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Repercussions of the Abandonment of Mediterranean Saltpans on Waterbird Communities

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Abstract.—The richness and abundance of waterbird species were compared in active and abandoned saltpans in southeastern Spain. The effects of traditional methods of salt extraction in Mediterranean wetlands on the avian community were evaluated, as well as the effects of the abandonment of coastal salinas in Europe due to their present low profitability. Major changes in the waterbird community were found in disused saltpans, which were mainly due to environmental changes after salt production ceased. The diversity of bird species and the abundance of the diving species increased following abandonment, but the number of Greater Flamingo (*Phoenicopterus ruber*) and some shorebirds declined. Management measures required to improve the ornithological diversity in abandoned saltpans are proposed. *Received 20 October 2001, accepted 5 March 2002.*

Key words.—Community, conservation, ecological effects, morphology, salinas, saltpans, Spain, waterbirds.

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Human exploitation during the 20th century has had major impacts on the ecological communities in wetlands (Finlayson *et al.* 1992; Yuma 1993; Montes *et al.* 1995; Barbosa 1997; Murias *et al.* 1997; Marques and Vicente 1999). One use of wetlands in Europe has been the precipitation and collection of marine salt in marshes or coastal salinas (Casado and Montes 1995; Bradley 1997). This utilization, normally associated with modifications of the original characteristics of the aquatic systems, has usually favored those bird species dependent on saline or hypersaline habitats (Hidalgo 1991; Robledano *et al.* 1992; Castro 1993; Pérez-Hurtado and Hortas 1993; Barbosa 1997; Murias *et al.* 1997). Various authors agree that the abandonment of this industrial activity or its transformation to other uses have negative repercussions on the avifauna (Finlayson *et al.* 1992; Pérez-Hurtado *et al.* 1993; López Carrique *et al.* 1996; Bradley 1997; Viada 1999). However, during recent decades, the saltpan industry on European coasts has entered a phase of decline due to economic recession, with consequential changes in the use of the wetlands (Anonymous 1992; Castro 1993; Casado and Montes 1995; Montes *et al.* 1995). Thus in many regions, such as southeastern Spain, the majority of salinas have been permanently closed (Robledano *et al.* 1992; Matamala 1996). There is a need to evaluate the effects of this widespread abandonment of saltpans on their avian communities.

In the present study, we analyze the effects of the cessation of salt production in salinas in southeastern Spain on their waterbird community. We compare the avifauna before and after abandonment and contrast it with those found on other saltpans that remain active. Management strategies to improve the diversity and numbers of birds in the abandoned salinas are proposed.

STUDY AREA AND METHODS

We studied two saltpan complexes, Salinas de Cabo de Gata and Salinas de Cerrillos (CG and CE respectively). The former was still in use and the latter was abandoned in 1988. Both areas are now protected and considered of international importance to birds (Guirado *et al.* 1997; Viada 1999).

The two complexes are located in the Bay of Almería and separated by 40 km (Almería, southeast Spain; CG:

36°47'N, 2°14'W; CE: 36°44'N, 2°40'W). This region has low and seasonal rainfall, with the highest levels between September and February and lowest in July and August (Capel 1990).

These saltpan complexes were established in extensive natural coastal lowlands (Castro 1993; Sánchez and Molina 1996). Until 1988, both sites were in full working order, introducing seawater to a series of different types of pools (evaporators, heaters and crystallizers). Evaporation loss, decanting of iron oxides, carbonates and gypsum occurred, until water reached the precipitation pans or crystallizers, where the salt was harvested (principally sodium chloride; Vieira 1989; Castro 1993). This traditional method, still in use at CG, was responsible for the characteristics of the shallow and euhaline-hypersaline wetlands with high and permanent levels of flooding. At the end of the 1980s, the direct entry of seawater was stopped at CE when salt production ceased. As a consequence, lagoons in this wetland returned to something approaching their original state.

