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ORIGINAL ARTICLE

The status of Eleonora's Falcon (*Falco eleonorae*) in Greece

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Abstract With more than 80% of the species global population breeding in Greece, Eleonora's Falcon (*Falco eleonorae*) is reported to be the most important bird species in the country. A national population survey was conducted during the breeding seasons 2004–2006 in order to assess the species' breeding distribution and population size. This census was the first of its kind and was part of a global population survey, involving more than 80 field workers. Standard field protocols, described in the International Species Action Plan, and a GIS interactive database were developed. Data were stored and spatially explored in conjunction to historical information and past records. A total of about 17,660 falcons were counted or an estimated 12,300 breeding pairs, which were concentrated in six major regions, i.e., northeast Aegean, Sporades, east Cyclades, Antikythira, southwest Dodecanese and the satellite islets of eastern Crete. Compared to previous descriptions of breeding colonies and population status, spatial variation in site occupancy was detected with a population decline in one of the aforementioned regions and an apparent increase in all the rest. The results of this national survey, expected to be repeated every 10 years, provided guidance for reviewing the conservation status of Eleonora's Falcon in Greece and baseline information for future monitoring of its population.

Keywords Aegean Sea · Breeding distribution · Eleonora's Falcon · Population census

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Introduction

Eleonora's Falcon (*Falco eleonorae*) is a medium-sized raptor that breeds colonially on steep sea cliffs and islets. It is distributed over the entire Mediterranean region and the eastern Atlantic, from the Canary Islands to the coast of Morocco (Walter 1979; Cramp and Simmons 1980). The species is highly migratory, overwintering in eastern Africa and the Indian Ocean, especially Madagascar, and probably Tanzania (Hustler et al. 1990; Ristow and Wink 1995; Clark 1999; Gschweng et al. 2004). The falcons normally concentrate in their breeding grounds from mid-April to mid-October (Tucker and Heath 1994; Beaman and Madge 1998). However, during this period, immature and non-breeding individuals can be recorded far inland in north Africa, the Middle East and continental Europe (Ristow and Wink 1995; Mayol 1996; Handrinos and Akriotis 1997; Xirouchakis 2005).

Eleonora's Falcon is the latest breeder among the summer visitors of Europe. It has adapted its nesting period to the onset of autumn migration in the western Palearctic (Cramp and Simmons 1980). Eggs are laid by late July and

chicks are raised from the end of August until late September when passerine migrants are most abundant (Wink and Ristow 2000). Large insects constitute its main prey for the rest of the year as well as during the windless days of the breeding season when the migration flow is poor and bird supply becomes scarce (Walter 1979).

Prior to the present study, the global species population was estimated at 5,900–6,200 breeding pairs, with Greece being its main stronghold (>70%; BirdLife International 1999, 2004). The Greek population is largely distributed in the Aegean Sea, previously estimated at 4,500 breeding pairs. Compared to the 1990s, the species has undergone a moderate global decline of >10% with a noticeable negative trend in the wintering population as well as the number of breeding pairs in the Greek territory (Thorstrom and Rene de Roland 2000; Ferguson-Lees and Christie 2001; BirdLife International 2004). As a result, this species, previously regarded as rare, is now evaluated as declining in Europe (Birdlife International 2004). At present, Eleonora's Falcon is included in Annex I of the European Union's Wild Birds' Directive 79/409/EEC and constitutes a priority species for conservation, since its global population is concentrated in Europe, but faces an unfavourable conservation status (Council of Europe 1979; BirdLife International 2004).

The implementation of a well-coordinated international population survey was identified by the International Species Action Plan (Birdlife International 1999) as an urgent action for the species conservation. The Greek colonies were of top priority for fieldwork in order to determine its global status (Birdlife International 1999). In Greece, Eleonora's Falcon is presently listed in the Red Data Book as insufficiently known (Handrinos 1992), although due to its restricted breeding range and colonial character our knowledge on its distribution is considered to be adequate. However, many colonies are located on desolate islets or remote bare rocks that have never been censused, while others that may hold up to 300 pairs are difficult to survey (Tucker and Heath 1994; BirdLife International 1999). The latter is especially so due to unstable weather conditions, which affect fieldwork and determine the behaviour and detectability of the falcons. So far, the two most reliable surveys were carried out in the late 1970s by Walter (1979), who reported 56 colonies in the Aegean and 2,873 pairs (Handrinos and Akriotis 1997), and in the late 1990s, by the Hellenic Ornithological Society (HOS), that produced a population estimate of 4,450 breeding pairs (BirdLife International 1999).

