

Comparison of waterbird communities in a Mediterranean salina – saltmarsh complex

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ABSTRACT. Coastal wetlands provide habitat for large numbers and many species of waterbirds. Man-made salinas are a particular habitat type often found in such wetlands. This study is an initiative to understand the differences in bird communities between a salina (including evaporation ponds and prebasin) and a saltmarsh. Bird counts and nest surveys took place in the wetlands of Angelochori, Thessaloniki, Greece, in 1991, when the salina was inactive, and in 1997, 2000-01 when it was active. Counts in evaporation ponds were richer in species, abundance and nests compared to the prebasin and the saltmarsh. These three wetland types supported different bird communities. Similarities among bird communities depended on the inundation of the salina with seawater. Evaporation ponds in their inactive period presented low similarity with the communities of the prebasin and the saltmarsh; in the active period this was observed only for the saltmarsh. Species showing clear selection for the evaporation ponds were *Charadrius alexandrinus*, *Calidris alpina*, *Calidris minuta*, *Recurvirostra avosetta*, *Sterna hirundo*, *Sternula albifrons*, *Sterna sandvicensis* and *Haematopus ostralegus*; the prebasin was preferred by *Phoenicopterus roseus* and *Anas platyrhynchos*, and the saltmarsh by *Anas querquedula*, *Anas clypeata*, *Plegadis falcinellus*, *Tringa totanus*, *Tringa glareola*, *Tringa stagnatilis* and *Himantopus himantopus*.

KEY WORDS: conservation, shorebirds, waders, waterfowl, estuary

INTRODUCTION

Ecologists' knowledge of the functioning of ecosystems is needed to broaden the scientific basis of decisions on land use and management (DALE et al., 2000). In Europe, it is estimated that half to 2/3 of wetland areas have been destroyed, while degradation of the remaining wetlands continues (COMMISSION OF EUROPEAN COMMUNITIES, 1995). The need to maintain wetlands becomes imperative particularly for coastal wetlands due to increasing intensification of agriculture and pressures originating from housing needs and tourism (LOVVORN & BALDWIN, 1996; EUROPEAN ENVIRONMENT AGENCY, 2000).

Among other uses of coastal wetlands, salt collection in salinas is often a major activity. Coastal salinas (also known as solar ponds or saltworks) are anthropogenic habitats where salt is extracted from marine water through evaporation caused by solar radiation. They occur in large expanses in several geographical regions, extending, for example, over 1000 km² in the Mediterranean basin (SADOUL et al., 1998).

In the Mediterranean, over half of the approximately 500,000 migratory and wintering shorebirds that occur in the region use salinas (SADOUL et al., 1998). The latter provide important nesting, foraging and roosting habitats to waterbirds that prefer saline or hypersaline habitats (RUFINO et al., 1984; GOUTNER & PAPAPOSTAS, 1992;

MASERO & PEREZ-HURTADO, 2001). Findings suggest that salinas may be of particular value for some species, including waders and the greater flamingo (*Phoenicopterus roseus*) (MASERO et al., 2000; MASERO & PÉREZ-HURTADO, 2001; PARACUELLOS et al., 2002; BECHET et al., 2009; DIAS, 2009), but not for some others such as grebes and ducks (PARACUELLOS et al., 2002).

In some cases, salinas are constructed in saltmarsh areas (SADOUL et al., 1998), a major, widely distributed, coastal natural habitat. Saltmarshes with high structural and plant diversity, especially on sites where freshwater seepages provide a transition from fresh to brackish conditions, are particularly important for avifauna (MILSOM et al., 2000; SOKOS, 2006). For centuries saltmarshes have been subject to modification or destruction because of human activities (e.g. GOUTNER, 1997); further impacts on saltmarshes are expected by global sea level rise and warming (ADAM, 2002).

Although various studies have focused on birds either in salinas or saltmarshes (e.g. MILSOM et al., 2000; PARACUELLOS et al., 2002), the simultaneous comparison of waterbird communities in both land uses rarely takes place (e.g. BOLLMAN & THELIN, 1970; CATRY et al., 2004) and that is the aim of the present study. Additionally, the observed cessation and reactivation of the salina in our study area provided an excellent opportunity to detect the effect of that short-term habitat change in waterbird populations.

MATERIAL AND METHODS

The study area

The wider area of Central Macedonia is characterized by the presence of important wetlands for birds. The wetland of Angelochori ($40^{\circ} 29' N - 22^{\circ} 49' E$) is located on the east coast of the Thermaikos Gulf, near the city of Thessaloniki, Macedonia, Hellas (Greece). The climate is Mediterranean with a drought period during the summer.

