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Breeding biology and nesting site selection by the spur-winged plover *Hoplopterus spinosus* in the Evros Delta, NE Greece

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The breeding biology of the spur-winged plover *Hoplopterus spinosus* was studied in the Evros Delta during 2003. Nest selection was studied at a microhabitat level. The factors found to affect this selection were: distance from the nearest bush, sum of angles of optical scope on a radius of 50m, sum of angles of optical scope on a radius of 100m and distance from the nearest conspecific nest. The logistic regression model identified the factors: sum of angles of optical scope on a radius of 100m, surface covered by water, surface covered by bare ground and surface covered by the dominant plant as important microhabitat features for the prediction of the nest location. Regarding breeding performance, hatching success was estimated at 42%, while fledging success was estimated at 41%. Irregular flooding and trampling by grazing animals were the main factors found to affect nest failure. Management proposals for the protection of the species were given in relation to these factors.

Keywords: spur-winged plover; Evros Delta; breeding biology; nesting site selection; Greece

Introduction

The spur-winged plover, *Hoplopterus spinosus* (L., 1758), is a rare species in Europe as it only breeds in the Greek wetlands of Eastern Macedonia and Thrace. It is included in Annex I of the Directive 79/409 of the European Union. Its population in Greece is migratory and of an African origin (Snow and Perrins 1998). The species seems to have first colonized Greece in the last five or six decades (Makatsch 1962; Handrinos and Akriotis 1997) and continues to arrive at the large coastal wetlands of Macedonia and Thrace, where after extensive drainage and land-reclamation works as well as various human disturbances, it faces problems (Tucker and Heath 1994; Handrinos and Akriotis 1997).

The main breeding sites in Greece today are the Evros Delta, the wetland complex of Vistonida – Porto Lagos – Mitrikou Lakes and the Nestos Delta (Handrinos and Akriotis 1997). It has been reported that the Greek population has decreased since the 1970s (Tucker and Heath 1994; Handrinos and Akriotis 1997). In 1984 this population did not exceed 80 pairs (Hallmann 1986) and in 1994 it was between 32–45 pairs (Tucker and Heath 1994). Bauer and Muller (1969) estimated the population in the Evros Delta to be between 40 and 50 pairs. In the late 1960s a straight-line drainage canal ("Efthigrammisi") was constructed resulting in the loss

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of an important breeding area for the species, as the large silt areas, the islets and the sandy habitats created by the slow flow of the river were reduced, giving place to thick reed-beds unsuitable for the spur-winged plover (Hallmann 1986). In 1979 the population in the area was ten pairs and in 1982 it numbered only six pairs (Goutner 1983). During more recent surveys, an increase in the population of the species has been noted (15 and 25 pairs), establishing itself in new habitats with low halophytic vegetation close to fresh water (Makrigianni, pers. obs.).

Only a few studies have been conducted on the breeding biology of the species for areas other than the Evros Delta (Bauer 1960; Helversen 1962, 1963; Makatsch 1962; Czackes-Rado and Yom-Tov 1986/87; Yogev and Yom-Tov 1994, 1996; Yogev et al. 1996; Al-Safadi 1997) and none on the identification of the significant characteristics of the nesting habitat.

The aim of this study was to identify features that are important for the selection of nesting sites and to estimate the breeding success of the spur-winged plover in the Evros Delta. This information is expected to help managers to formulate the appropriate measures for the protection of the population by retaining microhabitat characteristics of the breeding area in a state appropriate for the species.

Study area and methods

Study area

The study area was the Evros Delta (40°44′–40°51′N and 25°30′–26°08′E), which is situated in northeastern Greece, on the border with Turkey. It covers an expanse of 20,000 ha, of which almost 9500 ha have been declared a Protected Area (Ramsar Site, SPA, pSCI). It includes large areas of agricultural land, flooded zones, freshwater canals, temporary freshwater marshes, wet meadows, lagoons, salt-marshes, sandy islands and almost all kinds of habitats typical of a Mediterranean delta (Figure 1).

Nesting site selection

From the arrival of the birds (around the end of February) the wetland was visited three times a week, resulting in 65 visits in total, with about 330 hours of observation and data collection. A map of the wetland (1:50,000) was used, superimposed on a grid of squares measuring 500 × 500m. In each square where the species was observed the numbers of individuals, the type of habitat and the activities of the birds were recorded. The records of birds with territorial behaviour (such as ousting invaders, copulating and nest site formulations) were noted in each survey on maps indicating the presence of the breeding pairs. The territory for each pair was calculated using all these points with 100% Minimum Convex polygons.

