BREEDING ECOLOGY OF THE EGYPTIAN VULTURE (*Neophron percnopterus)* POPULATION IN BEYPAZARI

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

BİLGECAN ŞEN

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
BIOLOGY

DECEMBER 2012

Approval of the thesis:

BREEDING ECOLOGY OF THE EGYPTIAN VULTURE (*Neophron percnopterus)* POPULATION IN BEYPAZARI

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ABSTRACT

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December 2012, 66 pages

The aim of this study was to determine the habitat features affecting nest site selection and breeding success of the endangered Egyptian Vultures (*Neophron percnopterus*) breeding around the town of Beypazarı. We searched and monitored nest sites in the study area (750 km^2) for the years 2010 and 2011. The differences in terms of habitat features between nest sites and random points distributed along cliffs, and between successful and failed nest sites were investigated using both parametric approaches and machine learning methods with 21 habitat variables. The size of the Beypazarı population of Egyptian Vultures was estimated to be 45 pairs. Seventeen nests in 2010 and 37 nests in 2011 were found and monitored. The breeding success of the population was estimated to be 100% in 2010 and 70% in 2011. Random Forests was the modeling technique with the highest accuracy and the modeling process chose 6 and 4 variables affecting nest site selection and breeding success of the species, respectively. Results showed that human impact was a potential factor governing the distribution of nest sites in the area and increased the probability of breeding failure as vultures clearly preferred to nest away from nearby villages, towns and roads, and nests on lower cliffs and nests that are close to the dump site (therefore the town center) was prone to failure. Utilization of elevation gradient and aspect showed trends similar to other populations of the species, with probability of nesting increasing at lower altitudes and for south facing cliffs. The overall results emphasize the potential conflict between human presence and the population of Egyptian Vultures in the area. Continuous monitoring of the nest sites and conservation activities towards raising public awareness are advised.

Keywords: Egyptian Vulture, breeding success, nest site selection, Random Forests, Beypazarı

ÖZ

BEYPAZARI KÜÇÜK AKBABA (*Neophron percnopterus*) POPULASYONUNUN ÜREME EKOLOJİSİ

Şen, Bilgecan

Yüksek Lisans, Biyoloji Bölümü

Tez Yöneticis: Doç. Dr. C. Can Bilgin

Aralık 2012, 66 sayfa

Bu çalışma ile Beypazarı çevresinde üreyen tehlike altındaki Küçük Akbaba populasyonunun üreme başarısını ve yuva yeri seçimini etkileyen çevresel faktörlerin belirlenmesi amaçlandı. Bu bağlamda, 2010 ve 2011 yılları boyunca 750 km^2'lik çalışma alanında Küçük Akbaba yuvaları araştırıldı ve izlendi. Yuva yerleri ile kayalıklar üzerine rastgele dağıtılan noktalar arasındaki ve üremede başarılı yuvalar ile başarısız yuvalar arasındaki çevresel farklar hem parametrik yaklaşımlar hem de yapay öğrenme yöntemleri kullanılarak 21 habitat değişkeni açısından incelendi. Beypazarı populasyonunun büyüklüğü 45 çift olarak saptandı. 2010 yılında 17 ve 2011 yılında 37 çiftin yuvası bulundu ve izlendi. Populasyonun üreme başarısı 2010 yılı için %100 ve 2011 yılı için %70 olarak saptandı. Random Forests tahmin yeteneği en yüksek model olarak belirlendi ve modelleme sürecinde 6 değişkenin yuva seçiminde, 4 değişkenin ise üreme başarısında etkili olduğu saptandı. Sonuçlar insan etkisinin, Küçük Akbaba'nın hem yuva yeri tercihinde hem de üreme başarısında önemli bir faktör olduğunu gösterdi. Nitekim çiftlerin bariz bir şekilde, köylerden, ilçe merkezlerinden ve yollardan uzak yuva yapmayı tercih ettiği ve alçak kayalıklarda yer alan ve Beypazarı çöplüğüne (dolayısıyla ilçe merkezine) yakın yuvaların üremede başarısız olma ihtimalinin daha fazla olduğu saptandı. Rakım ve bakı gibi değişkenlerin türün diğer populasyonlarına benzer eğilimler gösterdiği belirlendi; yuvalama ihtimali alçak rakımda ve güneye bakan kayalıklarda daha yüksekti. Genel olarak sonuçlar bölgedeki insan varlığı ve Küçük Akbaba populasyonu arasındaki potansiyel çatışmayı vurguladı. Yuvaların sürekli olarak izlenmesi ve halkı bilinçlendirmeye yönelik koruma aktivitelerinin uygulanması tavsiye edilmektedir.

Anahtar Kelimeler: Küçük Akbaba, üreme başarısı, yuva yeri seçimi, Random forests, Beypazarı

TO MY BELOVED GRANDFATHER

MAY HE REST IN PEACE...

ACKNOWLEDGEMENTS

I must first and foremost thank my advisor Can Bilgin as he accepted me as his student in a very desperate time of my life when I had to abandon my first effort on graduate education in another university. Through the time we spent together, either in class or when putting the pieces together that would eventually become my thesis, he provided much needed scientific support and guidance. I learned the very basics of conservation biology and ornithology from him.

Jose Tavares is the reason why I am studying Egyptian vultures or even striving to become a conservation biologist. He introduced me with this subject and the species and I learned how to birdwatch for the first time directly from him in our many fieldtrips together. I sincerely appreciate his continuous support on the Egyptian Vulture project and also his personal support and trust on the fact that I will overcome and endure many hardships that come along when studying vultures and raptors.

Doğa Derneği provided my first professional job experience and during that time allowed me to study on my thesis freely and without interruptions. This fact alone is enough to remember them for the rest of my life.

During my undergraduate years, when I was very sure of the fact that I will be studying mammals in the years to come, it was Utku Perktaş who introduced me to the world of birds. Acknowledging the fact that everything I have done so far originates back to him will not be an overstatement.

The BSPB Egyptian Vulture Team from Bulgaria thought me how to do proper field work when studying Egyptian vultures. I have never met anyone as talented and motivated on the field as them. Their perfectionist and hardworking approach on monitoring Egyptian Vultures increased the quality of this thesis significantly. I am forever indebted to Ivaylo Angelov and his team.

I am of course grateful to my parents and to Gamze Ayaz whom I will spend the rest of my life with (hopefully!). Without them, none of the work I have done would have and will have any real meaning.

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LIST OF ABBREVIATIONS

NND: Nearest Neighbor Distance

GLM: Generalized Linear Models

CART: Classification and Regression Trees

RF: Random Forests

AUC: Area under curve

ROC: Receiving Operator Curve

AICc: Corrected Akaike Information Criterion

DistVil: Distance to nearest village

MeanSlope: Mean slope of the 1 km radius area around the nest site

Open: Percantage cover of open areas in 1 km radius around the nest site

DistDirt: Distance to nearest dirt road

DistRoad: Distance nearest road

DistTown: Distance to nearest county/town

CliffHeight: Height of cliff at the level of the nest

DistDump: Distance to Beypazarı dump site

DistPen: Distance to nearest sheep pen

Forest: Percantage cover of forests in 1 km radius around the nest site

CHAPTER 1

INTRODUCTION

1.1. Biodiversity Crisis in Turkey

Turkey is in a biodiversity crisis. Every aspect of nature, from species level to habitat and ecosystem levels, is threatened with diverse and common anthropogenic pursuits such as deforestation, overgrazing, erosion, dams, pollution, wetland loss and touristic development (Şekercioğlu et al., 2011). Ranking only 109th out of 132 countries in the environmental performance index (EPI) in 2012 (Emerson et al., 2012), it is obvious that the national effort to tackle this crisis is inadequate.

Under such circumstances, the approach of Birdlife International, a global organization focusing on bird conservation, revolves around four goals:

- Species
- Sites
- Habitats
- People

Under the *Species* heading Birdlife prioritizes conserving and preventing the extinction of globally threatened bird species. Considering the fact that Turkey has 16 globally threatened bird species (IUCN, 2012), this is a viable conservation target for the country that will affect the current crisis.

Based on a stochastic model using 9916 bird species it was shown that scavengers will have the highest extinction rate by 2100; between 30% to 50% of scavenger bird species are expected go extinct or become functionally deficient (Sekercioğlu et al., 2004). This finding puts a special emphasis on the vultures in Turkey since all four European vultures not only breed in Turkey but also make up the most crowded breeding population of vultures after Spain in Europe. Unfortunately information on many key features of Turkish vultures – exact numbers, nesting and nutrition habits, migration routes etc. – is missing as there are only a handful of publications concerning these topics (Yamaç, 2006; Dik and Yamaç, 2008; Heredia et al, 1997; Vaassen, 2001; Vaassen and Aykurt, 2003; Sroubek, 2005).

Among the four European vultures (Cinereous, Griffon, Bearded and Egyptian) Egyptian Vulture is the only one that is globally threatened thus making it an important conservation target in Turkey in the light of the information given above.

1.2. The Egyptian Vulture

Vultures are obligate and primary scavengers whose diet consists of carcasses of various sizes. They are different from animals that opportunistically feed on carrion (secondary scavengers) as their many adaptations – long and bald head, exceptional soaring flight and low stomach pH – are specialized towards finding and consuming carcasses in a very efficient manner (Houston, 2001; Ruxton and Houston, 2004).

There are 23 species of vultures belonging to the families Cathartidae (New World vultures, n=7) and Accipitridae (Old World vultures, n=16) (Ogada et al., 2012). These two families have different evolutionary origins and their main scavenging traits have evolved independently as an example of convergent evolution. A similar relationship can be observed within the Accipitridae family. Gypaetine and Aegypinae subfamilies have evolved carrion eating life styles through convergence as well. Therefore, the animals that we call “vultures” actually belong to three separate lineages and their morphological and behavioral similarities are the result of parallel selective pressures rather than genetic relatedness (Seibold and Helbig, 1995; Wink, 1995; Lerner and Mindell, 2005).

The two vultures belonging to the Gypaetinae subfamily are the Egyptian Vulture (*Neophron percnopterus*) and the Bearded Vulture (*Gypaetus barbatus*). The conservation of these two species will also be significant in preserving a rare evolutionary lineage.

1.2.1. Physical Characteristics

The Egyptian Vulture is one of the smallest vultures with a wing span of only 155-180 cm and a weight of 1,5-2,5 kg. Its most characteristic features are the wedge shaped tail also shared by the Bearded Vulture and the yellow beak observed in majority of the adults (Figure 1.1). Juveniles have a rather dark plumage with black-brown feathers. Through the fourth and fifth winter, overall darkness of the feathers decrease gradually and the birds attain near adult plumage with black primaries and white body and secondaries. Even though the general morphology is very different from White Storks (*Ciconia ciconia*), the coloring of the feathers make it possible to mistake one for the other (Cramp and Simmons, 1980).

Figure 1.1. An adult Egyptian Vulture. Photo by Murat Çuhadaroğlu.

1.2.2. Feeding Habits

Egyptian vultures are not dominant when feeding on carrion together with larger vultures such as the Griffon Vulture or the Cinereous Vulture. Usually, after waiting for its turn, it can only feed on various scraps left from carcasses (Ferguson-Lees and Christie, 2001). This is not only a dominancy issue though, as its relatively weak bill can not tear up the skin of a big carrion and is more suited for softer tissues (Cramp and Simmons, 1980).

As a response to this limitation, Egyptian Vultures have adapted to feed on various organic material within its feeding range and to congregate on big rubbish dumps (Cramp and Simmons, 1980). Its main diet item can vary from rabbits to pigs or to slaughtered sheep depending on the location of the roost they use to spend the night (Ceballos and Donazar, 1990a). Opportunistic as they are (Margalida et al., 2012), their feeding habits also vary with their local fauna and depending on the presence and the contents of a rubbish dump, but in general it might be concluded that the preference is usually towards small bird and mammal remains (Vittorio and Campobello, 2002; Hidalgo et al., 2005).

1.2.3. Breeding Biology

European population of the Egyptian Vulture is migratory, breeding between March and August then migrating to the south of the Sahara in September. They are territorial and nest in cliffs usually with a clutch size of 2 (1-3). Pairs mate for life. Incubation period lasts 42 days and time to fledging after hatching takes another 70 to 90 days. Age of first breeding is the 5th winter (4-5 years) or later, and it has been observed that birds that did not yet attain adult plumage may also breed (Cramp and Simmons, 1980; Ferguson-Lees and Christie, 2001).

The Egyptian Vulture is a species with high copulation frequency when compared to other raptor species. Donázar et a.l (1994) report that during the fifteen days before laying, total number of copulations per female is 55±18. Reports for polyandry and extra pair copulations are rare for the species. In the Ebro Valley, Spain, out of 58 pairs only 5.4% of the females showed polyandrous behavior during 11 years (1980-1991). This number is lower than 14,3% which was observed in the Egyptian Vulture’s sister species Bearded Vulture (Tella, 1993). In a different study only one extra pair copulation was recorded out of 38 copulation attempts (Donázar et al., 1994).

Both members of the pair take part in incubation and in finding food for nestlings and fledglings (Cramp and Simmons, 1980; Newton, 1979). The length of the post fledgling period may vary greatly between 9 to 37 days. Fledglings are dependent on parents for food until migration and show aggressive behavior towards parents as feeding density decreases gradually in the post-fledging period (Ceballos and Donazar, 1990b; Donazar and Ceballos, 1990). Despite this dependency, fledglings migrate independently of and apparently earlier than their parents (Donazar and Ceballos, 1990). This behavior is completely opposite of Newton's generalization that bigger raptors tend to have longer post fledging periods and that many vultures remain in the care of their parents for months (Newton, 1979).

Egyptian Vultures has been observed to peck at cow dung or droppings of goats and sheep. Negro et al. (2002) postulate that this behavior is to obtain essential carotenoids that ungulate faeces are rich in; carotenoids will eventually form the yellow color of the beak and face. They argue that this is a behavioral adaptation for the demonstration of dominancy in mating through display of the yellow face.

1.2.4. Habitat Preference

Suitable cliffs with medium to large sized caves and ledges that allow nest building is the most important limiting factor for the distribution of the species as ground or tree nesting is rare and local (Ferguson-Lees and Christie, 2001; Gangoso and Palacios, 2005). It has been reported that limestone cliffs are especially suitable for Egyptian vulture nests since they are easily eroded and supply more caves (Mateo-Tomás and Olea, 2009).

The preferred landscape structure that surrounds a nest site is favored towards open lands coinciding with Egyptian Vulture's foraging needs. As a result, the species is usually associated with habitats such as steppes, savannas, plains, river banks and many other diverse open terrain (Cramp and Simmons, 1980; Ferguson-Lees and Christie, 2001).

Even though there are extreme cases of 4500 m in Ethiopia or 3600 m in Caucasus, Egyptian Vultures usually nest below 2000 m. Within this variation of elevation it has been shown that at a local context they may prefer either to nest at lower elevations (Mateo-Tomás and Olea, 2009) or higher elevations (Liberatori and Penteriani, 2001) when compared with randomly distributed points along cliffs.

Egyptian Vultures are usually tame and indifferent to man using rubbish dumps in towns or villages (Cramp and Simmons, 1980), sometimes nesting in ruined buildings near urban centers in India. However, the European population seems to be more distant to anthropogenic effects and structures, choosing areas with less road density (Mateo-Tomás and Olea, 2009), avoiding urbanized areas in favor of

Mediterranean vegetation (Sarà and Vittorio, 2003) or abandoning territories which are surrounded with extensive agriculture altogether (Carrete et al., 2007).