In 1991 (first year of our study), the mean air temperature during spring was $13.1^{\circ}C$ and precipitation 185.2mm (March-April-May). In the 1997, 2000-01 period, the mean air temperature during spring was $14.4^{\circ}C$ and precipitation 120.8mm (mean values for the three years according to the Meteorological Station of Thessaloniki Airport). The wetland is surrounded by a non-tidal coast in the west and cultivated fields in the east (Fig. 1). The study area included both the salina with its evaporation ponds and prebasin (Angelochori salina) and the saltmarsh.

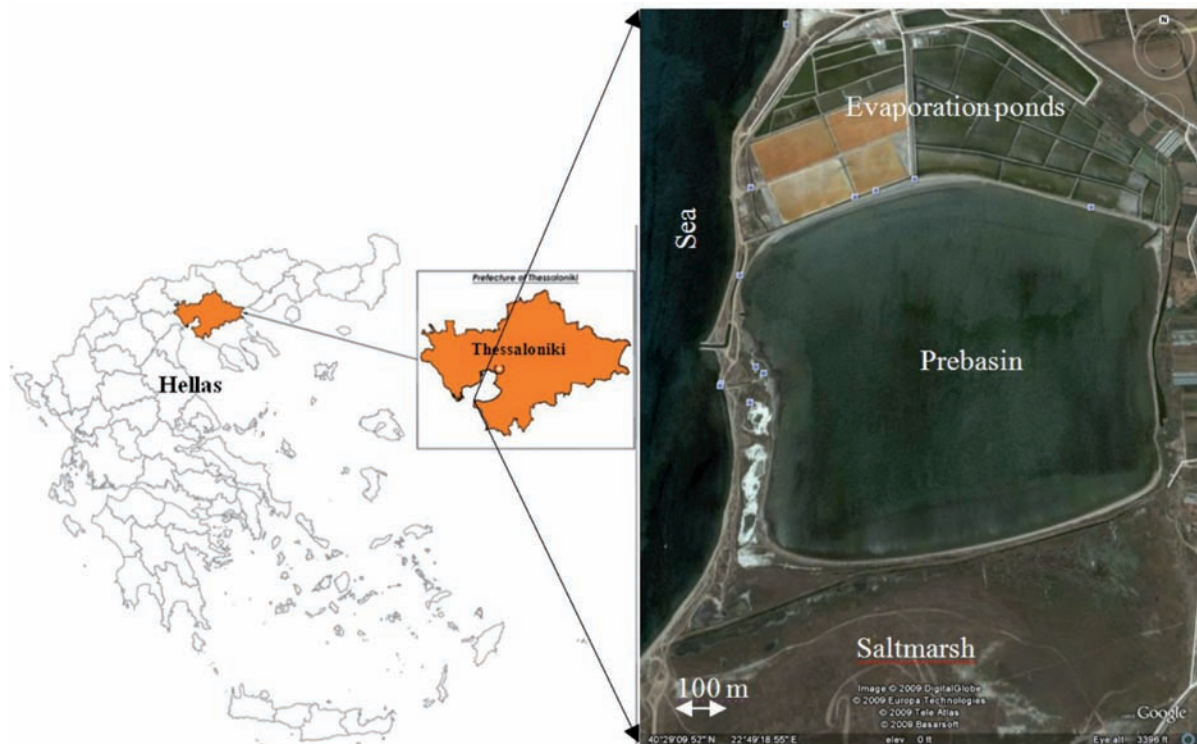


Fig. 1. – Satellite image of the study area (with map showing its location in Greece) with the localities of the three wetland types: evaporation ponds, prebasin and saltmarsh (source: Google Earth).

The evaporation ponds are delineated by small dykes without vegetation, about 30cm high, and the water depth varies from 0 to 15-20cm. Works aiming to improve salt harvesting in the salina prevented salt collection from 1989 to 1992. Thus, in the spring period of 1991, the evaporation ponds were not supplied with seawater and their flooded part extended over approx. 11ha, depending on the rainfalls. When the salina was active, in the spring periods of 1997, 2000-01, most of the ponds were flooded with seawater through the prebasin in late March – early April, and occupied an area of 20ha. Salt is usually collected during October; therefore in spring there is generally no or little human disturbance to birds using the wetlands.

