Great Tit (p-value$<$0.05).

However for Coal Tits, no significant relation was found (rho=-0.24, p-value=0.59)

(Figure 3.4).

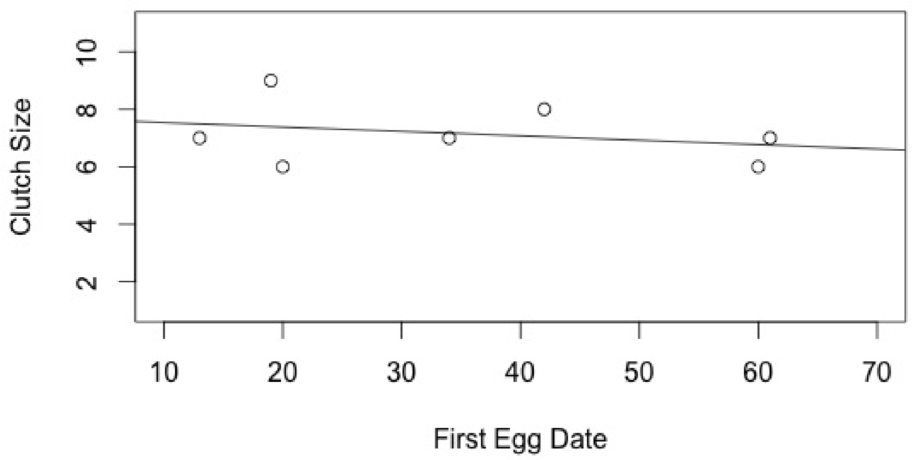

Figure 3.4: Relation between clutch size and first egg laying date for Coal Tit p-value>0.05).

3.1.3 Breeding Success

In 2013 and 2014, only pairs of Coal Tit in nest box #1 raised chicks that reached to fledging age. All other nest boxes that were occupied by Coal Tits between 2013 and 2015 had either unsuccessful breeding or only partial success. Collected data from 2013 and 2014 are shown in Table 3.2.

In the first year of study, one nest out of 9 nests belonged to a Great Tit pair. Due to lack of data, calculations for 2013 do not include all pairs. Number of occupied nests slightly increased in the second year of the study. In 2014, Great Tit pairs made up 10 out of 15 occupied nest boxes. In 2015 in total 16 nests were constructed where at least 9 of them were built by Great Tit pairs (Figure 3.5). Throughout the study, no second broods were detected. In total 3 nest boxes were re-used after completion of one breeding attempt, one in 2013 and two in 2015. However, it was not possible to identify which particular pairs were involved.

In 2013, 3 pairs of Coal Tit reproduced successfully out of 8 pairs. The total number

Table 3.2: Breeding data for both species. (CT: Coal Tit, GT: Great Tit, UN: Unknown, P.predated:Partially predated, D or P: Deserted or predated).

Nest Number	Species	Year	Total number of laid eggs	Number of chicks	Number of fledglings	Fate of the nest
1	CT	2013	2	0	0	D or P
45	CT	2013	1	0	0	D or P
38	CT	2013	UN	0	0	Predated
39	CT	2013	UN	0	0	Predated
1	CT	2013	6	4	4	Succeeded
2	CT	2013	6	4	4	Succeeded
41	CT	2013	7	7	7	Succeeded
42	CT	2013	9	9	UN	UN
46	CT	2014	8	UN	0	Predated
15	CT	2014	6	0	0	Predated
1	CT	2014	6	6	6	Succeeded
43	CT	2014	7	7	7	Succeeded
45	CT	2014	7	7	7	Succeeded
49	GT	2013	UN	UN	0	Predated
28	GT	2014	7	2	0	P.Predated
8	GT	2014	8	8	3	P.Predated
2	GT	2014	7	UN	0	Predated
5	GT	2014	7	6	0	Predated
42	GT	2014	8	5	0	Predated
47	GT	2014	10	6	0	Predated
18	GT	2014	9	9	0	Predated
30	GT	2014	6	5	0	Predated
35	GT	2014	7	7	7	Succeeded
49	GT	2014	6	4	4	Succeeded

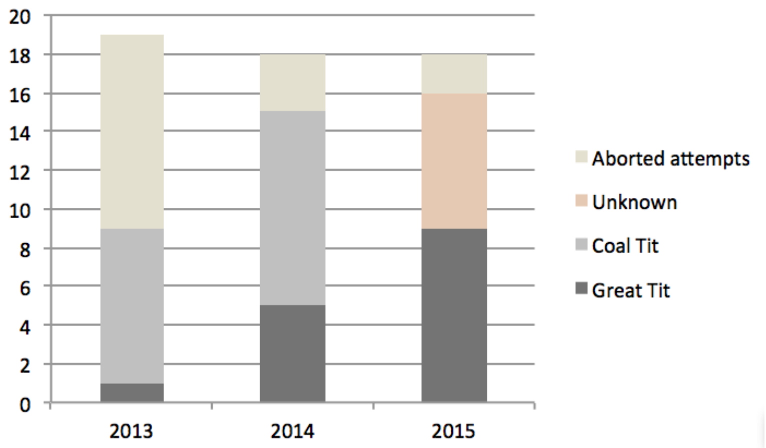

Figure 3.5: Total number of used nest boxes throughout the study separated into attempted nests and nests with laid eggs according to species.

of chicks hatched is unknown related with early predation. In 2014, for Coal Tit 3 nests out of 5 nests produced chicks that reached fledging age. Nesting success of Coal Tit is 37.5% and 60.0% for years 2013 and 2014, respectively. Overall nesting success is 50% for both years. Breeding success (Total number of fledged chicks/ Total number of laid eggs) of Coal Tit pairs for 2014 is 58 % and number of fledglings per nest is 1.9 in 2013 and 4.0 in 2014 (Table 3.3).