While the ecological characteristics of CG remain the same, those of CE have been altered (Table 1) as follows: i) the area of shallow and saline water was reduced by about 50%, becoming seasonal and dependent on rainfall; ii) given the lack of the control of water-level, underground water from local aquifers (supersaturated and contaminated by nutrients over the years) increased the water depth in some of the pools; iii) the salinity was lowered in such zones; iv) the cessation of seawater inflow, and the input of subterranean water increased the primary productivity of these flooded areas; v) the loss of salinity favored the increased cover of helophytes on the banks of such pools (for further information, see Sánchez and Molina 1996; Ortega *et al.* 2000).

With the aim of evaluating the possible variations in the waterbird community at CE in relation to the change of use after 1988, CG and CE were monitored simultaneously from 1979 onwards with the former acting as a control where no changes had occurred.

Table 1. The main environmental characteristics of Salinas de Cabo de Gata and Salinas de Cerrillos after 1988 (citing values from 1997). Surface area: total size of the wetland; Flooding level: average proportion of the area flooded in the winter (November-February) and summer (July-September) with respect to the total surface; Depth: the maximum water depth; Salinity: the average salinity over 12 months; pH: average pH value; PO_4^{-3}: average concentration of the phosphates; NO_3^-: average concentration of the nitrates; Chlorophyll-a, the average concentration of Chlorophyll-a; Helophyte coverage, the proportion of the total perimeter of the shore occupied by helophytes. Some data from Ortega *et al.* (2000).

	Salinas de Cabo de Gata	Salinas de Cerrillos
Surface area (ha)	269	390
Flooding level (%)	82	61-49
Depth (m)	0.5	1.3
Salinity (g l^{-1})	49	19
pH	7.9	8.0
PO_4^{-3} (µM)	<0.03	<0.03
NO_3^- (µM)	13	62
Chlorophyll-a (µg l^{-1})	2.3	24
Helophyte coverage (%)	15	38

The study was carried out during the two periods of the year, winter (November to February) and summer (July to October), when the birds made more intense use of the wetlands (Paracuellos 2001).

The counts of waterbirds made at CE before and after its abandonment were compared, as well as at CG for the same periods (1979-1988 and 1990-2000 respectively). The average value of the species richness and abundance of the bird species was calculated for the winter and summer seasons, for the periods before and after 1988.

For a community-scale study, only the waterbird species that used the salinas principally for feeding were taken into account. The species selected were divided into four guilds, according to their food searching behavior (Perrins and Ogilvie 1998): i) wading birds: Ardeidae, Threskiornithidae, Ciconiidae, Phoenicopteridae and Gruidae; ii) shorebirds: Rallidae except Common Coot (*Fulica atra*), Haematopodidae, Recurvirostridae, Charadriidae and Scolopacidae; iii) dabblers: Anserini, Tadornini and Anatini; iv) divers: Podicipedidae, Aythyni, Oxyurini and Common Coot. Moreover, to carry out the analysis for each site and for each period (before or after 1988), only those species with an average of at least 20 individuals in one or both areas were considered (Tables 2 and 3).

The percentage change in numbers of the principal species of shorebirds before and after 1988, using $[(a_i - b_i) \times b_i^{-1}] \times 100$, where b_i and a_i were the average values of the abundance of the species $_i$ in the periods before and after 1988, respectively. The relationship between this change and the average lengths of their respective tarsi and bills (sizes according to Perrins and Ogilvie 1998) were compared.

Differences in average values were tested for statistical significance using the Mann-Whitney U test, and the G test for frequencies. The analysis of relationships between pairs of variables was made using the Spearman rank correlation (Siegel and Castellan 1988).

RESULTS

During the study period, 53 and 66 waterbird species used the salinas for feeding at CG and CE respectively. When comparing the average values of the number of observed species, there were no important changes in the species richness at CG before and after 1988, but at CE there was a significant increase in richness (Fig. 1). This increase was mainly due to the addition of diving species not previously observed in the area (six new diving species, three wading birds, one shorebird and two dabbling ducks).

Wading birds and shorebirds were always the most abundant species in the CG community (Fig. 2). Although the latter group was also dominant at CE before its disuse,

Table 2. Average abundance (±SD) during winter of the main waterbird species at Salinas de Cabo de Gata and Salinas de Cerrillos before and after 1988. Statistical differences (Mann-Whitney U test) between both intervals are indicated: n.s., not significant; *P < 0.05; **P < 0.01. N, sample size (number of years). Guilds: ○, wading birds; ●, shorebirds; +, dabblers; □, divers.