The prebasin is a man-made lagoon with a total area 50ha, of which one third includes a muddy shore. According to Hellenic Saltworks Office in Angelochori, water depths vary from zero to a few centimetres in muddy areas, and up to 1.2m in the centre of the prebasin. In spring 1991, surface seawater did not enter the prebasin;

the contrary happened in the spring study periods of 1997, 2000-01.

To the south of the prebasin there is a saltmarsh, with an area of approx. 30ha, covered with halophytic vegetation (mainly *Salicornia fruticosa*, *Tamarix* spp. and *Arthrocnemum glaucum*), which is flooded during the rainy period and dries out in early summer. The extent of flooding varied from 17ha in the wet spring of 1991 to approx. 5ha in the dry periods of 1997 and 2000-01. The saltmarsh relief varies, thus creating ponds and small islands. The saltmarsh is grazed by cattle, which in some cases trample bird nests and chicks.

According to DIAS (2009) water depth, pond area and water salinity were the most important factors that explain the presence of the bird species on the salinas. In our study area the extent of flooding, water depth and salinity in the three wetland types depends on rainfall, evaporation and seawater entry. Salinity is highest in the ponds, with an average of 170ppt, medium in the prebasin (60-70ppt) and lowest in the saltmarsh (3-5ppt). During

the inactive period of 1991, salinity decreased in the ponds and the prebasin due to lack of entry of seawater in spring, although seawater did enter on one occasion during the summer (Hellenic Saltworks Office in Angelochori).

Waterbird surveys

Waterbird counts were carried out during spring in the study area when many wintering species, passage migrants and breeders coincide (GOUTNER et al., 2005). Waterbird surveys were conducted every 10 to 30 days during spring periods (5/3-29/5). In total, nine censuses were carried out in 1991, when the salina was inactive, and 16 in the 1997, 2000-01 period (five in 1997, six in 2000 and five in 2001) when the salina was active. These numbers of counts are adequate for the aims of such study (TUCKER, 1990; POMEROY & DRANZO, 1997; MURIAS et al., 2002).

Wetlands were surveyed in their total area by observers walking along specific transects and visiting specific positions around and inside the study area. Surveys were conducted from 9 a.m. to midday (12:00). All waterbird species were identified and counted with the use of either a 16-60 × 70 telescope or 10 × 50 binoculars. Given the open space of the study area, these counts were expected to lead to accurate assessments of abundance for most species (DAVIS & SMITH, 1998). Species unlikely to be detected with this census method, due to their dispersal or concealment in vegetation, are not considered here (e.g. *Gallinago gallinago*) or were not included in statistical analyses (*Charadrius alexandrinus*).

Nest surveys

Seven nest surveys were conducted only in 1991, from April 24th to August 11th by systematic rapid ground searching aimed at locating the nests without risking significant disturbance to nesting birds or chicks. Nest positions were marked on a map. Due to the difficulty in finding Redshank (*Tringa totanus*) nests, these were estimated indirectly from the number of birds (couples found) and their breeding behaviour (characteristic alarming calls near the nests).

Statistical analysis for the number of species and abundances

The aim of the present study was to compare the three wetland types as land uses, independently of the microhabitats provided by each one of them to different bird species. For instance, evaporation ponds were expected to have higher availability of preferred microhabitat for wader species than the prebasin due to their shallow waters, but the opposite was expected for *Phoenicopterus roseus*, which prefers deeper waters. For that reason and as the three wetland types had similar sizes, absolute numbers of species and abundances were used in statistical comparisons.

The one factor within subjects analysis of variance (ANOVA) (MEYERS et al., 2006) was used to compare the number of species and abundances per census, measured at the same date simultaneously for the three wetland types, thus compensating for the influence of weather

conditions and other factors on bird presence. The number of waterbird species was chosen as the response variable, the period as the within subject factor and the wetland type as the between subject factor. Normality and equality of variances were checked with the Kolmogorov-Smirnov and the Levene's test respectively (ZAR, 1996). The homogeneity of covariance was tested with the Mauchly Sphericity test. Whenever this test was significant, the F value was estimated with the Greenhouse – Geisser correction. In two cases, when some of the variables were not normally distributed, the non-parametric Friedman test was used. Post hoc tests were performed using the Bonferroni test, when there were multiple comparisons.

Statistical analysis for bird community similarity between wetland types

Similarity between waterbird communities of the three wetland types was investigated with the Bray-Curtis index. This widely-used technique reliably compares similarity in species composition and abundance between sample pairs (KREBS, 1999). The similarity was tested in each pair of wetland types for each count according to whether the salina was inactive (1991) or active (1997, 2000-01). Average similarities were compared via the one factor within subjects analysis of variance (ANOVA) (MEYERS et al., 2006).