Table 3.3: Breeding data for Coal Tit in 2013 and 2014. (Nesting Success= number of successful pairs/ number of breeding pairs).

Parameter / Year	Total number of breeding pairs	Total number of successful pairs	Total number of chicks	Total number of fledglings	Nesting success (%)	Fledgling per nest
2013	8	3	24	15	37.5	1.9
2014	5	3	>20	20	60	4.0

For Great Tit, there is an increase in the number of nest boxes used over the years. For the first year of study, the only Great Tit pair that used the nest box, was not able to raise any fledgling due to predation. In the second year, 3 nests out of 10 nests were able to produce fledglings. Therefore, the nesting success of Great Tit is 0% and 30% for 2013 and 2014, respectively. Overall nesting success is %27 for both years. Only in 2014 nests had fledglings. Breeding success (Total number of fledged chicks/ Total number of laid eggs) in 2014 for Great Tit pairs is 18% and number of fledglings per nest is 1.4. (Table 3.4)

Table 3.4: Breeding data for Great Tit for years 2013 and 2014.

Year	Total number of breeding pairs	Total number of successful pairs	Total number of chicks	Total number of fledglings	Nesting success (%)	Fledgling per nest
2013	1	0	UN	0	0	0
2014	10	3	>52	14	30	1.4

3.1.4 Nest Selection

All occupied nest boxes were attached to Black Pine trees, except for one nest (a maple tree, Acer sp.) in 2015. Logistical regression revealed that distance from man- made structures influences nest selection (Estimated standart error: 0.008, p-value$<$0.05). As the distance increased, the probability of occupation by a pair also increased (Figure 3.6)

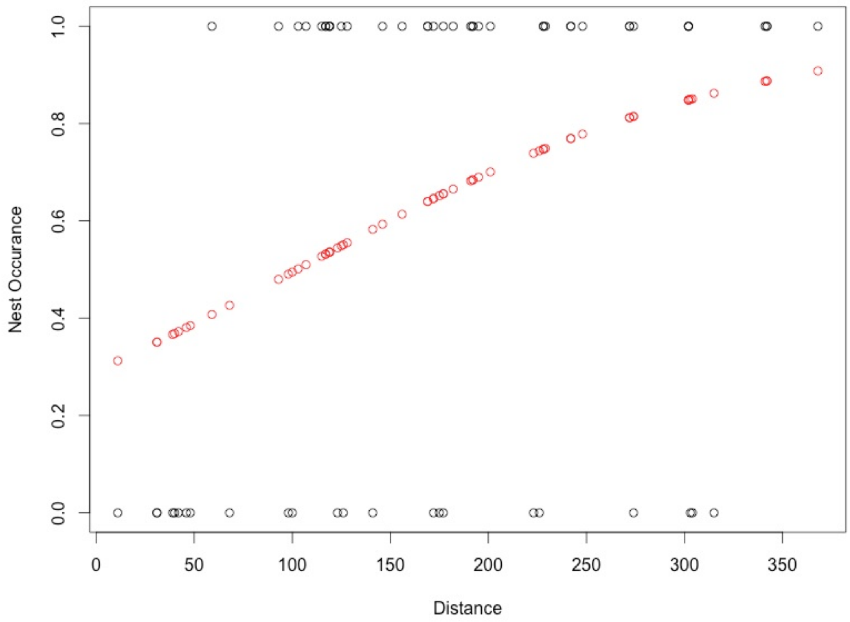

Figure 3.6: Sigmoidal curve fit for logistic regression analysis of distance (m) and nest occurrence. Black points: observed values, Red points: fitted values according to the model .

3.2 Reasons for Nest Failures

Predation was the most common cause for nest failure as it represents 42.5% in either for total nestling loss or reduction in number of fledglings (Figure 3.7). The other failed nests (n=6) were either deserted or predated, since it was not possible to identify the predation on parents those nests were not classified with certain fate. One nest box's fate is unknown, even though chicks were observed there was not any record of fledging or predation.

3.2.1 Agents of Predation

In 2013, predators were not identified at 3 nest boxes. In 2014 and 2015, camera traps identified the responsible predators for losses. The main predator for nests was documented as magpie (*Pica pica*) for 8 nest boxes (44% of all failed nests, more than half of nests with positively identified predators). From other evidence available, magpies are interpreted to be responsible for the losses in 2013 as well. Predation agents and their frequencies can be seen in Figure 3.8 below. Among predated nests

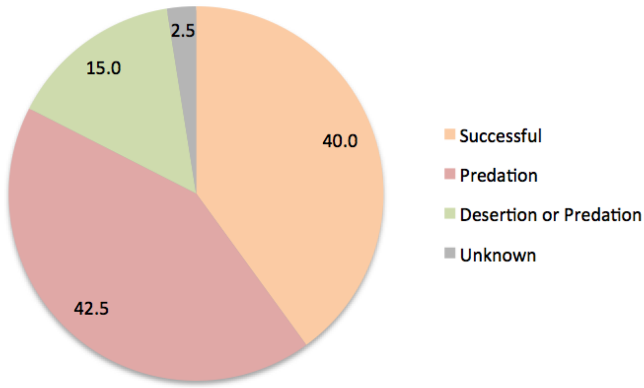

Figure 3.7: Fate of the nests between 2013 and 2015 (n=40).

where breeding species was known, a total of 4 out of 13 Coal Tit nests and 13 out of 20(from identified nests) Great Tit nests were predated.

