

## Article

# Population Status and Colony Characteristics of Eleonora's Falcon (*Falco eleonora*) in the National Marine Park of Alonissos—Northern Sporades, Greece

Dimitrios E. Bakaloudis , Evangelos G. Kotsonas \*  and Stavroula P. Saxoni

Laboratory of Wildlife and Freshwater Fish, School of Forestry and Natural Environment, Aristotle University of Thessaloniki, P.O. Box 241, 54 124 Thessaloniki, Greece; debakaloudis@for.auth.gr (D.E.B.); stav saxo@for.auth.gr (S.P.S.)

\* Correspondence: kotsonas@for.auth.gr

**Simple Summary:** Eleonora's Falcon is a colonial nesting, long-distance migrant with more than 80% of the global population breeding on Greek islands. It is a priority species for many protected areas including one of the largest Marine National Parks in Europe, the National Marine Park of Alonissos—Northern Sporades. We visited the area of the National Park twice during the breeding season of the species in 2021 and all individuals observed and active nests found were counted. We recorded 329 active nests allocated in 13 out of the 29 islands of the Park. Nests were located mainly in cliff cavities, oriented northwest and west above 12 m from the sea level. Greece is responsible for the protection of this emblematic bird of prey and the detailed information over the species population is crucial for its future management and conservation.

**Abstract:** Eleonora's Falcon is the commonest bird of prey in Greece, with more than 80% of the global population breeding on Greek islands. The aim of this study was to assess the population status and the colony characteristics for the species in the National Marine Park of Alonissos—Northern Sporades. Every island was circumnavigated twice in order to count individual birds and active nests during the breeding season of the species in 2021 by boat. Colony characteristics including nest category, nest height above sea level and nest orientation were recorded. The species was recorded nesting in 13 (12 uninhabited and 1 inhabited) out of 29 islands involving a total of 329 active nests. Most nests were in cliff cavities located between 12 m and 400 m above sea level, and had predominantly north-westerly and westerly orientations. These findings may inform conservation management decisions including minimization of disturbance in colonies, safeguarding colonies under threats, eradicating invasive species and protecting and enhancing the breeding habitat of the species in the specially protected area of the National Marine Park of Alonissos—Northern Sporades.

**Keywords:** priority species; monitoring; birds of prey; cliff cavities; colonial nesting; nest orientation



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## 1. Introduction

Monitoring of raptors is important for assessing the status and trend of their population [1] and hence for the implication of proper conservation actions and management measures [2,3]. Moreover, knowledge on diet [4,5], breeding output [6,7] and habitat use [5] can give further information on raptor ecology. Birds of prey are high-level predators and their populations are affected by habitat modifications, prey availability, pollutants and disturbances [3,8]. Furthermore, the availability and characteristics of nest sites [9] affect the population numbers and their breeding success, especially for cliff-nesting species [2,8,10].

Eleonora's Falcon (*Falco eleonora* Gené, 1839) is a medium-sized, migratory colonial falcon. It breeds in the Mediterranean Basin, while small breeding populations are found along the Atlantic coast of Morocco, and on the Canary Islands [11–13]. The species is a

long-distance migrant that overwinters in Madagascar and in East (E) and Southeast (SE) Africa [14–16].

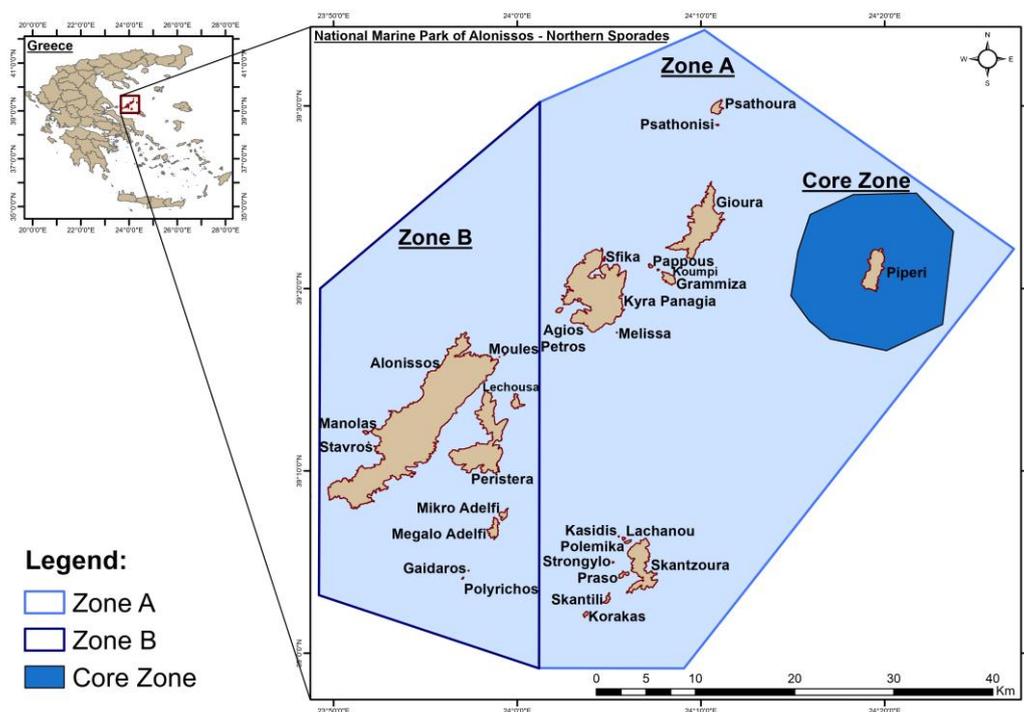
It is considered a species of “Least Concern” by the IUCN [17] and is legally protected by local, regional, national and European legislations [18]. Greece supports 86% of the European (>80% of the global) breeding population which accounts for 12,300 breeding pairs [17,19] distributed in seven major regions in the Aegean and Ionian Seas [17,19]. The Northern Sporades, in the northwest (NW) Aegean, support a significant portion of the species’ breeding population with 22 colonies and more than 300 pairs [13]. Eleonora’s Falcon is a priority species for the National Marine Park of Alonissos—Northern Sporades (NMPANS); however, its conservation status is uncertain due to a lack of population data.