		Salinas de Cabo de Gata			Salinas de Cerrillos		
		Before	After		Before	After	
N		6	8	Z	6	10	Z
Little Grebe (*Tachybaptus ruficollis*)	□	0 ± 0	0 ± 0	—	2 ± 3	83 ± 53	3.2**
Black-necked Grebe (*Podiceps nigricollis*)	□	25 ± 38	11 ± 5	n.s.	11 ± 15	143 ± 85	3.1**
Greater Flamingo (*Phoenicopterus ruber*)	○	252 ± 201	630 ± 81	3.0**	106 ± 72	141 ± 45	n.s.
Common Shelduck (*Tadorna tadorna*)	+	83 ± 6	18 ± 16	n.s.	28 ± 24	55 ± 48	n.s.
Eurasian Wigeon (*Anas penelope*)	+	9 ± 12	6 ± 12	n.s.	33 ± 30	10 ± 6	n.s.
Mallard (*Anas plathyrhynchos*)	+	28 ± 33	9 ± 0.7	n.s.	39 ± 27	36 ± 16	n.s.
Northern Shoveler (*Anas clypeata*)	+	18 ± 13	24 ± 13	n.s.	47 ± 50	150 ± 114	2.5*
Common Pochard (*Aythya ferina*)	□	15 ± 27	0 ± 0	n.s.	31 ± 44	29 ± 14	n.s.
White-headed Duck (*Oxyura leucocephala*)	□	0 ± 0	0 ± 0	—	0 ± 0	45 ± 36	3.2**
Common Coot (*Fulica atra*)	□	0 ± 0	0 ± 0	—	65 ± 79	57 ± 40	n.s.
Black-winged Stilt (*Himantopus himantopus*)	●	2 ± 3	28 ± 17	2.4*	14 ± 23	11 ± 4	n.s.
Avocet (*Recurvirostra avosetta*)	●	324 ± 121	278 ± 105	n.s.	58 ± 17	6 ± 5	3.2**
Kentish Plover (*Charadrius alexandrinus*)	●	6 ± 6	28 ± 12	2.7**	35 ± 41	45 ± 18	n.s.
Sanderling (*Calidris alba*)	●	7 ± 10	20 ± 13	2.3*	9 ± 2	26 ± 16	2.1*
Little Stint (*Calidris minuta*)	●	42 ± 27	69 ± 26	n.s.	29 ± 24	56 ± 27	n.s.
Dunlin (*Calidris alpina*)	●	67 ± 46	102 ± 59	n.s.	54 ± 24	50 ± 19	n.s.
Black-tailed Godwit (*Limosa limosa*)	●	120 ± 81	120 ± 45	n.s.	89 ± 70	3 ± 3	3.2**
Common Redshank (*Tringa totanus*)	●	56 ± 35	46 ± 26	n.s.	32 ± 23	24 ± 10	n.s.

from 1988 the diving bird guild contributed a greater proportion to the total number of individual birds, and shorebirds shortly decreased in number (Fig. 2).

To identify the species responsible for these changes, the most abundant species were analyzed separately (Tables 2 and 3). Some showed no changes in numbers during the study period or changed in a similar way at CG and CE, such as Little Egret (*Egretta garzetta*), Common Shelduck (*Tadorna tadorna*), Eurasian Wigeon (*Anas penelope*), Mallard (*Anas plathyrhynchos*), Common Pochard (*Aythya ferina),* Ringed Plover (*Charadrius hiaticula*), Sanderling (*Calidris alba*) and Little Stint (*Calidris minuta*). Another group of species showed marked and consistent differences between the salinas. This was the case of diving species, such as the Little Grebe (*Tachybaptus ruficollis*), Black-necked Grebe (*Podiceps nigricollis*), White-headed Duck (*Oxyura leucocephala*) and Common Coot, whose numbers remained stable before and after 1988 at CG, but showed a significant increase at CE (Tables 2 and 3). The opposite was found for species of wading birds and shorebirds, such as Greater Flamingo (*Phoenicopterus ruber*), Black-winged Stilt (*Himantopus himantopus*), Avocet (*Recurvirostra avosetta*), Kentish Plover (*Charadrius alexandrinus*), Curlew Sandpiper (*Calidris ferruginea*), Dunlin (*Calidris alpina*), Black-tailed Godwit (*Limosa limosa)* and Common Redshank (*Tringa totanus*), whose numbers remained nearly constant or increased at CG, but decreased or were stable at CE (Tables 2 and 3). A unique case was that of Northern Shoveler (*Anas clypeata*). Although its numbers increased significantly from one period to the other, it occurred at CG exclusively during summer and at CE only during the winter (Tables 2 and 3).