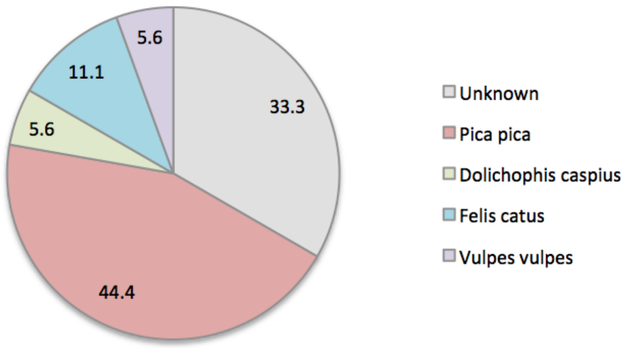

Figure 3.8: Predators and their frequencies for 2014.

An unusual occurance was filmed by a camera trap, where a fox was climbing up and reaching to the nest, however there is no record of it taking any nestlings out of the box by the camera trap. Since it had reached the nest box and no other predators were recorded near that nest box on that day, the fox was accepted as the predator. The other predators that were captured by traps are Caspian whipsnake (*Dolichophis caspius*) and domestic cat (*Felis catus*).

Camera traps also recorded Eurasian Jay (*Garrulus glandarius*), Syrian Woodpecker (*Dendrocopos syriacus*) and Eurasian Scops Owl (*Otus scops*). Especially Eurasian Jays were captured many times, which also was seen around nest boxes during controls. However, they were not able reach inside the nest box.

3.2.2 Stage of Predation

Earliest predation occurred at two nest boxes by magpie and fox, when nestlings were 3-4 days old. The mean age of nestlings at predation was 7.2 days. From Figure 3.9, it can be seen predation is highest on the first week after hatching compared to previous or later stages. Latest predation occurred by a Caspian whipsnake (*Dolichophis caspius*) while nestlings were 12 days old (2^{nd} week). After predation, parents abandoned the nest and nestlings were lost because of further predation by an unknown species. In some nests predation continued for a couple days once the predator located the nest.

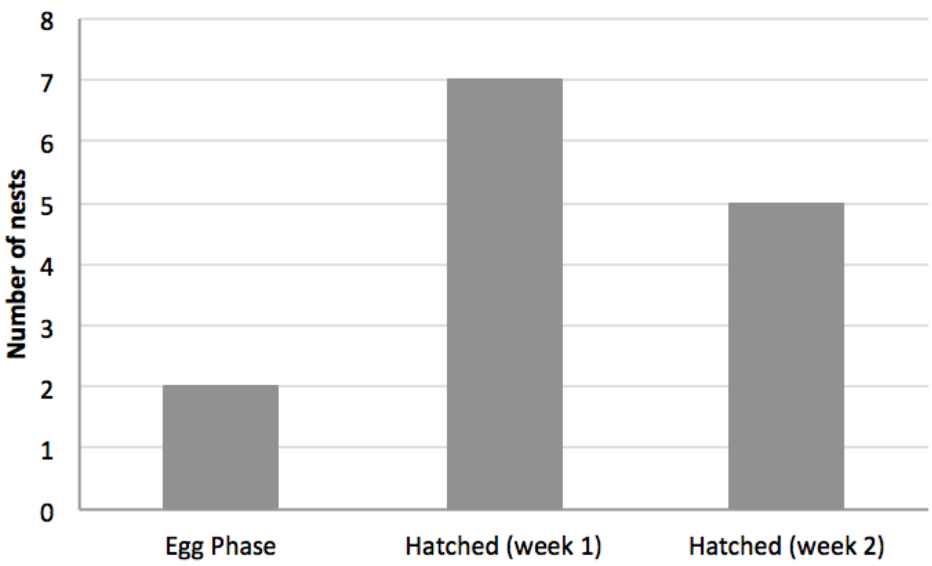

Figure 3.9: Number of nests that lost with predation according to different stages.

3.2.3 Predation and Distance from Man-Made Structures

The distance between nests and man-made structures was tested in order to assess the significance of these distances for nest occupancy or predation rates. Since almost all occupied nest boxes were on Black Pines, tree choices of pairs and predators were not tested.

Analysis showed that there was no significant relation between predation risk and distance from man-made structures (est.stndrt:-0.001, p-value>0.05) (Figure 3.10). Recorded predators are widely distributed in the study area and can be found at any distance.