The aim of this study was to estimate the population of Eleonora’s Falcon in the NMPANS and give insights into the colony characteristics of the species in this specially protected area. In this context, we collected data on individuals and active nests. Also, data on nest types, orientation and height of nests and nesting cliffs were recorded. We hypothesized that if crevices in cliffs exist in the area, then the falcons may use this nest type as observed in other parts of the species’ range [20,21]. Another hypothesis is that distance from the water surface might influence the Eleonora’s Falcon nest site selection. Based on earlier studies [21–23], we predicted that falcons locate their nests in the middle and upper parts of cliffs. Finally, the species may prefer to nest in sites with northeast (NE) to NW orientations as observed by earlier research in Sporades [22]. Such data is missing from the area of the NMPANS and we expect that our results will give insights into population size and the distribution of the colonies, along with the understanding of the nesting colony characteristics, which will enable better future monitoring and management of the species.

## 2. Materials and Methods

### 2.1. Study Area

The study was conducted in the NMPANS, in the NW Aegean Sea, Greece (Figure 1). The area has been under scientific interest since 1970 and was declared a National Marine Park by a Presidential Decree in 1992. It is one of the largest protected marine areas in Europe, covering 2315 km<sup>2</sup>. It includes 29 islands, islets and rocky islands, of which only one is inhabited. The islands have a combined coastline of 268.96 km while their sizes range from <0.1 to about 64 km<sup>2</sup>. The NMPANS is divided into two zones of protection. Zone A includes the eastern part of the NMPANS and the level of protection differs among the 19 islands included. The Core Zone is located in Zone A and includes Piperi Island and an area of 3 nautical miles around it, where no human activity is allowed except for scientific research and management. This area supports the highest concentration of caves suitable for the breeding of the Mediterranean Monk Seal (*Monachus monachus*). Zone B includes 10 islands in the western part of the NMPANS where most human activities are allowed. Alonissos is located in Zone B and is the only inhabited island with a population of 3138 residents [24]. Some areas in the NMPANS are open to tourism (disembarkation on a limited number of beaches, swimming, snorkeling and amateur fishing) during the whole breeding period of the species. Adult Eleonora’s Falcons have few predators; however, their nests may be predated by mammalian [Rats (*Rattus rattus*)] and avian [Yellow-legged Gulls (*Larus michahellis*), Scopoli’s Shearwaters (*Calonectris diomedea*), Ravens (*Corvus corax*) and Hooded Crows (*Corvus corone cornix*)] species that exist across the islands. Today, the area is under the responsibility of the Management Unit of Sporades National Park, which operates under the Natural Environment & Climate Change Agency of the Hellenic Ministry of Environment and Energy [25].



**Figure 1.** Map of the National Marine Park of Alonissos—Northern Sporades.

### 2.2. The Study Species

Eleonora's Falcons arrive at the breeding grounds between late April and late May. During that period, they disperse in various habitats for hunting and return to the breeding colonies to establish their territories in mid-July. The species inhabits rocky islands, steep coasts and rocky cliffs, where it breeds in colonies that can reach up to 200 pairs. It nests on the ground, usually in shady sites and the nest is a rough construction. Preferred nest sites are cliff cavities, rock ledges, under bushes or under boulders [26,27]. After the completion of the breeding in mid-October, the species starts its autumn migration to the wintering areas.