Taking into account that Greece plays a key role for the conservation and long term survival of the species, the principal aims of the present study were: (1) to provide a reliable estimate of the current population size of Eleonora's Falcon in Greece, and (2) to standardize census techniques so as to improve data collection in future population surveys. The ultimate aim was to provide a baseline population estimate in comparison to which repetition of future surveys (every 10 years) will allow assessment of the species population trends and to accurately define its conservation status at national level.

Methods

Study area

The study took place along the whole Greek coastline, covering the Ionian Sea that extends south of the Adriatic Sea in the western part of the country, the Aegean Sea that stretches between continental Greece and Asia Minor and the islets spreading over the Cretan and the Libyan Seas around the coasts of Crete (Fig. 1). A total of 9,838 islands, islets and rocks are found in these regions of which less than 100 are inhabited. This unique morphological trait provides the country with a coastline of about 15,000 km as these islands range in size from <1 to 8,261 km^2 (National Statistical Service of Greece 1999). Historically, the species' colonies are known to cluster in the major island complexes in the Aegean Sea (ca. 25°E, 38°N) (Powys 1860; Reiser 1905; Walter 1979). This Greek Archipelago covers an area of more than 200,000 km^2 and, with 8,110 islands, takes up almost 50% of the country's total coastline (Handrinos and Akriotis 1997). Its maximum length is 640 km and its width ranges from 195 to 400 km.

Bibliographical information

The existing literature on the distribution and status of Eleonora's Falcon was reviewed. Most of the available data were compiled from unpublished reports such as the archives of the Hellenic Ornithological Society and the Standard Data Forms of the Important Bird Areas (IBAs) database (Bourdakis and Varelitzidou 2000). For the latter, we searched in detail the IBA inventory, which was updated during 1995–1997 when many islands of Greece were visited by the HOS's ornithologists. In several cases, the surveys in island IBAs produced falcon counts of low quality. However, knowledge on the breeding distribution of the species was greatly enhanced.

Designation of survey sites

The selection of survey sites was carried out in three stages. First, we defined the major island complexes of

Fig. 1 Map of study area and breeding distribution of Eleonora's Falcon (*Falco eleonorae*) in Greece (2004–2006)

Greece and divided the Aegean Sea into sub-regions (Fig. 1). Second, we created an inventory of the known species' colonies. For the large islands (>10 km^2), we identified the fragments of the coastline that hosted suitable breeding habitat for the species. Last, we identified and excluded all the rocks and islets with a maximum altitude less than 10 m, or no vegetation at all, as they were considered to be frequently covered by the sea waves. In all cases, we used 1:50,000 scale topographical maps acquired from the Geographic Military Service of Greece and 1:100,000 scale naval maps provided by the Greek Ministry of Mercantile Marine (Hellenic Navy Hydrographic Service 2006). No fieldwork was carried out in Crete and the west part of Evia, while some large islands (e.g., Chios, Samos, Ikaria, Andros) were surveyed completely since time was available. As an Eleonora's Falcon colony, we defined every single islet or island occupied by the species where at least two breeding pairs were detected.

Site mapping

All islands of the study area were named using topographical maps and given a unique island reference code on a digitised map of the coastline of Greece (ArcGIS 8.3, ESRI 2006). A series of 1:250,000, 1:50,000, and 1:25,000 scale maps were produced on which ca. 1-km-long count sectors were delineated in the field (Bibby et al. 2000). Sector point limits were usually located at easily recognisable landmarks, e.g. prominent cliffs, capes, lighthouses, and were marked using a global positioning system (GPS Magellan, Meridian Colour). Islets with perimeter of less than 2 km were excluded from this partitioning system and considered to be a single sector (Fig. 2).