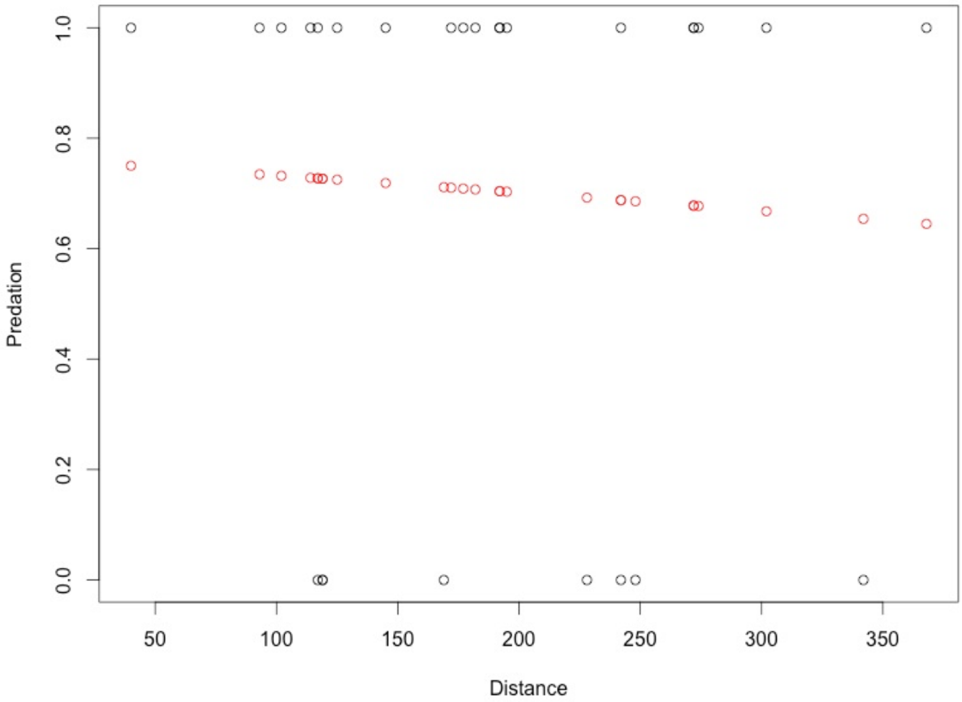

Figure 3.10: Sigmoidal curve fit for logistic regression analysis of distance (m) and predation rate. Black points: observed values, Red points: fitted values according to the model.

CHAPTER 4

DISCUSSION

4.1 Occupancy of Nest Boxes

Nest boxes are one of the major limiting factors for cavity nesting species. Therefore, implementation of artificial holes, in this case nest boxes, increases the possibilities of breeding for those species (Mand et al., 2005). Most studies so far are based on the findings of nest box provisions. However use of all installed next boxes is rare (Cowie & Hinsley, 1988; Costa et al., 2005; Kabasakal & Albayrak, 2012).

On METU campus, occupancy of nest boxes has increased since the year of installation. In the first year, 18% of the boxes were occupied; in following years this value was elevated to 30% and 32% respectively in 2014 and 2015. The observed lower rate in the first year is most probably related with the relatively late timing of installation. Egg laying in both species takes place around late March and early April (Blondel, 1985; Fidalgo, 1990; Pimentel & Nilsson, 2007). Before egg laying, there is usually a several weeks long duration necessary for nest site selection and nest building. Since the nest boxes were set up in the study area during March 2013, many pairs likely had already chosen their nesting sites at that time. In the following years, occupancy has increased probably due to presence of the nest boxes during the previous winter.

Great Tit prefers nest boxes over natural cavities for breeding (Mand et al., 2005). Moreover Great Tits are socially dominant over Coal Tits (Rhim et al., 2011), which could explain the observed increase in nest box occupancy by Great Tits. In the first year, 11% of the occupied nest boxes belonged to Great Tits, while this ratio became 66% in 2014, and was at least 37.5% in 2015. This finding could indicate competitive pressure on Coal Tits by the more dominant Great Tit in terms of nest sites.

In 2013 and 2015, two sparrow (*Passer domesticus or P. montanus*) pairs occupied a nest box each. Competition between sparrows and Great Tits was observed and sparrows were found to be dominant over the latter when it comes to protecting the nest (Barba et al., 1995). Even though it is too early to predict which species will use most of the nest boxes in the future, there is a possibility that the number of competing species for next boxes on campus (such as Blue Tit *Parus caeruleus* or Common Redstart, *Phoenicurus phoenicurus*) might increase.

Another finding from nest box use is about their preferred locations. The proportion of occupied next boxes increased further away from buildings or asphalt roads. This could be caused by two factors: Firstly, the presence of potential nesting holes might influence the number of nesting pairs in an area. Tree age is strongly related with availability of nest sites, as a tree gets older, the probability of suitable holes in that tree increases (Maziarz & Broughton, 2015). The trees in the study area generally are 40-60 years old with straight trunks. Therefore they do not provide much opportunities for nesting, which makes the nest boxes a valuable resource for tits, and can explain the observed higher rates of nest box use at locations distant from man-made structures (which provide plenty of holes for nesting, pers. obs.). Secondly, the higher abundance of domestic cats, formidable avian predators, near anthropogenic environments may push the birds to breed further away from such sites. Both of these factors might be at play here, although since no significant correlation was found between predation rates and distance from man-made structures the second explanation is weakened. For example, cat predation had occurred at distances of 93 and 300 meters from the buildings. It explains that, as all the predators are mobile and present throughout the study area, predation rates are unlikely to be related with distance from human structures.