Correspondence analysis (HAIR et al., 2006) was also used to explore relationships between the wetland types with regard to bird species and numbers. The variable "bird species" was weighted using the variable "number of species". The former was combined with the variable "wetland type" and then correspondence analysis was performed. In order to find the strength of the relationship between the categories of each variable, their distances were measured using the chi square method. The normalization for the distances was performed with the symmetrical method. The solution for the optimum number of dimensions (axes) was found by using the criterion of the variable with the fewer categories. This criterion defines that one should use "categories minus one" dimensions to represent the relationships (GARSON, 2008).

Statistical analysis for habitat selection

The Jacobs preference index (JACOBS, 1974) was used to make an assessment of the preference for the three wetland types by bird species taking into account the status of the function of the salina (inactive in 1991, active in 1997, 2000-01). The index (D) ranges from -1 (complete avoidance) to +1 (total selection); it is calculated by the form $D = (r - p) / (r + p - 2rp)$, where r is the proportion of individuals (of a specific bird species) in wetland type A, and p the proportion of the habitat area covered by wetland type A. The Jacobs index was calculated only for the species that were found in more than one wetland type. For species that were found in three or more censuses and with more than ten individuals in each period (inactive period in 1991, active period in 1997, 2000-01), index values between the two periods were compared via an independent samples T test. When there were violations of the assumptions of normality/equality of the variances, the alternative Mann-Whitney Test was used (ZAR, 1996).

RESULTS

Numbers and abundance of bird species – Bird community similarities between wetland types

In the 25 censuses carried out during the four spring seasons, 9528 birds belonging to 27 species were recorded in the three wetland types (Table 1); 21 species

were observed in the evaporation ponds, 20 in the prebasin and 20 in the saltmarsh. In 1991, we observed 24 species and in the 1997, 2000-01 periods we found 21 species. The most numerous species were *Recurvirostra avosetta*, *Himantopus himantopus*, *Charadrius alexandrinus*, *Phoenicopterus roseus*, *Tringa totanus*, *Philomachus pugnax*, *Tadorna tadorna* and *Anas querquedula*.

TABLE 1

List of bird species and total numbers of individuals in each wetland type (all visits included).

Species ^a	Species codes ^b	Evap. ponds	Prebasin	Saltmarsh
<i>Ardea cinerea</i> Linnaeus, 1758	Ard cin	10	13	11
<i>Egretta garzetta</i> Linnaeus, 1766	Egr garz	7	7	4
<i>Plegadis falcinellus</i> Linnaeus, 1766	Pleg falc	0	0	34
<i>Phoenicopterus roseus</i> Pallas, 1811	Phoen ros	40	925	8
<i>Anas platyrhynchos</i> Linnaeus, 1758	Anas plat	1	54	20
<i>Anas penelope</i> Linnaeus, 1758	Anas pen	0	4	0
<i>Anas acuta</i> Linnaeus, 1758	Anas ac	0	4	0
<i>Anas querquedula</i> Linnaeus, 1758	Anas querq	2	256	278
<i>Anas clypeata</i> Linnaeus, 1758	Anas clyp	0	4	48
<i>Tadorna tadorna</i> Linnaeus, 1758	Tad tad	308	226	105
<i>Fulica atra</i> Linnaeus, 1758	Ful at	0	13	0
<i>Haematopus ostralegus</i> Linnaeus, 1758	Haem ostr	19	1	2
<i>Charadrius alexandrinus</i> Linnaeus, 1758	-	744	>302	>177
<i>Calidris minuta</i> Leisler, 1812	Cal min	66	0	50
<i>Calidris alpina</i> Linnaeus, 1758	Cal alp	44	0	0
<i>Calidris ferruginea</i> Pontoppidan, 1763	Cal fer	35	0	29
<i>Philomachus pugnax</i> Linnaeus, 1758	Phil pugn	236	370	165
<i>Tringa totanus</i> Linnaeus, 1758	Trin tot	197	316	440
<i>Tringa nebularia</i> Gunnerus, 1767	Trin nebul	4	0	0
<i>Tringa glareola</i> Linnaeus, 1758	Trin glareo	10	6	66
<i>Tringa stagnatilis</i> Bechstein, 1803	Trin stagn	0	0	34
<i>Recurvirostra avosetta</i> Linnaeus, 1758	Recur avos	2034	78	56
<i>Himantopus himantopus</i> Linnaeus, 1758	Him him	206	403	642
<i>Burhinus oedicnemus</i> Linnaeus, 1758	Burh ohed	4	4	7
<i>Sterna hirundo</i> Linnaeus, 1758	St hir	97	8	2
<i>Sterna sandvicensis</i> Latham, 1787	St sandv	118	0	0
<i>Sternula albifrons</i> Pallas, 1764	St albifr	164	10	0
Total		4346	3004	2178

^aSpecies names according to Legakis and Maragou (2009)

^bSpecies codes as used in Figs 3-4 are given in this column.