Table 3. Average abundance (±SD) during summer of the main waterbird species at Salinas de Cabo de Gata and Salinas de Cerrillos before and after 1988. Statistical differences (Mann-Whitney U test) between both intervals are also indicated: n.s., not significant; *P < 0.05; **P < 0.01; ***P < 0.001. N, sample size (number of years). Feeding guilds: ○, wading birds; ●, shorebirds; +, dabblers; □, divers.

		Salinas de Cabo de Gata			Salinas de Cerrillos		
Species		Before	After		Before	After	
N		4	7	Z	7	9	Z
Little Grebe (*Tachybaptus ruficollis*)	□	0 ± 1	0 ± 0	n.s.	4 ± 6	68 ± 41	3.3***
Black-necked Grebe (*Podiceps nigricollis*)	□	17 ± 23	5 ± 4	n.s.	2 ± 1	70 ± 49	3.3***
Little Egret (*Egretta garzetta*)	○	17 ± 4	33 ± 7	2.6**	7 ± 1	23 ± 10	2.9**
Greater Flamingo (*Phoenicopterus ruber*)	○	1054 ± 168	1174 ± 187	n.s.	505 ± 216	242 ± 149	2.5*
Mallard (*Anas plathyrhynchos*)	+	23 ± 9	11 ± 10	n.s.	39 ± 40	50 ± 8	n.s.
Northern Shoveler (*Anas clypeata*)	+	8 ± 10	45 ± 30	2.4*	58 ± 70	22 ± 25	n.s.
Common Coot (*Fulica atra*)	□	0 ± 0	0 ± 0	—	27 ± 37	95 ± 82	2.2*
Black-winged Stilt (*Himantopus himantopus*)	●	56 ± 22	48 ± 9	n.s.	43 ± 27	34 ± 5	n.s.
Avocet (*Recurvirostra avosetta*)	●	387 ± 135	397 ± 110	n.s.	171 ± 108	24 ± 38	2.5*
Ringed Plover (*Charadrius hiaticula*)	●	8 ± 4	7 ± 3	n.s.	31 ± 45	9 ± 5	n.s.
Kentish Plover (*Charadrius alexandrinus*)	●	80 ± 30	122 ± 42	n.s.	118 ± 87	122 ± 57	n.s.
Sanderling (*Calidris alba*)	●	8 ± 5	18 ± 18	n.s.	20 ± 26	15 ± 11	n.s.
Little Stint (*Calidris minuta*)	●	47 ± 11	59 ± 17	n.s.	98 ± 110	33 ± 13	n.s.
Curlew Sandpiper (*Calidris ferruginea*)	●	21 ± 13	22 ± 9	n.s.	84 ± 103	4 ± 7	3.0**
Dunlin (*Calidris alpina*)	●	40 ± 20	31 ± 14	n.s.	156 ± 148	22 ± 13	2.9**
Black-tailed Godwit (*Limosa limosa*)	●	191 ± 17	136 ± 24	2.5*	266 ± 157	2 ± 2	3.3***
Common Redshank (*Tringa totanus*)	●	114 ± 35	97 ± 16	n.s.	70 ± 35	21 ± 8	2.4*

On analyzing the relationship between the change in numbers of the main species of shorebirds at both sites from before and after 1988 and the average length of their tarsi and bills, a significant relationship was found at CE during winter (Fig. 3), but not for either site in summer or for CG in winter (N = 10 and 8 respectively: $r_s > -0.7$, n.s.).