4.2 Phenology

One of the major parameters that influences phenology of breeding in birds is geographical location. Clutch size and laying date show a gradual adjustment to changes, where both parameters increase at higher latitudes (in large scale) and/or altitudes (Lack, 1948; Sanz, 1998; Jetz et al., 2008). Also another trigger for breeding season for Great Tit was found to be the emergence of caterpillars (Perrins, 1989).

At similar latitudes, laying date for Great Tits varies between February and April (Costa et al., 2005; Pimentel & Nilsson, 2007; Sanz et al., 2010; Bellavita & Sorace, 1991; Snow & Perrins, 1998). For Coal Tits it extends from March until May (Sanz et al., 1993; Fidalgo, 1990; Blondel et al., 1985). Research conducted at the same locations for both species show that Great Tits start to breed later than Coal Tits: 7-8 May and 2-6 May in Southern Ankara, Turkey, and 18 April and 13 March in Portugal respectively for Great Tit and Coal Tit (Kiziroğlu, 1982; Fidalgo, 1990). A similar result was found at METU. Mean dates were 5^{th} of May and 21^{st} of April for Great Tit and Coal Tit, respectively. Another parameter that influences laying date is altitude. There is a positive relation between altitude and laying date for both species (Figures 4.1 and 4.2) and results at METU roughly fit the trend line including other studies. Both species start to breed earlier than what was found in years between 1978 and 1980 at Beynam forest (Ankara). Both species were found to start breeding earlier than that was found by Kiziroğlu in late 1970s. This finding can partly be explained by an increasing temperature trend in Turkey (Türkeş et al., 2002; Öztürk et al., 2012). Changes in laying dates have been also documented in a study that has been conducting in England since 1947 (McCleery & Perrins, 1998). However, it is not possible to provide a conclusive explanation and more detailed observations should be done including different part of Turkey and taking climatic variables into account.

In Europe, it was found that breeding period coincides with the time of the emergence of insect prey, the main food source of tits (Perrins, 1970; Daan et al., 1988). In this study, it was not possible to detect any links between timing of breeding in tits and the abundance of their prey, but it might certainly influence the observed phenology.

Many factors are needed to explain the trends in differences in clutch size (Lack, 1948). General interval for clutches varies from 3 to 18 for Great Tit and 5 to 13 for Coal Tit (Snow & Perrins, 1998). Similar to laying date, the parameters that influence the total number of laid eggs are latitude and altitude. Mean values shows that

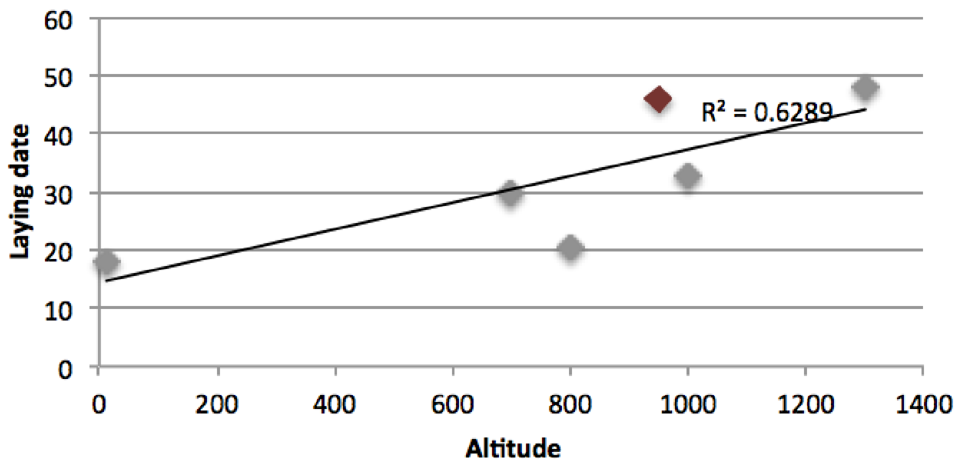

Figure 4.1: Relation between laying date and altitude for Great Tit (R^2 = 0.63) (Red symbol: METU)(Kabasakal & Albayrak, 2013; Sanz et al., 2010; Belda et al., 1991; Kiziroğlu, 1982;Fidalgo, 1980).

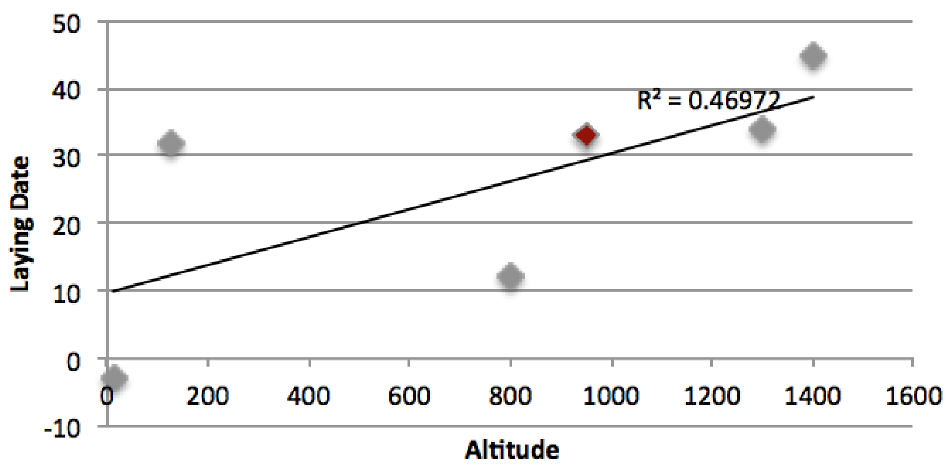

Figure 4.2: Relation between laying date and altitude for Coal Tit (R^2 =0.47) (Red symbol: METU) (Sanz, 1993; Fidalgo, 1990; Blondel, 1985; Kiziroğlu, 1982).