Timing of field work

The best time of the year to survey Eleonora's Falcon is early September, not later than the 15th when eggs have hatched and falcons are still attached to their nesting sites (BirdLife International 1999). In the present study, census work was conducted during the breeding seasons 2004–2006 from 20 August to 20 September each year. Fortunately, Eleonora's Falcon shows a high degree of site tenacity (Ristow et al. 1979), and thus it was possible to spread the census work in successive years. Fieldwork was carried out in days with winds up to 6 on the Beaufort scale, ideally from 0900 to 1700 hours, though birds were less active from 1200 to 1400 hours. The time allocated to each survey site fluctuated according to its size, height and length. Overall, up to five teams were occupied simultaneously in fieldwork and more than 80 fieldworkers were involved in census work.

Counting procedure

Counts were made from speed boats or caiques, which sailed at a distance of 50 m from the coast or equal to the cliff height. The field team normally consisted of three fieldworkers (minimum), i.e., two observers and one data recorder, and the skipper. In low cliffs (up to 50 m) or small flat islets, birds were flushed with the use of the boat

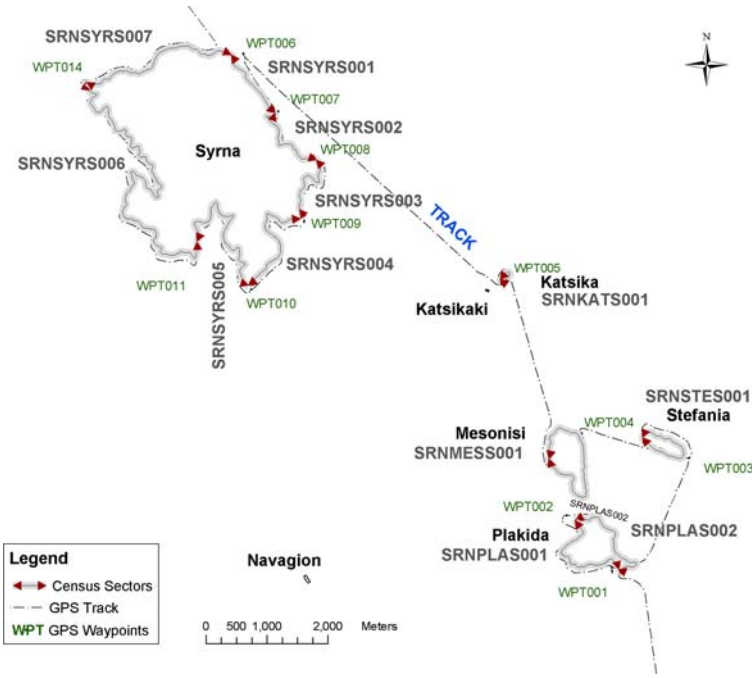

Fig. 2 Example of survey route and sectors created in the population census of Eleonora's Falcon in Greece (2004–2006)

pipe, whistles and human voices aided by a speaking trumpet, while in high vertical cliffs (>50 m) powerful horns (120 DB) were used. The vessel was either still or slowly sailing (2–4 knots/h) depending on the birds' abundance. The usual response of falcons to the noise was to leave their roosts or nests, circle around in the sky for 30–60 s and then return to their perch. In small colonies (<100 individuals), all birds seen in a 360° scan above a stationary boat were counted instantaneously every 200–400 m of coastline (Gould 1974). In contrast, in larger colonies this "snap-shot" sampling technique was not feasible. In this case, a 180° scan was carried out ahead of the boat as it moved slowly along the coast (Tasker et al. 1984). The number of individuals spotted by unaided eye was tallied regardless of their breeding status, as non-breeders could not be distinguished by this technique. As a rule, one fieldworker used the horn to flush the birds while the other counted them. When there were more that two observers on the boat the average figure of the counts was assigned as the total number of falcons for a sector. In the case of duplicate counts, performed in different dates within the same breeding period, the maximum figure was taken into account.