Eleonora's Falcon is a monogamous species that reproduces in late summer. The species has adapted its breeding cycle to the fall migration of small birds [12]. The female lays about three eggs at the end of July and a remarkable synchrony is observed in the laying of pairs in most colonies. The female is responsible for the incubation, which starts from the laying of the first egg and lasts 28–30 days [26]. Egg hatching is asynchronous and occurs at the end of August. The fledging period is about 35–37 days. The male provides food, mainly small birds and insects that it catches in the air with its claws [28,29], to both the incubating female and the chicks. The chicks usually leave the nest in the last days of September.

### 2.3. Field Data Collection

The perimeter of every island in the NMPANS was surveyed [30,31] twice (27 to 31 July and 24 to 28 August) during the breeding season of the species in 2021. Fieldwork was carried out between 7 a.m. and 3 p.m. on days with windspeed not exceeding 6–8 m/s. Counts were made from a still or low-speed (4–7 km/h) sailing boat at a distance of 50 m from the coast to a distance similar to the height of the cliff surveyed [19], with the use of 20×50 binoculars. Two observers were recording simultaneously. The first (always the same) was recording the individuals in the air and/or on the cliffs, and the second was scanning the entire cliff for active nests. Active nests were spotted by the adult behavior, the presence of chicks and feces. The maximum number of individual birds and active nests recorded during the two visits was used for further analyses. The density of the species was calculated as the number of individuals per km of coastline.

Earlier research conducted by Dimalexis et al. [19] used horns and other noise-producing equipment for flashing individuals from their nests or roost before counting. The flaws of their counting method have been clearly recognized and the present study deviated from this. Thus, we counted individual falcons without the use of such equipment. Their approach is not suitable for counting individuals due to the possible negative effects of noise on different aspects of the breeding performance [32,33]. Also, a nest-attendance index [34] proposed by Dimalexis et al. [19] was used to estimate the number of breeding pairs in our study area. This index related the counted individuals to the number of breeding pairs for Eleonora's Falcon and expressed as:

$$\text{Number of pairs} = \frac{\text{number of individuals counted}}{2} \times 1.4 \quad (1)$$

This index was calculated using data from 20 years for Eleonora's Falcon and concluded that every individual counted indicated the presence of 0.7 breeding pairs. The positions of nests were taken using a handheld GPS unit (Garmin Oregon 450t; Garmin (Europe) Ltd. Hampshire, UK) and plotted on a map. For every nest, we recorded the "type", which was assigned in four categories: (1) under bush, (2) under boulder, (3) on rock ledge and (4) on cliff cavity. The "orientation" [north (N), northeast (NE), east (E), southeast (SE), south (S), southwest (SW), west (W), northwest (NW)] for each nest and nesting cliff was recorded. Each nest cliff was divided into three sections, namely lower, middle and upper third, and the relevant section was noted for each nest. Also, for each nesting cliff, the "maximum height" was taken from topographic maps and expressed as mean  $\pm$  standard deviation (SD). Finally, the height above sea level (a.s.l.) of the lowest nest was also measured (mean  $\pm$  SD) and it was defined as the starting height of each colony.

#### 2.4. Statistical Analyses

Goodness of fit chi-square ( $\chi^2$ ) analysis was used to determine whether the frequency of nests distributed uniformly among a) the three height sections and b) the eight orientations. Residuals (res.) were used to reveal significant deviations between the observed and expected values. Chi-square analyses were carried out using SPSS (version 25.0), and differences were considered significant when  $p < 0.05$ .

### 3. Results

#### 3.1. Population Status

The area of the NMPANS was covered completely and the species was detected on 13 (45%) out of the 29 islands, islets and rocky islands (Table 1). A maximum of 356 individuals were counted during both surveys. Also, 249 breeding pairs approximately were estimated by using the nest-attendance index. The density of the falcons was 1.47 individuals/km of coastline. Nest counts resulted in a total of 329 active nests. The bulk of the nests was recorded on Piperi Island (36%), followed by Alonnisos (27%), Gioura (18%), Kyra Panagia (5%), Polemika (4%) and Strongylo (4%), while the rest of the islands supported a much smaller proportion of nests.

**Table 1.** Population size of Eleonora's Falcon in the National Marine Park of Alonissos—Northern Sporades during the breeding season of 2021.

Island	Number of Individuals	Number of Individuals/km of Coastline	Estimated Number of Breeding Pairs <sup>1</sup>	Number of Active Nests Recorded
Piperi	134	9.0	93.8	121
Gioura	59	2.0	41.3	60
Grammiza	2	0.4	1.4	1
Kyra Panagia	20	0.5	14	18
Peristera	5	0.1	3.5	3
Alonissos	97	1.2	67.9	89

Table 1. Cont.