The nesting habitat was measured within the territories. As some of the pairs produced more than one clutch the first was used in the analysis. The analysis of the nesting habitat was studied on two scales: at the nest site and at the territory level. At the nest site, habitat features such as distances from the edge of the bush, nearest plant (including herbs), nearest dominant plant, nearest source of potential disturbance, nearest conspecific nest, as well as the sum of the angles of optical scope (a type of measure on the openness of the area) on a radius of 50m and 100m were calculated using a measuring tape or a compass. As a potential disturbance, the

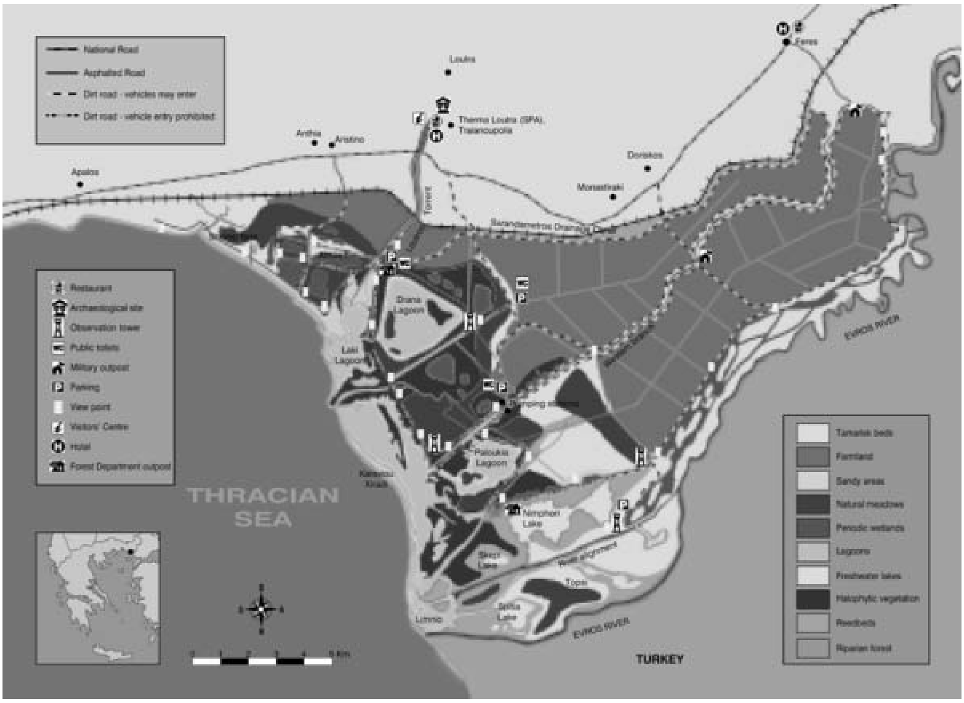

Figure 1. Map of the study area.

closest distance of either dyke or canal used by people or livestock was considered. At the territory level, the coverage of different types of land cover was visually estimated and the nest distance from the nearest plant of the dominant species was calculated using a measuring tape (Table 1).

Quickly changing parameters – due mainly to water evaporation – were measured while birds were still in the nests (distance from water and water/bare ground/dominant plant/vegetation/low vegetation cover). In all other cases, the measurements were taken after the birds had abandoned the nesting place.

Seven sub-areas were distinguished based on the spatial aggregative distribution of nests (sub-colonies). The sub-colonies were actually separated by physical limits (such as a large area of water or forested areas). These areas were further divided into squares of 10m $\times$ 10m and the same number of random points as the nest sites was taken from them in order to study the nesting selection. Whenever a randomly chosen square was in a location that could not be used by the species (water, tamarisks, etc.), it was excluded.

Comparisons between nesting sites and the corresponding random sites for the mean values of each habitat feature were made by paired *t*-test (paired, as the choice of the random points was not independent from the nests). The distribution of each habitat feature was checked for normality with the Kolmogorov-Smirnov test. All distances were transformed into square roots and the percentages were arcsine-transformed. In one case (distance to the nearest plant) the Wilcoxon test was applied (Field 2000) as normality was not achieved by the transformations used.

Table 1. Nesting place selection factors.