Great Tit generally produces a similar clutch size at METU (7.5) compared to other countries e.g. 6-7 in Portugal and Spain, including recent studies at similar latitudes (Fidalgo, 1990; Belda et al., 1998; Costa et al., 2005; Silva et al., 2012; Mackenzie et al., 2014). In Turkey, the mean clutch size is exactly the same value (7.5) with the study of Kiziroğlu (1982) but is lower than Kabasakal's (2012) findings (8.8). In the case of Coal Tit, clutch size (6.8 at METU) shows a lower value compared to a pine forest in Spain (7.8) and a higher value than in Portugal (6.2) (Fidalgo, 1990; Sanz et al., 1993) . In Turkey, only Kiziroğlu's study (1982) provides clutch size value for Coal Tit (7.9), which is higher than for METU.

Latitudinal differences are not sufficient on their own to explain the differences observed within Turkey. Habitat type might also influence clutch size; for example, smaller clutches were found in pine forests compared to other (e.g. deciduous) forest types (van Balen, 1973). Additionally, the high predation rate documented at METU might lead to a lower clutch size for Great Tit in the campus. However, it is not possible to extract the main cause for low clutch size, as it is a parameter that is affected by many different factors.

Altitudinal influence on clutch sizes can be seen at Figures 4.3 and 4.4, where a positive relation is present for Coal Tits, whereas no obvious relation between altitude and clutch size appears to exist for Great Tits.

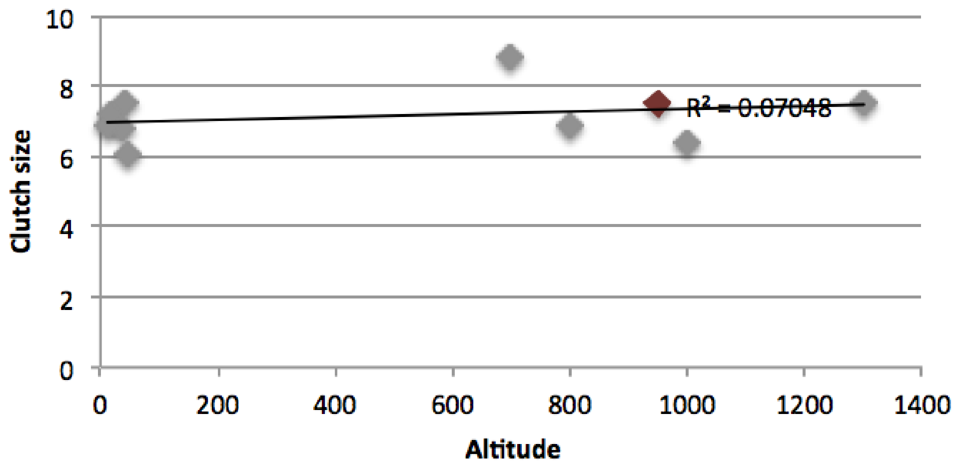

Figure 4.3: Relation between clutch size and altitude for Great Tit (Red symbol: METU) (R^2 = 0.07) (Mackenzie et al., 2014; Kabasakal & Albayrak, 2013; Sanz et al., 2010; Pimentel & Nilsson, 2007; Costa, 2005; Belda et al., 1991; Kiziroğlu, 1982; Fidalgo, 1980).

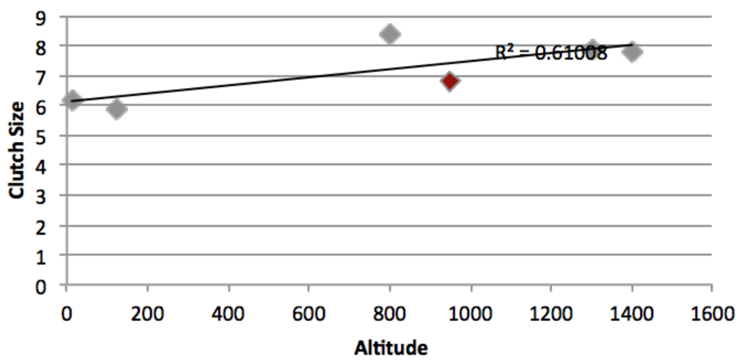

Figure 4.4: Relation between clutch size and altitude for Coal Tit (Red symbol: METU) (R^2 = 0.62) (Sanz, 1993; Fidalgo, 1990; Blondel, 1985; Kiziroğlu, 1982).