Island	Number of Individuals	Number of Individuals/km of Coastline	Estimated Number of Breeding Pairs <sup>1</sup>	Number of Active Nests Recorded
Megalo Adelfi	3	0.5	2.1	4
Mikro Adelfi	2	0.6	1.4	1
Polemika	8	5.4	5.6	13
Skantzoura	1	0.1	0.7	1
Strongylo	12	24.5	8.4	12
Skantili	7	1.6	4.9	4
Korakas	6	1.3	4.2	2
Total	356	1.5	249.2	329

<sup>1</sup> The number of breeding pairs is estimated by the following equation: Number of pairs = number of individuals counted/2 × 1.4.

### 3.2. Nest Sites

Four categories of nesting sites of Eleonora’s Falcon were identified in the NMPANS (Figure 2). Specifically, out of a total of 329 active nests, 309 (93.9%) were located in cliff cavities, followed by those under boulders (3.6%). Fewer nests were found under bushes (1.8%) and only 2 nests (0.6%) were found on rock ledges. Nests in cliff cavities were found on all islands except for Strongylo and Korakas, while nests under bushes were spotted on Alonissos, Strongylo and Korakas islands. Additionally, nests under boulders were found at Piperi, Strongylo and Korakas, while nests on rock ledges were found only on the island of Alonissos.

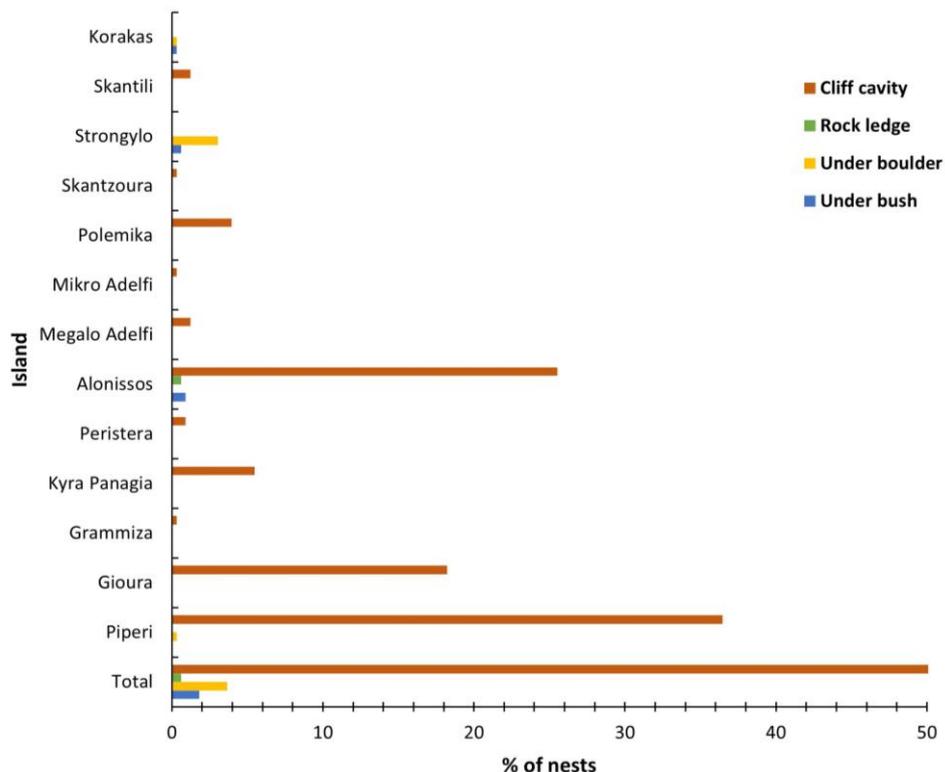
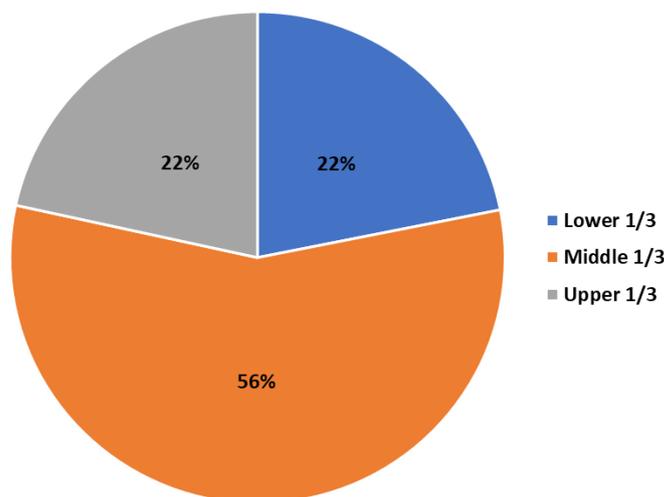


Figure 2. Percent (%) of Eleonora’s Falcon nest types on the islands of the National Marine Park of Alonissos—Northern Sporades. The percent of cliff cavities in the “total” category is 93.9%. The horizontal axis ended at 50% to increase the visibility of the bars.