1.2.5. Global Population Size and Distribution

Egyptian Vultures are widely distributed throughout Europe, North Africa, sub-Saharan Africa, the Middle East, Central Asia and India (Figure 1.2). Birdlife International's estimate of the European breeding population is 3300-5050 pairs, roughly equivalent to 25-49% of the world population; a crude estimate for the global population size would be 20,000 to 63,000 individuals (Birdlife, 2012).

The mainland population of the Egyptian Vulture is comprised of two subspecies: *Neophron percnopterus percnopterus* and *N. p. giniginanus*. The latter subspecies is a resident in the Indian subcontinent and generally smaller in all measurements with an all yellow bill in adults; *N. p. percnopterus* has a bill with a black tip (Ferguson-Lees and Christie, 2001). Apart from the mainland, the small Canary archipelago population was also shown to be a different subspecies (*N. p. majorensis*) with even larger bodies than the European population (Donazar, Negro, et al., 2002).

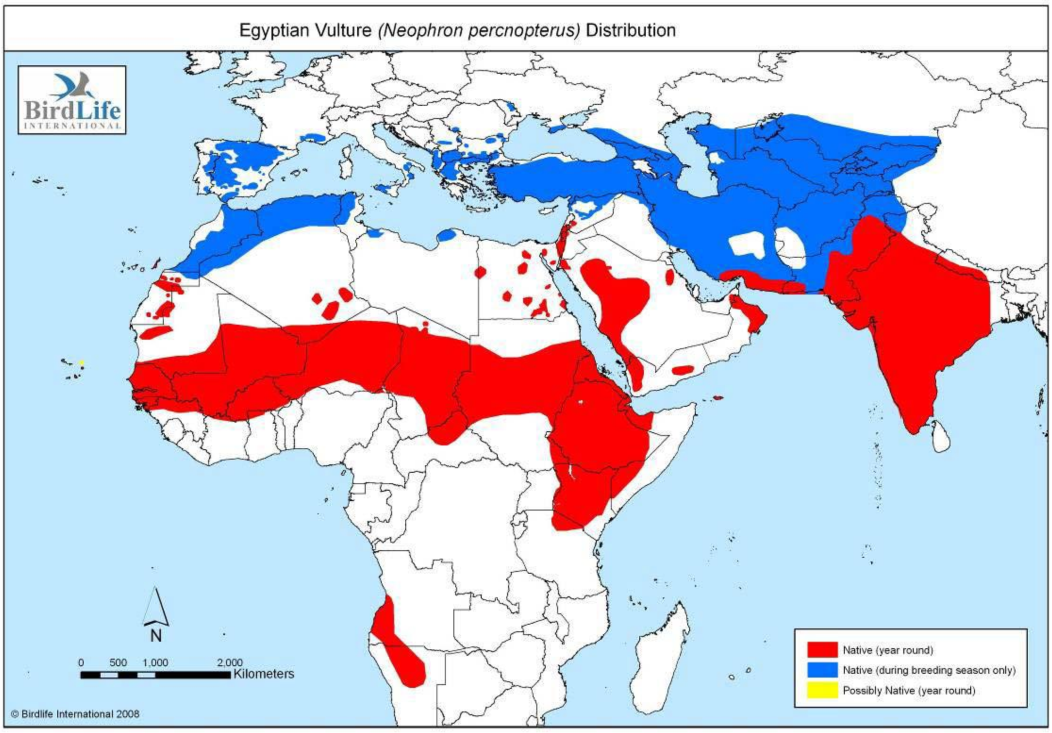

Figure 1.2. Global distribution of the Egyptian Vulture (Inigo et al., 2008).

The Turkish population of Egyptian Vultures might as well be the largest breeding population after Spain; Birdlife's estimate is 1500-3000 pairs. The wide range in the estimate is caused by lack of information. The species is distributed through most of Turkey except for the coastline and large plains without hills (Figure 1.3).

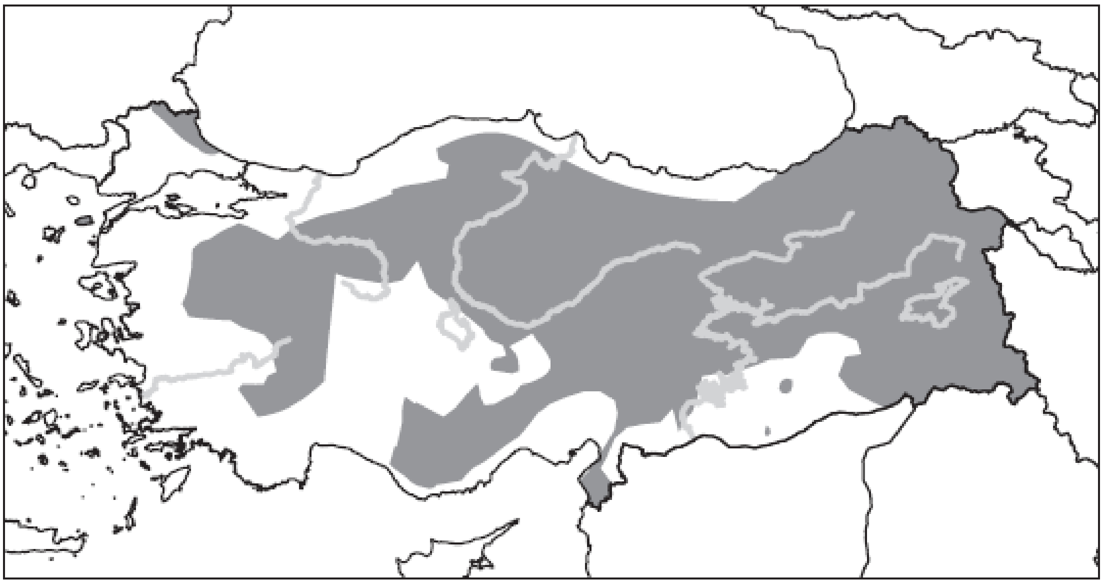

Figure 1.3. Distribution of the Egyptian Vulture in Turkey (Kirwan et al., 2008).

1.2.6. Conservation Status and Threats

The Egyptian Vulture is classified as Endangered with a declining population trend since 2007 by IUCN. Five main threats have been identified and were included in the "Species Action Plan for the Egyptian Vulture in the European Union" (Inigo et al., 2008). We defined four threats with certain modifications to the species action plan. The fifth threat, decline of extensively bred livestock, was incorporated into the heading "Strict European Union Sanitary Legislation."

1.2.6.1. Poisoning

The Egyptian Vulture is an agile raptor as a direct result of its light build and small size (Cramp and Simmons, 1980). When this trait is combined with its opportunistic nature, poisoning by the consumption of poisoned baits which are originally intended for mammalian predators becomes a significant threat, especially affecting adult individuals (Hernández and Margalida, 2009). This type of poisoning is suggested to be one of the most critical threats affecting the Egyptian Vulture populations in the European Union (Inigo et al., 2008).

Unfortunately poisoned baits are not the only way for the species to be exposed to dangerous chemicals. The anti-inflammatory drug diclofenac which was widely used as a veterinary medicine to treat livestock, caused a catastrophic vulture population decline in Indian subcontinent, mainly affecting *Gyps* spp. (Oaks et al., 2004; Green et al., 2004). Even though with a later onset, a rapid and a significant decline was also observed for Egyptian Vultures raising the question whether diclofenac is responsible for this downward trend as well (Cuthbert et al., 2006). On the other hand, several veterinary antibiotic residuals were found in the nestlings in the Egyptian Vultures in central Spain. These residuals, passed to vultures from medicated livestock, could damage livers and kidneys of the vultures and may result in an increased mortality after continuous exposure (Lemus et al., 2008).

Another but more limited type of poisoning is through the ingestion of lead shots from hunted animal remains. Blood sampling of the Canary Islands population of Egyptian Vultures showed high toxicity levels (Donazar, Palacios, et al., 2002).

1.2.6.2. Strict European Union Sanitary Legislation

Following the bovine spongiform encephalopathy (mad cow disease) crisis (Tella, 2001), sanitary legislation in the European Union forbid leaving livestock carcasses in the wild with continuous industrial disposal of 80% of the animal carcasses generated in extensive livestock farms (Margalida et al., 2010). Necessary regulations were made in the legislation in the following years ensuring a constant supply of food through the so called “vulture restaurants”. However, vulture restaurants provide a very predictable feeding opportunity to a species guild adapted to a highly available, unpredictable and randomly distributed (both in time and space) food source, resulting in an artificial modification of habitat quality (Houston, 2001; Donázar et al., 2009). The research on this topic is limited but it has been shown that a reduction in carrion density either left on the field or in a vulture restaurant may induce a dietary shift in Griffon Vultures, leading to a diet overlap with the Egyptian vulture. It is argued that in the short term this could have a negative effect on Egyptian Vultures as Griffons are the dominant species (Donazar et al., 2010). In March 2011 new EU regulations were introduced allowing farmers to abandon their animals either in the field or in the feeding stations, creating a more unpredictable environment that is reminiscent of what vultures are adapted to (Margalida et al., 2012).

1.2.6.3. Collisions with Wind Turbines

Data concerning the long term impacts of wind turbines on Egyptian Vultures is scarce. But what little available is sufficient to demonstrate that the global trend of building wind farms may have severe affects on the decline of the Egyptian Vulture. Through population viability analysis, Carrete et al. (2009) showed that wind turbines closer to breeding territories than 15 km increase the mortality rate of breeding individuals. Even though this rate is small (0.015), in the long term it increases the possibility of extinction of all the Spanish meta-population of Egyptian Vultures. Since taking precautions against wind farms is easier and more applicable than trying to prevent poisoning incidents which are highly uncontrollable, it was advised that turbines threatening breeding pairs should be powered down or never built at all.

1.2.6.4. Disturbance from Human Activities

Despite the fact that all the threats explained above can be described as human disturbance, “activities” under this heading refer to more direct disturbances such as modern outdoor pass times (trekking, biking, climbing etc.). Zuberogoitia et al. (2008) reported that out of 100 breeding attempts they observed, 42 were affected through human disturbance. Thirteen cases were related to forestry work which involved cutting open new forest tracks too close to breeding territories. Similar to the precautions against the wind farms, forming spatial buffer zones that will forbid building forest tracks or pass time activities close to territories was advised.

1.3. Aims and Scope of this Study

As indicated before, scientific research regarding the biology and the ecology of the vultures in Turkey are scarce. Thus, it is natural for any initial studies that focus on closing this knowledge gap to have an exploratory nature. In this study, we wanted to provide answers to very simple ecological questions on the population ecology of Egyptian vultures such as:

- Where do they breed and which environmental factors affect their breeding distribution?
- What is their population size?
- What is their yearly breeding success and how many young do they produce each year?
- What are the major threats affecting their breeding success?

Answering these questions at a national scale requires many years of research in a very large study area covering many different types of habitats and is beyond the scope of this study. Instead we focused on a smaller, local scale where species was known to be breeding based on amateur birdwatcher records. Our aim for this study was to answer these questions for the population of Egyptian Vultures in Beypazarı.

CHAPTER 2

MATERIALS AND METHODS

2.1. Study Area

Beypazarı is a province of Ankara, 100 km away from the city center with a population of 47,014 people (TİK, 2011; Figure 2.1). The immediate area around Beypazarı contains 3 Key Biodiversity Areas, namely: Kirmir Valley, Sarıyar Dam and Nallıhan Hills (Eken et al., 2006). This fact demonstrates the area's rich biodiversity but also emphasizes its community structure which is mainly composed of rare, endemic and threatened species.

This biodiversity is a direct result of the transaction of three floristic zones in the area: Euro-Siberian, Irano-Turanian and Mediterranean. The south-western part of the area is mainly composed of steppe habitat with agricultural fields concentrating around the Sarıyar Dam reservoir. Proportion of forested land increases as one goes north, with Black Pine (*Pinus nigra*) in the East and Turkish Pine (*Pinus brutia*) in the West. The endemic plant species distributed throughout the area include *Verbascum gypsicola*, *Salsola grandis* and *Astragalus beypazaricus* (Eken et al, 2006). Even though sightings of Griffon Vulture (*Gyps fulvus*), Cinereous Vulture (*Aegypius monachus*) and Bearded Vulture (*Gypaetus barbatus*) are common throughout the area, we did not come across any vulture nests apart from those of Egyptian Vulture in our fieldtrips. Other nesting raptors include Long-Legged Buzzard (*Buteo rufinus*), Black Kite (*Milvus migrans*), Golden Eagle (*Aquila chrysaetos*), White-tailed Eagle (*Haliaeetus albicilla*) and Eagle Owl (*Bubo bubo*). Black Storks (*Ciconia nigra*) have a very dense population in the area, perhaps even more crowded than that of Egyptian Vultures. The presence of rivers and creeks such as Kirmir and Aladağ in the Pleistocene period caused the formation of numerous valleys with steep cliffs through continuous erosion (Eken et al., 2006), the effects of which can be seen in the diversity of the cliff nesting raptors mentioned above.

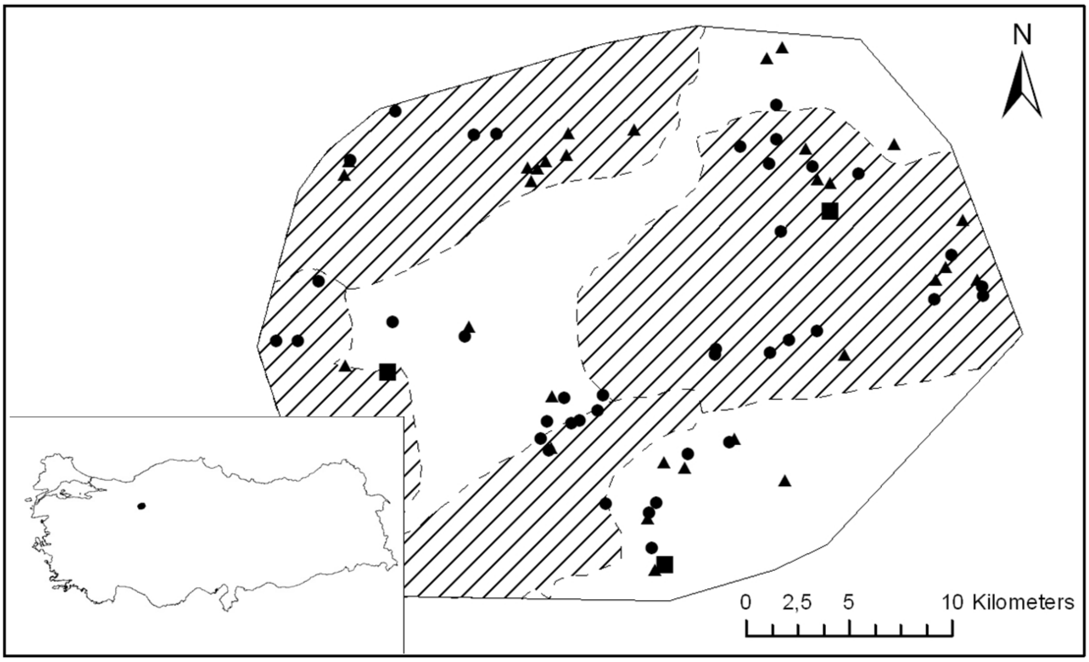

Figure 2.1. Study Area. Circles: Nest sites. Triangles: Random points distributed for modelling process. Squares: Town centers. Lined areas indicate the key biodiversity areas inside the study area.