DISCUSSION

Consistent changes over time in the waterbird community at both CG and CE could not be due to changes occurring in the study areas, and could be the result of regional or extraregional trends on a larger scale (see Dolz and García 1992; Tucker and Heath 1994; Rose and Scott 1997; Delany *et al.* 1999). However, changes in the bird community occurring at CE but not at CG, are likely to be related to the changes at the former site following the abandonment of salt production. Thus, the observed increase in the species richness at CE after the cessation of salt extraction was probably due to deeper, brackish, more productive water and with a greater cover of helophytic vegetation in concrete enclaves within the abandoned saltpans. This favored the increase of bird species diversity because the original species could still persist in the remaining shallow water bodies, while other new species, feeding principally by diving, used the new deeper and brackish pools. These pools provided suitable requirements for this guild of divers (Nilsson 1972a, b, 1978; Hobaugh and Teer 1981; Ydenberg 1988; Owen and Black 1990; Halse *et al.* 1993; Castro *et al.* 1994; Boyd 1997).

The decline in abundance of Greater Flamingo and certain species of shorebirds at CE following abandonment was probably due to the reduced size of shallow and salty waterbodies suitable for feeding (Finlayson *et al.* 1992; Pérez-Hurtado and Hortas 1993; Pérez-Hurtado *et al.* 1993; Barbosa 1997). However, this change did not affect all the

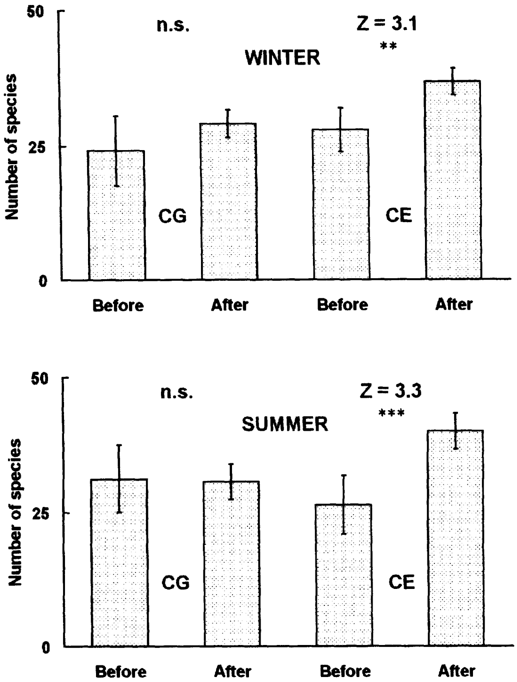


Figure 1. Average species richness (±SD) during the winter and summer of the waterbirds at Salinas de Cabo de Gata (CG) and Salinas de Cerrillos (CE) before and after 1988. The statistical differences (Mann-Whitney U test) between intervals are indicated: n.s., not significant; **P < 0.01; ***P < 0.001. For sample size see Tables 2 and 3.

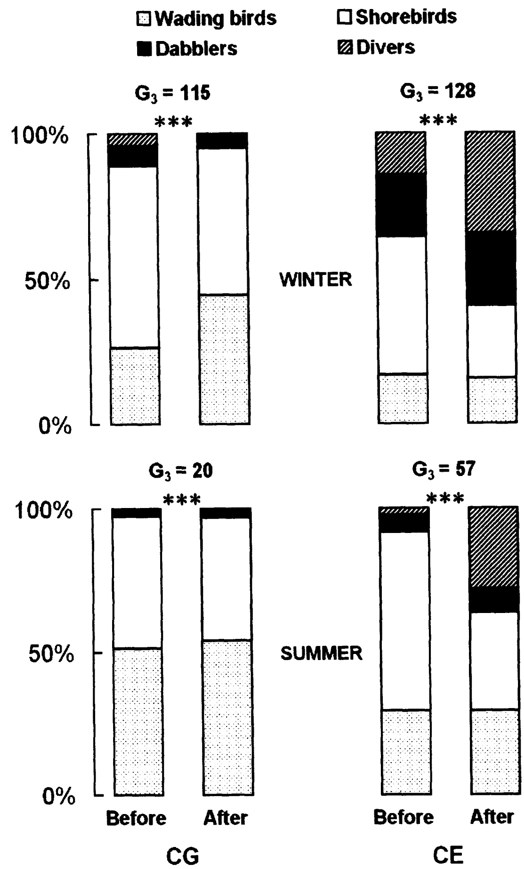
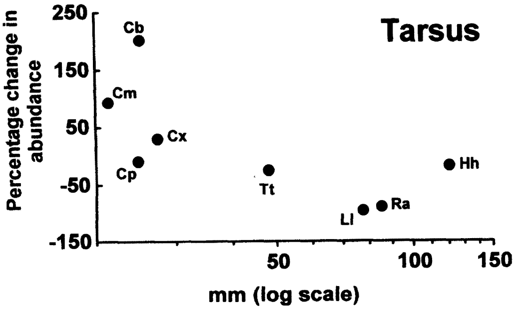