4.3 Low Breeding Success

High predation rates likely lead to low breeding success in METU populations of Great Tit and Coal Tit. Overall success rates were found to be 56% and 18% for Coal Tit and Great Tit, respectively. In other studies, success rates for both species are higher compared to METU. For example, these rates are 77% and 56% (for Great Tit) and 90% and 84% (for Coal Tit) in Spain and Portugal, respectively (Fidalgo, 1990; Sanz et al., 1993; Costa et al., 2005; Sanz et al., 2010). However those studies were mainly carried out in natural forests away from human settlements, which indicates much lower rates of human disturbance. Predation is the primary factor that shapes breeding success in this study. However other parameters, such as habitat conditions (i.e. food abundance), may have lowered breeding success.

Even though some parts of the METU Campus is an important stop for migratory birds (Keşaplı & Bilgin 2005), overall resource distribution through the areas with nest boxes does not indicate a high quality area to produce successful broods. Since nest boxes mimic natural holes on a tree, they offer nesting places for birds and may mislead the pairs to low-quality areas (Mand et al., 2005). Therefore unsuitable locations may become attractive. As a result, sites that were not preferred by pairs may be now chosen due to an unnatural influence. Unsuitability of the area might be related to limited food abundance. Therefore, such sites might affect the success of the pairs negatively.

Another possible explanation for the low success could be the link with the human population in the area. Since the study locations are close to university buildings and visited frequently by the students, this could cause disturbance for the pairs. Pairs have low breeding success at sites where human population is high and habitats are converted (Schalaepher et al., 2002). Both conditions apply to METU campus and observed low success can be explained by those changes. Additionally, it is found that traffic noise also lowers breeding success (Halfwerk et al., 2011), which is also present in the campus as it is close to one of the main roads of Ankara. Vehicle transport is also common inside the campus.

4.4 Importance of Predation

In this study, causes of nest failures were identified as desertion and predation, with the latter being a much more influential factor. Both species have suffered from high predation pressure as it made up 42.5% of nest failures. Unfortunately, studies elsewhere rarely included data on rates or agents of predation, so there are few studies that can be compared with the findings at METU campus.

At similar latitudes, only a few studies in Spain or Southern France reported on the predators and the severity of the predation. For Great Tit, rates were between 6% and 14% at four different forested areas, mainly covered with pine species (Sanz et al., 2010). Silva's study found the main cause of failure as starvation of nestlings (Silva et al., 2012). At two different locations in Southern France, 13% of the laid clutches were exposed to predation (Blondel, 1985). Additionally there are two studies from Turkey, where predation rates can be deduced. Both studies were carried out at the same pine forest, Lütfi Büyükyıldırım Research Forest, Antalya, in southern Turkey. Kabasakal et al. (2013) reported that 25% of the nests failed due to predation. In an earlier study conducted by Ministry of Forestry (Cakar et al., 2004), predation was reported as an overall sum where it was 8% for six different species including Great Tit and Coal Tit. Based on these comparisons, it is clear that predation pressure at METU campus is extremely high, probably playing a significant role in the dynamics of the those populations.

First of all, it reduces the average number of fledglings per attempted nest down to 1.4 for Great Tits, and 4.0 for Coal Tits. Predation pressure appears to be greater on Great Tits than on Coal Tits. When the expected high rates of mortality in their first winter is considered, the Great Tit population on campus is likely not able to grow, and might even be declining. On the other hand, no perceived changes in population levels during the last two decades were reported (C. Bilgin, pers. comm.). Therefore, either breeding success is much higher at "natural" nest holes near man-made structures and can compensate for the losses, or continual immigration from neighboring populations keeps the population levels stable.

Magpie was the main predator since it caused more than half (44%) of the nest failures of identified predators (67%). Two other recorded predators (domestic cat and fox) were not reported by other studies while snakes, which was the predator in only one nest in this study, have been reported (Blondel, 1985; Kabasakal et al., 2013, Kaçar et al., 2004; Sanz et al., 2010). Magpie is an opportunistic species and is one of the most abundant species at METU. Many predators shift their diet seasonally, based on the availability of resources (Begon et al., 1996). It has been observed that magpies find and predate experimental nests with small eggs within at most three days during spring season in the campus (C. Bilgin, unpublished data, 2014), suggesting that they are very effective as nest predators during that period.

CHAPTER 5

CONCLUSION

In this study breeding ecology of two Paridae species were investigated with the use of nest boxes at METU, Ankara. Great Tits and Coal Tits were found to build nests in the installed boxes. Findings show that laying dates and clutch size of both species are within the range of values that were found in other studies at similar latitudes. However, recorded breeding success was lower than other published studies.

The main reason behind the observed low breeding success was a very high rate of predation, which was mainly caused by magpies. Number of fledglings were only 4.0 and 1.8 for Coal Tits and Great Tits, respectively. These values indicate that the local population of Great Tit is highly impacted by predation and should lead to a decline in population size. It is possible that installation of nest boxes has led to an "Ecological Trap". The term was described in Schlaepher et al. (2002) as "the situation in which a bird's choice of nesting habitat led to nest failure because of a recent anthropogenic change in the environment that broke the normal cue-habitat quality correlation". In the frame of this definition, placement of nest boxes could be the recent human impact and might have led to a decline in the breeding success of the species. Therefore, the population is either in need of immigration from other locations to sustain itself or has a higher success in nests at natural cavities, compensating for the failures at the nest boxes.