### 3.3. Colony and Nest Height

The majority of the nests were located in the middle 1/3 (mean height a.s.l.: 69.8 m; range 13.3–266.7 m, n = 186) of the cliff, while a similar number of nests were located

on the lower (mean height a.s.l.: 34.9 m; range 6.7–133.3 m,  $n = 72$ ) and the upper 1/3 (mean height a.s.l.: 104.8 m; range 20–400 m,  $n = 71$ ) of the cliff (Figure 3). Nests were distributed unevenly among the three cliff height categories ( $\chi^2 = 79.702$ , d.f. = 2,  $p < 0.001$ ). More nests (res. = +76.3) were significantly observed in the middle third of the cliffs than expected, while a lower number of nests were found in the upper (res. = −38.7) and lower (res. = −37.7) thirds of the cliffs than expected.



**Figure 3.** Distribution of Eleonora’s Falcon nests ( $n = 329$ ) in relation to their position [lower 1/3 ( $n = 72$ ), middle 1/3 ( $n = 186$ ), upper 1/3 ( $n = 71$ )] on the cliff on the islands of the National Marine Park of Alonissos—Northern Sporades.

The average initiation height of colonies ( $n = 69$ ) was  $34.6 \pm 29.6$  m (range: 12–200 m) a.s.l. and the mean height of the cliffs ( $n = 69$ ) with nests was  $104.8 \pm 83.8$  m (range: 20–400 m) a.s.l. (Table 2).

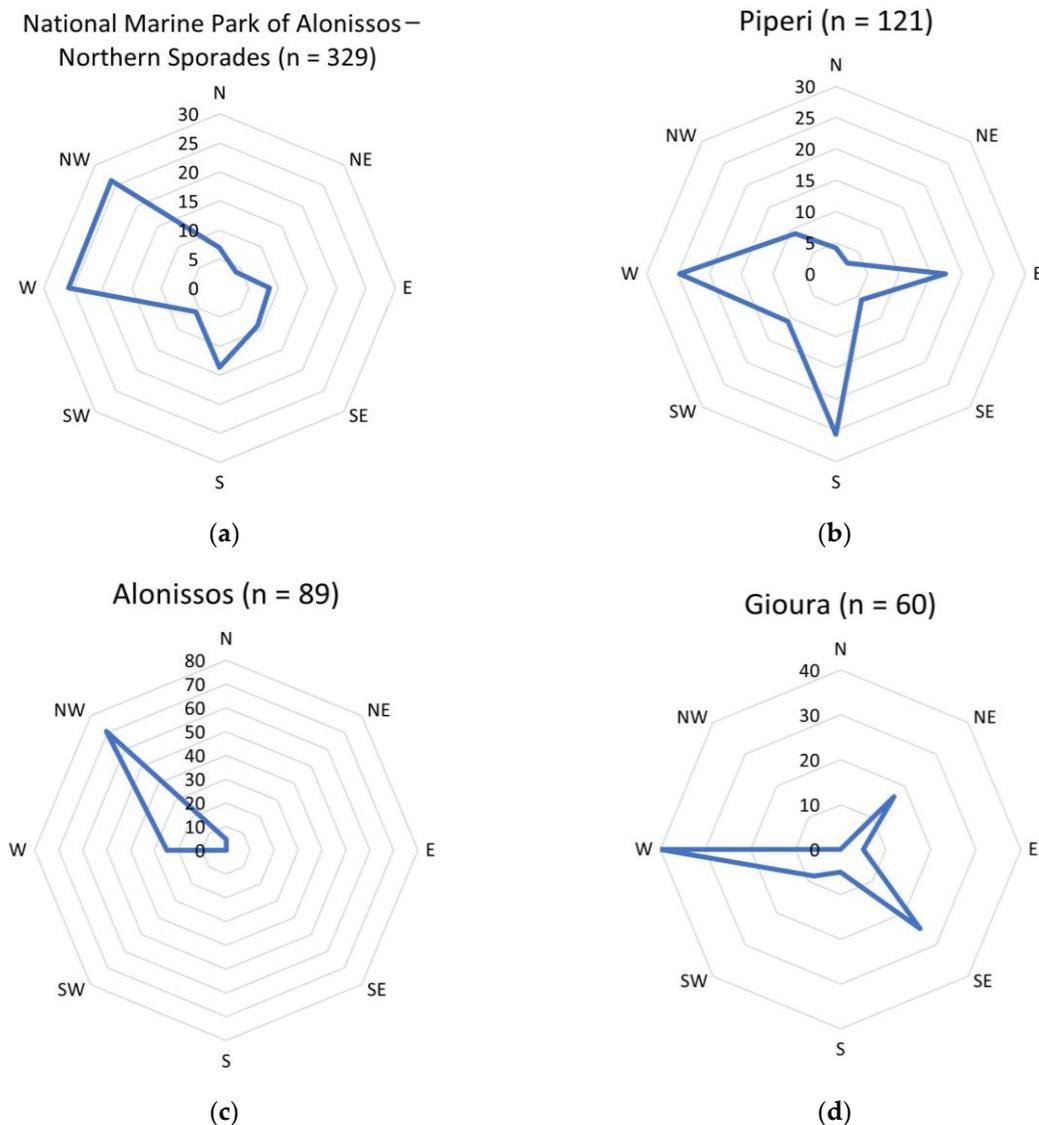
**Table 2.** Mean ( $\pm$ SD) and range of colony initiation height and maximum height of nesting cliffs on the most important nesting islands of the National Marine Park of Alonissos—Northern Sporades.