We conducted the field trips in an approximately 750 km^2 area (Figure 2.1). Preliminary inventories in 2010 showed that pair density in the area was very high and our initial study area was too wide to thoroughly monitor every possible pair. Therefore we limited the study area down to its current size in 2011 (Figure 2.1). We determined the lowest slopes of the Köroglu mountain range as a natural border to the north. Towards the south, east and west, the density of suitable cliffs decrease progressively and the amount of open land increases. In the west Nallıhan Bird paradise, in the east Acısu village, and in the south Oymaağaç village were determined as boundaries. Even though this study area was drawn with consideration of habitat features of the wider area, it does not mean that the population we study is limited by those boundaries. Pairs that are found outside this study area can be considered as part of Beypazarı population in the future studies. It is important to note that there are other towns and municipalities in the area but Beypazarı is the biggest town and acts as a major trade center. Therefore, even though the study population extends outside of the Beypazarı county borders we still named it the "Beypazarı population" for ease of communication.

The elevation in the study area changes from 440 meters in valley bottoms in the south to 1804 meters through mountainous regions in the north. The average annual temperature and precipitation is 13ºC and 398 mm, respectively (Akman, 1990).

2.2. Locating Nests and Pairs

It is logical to divide the breeding season of the Egyptian vultures into successive stages as suggested by Newton (1979): (i) Occupation of territories and pair formation, (ii) pre-laying, (iii) laying, (iv) incubation, (v) nestling and (vi) post-fledging periods. It is not always practical during fieldwork to distinguish the first three stages so we used "pre-laying period" as covering all stages until the beginning of incubation in the breeding season. Also, since breeding success of a raptor is determined by the status of the nests just before juveniles fledge (Steenhof and Newton, 2007), post fledging period is not included in this study.

We located nests and pairs mainly in the pre-laying period. Since the field study in 2010 was a preliminary inventory of the species in the area, the methodology for finding nests and pairs differed slightly between 2010 and 2011 and is explained under separate headings. The method for nest observations conducted in incubation and nestling periods was the same for both years so it is discussed under the same heading.

2.2.1. Finding nests in 2010

As indicated before, Egyptian Vulture is a territorial and cliff nesting species. In that respect finding pairs and nests is a relatively straightforward process. In this first year of the study, we marked cliffs and rock formations around Beypazarı using Google Earth. We prioritized checking marked cliffs for nest presence but not every cliff could be determined on a map. Therefore, we observed every cliff that could potentially inhabit nests during the field work. A wide area from the village Kargı in the south and Kıbrısçık in Bolu in the north was checked for vulture presence. Pair finding took place in the first week of April and lasted for 6 days. April is the best month for mapping pairs of Egyptian Vultures because most of the pairs in our study area are in the pre-laying period through April thus showing high aerial activity near their nest sites, similar to other raptor species (Newton, 1979).

When we observed two Egyptian Vultures flying over a cliff, we marked the cliff as potential territory and noted those two vultures as a potential pair (Cramp and Simmons, 1980; Ferguson-Lees and Christie, 2001; Newton and Steenhof, 2007). This simple approach proved to be satisfactory as later in the nest finding process we were able to find nests in those territories, concluding that the cliff is indeed occupied by a breeding pair. A better way to decide if two vultures flying together is a pair is to observe them and look for specific behavioral patterns (Cramp and Simmons, 1980; Ferguson-Lees and Christie, 2001). If for example two vultures copulate then they are definitely a pair and their territory must be nearby (Newton, 1979). We have occasionally observed vultures copulating and were able to find nests close to where the copulation took place.

Another sign to look for is aerial displays which can either be a part of the pair formation process, or a form of territorial defense if another raptor is in the territory (Cramp and Simmons, 1980; Ferguson-Lees and Christie, 2001). One common type of aerial display is characterized by quick dives and ascents in rapid succession. This is not specific to Egyptian Vultures and can be observed in other raptors as well (Newton, 1979). We did not observe this type of behavior as often as copulation. There are times when one can see neither a behavioral pattern nor can find a nest in the potential territory. The best way to understand the presence of a territory in such cases is to observe the site more than once throughout the breeding season, and sometimes across years. If one can see two Egyptian Vultures in the territory in a frequent manner then they are most likely a pair, and the cliff and a limited unknown area surrounding it is, with a high probability, the territory of that pair. There is no other known reason for two Egyptian Vultures to be frequently observed in the same cliff and territory.

With those methodological details in mind we observed the cliffs in the aforementioned area for 6 days and determined definite, and sometimes potential pairs. This was the first time in Turkey that Egyptian vultures in a given area were mapped in a systematic way.

Finding the nests in the territories of the pairs is a more rigorous process depending on the nest type. Nests on ledges are somewhat easier to find and observe (Figure 2.2) but nests inside deep caves (Figure 2.3) need more time and attention both to observe and find. A nest inside a cave may not present any clue or sign, such as sticks or droppings for the observer to acknowledge it as a proper nest. Even when nests are relatively visible they may be hard to find on a 4 km long cliff. Once the incubation starts most adults show only their heads when incubating, making it hard to observe from a distance. Therefore, the best time for finding nests is in the pre-laying period, several days before incubation begins. Pairs spend more time during this period in their territories and around potential nest sites and they can be observed carrying nest material (e.g. wooden sticks, wool) to the nest itself. This is the best way to identify a nest before incubation begins. Especially for secluded caves without any proper sign of a nest site, observing an adult Egyptian Vulture carrying nest material to the cave is the only way to define it as a nest in the pre-laying period. In such caves, once the incubation begins the incubating bird will not be visible. Other methods to observe such nests are explained in the “Nest Monitoring” section.

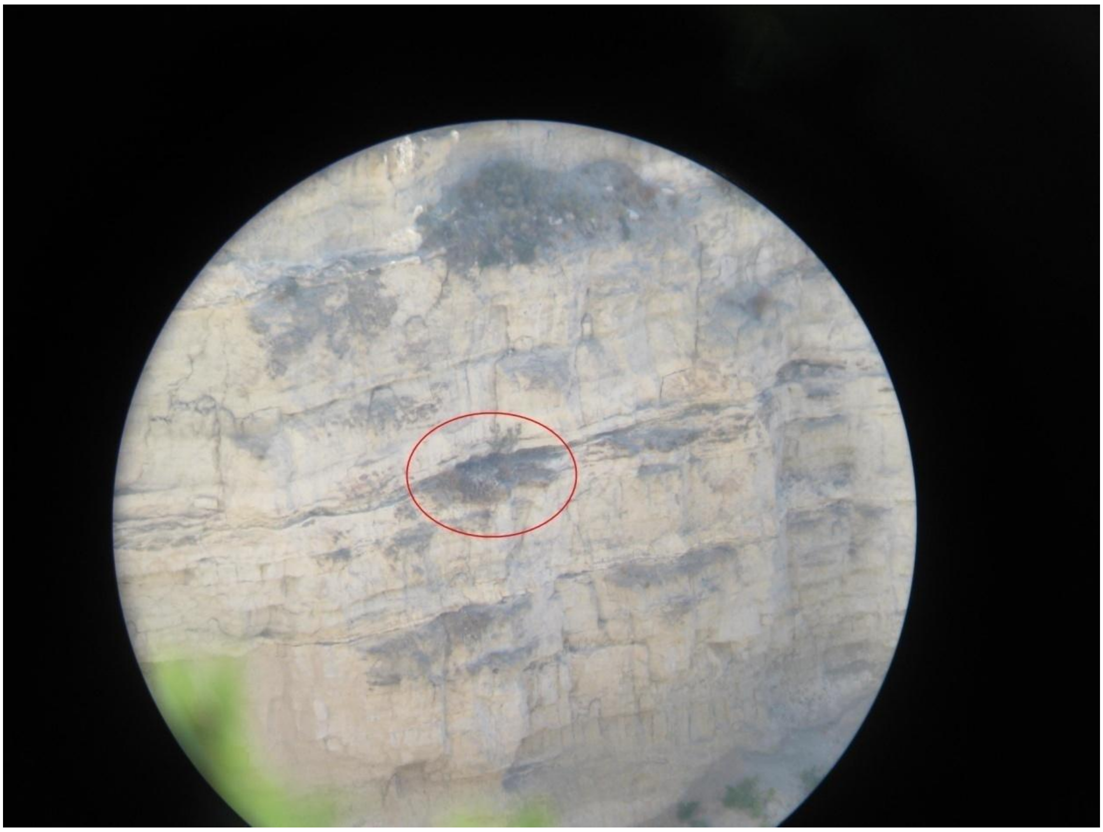

Figure 2.2. Nest on a ledge. Both the observation point and the nest’s outward structure is an advantage for visibility during monitoring.

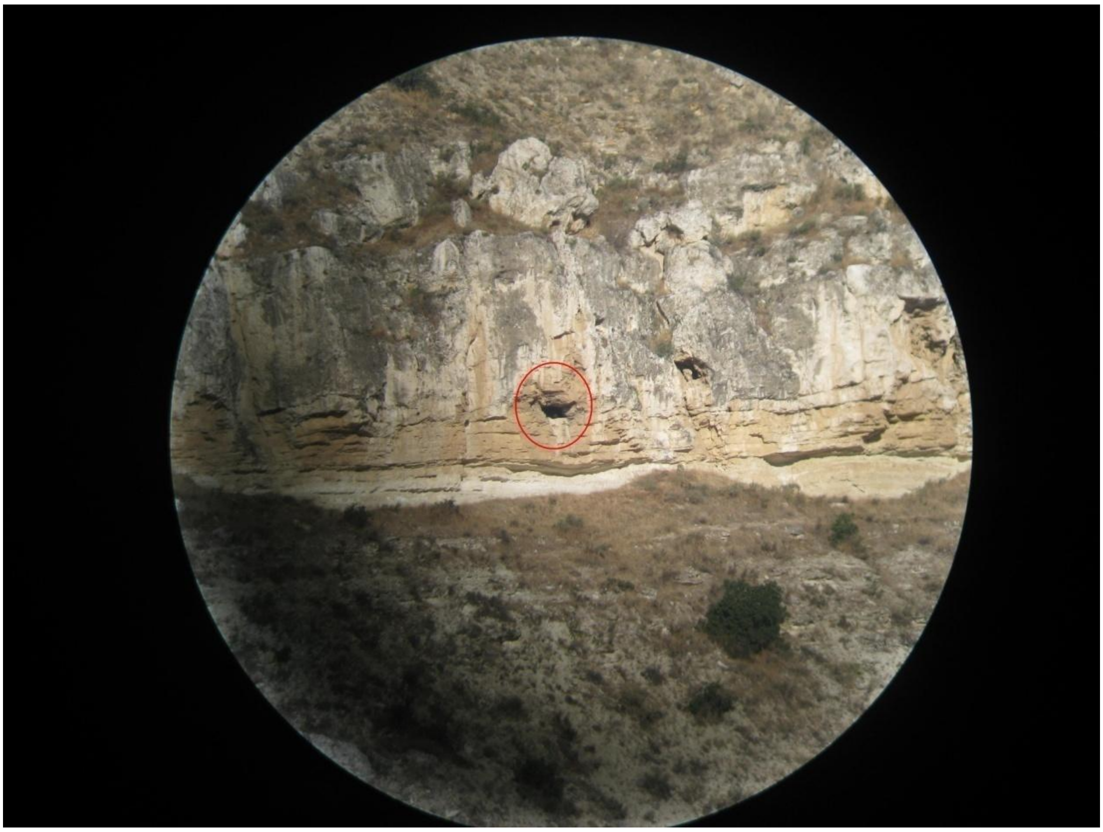

Figure 2.3. Nest inside a deep cave. Monitoring is dependent on behavioral clues of adults since incubating birds are usually not visible.

Because of logistics and funding problems in this first year, we started looking for the nest sites of the detected pairs in early May. Therefore we missed the pre-laying period and most of the pairs had already started incubating. This made nest finding very hard and time consuming, and resulted in finding a low number of nest sites (see Results). We spent 18 field days between April 30 and June 21 for locating nests. Afterwards all effort was concentrated on monitoring known nest sites.

2.2.2. Finding nests in 2011

Egyptian Vulture pairs have high fidelity to their territories and nests, and may use the same sites over years (Snow and Perrins, 1980). This might be the case in Beypazarı population as well, since out of 19 pairs that we regularly observed in 2010 (see Results) only 1 presumably changed its nest to a site closer to the older one on the same cliff. Because of the high re-occupancy rates we had the opportunity to look for new pairs and nest sites in 2011.

The methodology to find pairs and nests in 2011 did not differ from 2010 except for the details explained above. We spent 14 field days between April 5 and April 22 for locating nests and pairs. Since we started the fieldtrips earlier in 2011, it was easier to locate nests because of the behavioral patterns explained above. While all of the pairs had begun incubating by the time we found their nests in 2010, only a few were incubating in 2011. After April, all effort was concentrated on monitoring known nest sites.

As we did not climb or descend to Egyptian Vulture nests, we were not able mark their exact locations. Therefore, all of the found nests were marked on Google Earth with the help of nest site photographs and GPS points near nests in both 2010 and 2011.

2.3. Territory and Nest Monitoring

The methodology for monitoring nests depends on the nest type (ledge or deep cave) and the period of the breeding season (incubation or nestling).

For nests on ledges or in shallow caves, observations are relatively easy because both the incubating adult and the hatched nestlings can be easily seen. In such cases when we determined the status of nest sites quickly, observations were momentarily conducted to avoid disturbance. However, in the nestling period, when chicks had just hatched, it was possible to see only an empty nest as adults tend to leave the nest for short periods of time. It is easy to mistake those nests as failed, so we observed them for an additional 15-30 minutes to see a movement from chicks.

For deep caves, observations are very time consuming. In such nests, during the incubation period the incubating adult cannot be seen. Both sexes incubate (Snow and Perrins, 1980), so for a couple of times during the day, one partner leaves the nest with the other one to incubate while it forages for food. This behavior is called a “changeover” (Newton, 1979). An adult Egyptian Vulture does not leave the nest until its partner arrives at the nest to take up incubation role. Therefore, on the field, when we saw an adult flying into one of the nests in a deep cave and just afterwards saw an adult flying out of the nest, we assumed that was a changeover and the nest was still active. In deep cave nests, as long as the fledged juveniles do not fly out of the nest, neither the young nor incubating adults can be seen by conventional observations. Because adults have to feed the chicks, they bring back food to the nest for a couple of times every day. When we saw an adult carrying food material (in its beak) to the nest, we determined that nest was still active and eggs had hatched.

Identifiable behavioral patterns of breeding pairs are not frequent and require longer observations than other typical nest sites. We observed these nests for 2 hours at maximum. When we could not determine the status of a nest by the methods mentioned above, whether it is on a ledge or on a deep cave, we repeated the observations with the same methods on a different day until the status of the nest was determined. The details of when we determined a nest as successful or as failed is explained later in the section "Assessing Breeding Success".

In 2010, nest and territory monitoring took place from 30th of June to 13th of August (12 field days) and in 2011 from 5th of May to 25th of August (26 field days). When a pair did not lay eggs until May we monitored the approximate territory around the nest site to decide if the pair was going to breed that year and whether they were going to use a different nest site (Martínez and Blanco, 2002). Territory monitoring at those sites were continued until August, even if the pairs did not lay eggs. On average, there were 6.70 visits (min=4, max=8) per nest site in 2010 and 4.35 visits (min=2, max=8) per nest site in 2011.

2.4. Assessing Breeding Success

Breeding success of a raptor population can be decomposed into two parts: Nesting success and productivity. We defined them as in Newton and Steenhof (2007).