Factor	Nests Mean $\pm$ SD (range)	Random points Mean $\pm$ SD (range)	P
From the nest or random point			
Distance from bush (m)	33.07 $\pm$ 22.82 (1–110)	10.75 $\pm$ 15.54 (0.4–90)	<0.001
Sum of angles of optical scope on a radius of 50m	275.8 $\pm$ 74.90 (130–360)	183.2 $\pm$ 91.93 (40–360)	<0.001
Sum of angles of optical scope on a radius of 100m	197.1 $\pm$ 77.28 (56–360)	142.0 $\pm$ 87.90 (0–330)	0.001
Distance from water (m)	16.29 $\pm$ 20.55 (0.3–85)	11.90 $\pm$ 23.44 (0.2–144)	0.566
Distance from the nearest plant (m)	0.175 $\pm$ 0.182 (0.01–0.70)	0.302 $\pm$ 0.414 (0.01–2)	0.77
Distance from the nearest source of disturbance (m)	131.2 $\pm$ 120.4 (22–620)	107.8 $\pm$ 117.9 (1–660)	0.817
Distance from the nearest conspecific nest (m)	433.4 $\pm$ 971.2 (19–6651)	146.3 $\pm$ 135.6 (30–700)	<0.05
In the territory of the pair and the same area for random points			
Surface covered by water (%)	35.59 $\pm$ 20.84 (10–80)	35.84 $\pm$ 24.83 (0–85)	0.895
Surface covered by bare ground (%)	15.94 $\pm$ 10.17 (0–40)	15.42 $\pm$ 14.91 (0–80)	0.401
Distance from the dominant plant (m)	1.15 $\pm$ 4.114 (0.01–24)	0.619 $\pm$ 0.961 (0.01–5)	0.391
Surface covered by the dominant plant (%)	33.15 $\pm$ 21.86 (5–80)	26.14 $\pm$ 17.10 (4–80)	0.073
Total vegetation cover (%)	48.91 $\pm$ 21.85 (10–90)	49.64 $\pm$ 24.91 (10–98)	0.592
Total cover of low vegetation (%)	38.85 $\pm$ 24.37 (0–80)	36.54 $\pm$ 25.10 (0–93)	0.486
In a square 500m $\times$ 500 m with the nest or the random point as the centre			
Cover of saltwater habitat (%)	60.69 $\pm$ 15.46 (10–90)	59.80 $\pm$ 14.78 (20–90)	0.273
Cover of freshwater habitat (%)	39.91 $\pm$ 15.46 (10–90)	40.20 $\pm$ 14.78 (10–80)	0.273

Logistic regression was performed to predict the location where the species chooses to build its nest, using the backward stepwise selection procedure (Tarvin and Smith 1995; Kinnear and Gray 2000). To prevent multi-colinearity, the variables were tested with Variance Inflation Factor (VIF) Analysis (Quinn and Keough 2002). Variables with a tolerance value <0.1 or a VIF >10 were removed from the analyses (Bowerman and O'Connell 1990).

Breeding success

The number of eggs, of hatchlings and fledglings was counted for every pair and for every nest in order to determine the breeding success. For every pair and every clutch, the hatching and fledging success was calculated in relation to the eggs laid. The fledging success was also calculated in relation to the eggs hatched. At the same time, the failure of hatching and fledging was also calculated. A possible error could have occurred in estimating the number of fledglings but this error was minimized by the easy identification of the fledglings belonging to different families, due to the different temporal nesting activities among the pairs, as well as some degree of ringing of the young that was done during the study. The percentage of the pairs that produced at least one hatchling and of those that produced at least one fledgling was calculated in relation to the total number of pairs. Statistical analyses were performed using SPSS 10 and the significance level was set at $p<0.05$.

Results

Breeding biology

The first spur-winged plovers were observed at the end of February. The breeding procedures started a few days after the birds' arrival. The first copulations and territory establishment were observed on 6 March. The territory is usually selected by the male and often there is partial overlapping between the pairs. The mean area of a territory was calculated as 6.3ha.

Spur-winged plovers in the Evros Delta prefer areas with low halophytic vegetation in close proximity to freshwater (where it usually feeds). The territory of each pair is bordered by thick high vegetation, dykes or large areas of open water. The nest is constructed on the ground. The first egg-laying was observed on 23 April, and the last on 22 July (Figure 2). Most of the first layings were completed by 10 June.

Out of 30 pairs, 22 built one nest, seven built two nests and one built three nests. Of the seven pairs that built two nests, five lost their first clutch due to a disturbance to the nest (Table 2), while the other two produced a second clutch after a successful first brood. One pair made three consecutive nests after the first two were flooded. The distribution of clutch sizes is given in Table 3. The mean clutch size was 3.9 for all clutches, while for the first clutch it was 4.06 and for the second 3.44.