Figure 2. Average values during the winter and summer of the proportional contribution (%) of the species of different feeding guilds to the total abundance of waterbirds at Salinas de Cabo de Gata (CG) and Salinas de Cerrillos (CE) before and after 1988. The statistical differences (G test) between both intervals are also indicated: ***P < 0.001.

species in the same way, and we found a relationship between the change in numbers and the lengths of the tarsus and bill in the shorebird species. This relationship is probably explained by the relationships between the depth of water in habitats used by each species and their body dimensions (i.e., species with longer bills and tarsi use deeper water; Rubio 1986; Wiens 1992; Barbosa 1993 1997; Pérez-Hurtado and Hortas 1992; Pérez-Hurtado *et al.* 1993). Thus, as the size of shallow and salty lagoons decreased in CE after abandonment, those larger species adapted to feed in the interior and deeper zones (Greater Flamingo, Avocet and Black-tailed Godwit) were more affected because they had proportionally less remaining habitat than the smaller species (especially Sanderling and Little Stint), which used neighboring beaches as feeding habitat (Rubio 1986; Pérez-Hurtado and Hortas 1992; Barbosa 1993 1997). This relationship was not evident during the summer, probably because of the large variance in body dimensions of individuals, owing to the presence of adults and young of various sizes.

Management Implications

In some cases, the abandonment of saltpans is likely to have favorable repercussions on species richness, with the appearance of species of a high conservation importance, such as the White-headed Duck, listed as globally threatened (BirdLife International 2000). In order to improve the conditions for the Greater Flamingo and certain shorebirds following the abandonment of saltpans, the



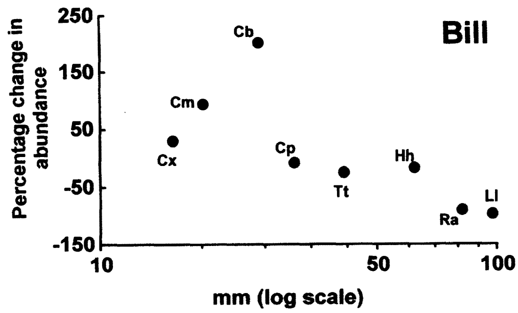


Figure 3. Relationship between the percentage change in abundance (%) form before to after 1988 of the main species of shorebirds at Salinas de Cerrillos during winter and the average sizes (mm) of the tarsus (Spearman rank correlation; $r_s = -0.7$, $P < 0.05$, $N = 8$) and bill (Spearman rank correlation; $r_s = -0.9$, $P < 0.01$, $N = 8$). Hh, Black-winged Stilt (*Himantopus himantopus*); Ra, Avocet (*Recurvirostra avosetta*); Cx, Kentish Plover (*Charadrius alexandrinus*); Cb, Sanderling (*Calidris alba*); Cm, Little Stint (*Calidris minuta*); Cp, Dunlin (*Calidris alpina*); Ll, Black-tailed Godwit (*Limosa limosa*); Tt, Common Redshank (*Tringa totanus*).

controlled re-flooding of the lagoons with seawater would be advisable. Moreover, with the object of not altering the habitat of the White-headed Duck, it is also recommended that this re-flooding should not affect the pools most related to underground water supplies (deeper and brackish pools).

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