Nesting success: The proportion of pairs that raise at least one young to the minimum acceptable age for assessing success in a given season, even if it takes >1 attempt. Usually reported per territorial pair or per laying pair.

Productivity: The number of young that reach the minimum acceptable age for assessing success; usually reported as the number of young produced per territorial pair or per occupied territory in a particular year.

We estimated nesting success and productivity per territorial pair, only using pairs with known nest sites that were regularly observed.

The important detail in these definitions is the “minimum acceptable age” of a young when we deduce the nest as successful. In a perfect theoretical situation a nest is successful only when at least one young is fully fledged and can leave the nest. However, it is a very unlikely to be observing the nest just when the young has fledged and ready to fly. Therefore, it is logical to determine a nest successful when at least one young has grown to near adult proportions (Newton and Steenhof, 2007). Another important thing to note is that the death of a fledged young does not make the nest it belonged unsuccessful. Since fledged individuals can fly away from the nest site, nesting period ends with fledging (Newton and Steenhof, 2007).

Steenhof (1987) suggests that for diurnal raptors minimum acceptable age should be 80% of the fledging age because the mortality greatly reduces after this threshold (Millsap, 1981). To age a juvenile raptor and in our case a juvenile Egyptian Vulture, one needs to climb to the nest and measure several morphological characteristics of the young (Donázar and Ceballos, 1989). This is not feasible in our study area, because there are many nests that we cannot climb as the type of rock of nesting cliffs and height of nests makes such a venture unsafe.

The time to fledgling is between 70 to 90 days (Snow and Perrins, 1980) and 80% of those values are 56 and 72. Considering the fact that incubation takes 42 days (Snow and Perrins, 1980), the total amount of time needed to determine a nest successful is between 98 to 114 days. If we assume that the earliest incubation begins on the 10th of April and the latest on the 10th of May, the range in which we can accept a nest as successful varies from 17th of July to 1st of September. Usually it is not possible to determine exactly when incubation began in a nest, so on average we determined a nest successful if it had at least one juvenile that is of near adult proportions within the time zone July 25 and August 25. If a nest became empty in either the incubation period or the nestling period and continued to stay that way (i.e. the pair did not breed again) until mid August, the nest was considered as failed.

2.5. Assessing Nest Site Characteristics

2.5.1. Random Point Distribution

To compare with the nest sites we generated random points along the cliffs in the study area. If the nest site selection pattern of the Egyptian Vultures in the area is different than random than the statistical models should be able to spot the difference between actual nests and random points.

We generated 350 random points with 200 meter radius circles in the study area using ArcGIS 9.3.1. Then we filtered out those points using the following rules and checking the locations of the points with Google Earth:

- If there were no cliffs within 200 meter of the point, that point was discarded. If there was a cliff, the point was moved to the nearest spot on that cliff.
- If the point was in a territory of a pair with an unknown nest - that was not included in the study - it was discarded.
- If the point was in a valley or on a cliff which was not regularly checked, it was discarded for the fact that there could be an unknown pair and nest very close to it.

After the filtering process 70 points were selected. Then, we checked the locations of the points in the field to make sure that the cliffs they are on are actually suitable for Egyptian Vultures to nest. Finally, only 30 points were included in the analysis. It is important to note that the exact location of these points does not necessarily indicate a suitable cave or a ledge that the Egyptian Vulture can nest but rather they represent a random point on an overall suitable cliff that the species can nest.

2.5.2. Habitat Variables

We selected 20 habitat variables to use in the statistical models that would investigate the differences between random points and actual nest sites. We included an additional variable (Nest Type) for the analysis of successful and failed nests. The habitat variables were chosen in parallel to other Egyptian vulture studies conducted in Spain and Italy (Mateo-Tomas and Olea, 2009; Carrete et al., 2007; Sara et al., 2003; Liberatori and Penteriani, 2001). The full list of variables and their abbreviations are on Table 2.1. All variables were calculated using ArcGIS 9.3.1.

20 of these variables were used in the studies referenced above but we used a different variable (Distance to nearest sheep pen) to link the importance of livestock presence to nest site selection. Also, several variables which were included in the models of Mateo-Tomas and Olea (2009) were not used in our analysis. Details of some those variables are discussed below.

2.5.2.1. Distance to Sheep Pen

The general approach to link the importance of livestock to Egyptian Vulture’s nest site selection is to use number of cows, goats, sheep, pigs etc in a predetermined area around the nest site (Mateo-Tomas and Olea, 2009; Carrete et al., 2007). Since our study area is very small compared to others (8500 km^2 in Mateo-Tomas and Olea, 2009; 25,414 km^2 in Sara Vittorio, 2003; all Spanish pairs in Carrete et al., 2007) and average nearest neighbor distance is only 1,5 kilometers, any number of livestock in a pair’s territory would also be accessible for other neighboring pairs, making the variable irrelevant for nest site selection at a smaller scale.

Instead we used “distance to nearest sheep pen” as a livestock variable. Cattle farming is rare around Beypazarı and the main source of income is sheep and goat rearing. Therefore, the number of sheep pens is very high in the study area. We were able to locate 33 sheep pens close to nest sites. We hypothesized that if livestock were significant for the nest site selection of the species at a smaller scale, perhaps through spending more time following herds, the possibility of an Egyptian vulture nest being closer to a sheep pen would be higher than a random point.

2.5.2.2. Distance to Dump Site

Distance to nearest dump site or feeding station (sometimes referred to as *mularades* in Spain) is a common variable used in models of nest site selection of Egyptian Vultures to investigate whether artificial feeding places have any effect on the species’ nesting behavior (Mateo-Tomas and Olea, 2009; Carrete et al., 2007; Liberatori and Penteriani, 2001). In our study area, due to its small scale, there was only one dump site that Egyptian vultures regularly visited. Therefore, the variable we used only referred to the distance to the Beypazarı dump site.

2.5.2.3. Nest Site and Cliff Variables

As indicated earlier, the 30 random points selected for analysis do not represent a ledge or a cave that an Egyptian vulture pair can nest but rather is a random spot on a cliff that potentially has caves and ledges suitable for Egyptian vultures. Directly selecting a cave or a ledge as random point was not feasible, as one must be sure that the cave or ledge in question must not be inhabited not by just Egyptian vultures but any other raptor or bird species. If they are inhabited, the research question changes and statistical models investigate differences of nest site selection of Egyptian vultures and all other bird species that nest on similar cliffs. To thoroughly understand the patterns that lead to the selection of a specific site, one must analyze the deviations from randomness which is represented by those 30 random points. To our knowledge, there were no previous studies of cliff nesting species in the area. Hence, we did not have the means to choose caves or ledges that were not used by Egyptian vultures as it was unknown whether they were being used or had been used by any other species. Therefore, we did not use some of the nest specific variables such as nest type and entrance cover in our analysis since it was not possible to calculate these for the random points. Also, since we were not able to climb up the nests, it was not possible to calculate the height of a nest from the ground accurately and this variable was also excluded from the analysis.

Another important variable usually included in the Egyptian Vulture nest site selection studies is cliff length. In our study area, because of the low average nearest neighbor distance (*NND*), many nests and random points share the same cliff face, resulting in the same value for the length of the cliff. This in turn, if used in analyses, would lead to spatial autocorrelation. For this reason, we did not use cliff length in our analyses.

2.5.2.4. Habitat Cover Variables

We used 6 variables which were related to habitat cover: Percentage cover of urbanized land, agricultural areas, open areas, water and forests within 1 kilometer radius of the nest. The sixth variable was the number of Corine habitat cover types within a radius of 1 kilometer. We used Corine Land Cover 2006 raster data Version 15 (2011) to correctly classify habitat cover types. We checked the accuracy of this classification by importing Corine data into Google Earth. Most of the land cover classification was correct and only a few changes were necessary.

We did not use circles with a bigger radius of as 2.5, 4 or 8 km (Mateo-Tomas and Olea, 2009; Carrete et al., 2007; Liberatori and Penteriani, 2001) for characterizing the nest site habitat, because of the low average NND of the population. If we used bigger circles, there would be high overlap leading to a significantly greater spatial autocorrelation in model residuals.

2.5.2.5. Intra- and Inter Specific Relationships

When they coexist, Griffon Vulture (*Gyps fulvus*) is a direct competitor of the Egyptian Vulture (Donazar et al., 2010), and variables such as the number of Griffon Vulture nests close to Egyptian Vulture nest sites had been used in some habitat models (Mateo-Tomas and Olea, 2009). However, Griffon vultures do not nest in our study area and they were a rare sight during our fieldtrips. We were able to locate nests of other raptors close to the nests of Egyptian vultures such as those of Long-legged Buzzards and Black Kites but apart from the nests that we found, there are no reliable data about those species for our study area. Therefore, the only variable that was related to intra- or inter-specific interactions of Egyptian vultures in our analysis was NND.

2.6. Statistical Methods

We used 3 different modeling techniques to define the relationship between the absence-presence of a nest (random point vs. actual nest) and the explanatory variables: Generalized Linear Models (GLM), Classification Trees (CART) and Random Forests (RF). Because our sample size was small (n=69 for nest site selection, n=37 for habitat effect on breeding success) we did not divide our data into training and test sets. All model results are obtained from the original data set.

We only used Random Forests for the analysis of the differences between failed and successful nests. After the analysis, all models were compared using accuracy (error rate of the model when predicting cross validated data), AUC (the area under the receiving operator curve (ROC)), sensitivity (rate of correctly classified presences) and specificity (rate of correctly classified absences). AUC gets values between 0.5 and 1. Better fitted models have higher values and are closer to 1.

Table 2.1. Variables used in the modeling process. Nest Type was only used in breeding success analyses. Elevation, aspect, slope and relief variables were calculated using a digital elevation model with 100 meters resolution.

Variable	Definition
Nest Site	
CliffHeight	Height of cliff at the level of the nest (m)
Aspect	Orientation of the nest (in degrees)
Elevation	Altitude of the nest (m)
Slope	Slope of the nesting cliff at the point of the nest (in degrees)
NestType	2 categories of nests: on a ledge or inside a cave
Landscape	
Habitat	
Water	Percantage cover of water in 1 km radius around the nest
Urban	Percantage cover of urbanized land in 1 km radius around the nest
Agri	Percantage cover of agricultural areas in 1 km radius around the nest (arable land, permanent crops, pasture)
Forest	Percantage cover of forests in 1 km radius around the nest (Coniferous and mixed forests, woodland shrubs)
Open	Percantage cover of open areas in 1 km radius around the nest (natural grasslands, sparsely vegetated)
Class	Number of Corine habitat types in 1 km radius around the nest
Relief	
MeanSlope	Mean slope of the 1 km radius area around the nest
IRR	Irregularity index calculated as the standard deviation of the MeanSlope
Food	
DistDump	Distance to Beypazarı dump site (m)
DistPen	Distance to nearest sheep pen (m)
Interspesific	
NND	Nearest neighbour distance (m)
Human Presence	
DistDirt	Distance to nearest dirt road (m)
DistPaved	Distance to nearest paved road (m)
DistRoad	Distance nearest road (dirt or paved) (m)
DistVillage	Distance to nearest village (m)
DistTown	Distance to nearest county/town (m)

We calculated these classification measures by cross validation using *caret* package in R statistical software.

Correlation in the final selected variables of the three different models was calculated as Pearson moment product correlation coefficient (Sokal and Rohlf, 1995). Variables that have the least contribution to the related model from the highly correlated variable pairs (r>0.5) were removed from the model.

Spatial autocorrelation was investigated by calculating the Moran’s I value for the model residuals.

All statistical models were performed using R statistical software (R version 2.6.2; The R Foundation for Statistical Computing, 2012).

2.6.1. Generalized Linear Models (GLM)

We first used generalized linear models with a binomial error distribution and a logit link function to model the differences between random points and real nests (Mccullagh and Nelder, 1989). This type of GLM is also called logistic regression. We employed a hierarchical method in which variables from landscape and nest site scales were modeled independently and chosen variables from the models of these two scales were then combined to construct final models. Models were compared using corrected Akaike Information Crietrion (AICc) and variable selection was carried out as multi model inference (Burnham and Anderson, 2002; see Appendix A for detailed description of the model).

2.6.2. Classification and Regression Trees (CART)

CART is a recursive partitioning technique in which the aim is to split the sample data depending on the explanatory variables so that each resulting node after the split will be as “pure” as possible either with lower error rates (categorical variables) or with lower within group variances (continuous variables) (Breiman et al., 1984). If the response variable is categorical (nominal) classification trees are used and if the response variable is continuous regression trees are used instead. Since our response variables are nominal (presence/absence and success/failure) we used only classification trees. Together with random forests, CART is also called a decision tree method (see Appendix B for detailed description of the model).

2.6.3. Random Forests (RF)

Random forests (RF) method is an improvement over CART (Breiman, 2001). Instead of growing just one tree, it grows a very high number of trees (as the name forest implies) and makes its predictions on a majority vote basis from every tree in the forest. We used variable importance scores and partial dependence plots to further investigate the affects of the explanatory variables on nest site selection and breeding success of the Egyptian Vulture (see Appendix C for detailed description of the model).

2.6.4. Spatial Autocorrelation

Spatial autocorrelation is the violation of the assumption of independence of the error terms in models when residuals that belong to cases closer in space tend to have similar values than residuals of cases far apart (Legendre and Legendre, 1998). One way to investigate the amount of spatial autocorrelation is to calculate Moran's I value of the model residuals. Formula for Moran's I value is as follows:

$$I = \frac{n}{S_0} \times \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} \times (y_i - \bar{y})(y_j - \bar{y})}{\sum_{i=1}^{n} (y_i - \bar{y})^2}$$

y_i and y_j are the model residuals at the sites i and j. w_{ij} is the distance weight and S_0 is the sum of all distance weights between all pairs of sites i and j. n is the number of observations.

Moran's I values for the models were calculated using *ape* package in R.

2.7. Dump Site Observations

We counted Egyptian vultures feeding on Beypazarı dump site on a weekly basis from a fixed location in 2010. Counts started between 6:30 and 7:30 am and lasted for 2-2.5 hours. Five independent counts were made per session, usually at 30-40 minutes intervals. Following Margalida and Boudet (2003) 3 age groups were defined: juvenile, immature (second and third winter), and adult (≥fourth winter) (aging guide by Clark and Schmitt (1998) was used).

In 2011, counts were monthly and we changed the location in which we conducted counts. Due to methodological differences between the years, results were not statistically compared.

CHAPTER 3

RESULTS

3.1. Population Size

We confirmed the presence of 45 territorial pairs by the end of the breeding season in 2011. Additionally, we located 8 potential pairs which were not monitored regularly in the study period (Figure 3.1). There were also 10 pairs that we located outside the study area in 2010. Even if we consider only the 45 confirmed pairs, the density of the Beypazarı population is extremely high: 6 pairs per 100 km^2.