Nesting site selection

Data were collected for a total of 34 nests and for 34 random points. The spur-winged plover in its suitable nesting microhabitat chooses to build its nest at those points that have a greater distance from bushes and a larger optical scope resulting in a greater openness of the area than any random point in the same habitat (t-paired

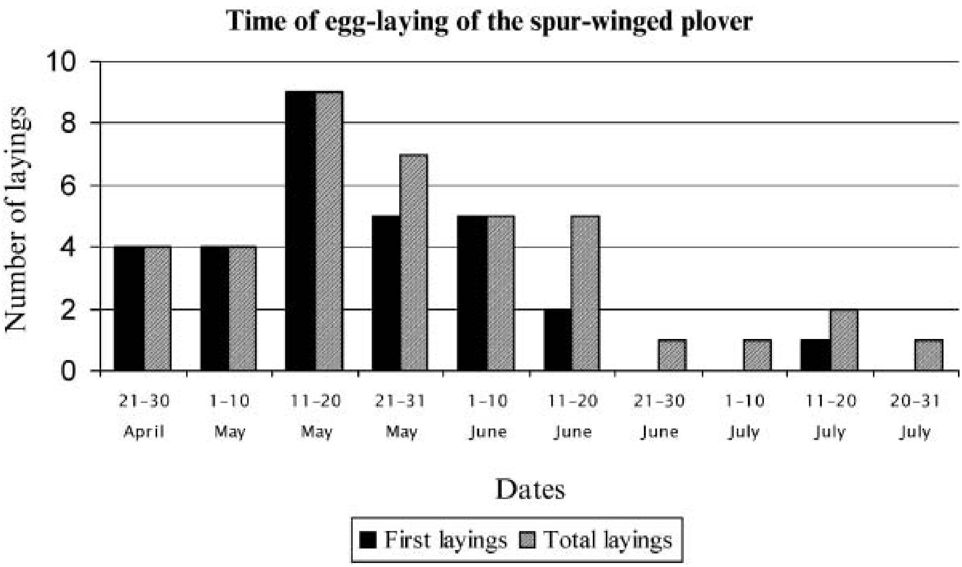

Figure 2. Time of egg-laying of the spur-winged plover (N=39 egg-layings).

test, Table 1). Additionally, the factor "Distance from the nearest conspecific nest" at the nest sites was found significantly larger than at the random points. There were no significant variables between nest sites and random points at the territory level.

Table 2. Reasons for hatching failure.

Reasons for failure	Number of nests	Percentage (%)
Flooding	10	50
Flooding from rainfall	4	20
Trampling by livestock (cows, horses)	3	15
Occupation by common terns	1	5
Unknown	2	10
Total	20	100

Table 3. Clutch size distribution of the spur-winged plover in the Evros Delta.

Clutch size (number of eggs per nest)	Number of nests	Percentage of nests (%)
2	2	5.1
3	2	5.1
4	33	84.6
5	1	2.6
6	1	2.6
Total	39	100

Prediction model

The final logistic regression model built by the backward selection procedure is based on four variables that concern the openness of the area and the coverage of water, bare ground and vegetation (Table 4a). The four variables are positively correlated with the presence of the nest sites. The model predicted the presence of the nest better than the absence: 76.9% (20 out of 26) of the nests and 70.8% (17 out of 24) of the random points were classified correctly. Overall, the model classified correctly 74% of the cases (Table 4b).

Breeding success

In total, 39 nests were built by 30 different pairs. The hatching success per clutch was 41% and 42% per pair (Table 5). The fledging success was similar, 39% and 41%,

Table 4. Logistic regression: a) selected factors, coefficients and significance; b) classification table

a)

Factor	Coefficient	Significance
Sum of angles of optical scope on a radius of 100m	0.012	0.022
Surface covered by water (%)	0.087	0.018
Surface covered by bare ground (%)	0.170	0.010
Surface covered by the dominant plant	0.101	0.019
Constant	−10.863	0.002

b)

Observed	Predicted		
	Random	Nest	% correct
Random	20	6	76.9
Nest	7	17	70.8
Total			74.0

Table 5. The reproduction success of the spur-winged plover.