Data recording and entry

Census data were recorded on datasheets along with general information (e.g. date, time, observers, weather conditions, etc.), sector name and GPS waypoints defining the limits of each sector, nesting habitat type, counts of other bird species, indications of human disturbance, etc. These data were downloaded or entered in a database and interactively connected with a GIS so that data, such as the location and size of each falcon colony, could be depicted in maps or related to geographical parameters. By this method, colony population size could be expressed as an absolute number or an index of abundance, i.e. birds counted per km of coastline.

Data analysis

A correction factor for the detectability of the birds would be ideal. However, it was practically impossible to determine a coefficient of detection by calculating the perpendicular distances of birds from the boat's route or to take sighting angles and ranges (Burnham et al. 1980). It was assumed that every bird flushed was detected by unaided eye and counted. Additionally, counts of individuals were related to the number of breeding pairs by a nest-attendance index (no. pairs = $n/2 \times 1.4$ where n was the number of individuals counted). More specifically, from a limited number of field tests, namely by monitoring periodically 15 "calibration" colonies (Bullock and Gomersall 1981), we concluded that every individual flushed corresponded to 0.7 pairs (data from 20 colony-years). Population size was estimated for each sector and colony (i.e.,islet or island) separately. Then, data were grouped for whole island complexes or sub-regions of the Aegean. The regional division would allow us to discern geographical patterns and core areas and would facilitate future

comparisons on the species distribution and abundance. The final Greek population estimate was derived by summing the regional totals.

Results

Survey coverage

The species known distribution was covered completely while out of the 1,579 islands, islets and rocks mapped in the study area, ca. 1,150 (73%) held potential breeding habitat for the falcons. A total of 965 islands were suitable for nesting (84% of the potential breeding habitat) and birds were recorded in 306 (31.7%) of them (Table 1). The surveyed area corresponded to 6,113.6 km of coastline (Table 1). Mean length of a survey sector was 2 km (SD = 2.1 km, range = 0.1–16.9 km, n = 2,492), while the total length of the occupied sectors (n = 904) accounted to 1,655 km, namely 27% of the coastline surveyed.

Breeding distribution

In general, the species distribution was divided into nine geographical regions, i.e. Northeast Aegean Sea, Sporades, Evia with its surrounding islets, Argosaronikos gulf, Cyclades, Dodecanese, Crete, Kythira and Eptanisa (Fig. 1). The centre of its breeding range covered primarily the Aegean archipelago including the Kythira area and the islets north of Crete. Falcons were found to be very scarce in the Ionian Sea (Eptanisa) and site occupancy was remarkably low considering the number of islands occurring in this region. Similarly falcons were very rare in the Argosaronikos and Evia regions where evidence of breeding activity was limited, in particular on the islets closer to the mainland. Furthermore, the species was absent from the islets on the south coast of Crete although nesting habitat was abundant. Overall, occupation of survey sites was greatest in two regions, namely the Sporades and the islets to the northeast of Crete. The proportion of islets occupied was intermediate in Kythira and the Dodecanese sub-regions (Table 1).

Table 1 Survey coverage of Eleonora's Falcon (*Falco eleonorae*) distribution range in Greece (2004–2006)

Region	No. islets mapped	No. islets surveyed	Coastline surveyed (km)	No. islets occupied	Site occupancy (%)
NE Aegean	209	115	1,071.3	41	35.7
Sporades	138	59	365.6	47	79.7
Evia	117	41	317.4	2	4.9
Argosaronikos	127	50	154.9	2	4
Cyclades	325	265	1,919.5	84	31.7
Dodecanese	293	235	1,107.3	95	40.4
Crete	39	39	210.4	23	59
Kythira	24	19	103.0	8	42.1
Eptanisa	307	142	864.4	5	3.5
Total	1,579	965	6,113.6	307	31.8

Population size and density

A total of 17,661 individuals were counted in the entire study area or an estimated 12,299 breeding pairs (Table 2). Falcon density was 11 individuals/km of occupied coastline. A total of 249 colonies were located (21.6% of the islands surveyed), which hosted on average an estimated 71 individuals (SD = 143) or 54 pairs (SD = 100, range = 2–977). The size and the perimeter of the smallest rocks (n = 7) where breeding falcons were flushed ranged from 0.05 to 0.49 ha and from 96.7 to 258 m, respectively. The majority of colonies (190) were small (<50 pairs) harbouring a total of 2,868 pairs. These figures revealed that 77% of the colonies held only 23.3% of the population. In contrast, 5,272 (43%) breeding pairs were concentrated in just 14 (5.6%) colonies (Fig. 3).