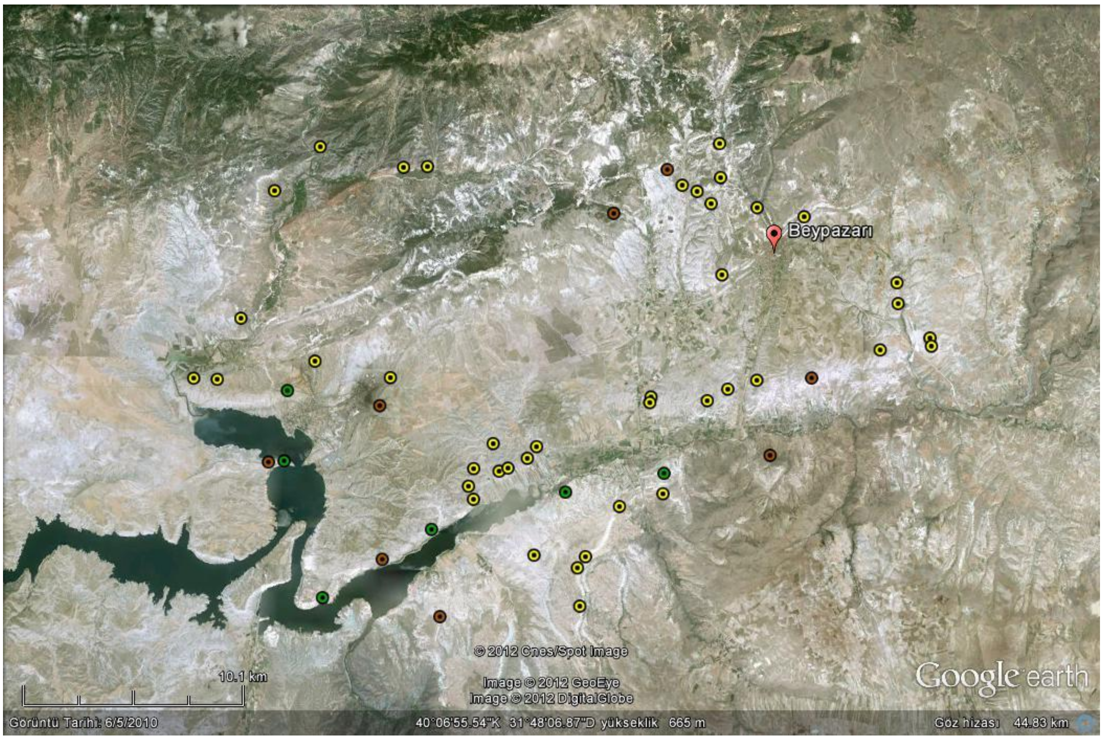

Figure 3.1. Nest and territorial pair distribution in the study area. Yellow dots: Confirmed nests. Green dots: Confirmed pairs with unknown nest sites. Brown dots: Potential pairs.

3.2. Breeding Success

Out of the 45 confirmed pairs, we found 19 nests in 2010 and increased this number to 39 nests in 2011 in which every nest belonged to a single pair and territory. We were able to determine the status of 17 nests in 2010 and 37 nests in 2011.

All 17 pairs were successful in 2010 with 28 fledglings. 11 pairs had two fledglings while 6 pairs had only one. Therefore nesting success is 1 (100%) and productivity is 1.65 (Table 3.1). 26 pairs were successful in 2011 with 32 fledglings while 11 pairs failed breeding: 3 pairs never laid eggs, and 8 pairs failed during incubation. Nesting success was 0.7 and productivity was 0.86 (Table 3.1).

Table 3.1. Breeding success for years 2010 and 2011

Year	Regularly Observed Pairs	Pairs with Known Breeding Status	Successful Pairs	Total Number of Fledglings	Failed Pairs	Nesting Success	Productivity
2010	19	17	17	28	0	1 (17/17)	1,65 (28/17)
2011	39	37	26	32	11	0,7 (26/37)	0,86 (32/37)

3.3. Nest Site Selection

3.3.1. GLM

After ranking the models with their respective AICc values, eliminating the models with the 2>ΔAICc from the best model and model filtering as Richards (2008) suggested, selected GLMs from the nest site scale included *Elevation* and *Aspect*, while at the landscape scale included *DistVil* and *MeanSlope* as variables. The combined models were constructed using these 4 variables and their every permutation. Table 3.2 shows the models within 2< ΔAICc range of the best model and their respective Akaike weights. After model filtering only 2 models were left: Aspect+Elevation and Elevation. These two models were averaged and a negative relationship between the possibility of a point being a nest and the *Elevation* and *Aspect* of a nest site was demonstrated.

Table 3.2. Combined models using selected variables form nest site and landscape scales. Only models within the range of 2< ΔAICc from the best model is shown. After the filtering process, models in bold were used for model averaging.

Models	AICc	ΔAICc	Weight
Aspect+Elevation	90,4	0	0,258
Elevation	91,1	0,73	0,179
Aspect+DistVil+Elevation	91,6	1,27	0,137
DistVil+Elevation	92,2	1,78	0,106

3.3.2. CART

The unpruned classification tree can be seen in Figure 3.2. The pruning process was carried out according to the *cp* and cross validation error rates in Figure 3.3. The size of the tree with the highest *cp* which was within one SE range of the cp with lowest cross validation error rate was 1 (Figure 3.3), so the tree was pruned back to its root. CART determined that explanatory variables have no statistically meaningful effect on nest site selection of the Egyptian Vultures.

3.3.3. RF

A default of *mtry*=4 was selected for the initial random forest model (Table 3.3). The OOB-error rate of the initial forest was 40.58% and 12 variables had negative variable importance scores (Table 3.4). These variables was discarded from the final forest models along with *Open* and *DistDirt* which was correlated with *DistVil* (0,516; p=0,000) and *DistRoad* (0,886; p=0,000), respectively, but had lower importance scores. *mtry*=4 was selected for the final forest construction (Table 3.3). The lowest OOB-error rate among the ten constructed final forests was 27.54%. The model was able to correctly classify 33 nests and 17 random points while misclassifying 6 nests and 13 random points.

Table 3.3. OOB-error rate comparison by mtry value for nest site selection forests. Values in bold were selected for model construction.

Initial Forests		Final Forests	
mtry	OOB-error	mtry	OOB-error
2	42,03%	1	30,43%
4	**42,03%**	**2**	**27,54%**
8	44,93%	4	33,33%

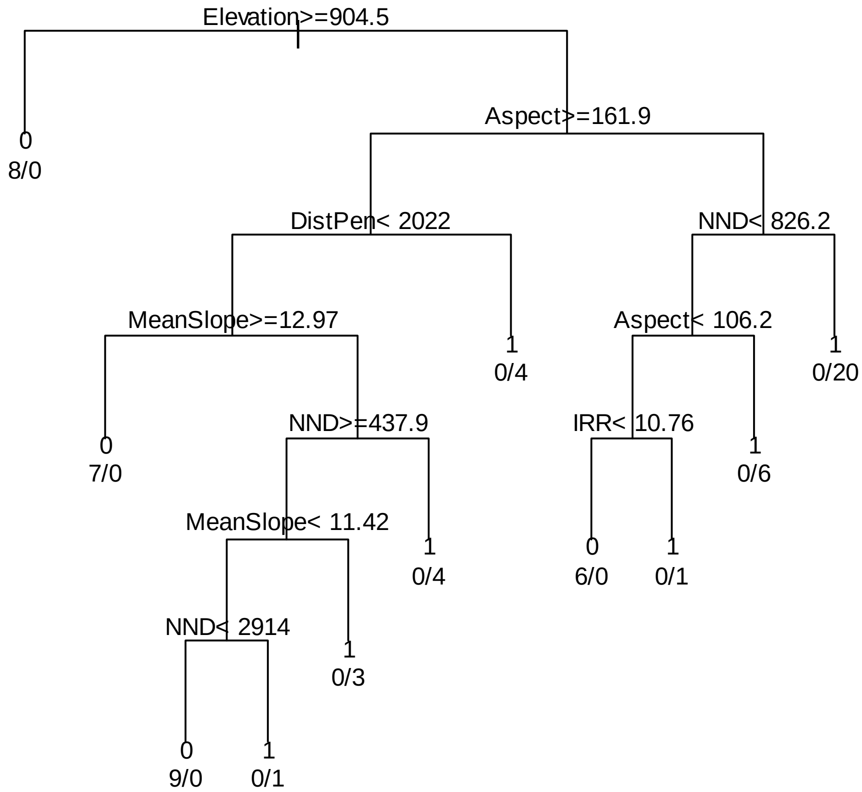

Figure 3.2. Unpruned classification tree for nest site selection. This model is an overfit. To read the tree: if a case is true for the rule above a node go left; if it is not go right. Final leaves are predictions: left of the slash is random point, right of the slash is actual nest site.

Similar to GLM, *Elevation* and *Aspect* were selected by RF as important variables which determine the nest site selection of Egyptian vultures (Table 3.4; Figure 3.4). Some variables that were “missed” by GLM were deemed important by RF such as *NND*, *DistTown*, *DistVil* and *DistRoad*. Partial dependence plots in Figure 3.5 and Figure 3.7 shows the detailed relationship between an explanatory variable used in the final forest and a measure of probability of a point being a nest site. The probability of nesting decreased with increasing elevation. Also, the effect of aspect was clearer when compared to GLM as the probability was highest for nests facing southeast. Plots also showed that pairs in Beypazarı preferred to put some distance from the nearest human settlements, either small or large. This effect was also apparent in the distance to nearest road as the species preferred not to nest too close to roads. The territorial behavior of the Egyptian vultures became apparent with increasing probability of nesting as the nearest neighbor distance increased to 1.5 km.

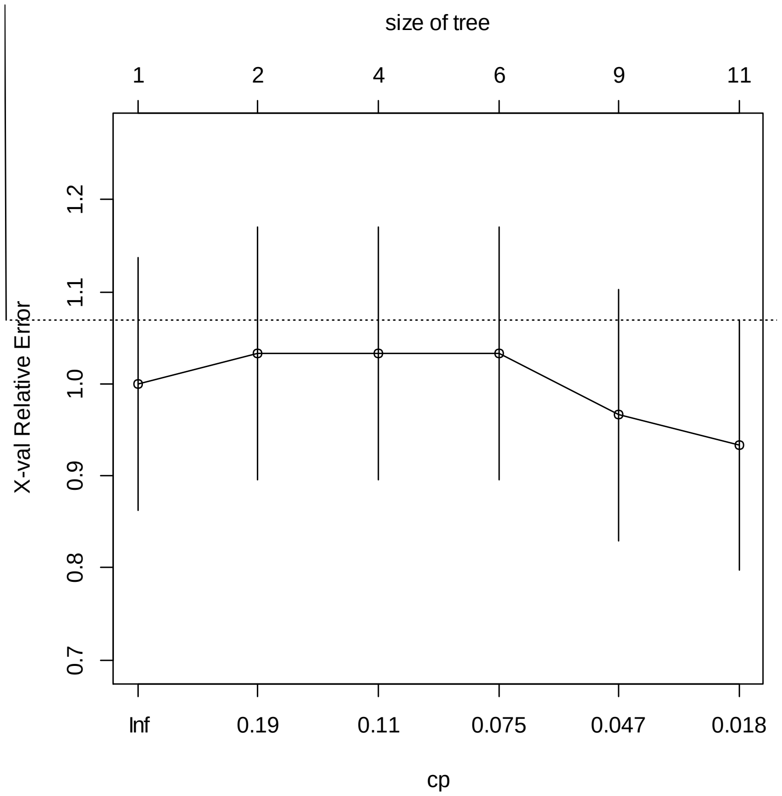

Figure 3.3. Mean cross validated error rates relative to the root node error after certain splits for the unprunned nest site selection tree. Solid vertical lines show the standard errors of the mean cross validated errors. Horizantal dashed line indicates the 1 SE zone of the lowest cross validation error. The tree size under this line with the highest *cp* is 1.

Table 3.4. Variable importance scores of the initial and final random forest models for nest site selection. Variables in bold were selected for the final forest construction.

Variable	Mean Decrase in Accuracy	Variable	Mean Decrase in Accuracy
Elevation	3,033	Elevation	4,566
NND	1,964	NND	3,905
DistRoad	1,321	DistVil	2,651
DistVil	1,316	DistRoad	2,381
Aspect	0,822	Aspect	2,361
DistTown	0,707	DistTown	2,316
Open	0,340		
DistDirt	0,173		
CliffHeight	-0,070		
DistPen	-0,285		
Class	-0,326		
Forest	-0,406		
DistPaved	-0,513		
DistDump	-0,585		
MeanSlope	-0,678		
Urban	-0,754		
Water	-0,711		
Agri	-0,712		
IRR	-1,161		
Slope	-1,477		

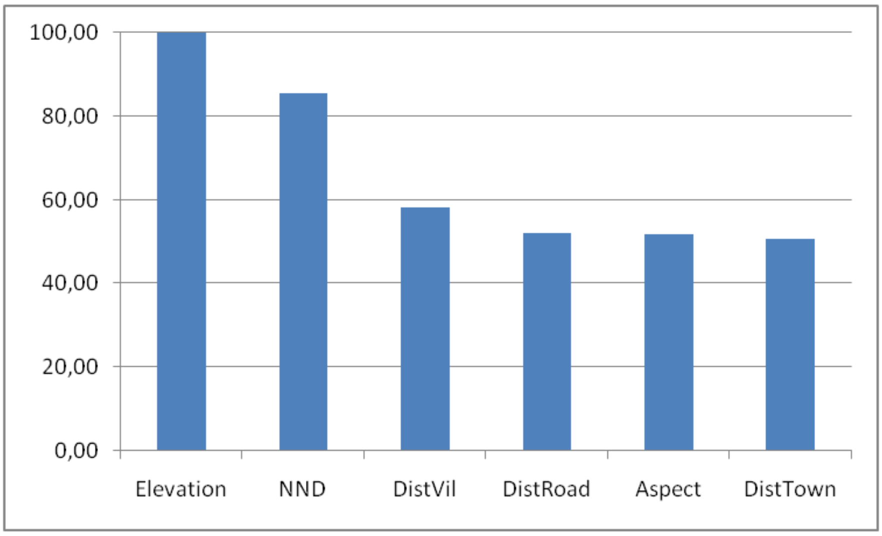

Figure 3.4. Variable importance scores of the final forest for nest site selection. Scores were scaled to 100 for easier interpretation.

3.4. Effects of Habitat Features on Breeding Success

We employed the same method with nest selection when using random forests to investigate the effects of 21 explanatory variables (an additional variable was nest type) on breeding success. The best *mtry* value for the initial forest construction was 4 (default value; Table 3.5). Initial forest had an OOB-error rate of 35.14%. Seventeen variables had negative importance scores (Table 3.6) and they were discarded from the final model. A value of *mtry*=1 was selected for final forest construction (Table 3.5). The lowest OOB-error rate among the ten constructed final forests was 27.03%; this was an 8% improvement over the initial forest. The model was able to correctly classify 22 successful and 5 failed nests, while misclassifying 4 successful and 6 failed nests.

Table 3.5. OOB-error rate comparison by mtry value for breeding success assesment forests. Values in bold were selected for model construction.