Number of pairs (nests)	30 (39)
Number of eggs produced	153
Number of hatchlings	63
Hatching percentage per pair (nest)	42% (41%)
Number of fledglings	61
Percentage of fledglings per pair (nest)	41% (39%)
Percentage of fledglings (in relation to the hatchlings) per pair (nest)	98% (97%)
Number of pairs with at least one hatchling	18
Percentage in relation to the total number of pairs	60%
Number of pairs with at least one fledgling	18
Percentage in relation to the total number of pairs	60%

respectively. The fledging percentage per egg hatched was extremely high: 97% for the total of clutches and 98% for the total of pairs. Sixty percent of the pairs were successful, in the sense that they produced at least one hatchling and at least one fledgling. Only two of the 63 hatchlings did not fledge, for unknown reasons (possibly predation).

For 49% of the nests, at least one egg hatched. More specifically, in ten nests (26% of the total nests), four eggs hatched, in six nests (15%) three eggs hatched, in two nests (5%) two eggs hatched and in one nest (3%) one egg hatched. No eggs hatched for a significant percentage of nests (51%). The overall reproductive success of the species in the Evros Delta is limited by hatching failures, the main reasons of which are tabulated in Table 2. Exactly half (50%) of the failed nests were flooded because the local organization that controls the water distribution in the area (TOEV) allows freshwater from the river to flow onto the breeding grounds of the spur-winged plover and other birds in order to prevent the intrusion of seawater during the summer (with no certain schedule).

Discussion

Breeding Biology

In the Evros Delta, the breeding season of the spur-winged plover is short (April to August) compared to the sedentary African and Israeli populations (Cramp and Simmons 1985).

As has been observed earlier in other breeding places in Greece, copulation continues during incubation (Makatsch 1962). The breeding habitat of the species is divided into sub-areas and the territories of adjacent pairs partially overlapped, which is in agreement with the birds' habits in other breeding areas (Helversen 1963). Territories are arranged in loose neighbourhood groups with other suitable habitat unoccupied (Cramp and Simmons 1985); it is quite likely that the species-specific habitat use, in addition to the site fidelity, are the main reasons for the arrangement of the territories. Fidelity to the breeding area of the Evros Delta, as ringing recoveries demonstrate (Makrigianni, unpublished data), reveals that the occupation of the same territories is a relative indication of the suitability of the habitat (Finn et al. 2002).

The nest is built on sandy or muddy ground, which can be with or without small materials (small pieces of wood or stone, shells and cow faeces), as in most cases in both Greece and Israel (Raines 1962; Ferguson-Lees 1965; Czackes-Rado and Yom-Tov 1986/87). The diameter of the nest is greater (18–25cm) in the Evros Delta than in Israel (7–10cm; Czackes-Rado and Yom-Tov 1986/87), the Gaza Stripe (12–15cm; Al-Safadi 1997), the Aliakmon Delta (15cm; Makatsch 1962) or the Nestos Delta (10–11cm; Helversen 1963). It is possible that the different substrata of the nesting habitat determine the size of the diameter of the nest sites, although the actual reasons for this are difficult to identify.

The clutch size in the Evros Delta was found to be 3.9 ± 0.62, similar to that of Israel (3.4 ± 0.84, $N = 632$; Yogev and Yom-Tov 1994). Clutches with five or six eggs are rare but have been reported previously (Helversen 1963; Yogev and Yom-Tov 1996). The mean clutch size is reduced later in the breeding period as is suggested by the data from Israel on the spur-winged plover (Yogev et al. 1996), but also for other bird species (Begon et al. 1996; Kazantzidis et al. 1997).

The fledging time (five weeks) in the present study was shorter than that reported in other studies (seven to eight weeks in Cramp and Simmons 1985). It is expected that the fledging time is shorter at the upper end of the ranges, but it is worth noting that Al-Safadi (1997) found that it lasted only 23 days in the Gaza Strip.

Nesting site selection

For the spur-winged plover the areas where water evaporates are important for breeding. Salinity, however, is not essential for this species (Wilde and Wilde 1965), a fact supported by data which show that in the Evros Delta the species used to breed on islets and the sandy banks of the river up until the end of the 1960s (Hallmann 1986). The species can adjust quickly to changes in habitats. In Israel, Yogev et al. (1996) found that the spur-winged plover had expanded into artificial habitats (water reservoirs, airports, sewage plants). In Greece, in more recent years, the species has bred in places where there is human and animal disturbance (Cramp and Simmons 1985; Handrinos and Akriotis 1997). The appropriate habitat for the reproduction of the species in the Evros Delta currently lies mostly in semi-natural areas, next to road tracks, within grazing lands.