Island	Colony Initiation Height (m)		Maximum Cliff Height (m)	
	Mean $\pm$ SD	Range	Mean $\pm$ SD	Range
Piperi	$32.5 \pm 28.5$ ( $n = 29$ )	12–150	$87.9 \pm 64.6$ ( $n = 29$ )	20–300
Gioura	$39 \pm 49.1$ ( $n = 13$ )	12–200	$106.1 \pm 103$ ( $n = 13$ )	20–400
Kyra Panagia	$31.7 \pm 16.1$ ( $n = 3$ )	20–50	$86.7 \pm 23.1$ ( $n = 3$ )	60–100
Alonissos	$43.5 \pm 16.4$ ( $n = 15$ )	18–80	$167.3 \pm 93.7$ ( $n = 15$ )	60–300
All islands	$34.6 \pm 29.6$ ( $n = 69$ )	12–200	$104.8 \pm 83.8$ ( $n = 69$ )	20–400

### 3.4. Nest and Nest Cliff Orientation

The orientation of nests was recorded for all occupied islands of the NMPANS (Figure 4). Nest distribution differed significantly between the orientation categories ( $\chi^2 = 142.465$ , d.f. = 7,  $p < 0.001$ ). More nests were significantly oriented to NW (res. = +44.9), W (res. = +43.9) and S (res. = +3.9) than expected. In contrast, less nests were significantly oriented to NE (res. = −28.1), SW (res. = −22.1), N (res. = −18.1), E (res. = −13.1) and SE (res. = −11.1) than expected. Overall, most of the nests (26.1%) had a NW orientation, followed by those with a W orientation (25.8%) (Figure 4a). Also, 13.7% of the nests had S, 9.1% had SE, 8.5% had E, 7% had N, 5.7% had SW and 3.9% had NE orientation in the

NMPANS. Among the islands with a great number of nests, a relative differentiation is observed in their orientation. On Piperi, a large proportion of nests had S and W orientation (Figure 4b), on Alonissos, most nests faced NW orientation (Figure 4c), while those on Gioura had a W (33.8%) or NW (20.6%) orientation, followed by those oriented S (10.3%), SW (10.3%), N (7.3%), E (8.8%), SE (5.9%) and NE (2.9%).



**Figure 4.** Orientation of Eleonora's Falcon nests: (a) in the entire National Marine Park of Alonissos—North Sporades, and on the most important nesting islands: (b) Piperi, (c) Alonissos and (d) Gioura.

#### 4. Discussion

We detected nesting Eleonora's Falcons on 13 out of 29 islands studied. A total of 356 individuals and 329 active nests were recorded, while approximately 249 breeding pairs were estimated by the nest-attendance index. Falcons nested mostly in cliff cavities at a height that ranges from 12 to less than 400 m a.s.l. and most of the nests had a NW or W orientation. Sporades is one of the major breeding areas for Eleonora's Falcons in Greece [19]. The total area of Sporades includes 138 islands, islets and rocky islets and hosts about 2377 breeding pairs allocated in 38 colonies [19]. The mean colony size in our study area is 34.6 breeding pairs (resulting from the active nests), lower than the mean Greek colony size which accounts for approximately 54 breeding pairs [19]. Past population