Initial Forests		Final Forests	
mtry	OOB-error	mtry	OOB-error
2	37,84%	**1**	**29,73%**
4	**35,14%**	2	35,14%
8	35,14%	4	37,84%

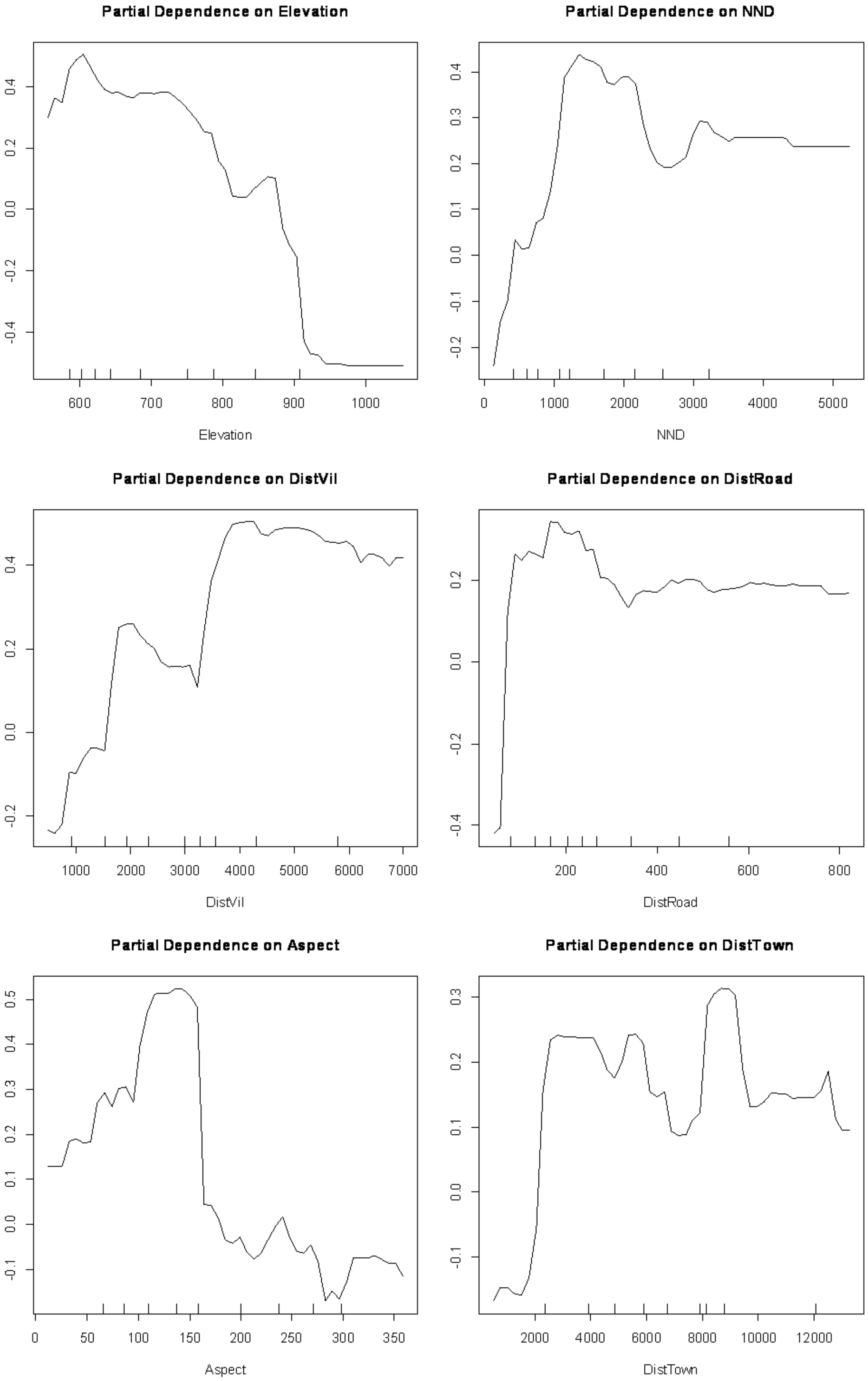

Figure 3.5. Partial dependence plots of Elevation, Aspect, NND, DistTown, DistRoad and DistVil from the final forest of nest site selection. Y axis is a measure for the probability of a point being a nest site (See appendix C for details). X axis is the related variable’s values.

Table 3.6. Variable importance scores of the initial and final random forest models for breeding success assesment. Variables in bold were selected for the final forest construction.

Initial Forest		Final Forest	
Variable	Mean Decrase in Accuracy	Variable	Mean Decrase in Accuracy
CliffHeight	1,890	CliffHeight	3,029
DistDump	1,876	DistDump	2,427
Aspect	1,320	DistPen	2,308
DistPen	0,388	Aspect	0,814
Slope	-0,024		
Forest	-0,124		
DistTown	-0,257		
DistVil	-0,315		
DistPaved	-0,432		
Class	-0,529		
Urban	-0,547		
IRR	-0,568		
Agri	-0,648		
Elevation	-0,660		
NestType	-0,772		
NND	-0,801		
Open	-0,876		
Water	-1,116		
DistRoad	-1,476		
MeanSlope	-1,497		
DistDirt	-1,608		

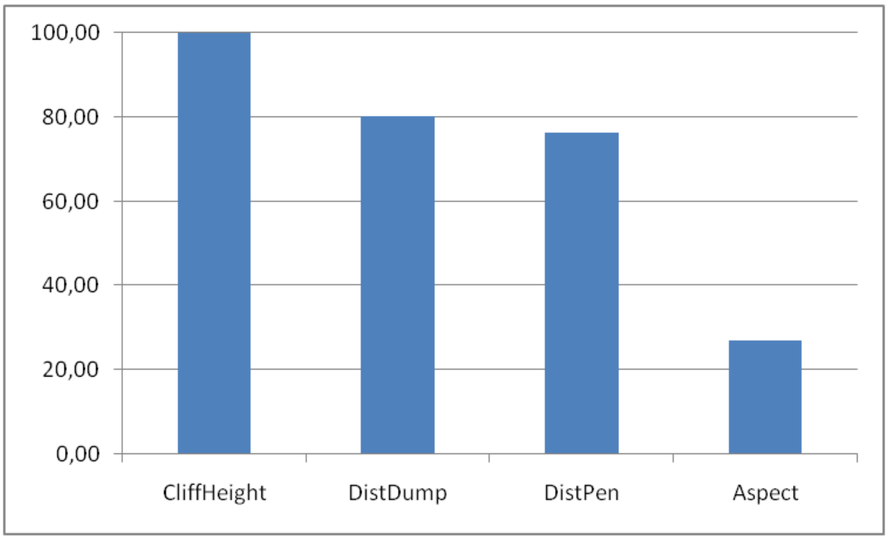

Figure 3.6. Variable importance scores of the final forest for breeding success assesment. Scores were scaled to 100 for easier interpretation.

Most important variable affecting the breeding success of Egyptian vultures was *CliffHeight* followed by *DistDump*, *DistPen* and *Aspect* (Table 3.6; Figure 3.6). Partial dependence plots in Figure 3.7 shows the relationship between the explanatory variables in the final forest and a measure of probability for breeding to be successful. Probability of success increased with higher cliffs but was mostly stable after 50 meters. In terms of orientation, nests facing northeast were more prone to failure. Parallel to the trend in nest site selection, probability of success increased with distance to the sheep pens, reaching its highest value around 1500 meters but this trend was reversed by a sharp decline through 2000 meters. The most obvious effect on breeding success was caused by distance to the Beypazarı dump site. The probability of success increased substantially as the distance increased.

3.5. Model Comparison

Comparisons were made only for the nest site selection models of GLM and RF as CART was not able construct a model linking the explanatory variables and the nest site selection of the species. Random forest had the highest scores for all of the classification measures. Both models were better at predicting presences than absences with higher scores for sensitivity than specificity.

Table 3.7. Comparison of the modeling techniques using 4 classification measures obtained by cross validation. Values in bold are the highest scores. Standard deviations are in brackets.

	RF	GLM
Accuracy	**0,740** (0,146)	0,669 (0,163)
AUC	**0,833** (0,147)	0,750 (0,188)
Sensitivity	**0,842** (0,139)	0,767 (0,222)
Specificity	**0,600** (0,378)	0,533 (0,358)

3.6. Spatial Autocorrelation

We checked for spatial autocorrelation only in the final random forest models of nest site selection and breeding success assessment. There was no significant autocorrelation at the α=0,05 level in neither of the models. (Nest site selection: Moran's I= 0,026 and *p*=0,286; Breeding success assessment: Moran's I= 0,026 and p=0,355).

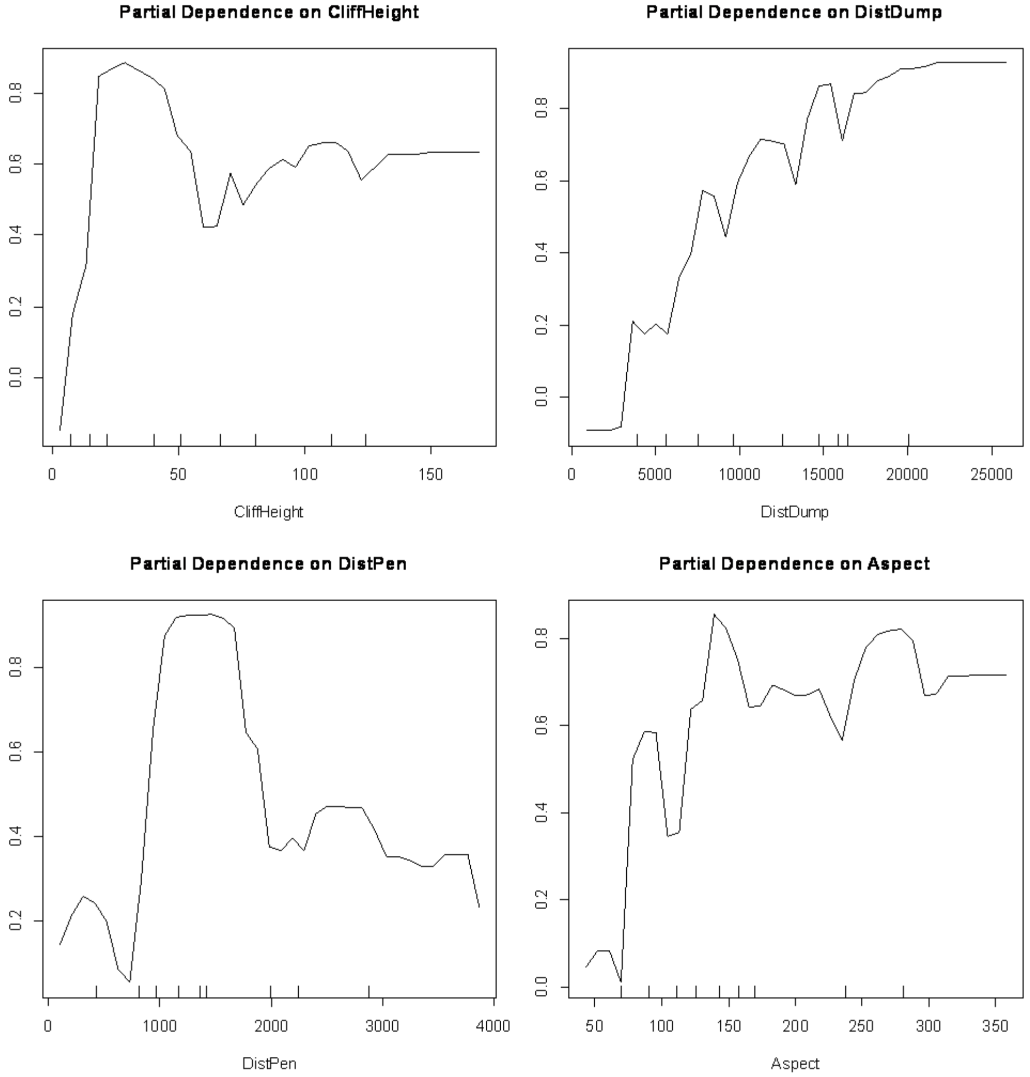

Figure 3.7. Partial dependence plots of CliffHeight, Aspect, DistPen and Elevation from the final forest of nest site selection. Y axis is a measure for the probability of a nest being successful. X axis is the related variable's values.

3.7. Dynamics of The Dump Site

A total of 62 hours was spent observing the dump site in two years. The maximum number of birds (60) was observed in June and July of 2010 (Figure 3.8). Young Egyptian vultures (second and third winter birds) arrived in May in both years. We observed juveniles only in one occasion in August 2010. The number of Egyptian vultures observed at the dump site was lower in 2011 compared to 2010 (Figure 3.9). Most Egyptian vultures at the dump site preferred to feed on unhatched chicken eggs dumped from a nearby poultry farm, even though remains of livestock were always available.

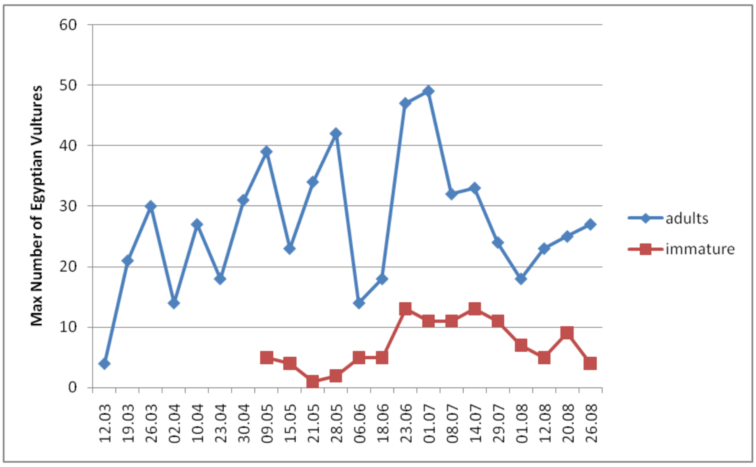

Figure 3.8. Maximum number of adult and immature Egyptian vultures counted at every visit to dump site in 2010.

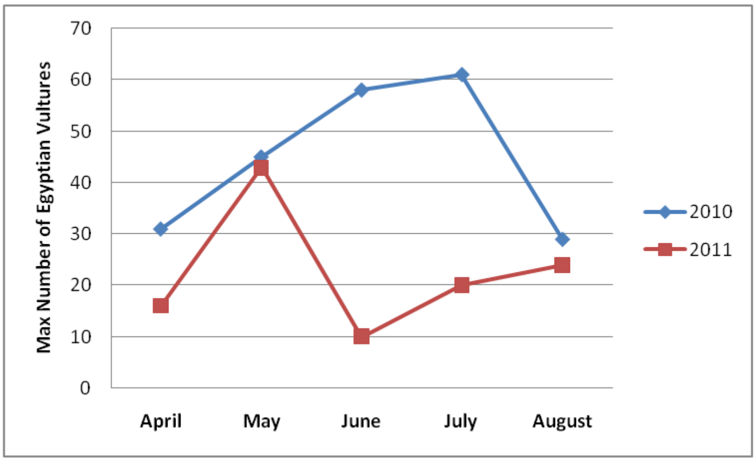

Figure 3.9. Comparison of monthly maximum number of Egyptian vultures (adult+immature) at the dump site for years 2010 and 2011.

CHAPTER 4

DISCUSSION

4.1. Methodological Details

The amount of time spent observing a nest site is different in other relevant Egyptian vulture studies. For example in the Second Spanish Survey of the Egyptian Vulture in 2000 (Carrete et al., 2007), every site was visited at least three times throughout the breeding season and was observed for at least 3 hours during every visit. This is substantially longer than our visits, but this survey was conducted by 600 birdwatchers at 1712 nest sites. This means that on average every bird watcher was responsible for only 3 sites. We had only one team in the field and most of the time our team consisted of only one driver and one observer. Therefore we could not afford to spend so much time on every nest site, especially because we had to deal with 10 times more nest sites per observer. However, the method we applied proved to be satisfactory, even though it is always better to spend more time observing a nest.