The bulk of the species population was located in six areas, i.e., northeast Aegean, south Sporades, east Cyclades, Antikythira, southwest Dodecanese and the islets neighbouring eastern Crete. In these areas, a total of about 10,000 individuals were counted, namely 56.6% of the total population. More specifically, significant falcon numbers (>300 individuals) were recorded in 18 island complexes where 12,144 (68.8%) individuals were counted. The highest numbers were recorded in two inhabited islands, i.e., Psara (40 km^2, 910 individuals) in the north Aegean and Antikythira (20 km^2, 1,395 individuals) at the southeast of Peloponnesus. The latter constitutes the largest colony worldwide (6–8% of the global population).

Discussion

Considering that nest counts produce higher numbers than direct observations of flying falcons, Greece possibly holds up to 90% of the species' global breeding population. A detailed inspection of the present findings suggested that site occupancy and regional population size depend on prey availability and consequently on favourable weather conditions. The largest colonies occurred in regions where summer winds ("meltemia") prevailed (>6 Beaufort scale) and so did the pulse of passerine migrants. On the other hand, a limited number of colonies held significant falcon

Table 2 Total and regional population size of Eleonora's Falcon in Greece (2004–2006)

Region	No. colonies	No. individuals	No. breeding pairs	No. individuals/km of occupied coastline	Mean colony size (pairs)
NE Aegean	31	3,312	2,307	26.3	74
Sporades	38	3,410	2,377	19	63
Evia	1	5	2	1.1	2
Argosaronikos	0	2	0	0.4	0
Cyclades	73	3,817	2,660	14.1	36
Dodecanese	80	3,944	2,743	15.1	34
Crete	18	1,586	1,106	23	61
Kythira	7	1,483	1,037	37.1	148
Eptanisa	1	102	67	5.1	67
Total	249	17,661	12,299	15.8 (Av.)	54 (Av.)

numbers irrespective of the wind force. These colonies were located on major migration corridors of the Aegean, e.g. the stretches between the Peloponnesus and the western peninsulas of Crete or the Dodecanese and the eastern tip of Crete. The absence of falcons from the islands of Evia, the Argosaronikos gulf and the Ionian Sea, and from the islets south of Crete, probably indicated the presence of a weak migration stream since the adjacent landmasses acted as daytime refuges for nocturnal migrants. Many small land birds that constituted the falcons' main prey, e.g.,flycatchers and warblers, migrate through the night (Moore 1987; Arkesson et al. 1996; Bolshakov 2000) and would pass over these islands and islets shortly after dark.

In comparison to past spatial data (Vaughan 1961; Makatsch 1969; Walter 1978), the species' distribution seemed unchanged, with the Aegean Sea being the centre of its breeding range (Walter 1979). During the last three decades the major breeding sites remained the same, although some large colonies should be considered as newly found. The number of locations where the presence of falcons was recorded has enlarged (249 vs 87 islands; Walter 1978) meaning that in previous surveys many localities had gone undetected. Similarly, the present population estimate is even larger than the most realistic estimate of the 1970s for the species global population size (12,000 individuals/9,000 breeders; Walter 1979). In particular, the population size at certain colonies was significantly underestimated in the 1970s (Table 3) as well as at national level in the 1990s (−260%; Birdlife International 1999; Bourdakis and Varelitzidou 2000). However, as concrete figures for most of the Aegean islands were lacking, this increase should be attributed to the improved monitoring scheme of the present study rather than to a true population increment. The better area coverage was reflected in certain regions where the increase in population estimates was extraordinary, namely NE Aegean (+390%), Sporades (+220%), Cyclades (+110%) or intermediate in Kythira (+50%) and Dodecanese (+25%). In contrast, in the region of Crete, a population decline at a rate of 15% per year during the