In order to improve our understanding of population dynamics and breeding success of those two species further, following suggestions for the future can be made:

1. To reduce the predation pressure nest boxes could be built deeper, which might

hinder the predators to reach the nestlings.

2. A tube could be attached towards the inside (or outside) of the box entrance to avoid magpies or cats reach the bottom of the nest.

3. Observing the predation occurrence at natural and other available holes such as cavities on the buildings or other structures might provide more insight into the use of nest boxes and whether they really act as ecological traps. It is not possible to easily conclude natural cavities or next boxes has lower predation rates, since it varies in different studies (Nilsson, 1975; Nilsson, 1984; Evan et al., 2002). This variation is most likely related with the presence or absence of particular predators. Therefore, comparing predation rates among modified versus unmodified entrances would help to formulate new approaches to support local tit populations at similar sites.

Additionally, research can be developed in following years to assess other factors that possibly influence the breeding parameters in more detail, such as emergence of the prey (caterpillar) or particular climate variables. Although it is difficult and very much time consuming, estimates of total population size, survival and mobility of individuals can be done with mist net catches followed by ringing.

Members of Paridae are relatively easy to study as they readily breed in nest boxes. Such research also produce large amounts of data comparable with those in other countries. This study has created as a basis for further research at METU. In the end, integration of the conducted studies at different locations can help us understand changes in the environment globally and provide possible explanations for other species in terms of their ecology.

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APPENDIX A

MEASURED MORPHOLOGICAL PARAMETERS FOR COAL TITS AND GREAT TITS

For morphological measurements, techniques provided in Sutherland et al. (2004) were used as a guide. Wing lengths of individuals were measured with a stainless-steel ruler. Distance between carpal joint and tip of longest primary feather length was recorded. A digital caliper was used to measure tarsus length. All individuals were weighted with a 200 $\times$ 0.01 g mini digital scale.

Wing length, tarsus length and weight measurements were taken from each captured Great Tit and Coal Tit. In 2013, wing length measurements of fledglings were not complete. Average values for both species can be seen in Table A.1 and Table A.2.

Multiple linear regression analysis with dependent value of weight and independent values of body measures for each species did not show any significant relation between variables (for Great Tit adjusted R2:0.16, multiple R2: 0.25, p-value>0.05; for Coal Tit adjusted R2:0.15, multiple R2: 0.23, p-value>0.05). Comparison of two species in terms of weight showed that Coal Tit has lower body weight than Great Tit (p-value $<$ 0.05).

Table A.1: Body size values for Coal Tit (Mean±SD).

	Parent		Nestling	
	Female(4)	Male(3)	Female	Male
Wing length(cm)	6.65±0.77	7.16±0.9	4.7±0.19(10)	4.92±0.3(7)
Tarsus length(cm)	2.14±0.07	2.14±0.08	1.96±0.11(15)	2.08±0.23(9)
Weight(gr)	8.91±0.66	9.32±0.58	9.38±0.53(15)	10.66±0.61(9)

Table A.2: Body size values for Great Tit (Mean±SD).

	Parent		Nestling	
	Female(2)	Male(2)	Female(10)	Male(4)
Wing length(cm)	7.4±0.28	7.65±0.35	5.27±0.39	5.31±0.29
Tarsus length(cm)	2.12±0.14	2.32±0.17	2.2±0.12	2.14±0.21
Weight(gr)	15.87±0.64	16.56±0.13	16.49±2.62	15.91±3.61

APPENDIX B

SEX RATIO OF THE FLEDGLINGS

Sex of the parents and fledglings were identified with the purpose of additional data collection, which could be used for future studies. Preliminary assessment for the sex of the parents was made according to plumage coloration and this assessment was used as a control for the results of the blood tests.

Blood samples were taken from brachial vein, which lies along humerus bone. Site of the vein was cleared with alcohol first. With a 0.5 mm sterile syringe 2-3 drops of blood was taken and preserved in EDTA tubes. Until DNA analysis the samples were stored at 4°C. Research has shown that taking blood samples from brachial vein does not affect survival or reproduction rates of individuals (Sheldon et al., 2008; Lubjuhn et al., 1998).

DNA was isolated from both feather and blood samples collected from captured animals or from molted feathers in nests. To extract genomic DNA, Qiagen Blood and Tissue kit was used on the basis of standard kit protocols. CHD1F/CHDR primer set (Lee et al., 2010) was used to identify sex of birds by applying small modifications on the standart PCR conditions (Kunduz, 2012; Çakmak et al., unpublished). PCR products were run on 3 % of agarose gel at 80 Volts for 75 min to differentiate male and female bands. According to optimized conditions (Kunduz, 2012; Çakmak et al., unpublished), it is expected that males give a single band while females give two distinct bands.

In Total 35 Coal Tit and 18 Great Tit individuals were captured and sampled during two years. In some nests parents were not captured due to difficulties in trapping and to avoid premature fledging from nest. For Great Tit 14 fledglings from 5 nests and 4 parents from 3 nests, and for Coal Tit 28 fledglings from 5 nests and 7 adults from 4 nests were sampled.

Sexes of 3 nestlings and 1 nestling from two Coal Tit nests were not identified among the samples of 2013, thus those two nest boxes were excluded from calculations. Percentages of female sex ratio were found to be 71% for Great Tit and 69% for Coal Tit in 2014.