Zuberogoitia et al., (2008) discusses that the minimum safe distance for monitoring nests should be more than 600 meters. He claims that when approached closer than 300 meters Egyptian vultures are disturbed so much that they are prevented from entering the nest to feed the chicks. This may not apply for our study area since there were nests as close as 100 meters to highly active paved roads yet they were successful in both 2010 and 2011. Therefore we usually observed every nest form different distances depending on its location. If the pair was agitated we increased the observation distance but this was a very rare occasion and agitated pairs successfully bred afterwards. Overall, we assume that we did not have any effect on the breeding success of the observed pairs. Whether human activities have a negative effect or not on Egyptian vulture breeding success in the area will be discussed below.

4.2. Density and Distribution

The density of the Beypazarı Egyptian Vulture population is very high, with 6 pairs per 100 km^2. This finding is comparable to some of the Spanish populations with the highest density. In the Bardenas Reales region of the Ebro Valley Spain, Donazar and Ceballos (1989) reported 1 pair/14.5 km^2 which is equal to 6.9 pairs per 100 km^2. Even though it is an old record, authors once acknowledged this population (40 pairs) as “one of the densest in Europe”. In a recent study comprising a wider area in Northern Spain, Mateo-Tomás and Olea (2009) found a much less density with only 0.14 territories/100 km^2. Most importantly, they indicated that this low density climbs up to 6 territories per 100 km^2 in certain areas with a high breeding pair concentration.

When compared with others in Europe, the importance and density of the Beypazarı population stand out even more. In the Italian peninsula, Egyptian Vultures faced a sharp decline from 29 pairs to 9 pairs between 1970 and early 1990s (Liberatori and Penteriani, 2001). A similar situation was observed for the island of Sicily, with number of pairs declining from 29 in 1980 to 13 in 2002 (Sarà and Vittorio, 2003). While France and Portugal are estimated to have 87 and 90 pairs of Egyptian Vultures, respectively, Balkan populations are relatively small with 30-35 pairs for Macedonia, 40-45 pairs for Bulgaria and 30-50 pairs for Greece (Inigo et al., 2008). Considering these European population estimates, it is safe to say that the density of the Beypazarı population of Egyptian Vultures is one of the highest in Europe.

It is also important to note that we have included only the intensively monitored pairs in the population estimate. As indicated in the results section there were 8 potential pairs that were monitored regularly but whose nests were not found. In case they are confirmed to be breeding pairs, population size and density will increase even further. It is also possible that there are pairs that we “missed” during our surveys of the study area, since the population has only been studied for 2 years. The exact size of the population can only be determined through extensive and regular monitoring in the future.

The distribution of the Beypazarı population is not limited to the study area boundaries. Extending this area will also increase the size of the population if not the density. The natural borders of the population is unknown but it can be seen from

Figure 1.3 that it extends in all possible directions being limited by the coastline in the north and west and by an extensive plain in the south. How much of the population is continuous across that range and whether it shows a patchy distribution resembling a meta-population structure is a topic for future studies. It is highly possible that within such a structure Beypazarı population acts as a core area with high breeding pair concentration, similar to what was described in Mateo-Tomás and Olea (2009).

4.3. Nest Site Selection Patterns

4.3.1. Elevation

Elevation of a nest site was the most important variable determined by the final random forest model, having twice as more contribution to the model’s accuracy (OOB-error rate) than other variables (except *NND*) included in the model (Figure 3.5). The negative trend outlined by the partial dependence plot shows that species have a strong preference for nesting at lower elevations (Figure 3.5). The probability of a point being a nest reaches its highest value around 600 meters and there are no nest sites above 900 meters, even though the maximum elevation of the study area is 1800 meters.

Despite the fact that the elevation in which the species nest is highly variable at a global scale (see Introduction), the general negative trend between the probability of nesting and *elevation* was observed in other studies and was attributed to adverse climatic conditions on high altitudes (Mateo-Tomás and Olea, 2009). *Elevation* was also deemed important for a population of Bearded Vultures in Spain which preferred to nest in mid-elevations avoiding low or high altitudes (Donázar et al., 1993). Bearded vultures were reported to avoid lower elevations due to dense forested areas devoid of foraging habitat. This could be the reason why Egyptian Vultures prefer to nest at lower altitudes in Beypazarı. In our study area dense forests are concentrated at higher elevations, contrary to the Bearded Vulture population studied in Spain. The southern and lower part of the study area is mainly composed of open steppe habitat providing the necessary feeding opportunities with extensive animal husbandry as well as a large dumpsite. Vultures are adapted to slow soaring flight for searching carcasses with low energy expenditure (Houston, 2001; Ruxton and Houston, 2004) and Old World vultures rely heavily on their eyesight when locating food sources. Densely forested areas are not suitable for such feeding habits since in many cases it would be not possible for vultures to locate a carcass lying on the forest ground.

Another important point is the fact that Egyptian Vultures can only carry food in their beaks and this corresponds to a small amount (Snow and Perrins, 1980). Several feeding trips per day between the nest and foraging area might be necessary. When nests are located on high elevation away from foraging areas, energy requirements of these trips might actually exceed the energy gained during foraging (Bergier and Cheylan, 1980).

Even though we included habitat cover variables in the model, none of them (except *Open*) were selected by the random forest model since they had a negative effect to the models accuracy. One might expect that, if the arguments above are true, the *Forest* variable should have been selected by the model perhaps showing a similar trend with elevation. We argue that a 1 km radius around a nest site is not representative of the species' home range as has been shown by other studies (Carrete et al., 2007; Mateo-Tomás and Olea, 2009), and if the study area is extended especially towards north enabling the use of wider areas (2.5, 4 or 8 km) around nest sites, the forest variable might be selected by the final model.

4.3.2. Human Disturbance

Since human establishments tend to be located at lower elevations, the nest site preference of the population in Beypazarı may increase the risk of human conflict (Mateo-Tomás and Olea, 2009). This is prevalent in the final random forest model as among the 6 variables included in the model, 3 are related to human disturbance (*DistRoad*, *DistTown* and *DistVil*).

All these variables show a similar trend in partial dependence plots, stabilizing after a sharp increase in probability of a point being a nest (Figure 3.5). The highest probabilities for nesting in relation to human disturbance are attained at 150-200 meters from the nearest road, 2 km from the nearest town and at 4 km from the nearest village. These results clearly indicate that Egyptian vultures nesting in the study area prefer cliffs with a certain distance to human settlements. This trend has been noted before as Egyptian Vultures in Sicily also chose nest sites where human settlements are underrepresented (Sarà and Vittorio, 2003). Even though the species is not disturbed by, and may be indifferent to, the constant human presence, dogs or construction machinery when feeding at the dump site (personal observations), it is apparent that their behavior is rather different at the nest site, with the birds preferring a relative amount of seclusion.

4.3.3. Nearest Neighbor Distance (NND)

One of the regulators of the density of a raptor population in any given area is food supply (Newton, 1979). The abundance in food sources might alter a raptor's territorial behavior in terms of reduced aggressiveness and increased attacking distance when an intruder bird is present within the territory leading to decrease in NND (Newton, 1979). Therefore, for territorial species, we can consider *NND* both as a proxy for population density and habitat quality.

When compared with other European populations (Bulgaria: 2750 m, Pyrenean chain: 6830m, Catalonia: 7000 m, Italian peninsula: 24,511 m; see references in Liberatori and Penteriani, 2001) *NND* of the Beypazarı population is very low with a mean value of 1510 meters. The partial dependence plot on Figure 3.5 also shows that probability of nesting is highest when *NND* is between 1000 and 2000 meters.

Low *NND* and high population density in Beypazarı emphasize the high habitat quality with respect to Egyptian Vulture's nesting habits. Whether this quality is a result of food abundance, availability of nest sites or other habitat variables is a point of interest for future studies. The increasing probability of nesting through 2000 meters in partial dependence plot is a result of the species' territorial behavior. Apparently, even when the habitat quality allows a high density population to exist, Egyptian Vultures prefer to distance themselves a certain amount from their nearest neighbor when choosing a nest site, indicating the existence of intra-specific competition for nesting space.

4.3.4. Aspect

The nests of the Egyptian vulture were reported to either have a mixed orientation (Grubac, 1989), or be predominantly exposed to southern directions (Liberatori and Penteriani, 2001; Vlachos, et al., 1998). In our study area, the probability of nesting was highest when aspect was between 100 and 150 degrees, indicating a southeastern exposure of the nest site. The possible reasons for this preference are not discussed extensively in the raptor literature, but it might be related with the optimal use of sunshine (Carlon, 1992).

4.4. Breeding Success and Productivity

There was an apparent decline in breeding success and productivity in 2011 compared to 2010 (70% vs 100% and 0.86 vs 1.65, respectively). One of the possible reasons for this decline might be related to biased sampling towards monitoring nests with higher possibilities of success in 2010. However, out of 17 nests that were regularly monitored and determined as successful in 2010, 5 failed in breeding either in incubation period or early nestling stage in 2011. Therefore, we can safely assume that the decrease in breeding success and productivity is not an issue of sampling bias and corresponds to either an environmental problem for the species or a random fluctuation in breeding parameters.

Productivity estimates for the European populations of the species as reported in the species action plan (Inigo et al., 2008) is as follows: Bulgaria (0.76 juveniles /pair), FYR of Macedonia (0.83), France (0.6), Italy (0.99) and Spain (0.91). The mean productivity for all these populations is 0.89 while the two year average productivity is 1.11 for Beypazarı (with a significantly higher value in 2010, but below the European mean in 2011).

The final random forest model for assessing breeding success might provide some insight for the possible reasons of breeding failures in 2011. The model included 4 variables (Figure 3.6). For *CliffHeight*, even though there is a slight decline after fifty meters, low cliffs have lower probability for breeding success (Figure 3.7). *CliffHeight* does not necessarily represent nest height as there may be nests at the lower portions of high cliffs. However, low and small cliffs cannot show such variation and nests situated at such sites will be closer to ground level. Nests either on low cliffs or on the lower portions of the high cliffs are prone to predation from red foxes (*Vulpes vulpes*; Donazar and Ceballos, 1988) or to human disturbance. Red foxes are a common sight in the study area (personal observation) and the population’s preference toward distant cliffs from towns or villages (therefore, from human disturbance) was emphasized by nest site selection model. It is also important to note that Golden Eagles (*Aquila chrysateos*) and Eagle Owls (*Bubo bubo*) are also potential predators of the species (Tella and Mañosa, 1993; Mateo-Tomás and Olea, 2007) and they both breed in the study area, sometimes close to Egyptian Vulture territories (personal observation).

The partial dependence plot in Figure 3.7 shows a clear positive trend between distance of a nest to the dump site and its probability of success. We argue that this is not directly related to the dump site itself but more to the distance to Beypazarı town center which is only 2 km away from the dump site. Beypazarı is the biggest town in the study area in terms of both population and urban landscape. Pairs nesting very close to the dump site might be prone to human disturbance as a side effect. For example, 2 pairs nesting in İnözü Valley failed breeding. The valley is a touristic center with several social complexes hosting wedding organizations throughout the summer season and it is only 2 km away from both the dump site and the town center. Constant presence of vehicles, large tourist groups and loud music might have led to their failure.

The real effect of the dump site to breeding success may not be easily inferred from the random forest model but rather from the dump site observations and counts conducted in 2010 and 2011. The Egyptian vulture population in Beypazarı used the dump site as an extensive food source as can be seen from Figure 3.8. The number of Egyptian Vultures counted at the dump site increased to 60 individuals through late in the breeding season (June-July), possibly after eggs hatched when pairs had more time for foraging trips. The main food source was unhatched eggs dumped from a nearby incubation factory. Despite the fact that there was a slaughter house nearby also regularly dumping livestock remains (mainly internal organs), Egyptian Vultures always congregated around eggs. The incubation factory closed in 2011 and stopped dumping eggs to the dump site. The number of the Egyptian Vultures counted at the dump site was lower in 2011 than 2010 (Figure 3.9) and the ones that were observed were not feeding but usually perching around the dump site. The influence of food supply (or prey items) on breeding rates of raptors is a well established phenomenon (Newton, 1979). We argue that the decrease in breeding rates in 2011 might be related to reduced food supply from the dump site in Beypazarı. Even though high density and low NND of the population signifies the habitat quality of the study area, it is unclear whether the natural environment could sustain such a dense population in the absence of a dump site as regular food source.

The effect of the last two variables (aspect and distance to nearest sheep pen) to breeding success is unclear. Distance to sheep pen might act as a proxy to disturbance similar to distance to towns and villages since every sheep pen has a few housing around it but the reason why probability of success declines following an increase to 2000 meters is unknown. Only nests facing northeast were prone to breeding failure, but similar with distance to sheep pen there are no obvious reasons for a similar trend. Since the sample size of breeding success analysis is small with 37 nests and the model was only able classify 5 of 11 breeding failures, it is possible that these variables are chosen arbitrarily by the model.

4.5. Model Performance

Random forests (RF) performed better than GLM and CART in all model comparison parameters considered (Table 3.7). RF's overall consistent and superior performance when compared with a wide range of other modeling methods such as support vector machines, discriminant analysis, artificial neural networks and GAM was demonstrated in other studies (Cutler et al., 2007; Kampichler et al., 2010; Yen et al., 2011; Oppel et al., 2011). The suitability of RF for nest site selection modeling is not only apparent in its high predictive capabilities even when sample sizes are small, but also in its ease of use when compared with hierarchical modeling using GLM where sometimes one has to build more than thousand models to compare (Mateo-Tomás and Olea, 2009), and in its visualizing capabilities by partial dependence plots, thus providing further insight into the relationship between response and explanatory variables.

In the study by Kampichler et al. (2010), where several modeling techniques were scored according to their performance, effort etc. CART had the highest score just above RF. This is certainly not true in our case since CART was not able construct a successful model for nest site selection and the tree was pruned back to its root. Even though RF shares the same technique in its core with CART, the randomness introduced with *mtry* values and bootstrap sampling and the fact that prediction is made through a high number of trees increases modeling performance and accuracy in a significant manner.

GLM’s overall performance was close to RF and it proved to be a robust modeling technique as it was used in many species distribution modeling studies (Rushton et al., 2004; Guisan and Thuiller, 2005). However, selecting only 2 explanatory variables was a disadvantage and did not provide much insight into the nest selection patterns of the species. The reason for selecting such a low number of variables is because we set the limit of ΔAICc to 2. Richards (2008) suggest using the limit of ΔAICc as 6 instead of 2 and Mateo-Tomás and Olea, (2009) used Akaike weights to choose models until their sum of weights reached 0.95. When we used either approach, our models’ selective capabilities reduced greatly, so much that in the overall landscape scale all of the variables were selected to be included in the combined model. Therefore, we instead decided on a more conservative approach by setting the ΔAICc limit to 2 for variable selection.

Even though RF showed an acceptable and reasonable performance when considered its AUC and accuracy values, there is room for improvement. For example, Mateo-Tomás and Olea (2009) constructed a model for nest site selection of Egyptian Vultures using GLM with 0.97 AUC and 92% accuracy. There are several reasons for difference of 0.14 AUC and 20% accuracy when compared with our model. First and foremost, the sample size and scale of this study is relatively small. Extension of the study area and inclusion of more nest sites followed by more random points will increase the performance of the model whether it is RF or GLM. Extension of the study area will also make it possible to use wider circles with a radius of 2.5 km or 5 km since spatial autocorrelation will not be an issue either with increasing *NND* as a wider study area encompassing low nest density areas will have less overlap of these wider circles, or with using only a sample of nest sites apart from each other to a predetermined minimum distance for reduced correlation. Also, some of the key variables are missing from the nest site scale such as nest height, cliff length or entrance cover. Through continuous monitoring in the area, caves and ledges that are not inhabited with any raptor species but suitable for Egyptian Vultures to nest might be identified and they may be used for comparison with occupied nests instead of the random points. Therefore aforementioned variables can be calculated for these uninhabited caves and ledges as well. The inclusion of all these variables might provide more explanatory power to the models constructed. As for the case of assessing breeding success, using a rate of success (number of successful years/number years monitored) for every nest through several years of monitoring will provide a better response variable that might increase the accuracy of the model.