The mean number of waterbird species per census between wetland types was slightly higher in the ponds (Table 2), but the application of the one factor within subjects ANOVA did not reveal significant differences, either in the 1991 or in the 1997, 2000-01 period [1991: Greenhouse-Geisser $F(1.209, 9.672)=1.258$, $p>0.05$; 1997, 2000-01: Sphericity assumed $F(2, 20)=2.482$, $p>0.05$].

There was no significant difference in mean waterbird abundance per census between the wetlands in 1991 (Friedman $X^2(2)=3.556$, exact $p>0.05$). For the 1997, 2000-01 period, however, there were differences between the wetlands (Friedman $X^2(2)=10.364$, exact $p=0.004<0.01$). The Bonferroni test revealed that the difference in abundance was significant only between ponds

and saltmarsh ($p=0.005<0.01$). For the same wetland types, no significant differences were found in the number of waterbird species and abundance within the study periods ($p>>0.05$).

Bray-Curtis percent similarities are showed in Fig. 2. Mean similarity values of wetland pairs were different in both periods (1991: Sphericity assumed $F(2, 16)=41.5$, $p=0.000$, 1997, 2000-01: Sphericity assumed $F(2, 30)=8.3$, $p=0.001$). During 1991, the Prebasin-to-Saltmarsh mean similarity was higher than Ponds-to-Prebasin ($p=0.001$) and Ponds-to-Saltmarsh ($p=0.000$). Between Ponds-to-Prebasin and Ponds-to-Saltmarsh we did not find significant difference ($p=1$). During 1997, 2000-01 Ponds-to-Saltmarsh mean similarity was lower than

Ponds-to-Prebasin ($p=0.003$) and Prebasin-to-Saltmarsh ($p=0.037$). Ponds-to-Prebasin similarity was higher than

the Prebasin-to-Saltmarsh, which, however, was not statistically significant (ANOVA, $p = 0.41$).

TABLE 2

Mean number (\pm SE) of waterbird species (sp.) and abundance (ab.) per count in each wetland type of the Angelochori wetland in the spring of 1991 (inactive salina) and in the springs of 1997, 2000-01 (active salina) (Spring 1991: $n=9$ counts; Springs 1997, 2000-01: $n=16$ counts).

	Ponds		Prebasin		Saltmarsh	
	'91	'97, '00 -'01	'91	'97, '00 -'01	'91	'97, '00 -'01
sp.	6.56 \pm 0.44	6 \pm 0.81	5 \pm 0.6	4.64 \pm 0.87	5.67 \pm 0.99	3.91 \pm 1.06
ab.	125.8 \pm 21.5	209.9 \pm 40.5 ^a	84.1 \pm 12.4	157.91 \pm 63.5	91.56 \pm 22.4	105.82 \pm 41 ^b

The two letters (^a, ^b) indicate the only significant different counts at the 0.05 level.

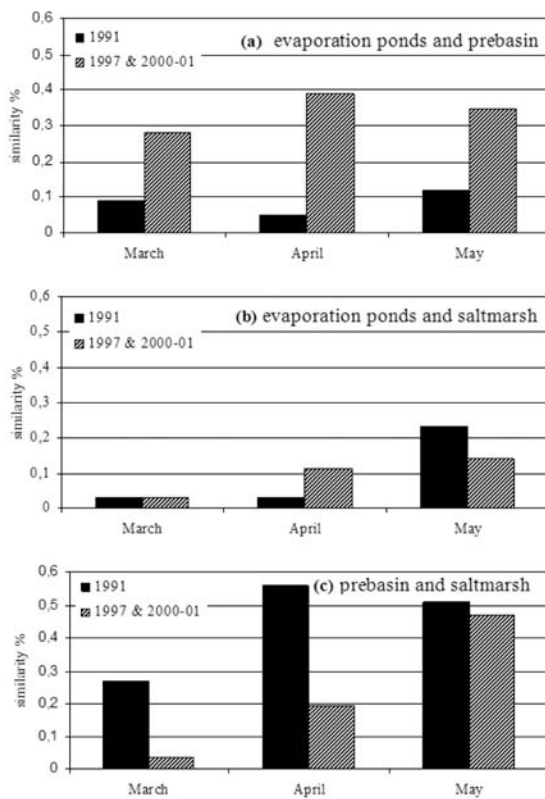


Fig. 2. – Bray-Curtis percent similarity between a) evaporation ponds and prebasin, b) evaporation ponds and saltmarsh, c) prebasin and saltmarsh, for each month.