When choosing to build its nest, the spur-winged plover has certain demands on both the place and the microhabitat that surrounds it. The surface covered by bare ground was not a significant factor for microhabitat selection, but on the other hand, it was the most important variable, together with the cover of the dominant plant in the prediction model. The environmental characteristics around nests play an important role in the nesting habitat selection of this species as determined by the prediction model. Nesting in a safe habitat offers keen awareness against possible predators or invaders, as also indicated by the significance of the openness of the area and the distance from bushes around the nests (Helversen 1962).

At the territory level, most of the surface is covered by freshwater and low vegetation. The freshwater area is an essential place for feeding (Cramp and Simmons 1985) and it also constitutes a motive for the establishment and reproduction of the species (Rolstad et al. 2000). Low vegetation provides useful cover to conceal the hatchlings from enemies. (Helversen 1962; Makatch 1962)

The density of the nests depends mainly on the type of habitat and the fidelity of the nesting place. The nearest-neighbouring nest distances of the species were found to be higher than those of the random points. It must be noted however, that the distance of random points to the nearest nest was expected to be less than that between nests, as random points are located somewhere between the nests and there is no restriction on how close to a nest a random point might be assigned. Along the "Eastern Bank", and for 6 km, 21 pairs were observed, with one pair every 6.3 ha. In the Nestos Delta, density was calculated to be one pair per 2.6 ha (Helversen 1962, 1963). In Uganda, one pair was observed every 200m on either side of a road for 1.6 km with the exception of isolated pairs (Cramp and Simmons 1985), which is comparable to the case of the Evros Delta. There seems to be a lower density in the Evros Delta, probably due to the local geomorphology of the area and the availability of suitable nesting habitats. Indication for this is the decline of the population following the construction of the drainage canal (Hallmann 1986). Further evidence is that isolated pairs or pairs on the margins of the breeding area are either young, or are those that have not established territories in previous years (Makrigianni, pers. obs. by ringing recoveries).

Breeding success

Breeding success is very much affected by human factors, which are not controlled. One third of the nests were destroyed on account of either flooding or trampling by grazing animals. In the present research, 41% of the total eggs hatched, a much smaller number than that recorded in Israel (86.4%) where the breeding areas studied were inside sewage treatment plants with a controlled water level and no livestock (Yogev et al. 1996). In the Evros Delta, it appears that the irregular flooding of the breeding areas has a negative impact on the species. Not only does it result in serious alterations to the breeding grounds, but it also causes flooding of the actual nests. We believe that an agreement could be reached with TOEV, the local organization that controls the water level, to keep it stable during the breeding season (at least from April to July), permitting the purpose of the flooding, which is to protect the area from salt-water intrusion, still to be achieved. This action would likewise benefit additional species (such as black-winged stilts *Himantopus himantopus* (L., 1758), stone curlews *Burhinus oedicnemus* (L., 1758), redshanks *Tringa tetanus* (L., 1758), lapwings *Vanellus vanellus* (L., 1758) and others.

The free grazing of horses and cattle without the presence of a herdsperson is carried out in the protected area and disturbs not only the adult birds and their nests but also the hatchlings, as practically the entire area is encroached. It must be noted, however, that in the present study, grazing animals did not destroy many nests, contrary to the findings reported by Makatsch (1962) for the Aliakmon Delta or by Goutner (1993) for the avocets (*Recurvirostra avosetta* L., 1758) in the Evros Delta. Nevertheless, it is felt that free grazing should be prohibited in the protected area, an action that will favour the spur-winged plover as well as the vegetation in the area. It was found that hooded crows *Corvus corone* L., 1758 and Egyptian mongooses *Herpestes ichneumon* (L., 1758) preyed upon many eggs in Israel (Yogev and Yom-Tov 1994; Yogev et al. 1996) but in our study crows, raptors, wild mammals and dogs do not seem to cause problems. Although the majority of nests are beside dirt tracks, which have daily traffic there is no evidence that the species is seriously disturbed by passing visitors or other users of the wetland.

Fledging, on the other hand, was extremely successful, since 61 of the 63 hatchlings managed to fly. This is believed to be due to the successful mechanisms that the species uses for the protection of the hatchlings (aggressive adults, help from other pairs, cryptic colours, co-operation between family members). The spur-winged plover has an adaptive strategy to maximize its breeding success. Some pairs produce more than one clutch per season in order to replace those lost, or to produce more fledglings. Similar findings have also been reported in other studies (Yogev and Yom-Tov 1994, 1996; Al-Safadi 1997). In sum, external factors could seriously reduce breeding success. Therefore, the long-term monitoring of the population is a vital element for the viability of the species.

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