CHAPTER 5

CONCLUSION

Vultures provide several ecosystem services, through consumption of carrion, in the form of sanitation and nutrient recycling (Sekercioğlu et al., 2004). The widespread decline in vulture species at a global scale has direct impact on human communities either economically or through sanitary issues. The absence of vultures prolongs the carcass decomposition time and increases the number of mammalians feeding from carcasses resulting in a high rate of disease transmission such as rabies (Ogada et al., 2012). This in turn endangers the well being of not only human populations but also wildlife and livestock animals (Ogada et al., 2012). In addition, Margalida et al., (2012) report that vultures remove 9.9 million tons of carcasses per year in Spain alone. The removal of carcasses through natural means and not through industrial destruction saves costs for farmers of up to 20 € per animal. This might correspond to a more than 200 million € saved every year. Since Turkey has the second biggest vulture population in Europe (Birdlife International, 2004), conservation of vulture species breeding in Turkey becomes imperative.

In this study we showed that Turkey hosts one of the biggest local Egyptian Vulture populations in Europe. The models we constructed suggest that human disturbance is limiting the distribution of this population through altering nest site selection and that it might be the cause of large number of breeding failures in 2011. Considering the species' vulnerability to human presence in breeding territories (Zuberogoitia et al., 2008), it is unknown whether its selection of nest sites at a certain distance from human settlements will be enough for the Beypazarı population to sustain itself in the near future. Unfortunately human disturbance is not only prevalent through distance to villages or towns. Beypazarı is a quickly developing town and construction of hydroelectric power plants, mines and roads are becoming common place. In fact some of these constructions take place only several hundred meters from several nest sites. To truly measure the impact of growing human communities in Beypazarı to the population of Egyptian Vultures, extensive monitoring of the species is essential. We also advise climbing to failed nest sites in the near future for detecting causes of failures. So far we did not come upon a carcass of an Egyptian vulture, or witnessed or heard of a poisoning event or illegal hunting.

Finally, we propose Kirmir Valley and Nallıhan Hills to be considered as Important Bird Areas with A1 and B1 criteria as they hold important breeding numbers of Egyptian Vultures.

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APPENDIX A

GENERALIZED LINEAR MODELS (GLM)

GLM is similar in structure to ordinary linear regression. In fact linear regression can be considered as a GLM with a Gaussian distribution and identity link function (Zuur et al., 2009). In linear regression the assumption is that Y_i is distributed normally with the mean μ_i and the variance σ^2. The resulting simplest model with only one variable to consider can be written as follows:

$$\mu_i = \alpha + \beta X_i \qquad \text{or,}$$

$$Y_i = \alpha + \beta X_i + \varepsilon_i$$

In these models α is the intercept and β is the slope or the coefficient of variable X while ε_i is the error term of the observed case Y_i. If we consider the response variable Y_i to be the absence or presence of a nest site we would face several inconsistencies, because Y_i is assumed to be normally distributed and it can theoretically take any value between -∞ and +∞. Our response variable, however, is categorical - for example it can only be 1 (actual nest) or 0 (random point). The first step in a GLM to solve this problem is to consider the response variable not as categorical but as a probability. We define that π_i is the probability of a point being a nest and 1- π_i is the probability of a point being a random point. Now we can assume that Y_i is binomially distributed with the mean $N \times \pi_i$ and variance $N \times \pi_i \times (1 - \pi_i)$. When an identity link is used similar to the formula above, Y_i can take values below 0 and above 1 (Zuur et al., 2009). Since Y_i is a probability now, it must be between 0 and 1 and to change that we need to use a different link function. In the binomial case the regularly used link function is the “logit” link. Therefore, instead of modeling π_i as a direct function of explanatory variables, we first calculate O_i the odds of the i^{th} point. Odds can take values higher than 1 and when we take the natural logarithm of O_i, our new response variable $\log(O_i)$ can now have any value between -∞ and +∞. The simple linear regression function above changes into:

$$\mathrm{logit}(\pi_i) = \alpha + \beta X_i$$

Another important difference of GLM from linear regression is that when estimating the unknown parameters in a model, the intercept (α) and slope (β), ordinary least squares is used in linear regression but maximum likelihood estimation is preferred in GLM. The density function of binomial distribution is as follows:

$$f(y;\pi) = \binom{N}{y} \times \pi^{y} \times (1-\pi)^{N-y}$$

In this formula y is either 1 or 0 depending on whether it is a real nest or a random point, N is 1 because every π value is estimated on single points (nest or random), and π is estimated via logistic regression. The formula used in maximum likelihood estimation is:

$$L = \prod_{i} \binom{N}{y_i} \times \pi_i^{y_i} \times (1-\pi_i)^{N-y_i}$$

The aim is to maximize the L value. Therefore, in logistic regression we try to estimate the intercept (α) and slope (β) (that will in turn estimate π_i values for every point) which will maximize the L value.

There is a restriction on how many variables can be used depending on the sample size in GLM. The rule of thumb is n/10, e.g. if sample size is 100 one can only use 10 variables at a time. Since we had only 37 nests with the knowledge of success or failure, the maximum number of variables that we could have used were 4 when trying to identify the habitat features leading to nest failure. For that reason we did not use logistic regression for the modeling of nest success/failure.

We followed a hierarchical modeling procedure similar to Mateo-Tomas and Olea (2009) and Carrete et al (2007). We first divided the data into nest site and landscape scales, and then divided the landscape into 5 categories (Table 2.1). Variables were first modeled in their respective categories. Selected variables from the 5 categories were again modeled at the landscape scale. Finally, we constructed a combined model with selected variables at nest site and landscape scales. In every step of the modeling procedure, every possible permutation of the variables was modeled and the resulting models were ranked using corrected Akaike Information Criterion (AICc) (Burnham and Anderson, 2002). Only models with ΔAICc<2 from the best model (lowest AICc value) were considered and further model filtering were carried out following Richards (2008) in which complex models that did not improve upon simpler models (by lowering AICc) were removed. For example, if one model had only elevation as a variable with an AICc value of 95 and a more complex version of that model such as elevation+aspect had a AICc value of 96, the latter model were removed from the analysis since aspect did not have any positive contribution to the model performance. This procedure was repeated for every scale and category and the variables in the selected models of categories were again modeled together at the landscape scale. Variables from the selected models at the landscape and nest site scales were used to construct the combined models and after the model filtering, remaining models were averaged for multimodel inference (Burnham and Anderson, 2002) and a final averaged model were obtained. Since model comparisons were conducted using cross validation, a new model had to be built every time a new subset was left out from the data. Those new models were constructed using the variables that were included in the best (lowest AIC) combined model.

We used *MuMIn* package in R statistical software to compare multiple permutations of GLMs.

APPENDIX B

CLASSIFICATION AND REGRESSION TREES (CART)

In classification trees, we start with a root node in which the sample is not partitioned yet and the error rate is highest. For instance, in the nest site selection sample, there were a total of 69 points with 39 nests and 30 random points, and the root node error was 30/69=0.43 at the beginning. The aim is to reduce this error rate by splitting the sample depending on the explanatory variables and forming a tree. The commonly used algorithm to do so is called Gini index, and for a two category nominal response variable it is formulated as:

$$G = \sum_{j \neq k} p_{ij} \times p_{ik}$$

where k and j refer to categories as presence/absence and p is the proportion of that category at the ith leaf after splitting the data depending on an explanatory variable. The aim is to minimize the G value on the respective leaves after each split.

Data, either on the root node or on the other nodes following it, are always split in two, so a nod after a split forms two leaves. The splitting process differs depending on the type of the explanatory variable:

- When the explanatory variable is nominal with equal to or more than two categories, every permutation of the categories is tried out to split the response variable. For example with a 3 category nominal variable a, b and c, permutations of ab-c, ac-b and bc-a are considered, resulting in two leaves, and a G value for every permutation is calculated.
- When the explanatory variable is continuous, the response variable can only be partitioned in the original order of the continuous variables. For example, with a continuous variable of values 1, 2 and 3, splitting can only carried out

in two ways: either 12 in one leaf and 3 in the other, or 1 in one leaf and 23 in the other. Again, for every possible split G values are calculated.

At the root node, every explanatory variable is used to split the data in two by following the methods explained above and the variable and its appropriate permutation causing the lowest G value after the split is chosen. The data is now divided in two and two leaves have been formed. The process is repeated for the two leaves again using all the variables and for every other leaf afterwards until a pre-defined stop criterion is met or splitting is no longer feasible. When a leaf is split, it is called a node. The final leaves (or terminal nodes) that have not been split show how many splits were carried out when constructing the tree; if *m* is the number of leaves then number of splits is always *m*-1. Data is predicted from the final leaves. For example 11/2 in a leaf means that there are 11 nests and 2 random points in that leaf's prediction, hence error rate is 2/13=0.15. The error rate of the tree is calculated through all leaves and is usually presented as a "relative error rate" which is relative to the root node error.

It can be deduced that the earlier a variable is selected for a split, then the more important it is on affecting the response variable. Also, variables that are tied to each other through nodes throughout the tree are assumed to be interacting.

Much like in GLM, variable selection that will be included in the final model is an internal part of the CART. Without any criterion, the tree will overgrow and therefore will be an overfitting model (Figure 3.2). The relative error rate is not a good indicator when deciding the tree size, because it always decreases as the tree grows. The criterion to decide the size of the tree is the cost-complexity parameter (*cp*). The parameter cp is inversely correlated with the number of splits in a tree. As *cp* decreases, tree size increases and as a result explanatory power of the tree also increases but there is a chance that the model will overfit. As *cp* increases, tree becomes smaller, only a few variables are included in the final tree and the explanatory power of the tree is reduced. The aim then is to find the optimal *cp* for the constructed tree.

Cross validation is used to compare the effect of the different number of splits or *cp* on the error rate. Data is divided randomly into *k* subsets (default *k* is 10). Then *k* trees are grown fully without constraints, but at each tree one subset is left out and resulting tree is used to predict the subset that was left out. Error rate from that prediction is called cross validation error rate and it is unbiased when compared to the relative error rate. The data though is not predicted just once with the full tree but rather predicted after every split, so following any split we have *k* number of cross validation error rates. Therefore the mean and the standard deviation can be calculated using those error rates for every split and every *cp*. Finally the tree is pruned back to lowest number of splits or highest number of *cp* which is within one standard error of the split, or the *cp* with the lowest cross validation error rate. This way a simpler model is preferred over more complex ones that do not have a significant effect on the model's prediction performance. This is a direct analogy to what Richard (2008) suggested when selecting models in multi model inference.

We grew the tree fully using 20 variables and pruned it back by using the method explained above. We used *rpart* package in R statistical software for the construction of classification trees.

APPENDIX C

RANDOM FORESTS

The biggest difference of RF comes from the method which trees are grown. Before splitting a node in two, instead of contesting all variables for their *G* values like in CART, a pre-determined and randomly selected number of variables are tried out. This number is usually determined as the squared root of *m* (number of variables) and is called *mtry*. For example if *mtry* of a RF is 5, in every tree and in every split of those trees 5 variables are randomly selected and contested over the *G* value, and the one giving the lowest *G* value is selected as splitting criterion.

Another important difference of RF from CART is that a random bootstrap sample with replacement of the original data is used when growing each tree. In this way an average of 33% of all cases are left out during the construction of each tree. These cases that are left out are called “out of bag” (OOB) and are used for validating the data, an analogy of cross validation. When a case is OOB from a tree, it is dropped down from that tree and a prediction is made through the final leaves of the tree. For example, when a case of an actual nest is OOB from a tree, it will be predicted as an actual nest or a random point. Since in every tree an average of 33% of cases are left out, then in average a case will be left out in 33% of all trees. If we grow the forest with 1000 trees, our aforementioned case of actual nest site will be OOB from (on average) 333 trees and all of those trees will have a prediction on whether the case is a nest and or a random point. When the number of trees predicting the case to be an actual nest is higher than the number of trees predicting it to be a random point then the model’s prediction for that case is actual nest, if the opposite were true then the model would predict it to be a random point, which would be an error. This is the majority vote aspect of the RF. The rate of all the mis-predicted cases is called OOB error rate and it is an unbiased estimation for the model’s predictive capabilities.

The most important aspect of Random Forests is the variable importance measures in which we can deduce which variables have more effect on the prediction of cases. There are several importance measures, but we used what is usually defined as the "mean decrease in accuracy". Breiman (2002) simply named this as "measure 1". It is similar in structure to raw importance score or local importance score (Breiman and Cutler, 2005).

When estimating measure 1, OOB error rates for each tree in the forest are calculated. These error rates are not majority votes based, and simply refer to classification error for each individual tree. Then the variable under study, say *m*, is permuted over all OOB cases for each tree, and a new OOB error rate is calculated for every individual tree. If the variable *m* has an effect over predictions different than random, then the new error rates after the permutation should be higher. The difference between the original OOB error rate and permuted OOB error rate is calculated for each tree and the sum of these differences is divided by the number of trees in the forest. After normalizing this value, it gives us the mean decrease in accuracy when the values of variable *m* are random. This process is repeated for every variable in the study. If a variable caused more decrease when random, then it has more impact on the model's predictive capabilities. This way, every variable in the study can be compared with each other in terms of importance. In our study, we assumed that important variables reflected the nest site selection or habitat features that affected breeding performance of Egyptian vultures.

The only parameters to adjust when constructing random forests are the number of trees in the forest (*ntree*) and previously defined *mtry*. Because there is a significant random aspect of this method, OOB error rates and scores of variable importance measures can differ in every model. It has been shown that higher number of trees in a forest leads to better variable importance score stability (Genuer et al., 2010), so we used 2000 trees to construct every forest. We used the *tuneRF* function in the *randomForest* package in R to find the best *mtry* value. This function, starting with a pre-determined value of *mtry*, multiplies or divides *mtry* by a factor and builds forests until OOB error rate does not improve. In our case, *tuneRF* (with a factor of 2) built 3 forests with *mtry* values of 2, 4 and 8 in the initial model construction and 1, 2 and 4 in the final forest construction for both nest site selection and breeding success assessment. From these forests we chose the *mtry* value of the forest with the lowest OOB error rate. If OOB error rates were equal we chose the default *mtry* value. Then we grew the initial forest using the chosen *mtry* value. In the second step, to improve the OOB error rate of the initial forest, we eliminated variables which had a negative variable importance score. A negative score means that a random permutation of a variable performs better than its original combination, indicating that the variable is increasing the OOB error rate. After the elimination we used *tuneRF* for the second time and chose the best *mtry* value for the final forest, repeating the aforementioned method. We constructed 10 forests using those *mtry* values and chose the forest with the lowest OOB-error rate to be the final forest.

We used partial dependence plots to illustrate the individual effects of the variables on the probability of a point being a nest (Hastie et al., 2009). The function to draw partial dependence plots is as follows:

$$f(x) = logp_{\mathrm{k}}(x) - 1/K \times \sum_{j=1}^{K} \left(logp_j(\mathrm{x}) \right)$$

K is the number of classes. p_k is the fraction of votes for the class that is being plotted and p_j is the fraction of votes for class j.

We used *randomForest* package in R to construct the forests.