The correspondence analysis was applied twice (Fig. 3). Since the variable with the fewer categories had three categories, a two dimension solution was chosen. For the 1991 period, the two-dimension solution fitted well to the data (Type I error < 0.1%) ($X^2(44)=1406.75$, $p=0.000<0.001$). The first dimension accounted for 54% of the total variance, while the second for 21.3%. For the 1997, 2000-01 period, the two-dimension solution also fitted well to the data (Type I error < 0.1%) ($X^2(38)=4428.02$, $p=0.000<0.001$). The first dimension accounted for 56.2% of the total variance, while the second for 33.4%. The correspondence analysis identified different bird communities in each wetland type and that some species, such as *Ardea cinerea*, selected other wetland type between the two periods.

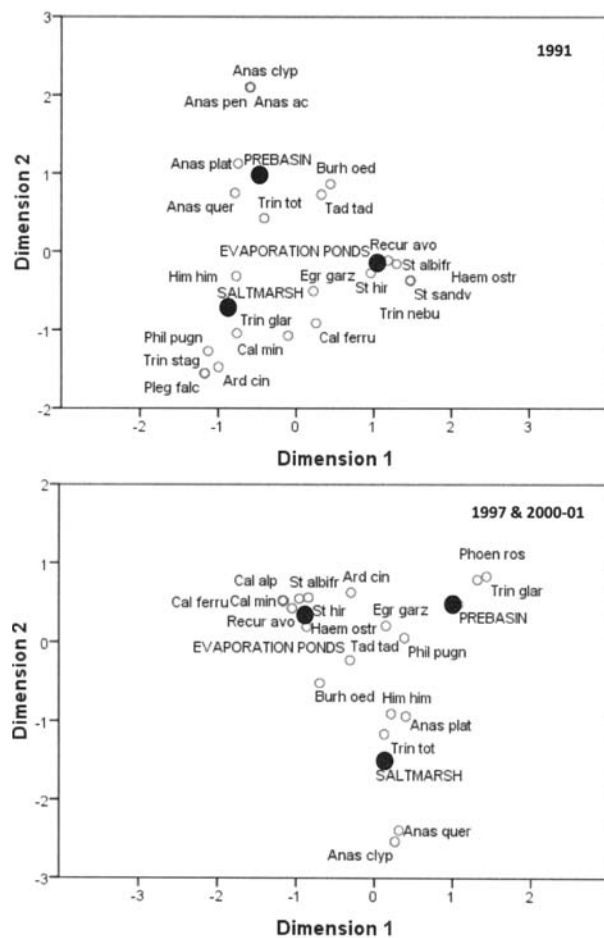


Fig. 3. – Correspondence analysis' bi-plot of wetland type with regard to bird species during the spring of 1991 (salina inactive) and springs 1997, 2000-01 (salina active).

Habitat selection

The selection of habitat by 18 waterbird species that used more than one wetland type, are examined in Fig. 4. Jacobs preference indices are not significantly different between the 1991 and 1997, 2000-01 periods for most of the species (T test or Mann-Whitney U: -0.122–3,7, df: 3–17, $p=0.059–0.844$), except for *P. pugnax* (Mann-Whitney U: 1.1, df: 9, $p=0.018$) and *Ardea cinerea* (Mann-Whitney U: 0, df: 5, $p=0.042$). *P. pugnax* selected the salt-

marsh in 1991, but in 1997, 2000-01 it did not show any particular preference for any wetland type. *A. cinerea* selected the saltmarsh in 1991, but in 1997, 2000-01 it selected the ponds.