data is missing for the majority of the islands in the NMPANS and our research gives a detailed status for Eleonora's Falcon in the entire area of the National Park. However, during a study conducted for four consecutive years (2004–2007), six islands belonging to the NMPANS (i.e., Korakas, Lachanou, Strongylo, Skantili, Polemika and Gaidaros) were searched for active nests [35]. Our results showed that among the six aforementioned islands, the Strongylo hosted the highest number (12) of active nests in 2021, while in 2007, the island supported only four nests (range: 4–10 nests during the four years). An annual nesting variation was observed on Skantili Island where two nests were found in 2007 (range: 2–6 nests during the four years), while we found four nests in 2021. Also, the number of nests on Korakas Island remained low during the 14-year interval period. Two nests were recorded in 2007 (range: 2–10 nests during the four years) and in 2021, our research team recorded the same number of nests. On the other hand, Polemika had no active nests in 2007 (range: 0–1 nests during the four years), and our results showed one active nest in 2021, suggesting that the species nests occasionally on this island. Finally, we have not recorded active nests on the islands Lachanou and Gaidaros in 2021, while the 2007 research showed three (range: 3–4 nests during the four years) and no (range: 0–1 nests during the four years) active nests, in Lachanou and Gaidaros, respectively. A possible explanation for this is that Lachanou was a former breeding island, which has been deserted or possibly nesting varies annually. On the other hand, Gaidaros is used by the falcons for occasional nesting.

In general, the species tend to occupy uninhabited islands, but also nest on large inhabited islands [19]. The highest number of active nests was recorded in the Core Zone on Piperi Island ( $n = 121$  nests), which is an area of full protection and no human activities are allowed. Furthermore, the inhabited island of Alonissos where human activities are present, hosted the second-highest number of nests ( $n = 89$  nests). Human presence may have a negative effect on the breeding output of the species [26] and may affect the selection of nesting sites [36]. However, on Alonissos, the species occupied the NW part of the island, where vertical cliffs with available crevices exist and the human presence is minor due to the absence of tourists and other activities. So, under effective protection, humans may pose no threats to the falcons in their breeding grounds [37]. In terms of population density, Strongylo Island showed higher values due to its small area, indicating available suitable nesting sites [11]. Under high population densities, Eleonora's Falcons used to defend the colony communally and hunt in groups [11,27,38,39], while behaviors, like the piracy of food, have been observed [22].

In the NMPANS, Eleonora's Falcons breed colonially on concave coasts, with elevated and steep cliffs. Ristow and Wink [26] noted that the position and orientation of Eleonora's Falcon nests indicate the level of nest protection, as observed for other raptors [9,40]. Falcons used to nest in shady sites, not directly exposed to sunlight, at a distance from sea level in inaccessible sites in order to prevent clutch and brood losses due to wave action and predators.

The islands of the NMPANS are characterized by high vertical cliffs with a plethora of suitable nesting sites for Eleonora's Falcon. Our results showed that about 93% of the nests in the NMPANS were in cliff cavities. This tendency of the species to nest in cavities in vertical cliffs is common across its range and observed on San Pietro Island, Italy [20], the Columbretes Islands, Spain [21], the Balearic Islands [41,42], Cyprus [43] and Algeria [23,44]. Smaller islands that lack vertical cliffs, provide other nest categories to the species. The nests on the flat small islands Strongylo and Korakas were spotted on the ground under boulders and bushes, while the only nest found on Skantzoura was at the entrance of a cave.

The height of the nest a.s.l. is crucial for the survival and the breeding success of the species. Nests in our study area were located from 12 m to about 400 m a.s.l. with higher frequencies in middle heights. In general, the species on Greek islands used to nest at a mean height of 26.5 m a.s.l. [22]. However, nests were observed very close to the water and in some cases at a distance of almost 2 m from the sea level. Data from other Mediterranean

areas showed that the species used a wide variety of nesting heights, depending on the availability of sites. On San Pietro Island in Italy, the species nests in a range of 5 to 110 m a.s.l. [20] and on the Canary Islands, from 40 to 225 m a.s.l. [45]. At the Columbretes Islands in Spain, the falcons preferred to nest in the upper parts of the cliffs [21] and a similar pattern was observed in Algeria [23] and on the Balearic Islands where the species nested at 150–200 m. Another study from the Balearic Islands showed that the species preferred lower nesting heights (15–38 m). Similarly, in two colonies in Cyprus, the species nested at low and medium heights of 5–25 m and 40–80 m, respectively [43]. A possible explanation for this preference is the protection from weather elements. In the area of the NMPANS, extremely strong north winds prevail during August. This period coincides with the chick-rearing period of the species. The strong winds cause significant turbulence in the sea which may drown the nestlings in nests very close to the sea level. Eleonora's Falcons breeding on small islands tend to select nesting sites away from the wave action closer to the inter parts with steep slopes [27]. Nests close to the coast on these islands may suffer greater nest failures by the wave action during heavy storms with strong winds that prevail during the summer [27,36]. In contrast to small islets, the larger ones pose a threat to the species due to the presence of predators. Another explanation is that the species nests in these heights in order to avoid predators in the NMPANS. Rats have been introduced unintentionally across the islands of the NMPANS. The management authority applied extensive programs for their eradication due to their possible negative effects on the nesting birds. Rat is a typical terrestrial predator for the nesting Eleonora's Falcons on Mediterranean islands [27]. The species tend to use crevices in vertical cliffs with less accessibility on these islands in order to avoid rat predation. Also, elevated nests are more hidden from predators and favor the movement from and to the colony [11,27,36].