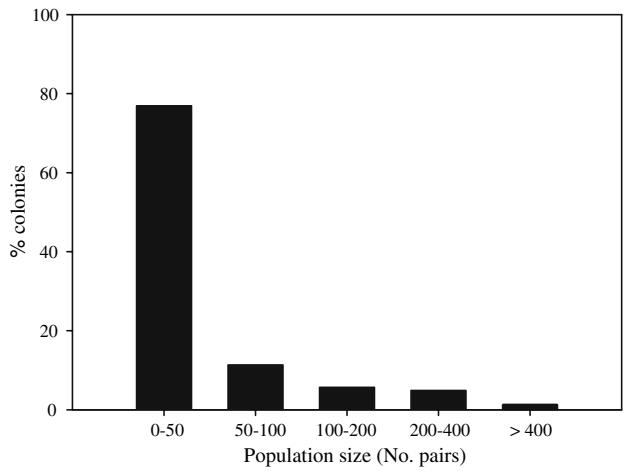

Fig. 3 Frequency distribution of colony size of Eleonora's Falcon in Greece (2004–2006)

Table 3 Comparison of past (Walter 1979) and present population estimates (number of pairs) of Eleonora's Falcon

Region	No. colonies	1970s average estimate	Current estimate	Difference (%)
NE Aegean	1	15	162	+980
Sporades	5	95	506	+433
Cyclades	21	727	1,052	+45
Dodecanese	18	440	526	+20
Crete	12	665	921	+38
Kythira	2	85	504	+492
Total	59	2,112	4,174	+98

period 1997–2000 (Ristow 2001) has been reported for certain colonies, which have been closely monitored since 1965 (Ristow et al. 1989, 1991). This negative trend was attributed to incidences of secondary poisoning in the foraging areas over Crete (Ristow et al. 2000; Tsatsakis et al. 2001; Xirouchakis 2004), though deterioration of food abundance in both the wintering and breeding quarters should not be ruled out (Tingle and McWilliam 1999; Thorstrom and Rene de Roland 2000; Sanderson et al. 2006).

In conclusion, Eleonora's Falcon is by far the most important bird species breeding in Greece. Its national conservation status should be re-evaluated from "insufficiently known" to "vulnerable", since more than 30% of the breeding population occurs in a dozen of islets and data on population trends are still lacking. In the European context, it should be considered as "data deficient" until concrete data on its global population size become available.

Zusammenfassung

Status des Eleonorenfalken (*Falco eleonorae*) in Griechenland

Der Eleonorenfalke wird als die wichtigste Vogelart Griechenlands bezeichnet, da über 80% der Weltpopulation der Art in Griechenland brütet. In den Brutzeiten 2004–2006 wurde eine landesweite Populationserhebung durchgeführt, um Populationsgröße sowie Verteilung der Brutpaare zu erfassen. Diese Zählung war die erste ihrer Art und Teil einer weltweiten Zählung. 80 Mitarbeiter beteiligten sich daran. Dazu wurden standardisierte Protokolle für die Erfassung, beschrieben im International Species Action Plan, und eine interaktive GIS-Datenbank erstellt. Die gewonnenen Daten wurden gespeichert und die räumliche Verteilung der Art mit historischen Informationen und älteren Daten verglichen. Insgesamt wurden etwa 17.660 Falken bzw. 12.300 Brutpaare gezählt, die sich auf sechs größere Gebiete konzentrierten, nämlich in der Nordost-Ägäis, den Sporaden, den Ost-Kykladen, den südwestlichen Teilen der Dodekanes und den Satelliten-Inseln von Ost-Kreta. Im Vergleich mit älteren Aufzeichnungen von Brutgebieten und Populationsstatus wurden räumliche Veränderungen festgestellt mit einem Bestandrückgang in einem der vorgenannten Gebiete und einem anscheinenden Anwachsen der Population in den restlichen. Die Ergebnisse dieser nationalen Erhebung, die nun alle 10 Jahre wiederholt werden soll, stellten eine Grundlage zur Verfügung für die Überarbeitung des Schutzstatus des Eleonorenfalken in Griechenland und sind eine Datengrundlage für künftiges Monitoring der Art.

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