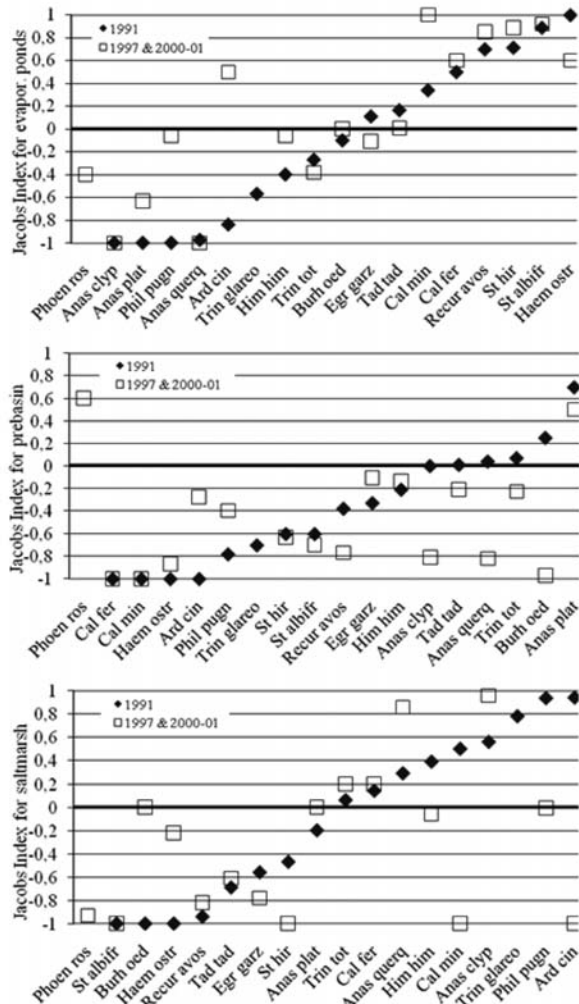


Fig. 4. – Wetland type selection of 18 bird species (codes names given in Table 1) as shown by the Jacobs preference indices. Points show mean index values from each count in which the species was found during the spring of 1991 (salina inactive) and the springs of 1997, 2000-01 (salina active).

Nest survey

In total, 335 nests belonging to seven waterbird species were found (Table 3). Most of the nests were found in the evaporation ponds, on the dykes and also at the bottom of dry ponds. At the saltmarsh, the nests of *H. himantopus* were in halophytic vegetation. The same was concluded for *T. totanus* based on the observed breeding individuals located in the saltmarsh and their breeding behaviour.

Thus, species with a mean Jacobs index of more than 0.6 are:

- seven for the evaporation ponds: *Calidris minuta*, *C. alpina*, *R. avosetta*, *Sterna hirundo*, *Sternula albifrons*, *S. sandvicensis* and *Haematopus ostralegus*,

- two for the prebasin: *Anas platyrhynchos*, *P. roseus*, and
- five for the saltmarsh: *Anas querquedula*, *A. clypeata*, *Plegadis falcinellus*, *Tringa glareola*, *T. stagnatilis*.

TABLE 3

Minimum number of nests in each wetland type during the spring and summer of 1991.

	Ponds	Prebasin	Saltmarsh
<i>Recurvirostra avosetta</i>	118		
<i>Charadrius alexandrinus</i>	69	16	
<i>Sternula albifrons</i>	41		
<i>Sterna hirundo</i>	30		
<i>Burhinus oedicephalus</i>	2		
<i>Himantopus himantopus</i>			46
<i>Tringa totanus</i> *			13
Total	260	16	59

*Nests were estimated indirectly from the number of couples found and their characteristic alarming calls near the nests.

DISCUSSION

The correspondence analysis identified different bird communities in each wetland type. However, significantly higher mean abundance was found in the 1997, 2000-01 period in active evaporation ponds in comparison with the saltmarsh (Table 2). This difference was caused by the selection of ponds shown by *R. avosetta*, *Calidris* spp. and *Sterna* spp.. It is also noteworthy that *P. pugnax* and *A. cinerea* selected the evaporation ponds more when these were active, that is in the 1997, 2000-01 period. This can be attributed mainly to the flooding of the salina with seawater and the increase of its flooded area (DIAS et al., 2009). In contrast, the flooded area of the saltmarsh decreased due to lower precipitation in comparison with the 1991 period. Studies have shown that shorebirds respond to variation in prey density, with a positive correlation between prey density and bird density (VELASQUEZ, 1992; MASERO, 2003; SANCHEZ et al., 2006). Bird counts in San Francisco Bay from 1964 to 1966 showed the highest densities of birds in salt ponds, followed by tidal flats, open water, and tidal marshes (BOLLMAN & THELIN, 1970). The same pattern appears to occur in our study area, where the higher salinity and water levels, in the 1997, 2000-01 period, seem to have improved food availability for many waterbird species in ponds.