The orientation of the preferred nests and nest cliffs may serve different aspects during the breeding cycle of the species. Most of the nest cliffs in the NMPANS had a W (33.8%) or NW (20.6%) orientation. Our findings comply with a past study, which showed that colonies in Sporades faced NW, N and NE orientations [22]. A possible explanation for this tendency is the morphology of the islands in the NMPANS. The majority of nesting islands have high vertical cliffs with many cavities, especially along their W and NW coasts. On the other hand, the remaining coastline includes well-vegetated low-altitude areas and concave bays with beaches. Similarly, Eleonora's Falcons prefer nesting sites with W and NW orientations on the island of San Pietro in Italy [20], NW and SW orientations on Sardinia [46] and SW orientation on the Canary Islands [45]. However, a high number of nests on Piperi Island (Core Zone), which supports the highest breeding population of the species, orients S and E, and on Gioura Island, nests face SE and NE orientations. This is true due to the availability of nesting sites in these orientations on these islands. The prevailing N winds in the area during the nestling phase of the species indicate that most of the nests in our study area are exposed. This is in contrast with the pattern observed in the majority of Greek islands, where the species tend to nest in sites protected by strong winds with SE orientation [22]. Also, results from the Balearic Islands reported that the species prefers to nest in S [42], SE [47] and NE [41] orientations. On the other hand, on the Columbretes Islands in Spain, the species prefers E orientations [36] in sites exposed to strong winds for more rapid and economic flights from the nest [36]. Across the Mediterranean, the species nests in sites with various orientations. Site availability is an important factor for the presence of a species in an area [8] and different theories have been proposed to explain the variation in orientation preferences. Some scientists linked the nest orientation with the fall migration routes of the passerines, which are the major prey category of the species during the rearing of the chicks [41]. Others suggested that the orientation may be associated with the protection of the nestlings from overheating in sites exposed to direct sunlight [11] and from winds in exposed sites [27,36].

Our results showed that the counting of active nests usually produced higher numbers of breeding pairs than the number estimated by the nest-attendance index. There are several possible explanations for this finding and thus these results need to be interpreted

with caution. Our research team tried to locate all possible active nests across all islands. However, the number of active nests may be overestimated or underestimated. Some nests were assigned as active due to the presence of feces at the entrance. Feces may indicate that the entrance is used as a perch and does not constitute a nest. On the other hand, finding some nests in colonial raptors may be difficult, especially in tall vertical cliffs [48]. An alternative solution, though less exhaustive is counting individuals moving to and from the colony [48]. This method causes less disturbance to the breeding birds. In contrast to earlier research [19] where horns and other noise-producing equipment (boat pipe, whistles, speaking trumpet) were used for flashing individuals from the nests or roosts, we counted individuals unaided and with the less possible disturbance. The strict protection status of the NMPANS, the sensitivity of the area to human activities and the possible nesting failure during the breeding period of the Eleonora's Falcon led our research team to deviate from this method. Noise may affect raptors in many different ways, including stress response, changes in reproductive success as the desertion of eggs during the incubation period and changes in parental care during the nestling rearing period [32,33]. Counting individual Eleonora's Falcon may result in an underestimation of their population. According to Walter [11], Eleonora's Falcons seen in the vicinity of the colonies comprise about 10% of the breeding population. This could be another possible explanation for the lower number of breeding pairs estimated by the nest-attendance index.

We are aware that our research may have some limitations. The first is that it is a single-year study and offers no long-term results on population trends. An additional is that data collection is restricted to a specific area. Also, we appreciate that the availability of nesting sites is of interest to many species. However, this was not included in our scope and no data were collected for nesting site availability. Inevitably, there were some problems concerning over- and underestimation of population size due to the different estimation techniques. We tried to count all individuals seen in the field, but pseudoreplication may probably occurred. Finally, we encountered no particular difficulties during the fieldwork, since the experienced staff of the Management Body provided valuable help. Future research should focus on investigating the breeding output across the islands. Furthermore, research is needed to determine whether predators and/or touristic activities may pose threats to Eleonora's Falcon population on the Sporades Islands.

## 5. Conclusions

This research underlined the importance of the NMPANS for the breeding population of Eleonora's Falcon. We provided further data on the population status and the distribution of colonies across the islands. The results of this study are crucial for the establishment of a monitoring program of the species population in the area. Moreover, the findings of our research have considerable management implications and can help the proper and better application of the management and conservation measures, including minimization of disturbance in colonies, safeguarding colonies under threats, eradicating invasive species and protecting and enhancing the breeding habitat of Eleonora's Falcon across the protection Zones of the NMPANS.

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