Nevertheless, different waterbird species or groups respond to salinity in various ways (STRALBERG et al., 2003). Thus, in our study area, avoidance of the prebasin increased for *A. clypeata* and *A. querquedula* after its inundation with seawater. The same has also been found in other studies (MURIAS et al., 2002, PARACUELLOS et al., 2002, STRALBERG et al., 2003).

The bird community of the prebasin is of intermediate similarity to the bird communities of the ponds and the saltmarsh (Figs 2-3). This could be attributed to the position of the prebasin between the other two wetlands, although the distance between them is only a few hundred

meters and thus a waterbird requires minimal effort to fly from one to the other. Therefore, this explanation does not seem very likely. Another reason may be water salinity; when the salina was inactive and the prebasin water came from rainfalls, its bird community resembled more the saltmarsh bird community. When the ponds were irrigated with seawater through the prebasin (1997, 2000-01), their bird community similarity increased, but not significantly (Fig. 2). Similarly, PARACUELLOS et al. (2002) and MURIAS et al. (2002) have found that the abandonment of a salina causes changes in the waterbird community, such as the decrease of some waders and greater flamingo and the increase of ducks and diving bird species.

The observed use of available breeding habitat was different between waterbird species, with most species nesting in the ponds. Four species made their nests in the evaporation ponds, one both in ponds and the prebasin, and two species in the saltmarsh (1991). Most of the nests found in the ponds and the saltmarsh belonged to *R. avo-setta* and to *H. himantopus*, respectively. RINTOUL et al. (2003) found that *Recurvirostra americana* made greater use of ponds than saltmarsh, but for *Himantopus mexicanus* no preference was found. *Himantopus* spp. prefer vegetated areas for their nests (RINTOUL et al., 2003), a feature lacking from the dykes of the evaporation ponds in our study area.

CONCLUSIONS AND WETLAND COMPLEX CONSERVATION

From a bird conservation point of view, the objective is to determine how management of the wetland complex could improve for birds, especially for threatened species. Firstly, all three different wetland types have their own value for bird species. However, based on wetland type and breeding habitat selection, the evaporation ponds, followed by the saltmarsh, have higher value than the prebasin. Consequently, habitat improvement and partial expansion of, firstly, the evaporation ponds and, secondly, the saltmarsh area at the expense of the presently larger prebasin area, are actions that could potentially increase waterbird diversity. Nevertheless, it is essential to gain a better understanding of bird requirements and carrying capacities in different microhabitats, for at least the threatened species, as proposed in other studies (e.g. GOSS-CUSTARD et al., 1996). For example, the establishment of herbaceous vegetation on the dykes of the evaporation ponds is expected to improve the breeding habitat for *H. himantopus* (RINTOUL et al., 2003). However, this may degrade the habitat for some other species that prefer to nest on bare dykes.

The abandonment of the salina operation by the salt industry for two years did not significantly change bird diversity and abundance; however, changes in habitat selection by certain species were recorded. Therefore, if management of the salina – apart from its salt production target – aims not only at general avian conservation, but focuses on the conservation of specific species (such as threatened or flag species), the manager should take special measures.

A better understanding of the ecological requirements of waterbirds at the microhabitat level will contribute to the effective management of such a wetland complex. The current trend to cease or consolidate salt production in many parts of the Mediterranean has created many inactive and intermittently exploited salinas with hydrological infrastructures falling into ruins (PETANIDOU & DALAKA, 2009). Thus, in order to conserve salina waterbird species the inundation of salinas with seawater before the egg laying period (to protect nests from flooding) would be advisable. With regard to the saltmarsh birds, the implementation of habitat improvement techniques for the increase and retention of rainfall waters would ameliorate conditions for wintering waterfowl and nesting waterbirds (*H. himantopus*, *T. totanus*). Such activities can also be favourable to the development of sustainable human activities, as in the case of wetlands in the Camargue, France (SKINNER & ZALEWSKI, 1995; CUFF & RAYMENT, 1997).

ACKNOWLEDGEMENTS

Authors express their gratitude to: a) Mr. Panagiotis Latsoudis, ornithologist, for field assistance in four bird counts, b) the Meteorological Station of Thessaloniki Airport for providing meteorological data on the study area, and c) the Hellenic Saltworks Office in Angelochori for providing information on the management of the salina and data on salinity levels in its different compartments.

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Received: April 15, 2010

Accepted: March 17, 2011

Branch editor: Lens Luc