In press

EFFECTS OF LONG-TERM HABITAT FRAGMENTATION ON A WETLAND BIRD COMMUNITY

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RÉSUMÉ. — *Effets de la fragmentation à long terme de l'habitat sur une communauté d'oiseaux des zones humides.* — L'évolution au cours des 50 dernières années d'une zone humide d'importance internationale pour les oiseaux de la province d'Almeria en Espagne, Albuferas d'Adra, qui a été soumise à de fortes pressions agricoles, a été analysée, de même que les modifications de sa communauté avienne. La fragmentation de l´habitat pendant toute la deuxième moitié du 20^{e} siècle a principalement concerné la roselière périphérique, dont les caractéristiques (surface, isolement des fragments) ont été fortement modifiées par les activités agricoles. Ce sont ces changements qui ont vraisemblablement causé la perte de plusieurs espèces rares de passereaux paludicoles nicheurs très dépendants de la roselière. Les espèces plus abondantes à l'échelle régionale sont celles qui semblent avoir le mieux résisté à la fragmentation de la roselière, apparemment parce qu'elles disposaient de plus d'individus susceptibles de coloniser les fragments. La conservation, la création ou la restauration de vastes zones humides et de leurs roselières sont nécessaires pour maintenir ou récupérer le plus grand nombre d'espèces aviennes paludicoles dans le sud de l'Espagne et permettre la nidification d'espèces menacées comme la Lusciniole à moustaches *(Acrocephalus melanopogon)* et le Bruant des roseaux *(Emberiza schoeniclus).*

SUMMARY. — The recent changes of an internationally important wetland for birds, Albuferas of Adra (Almería province, Spain), were analysed focussing on the long-term human impact on the landscape and its biological consequences for the avian community. Habitat fragmentation throughout the second half of the 20th century affected mainly the peripheral reed beds *(Phragmites australis)* most accessible to humans. These changes presumably caused the loss of the only nesting marsh passerines, the bird guild most dependent on emergent vegetation. More abundant species had greater capacity to occupy reed-bed patches apparently by having more colonizing individuals than did rarer species. Conservation, creation or restoration of marsh habitats in endangered and ecologically valuable wetlands are vital to maintain and recover the greatest number of marsh species, such as the threatened Moustached warbler *(Acrocephalus melanopogon)* and Reed bunting *(Emberiza schoeniclus)*.

Wetlands are of great conservational interest for having among the world's highest biological diversity and productivity (e.g., Whittaker & Likens, 1973 ; Gibbs, 1993 ; Casado & Montes, 1995). Furthermore, various globally threatened avian species depend on them (Tucker & Evans, 1997 ; IUCN, 2007). In recent decades, wetlands have declined worldwide due mainly to habitat loss by human activities, negatively affecting birds, particularly rarer or more sensitive species (Owen & Black, 1990 ; Finlayson *et al.,* 1992 ; Tscharntke, 1992 ; Weller, 1994 ; Casado & Montes, 1995 ; Tucker & Evans, 1997 ; Foppen, 2001 ; Parsons *et al.,* 2002). Nevertheless, works which empirically analyse long-term habitat loss and its consequences on species richness are scarce (see Shafer, 1990 ; Opdam, 1991 ; Wu *et al.,* 1997 ; Duncan *et al.,* 1999).

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The wetland of Albuferas of Adra (Almería, Spain) is a complex protected since 1989 for its high ecological value (Law 2/1989, 18 July, BOJA 60, 27 July 1989, Andalusian Government), being considered of international importance for birds (Ramsar site from 1994, BOE 273, 15 November 1994, Spain ; Specially Protected Area from 2002, according to the Birds Directive 79/409/EEC, DOCE L 103, 25 April 1979). Because of its importance, the Albuferas of Adra has received broad attention, with numerous surveys on its avifauna from the second half of the 20th century on. However, the wetland has been encroached upon for agriculture (Sermet, 1950), particularly greenhouses from the 1980s, filling in marsh zones (Paracuellos, 2006a). With information concerning the morphological and avian changes in the wetland over the last fifty years also being available, Adra serves as a good case study to evaluate the repercussions of the long-term landscape alteration over time on the bird community of an endangered and ecologically valuable wetland surrounded by a semiarid environment.

In this study, I analyse the biological repercussions of the alterations in the Albuferas of Adra from middle of the 20th century to beginning of the 21st century, examining three patterns : (1) the temporal trends in the spatial morphology (habitat size, fragmentation, isolation and interface degrees) of the wetland ; (2) the equivalent occurrence patterns of the avifauna, such as the threatened Moustached warbler *(Acrocephalus melanopogon)* and the Reed bunting *(Emberiza schoeniclus)* ; and (3) the relationships between the morphological characteristics of the wetland and the composition of their avifauna over time.

MATERIAL AND METHODS

Albuferas of Adra, located in a semi-arid region (Capel, 1990), is a Mediterranean wetland complex in the delta of the Adra river (36º 47’N, 2º 59’W, Almería, south-eastern Spain ; Martínez Vidal & Castro, 1990).

The wetland complex consisted, some 50 years ago, of two main lagoons > 80 ha with > 3 m depth of permanent, brackish, and eutrophic open waters circled by belts of emergent vegetation, the peripheral territory being occupied by sandy coastal formations, where human presence was scarce. However, from the end of the 20th century onwards, nearly all the surrounding land of marshes was taken over by agriculture, predominantly greenhouses (Gómez Mercado & Paracuellos, 1995-96 ; Fig. 1).

The submerged vegetation is composed mainly of Sago pondweed *(Potamogeton pectinatus)* and Spiny naiad *(Najas marina)*. In the shallower surrounding zones a reed bed developed, where Common reed *(Phragmites australis)* predominates, although Tamarisk *(Tamarix canariensis),* Cattails *(Typha* sp.) and Sedge *(Cladium mariscus)* are also common (Gómez Mercado & Paracuellos, 1995-96 ; Ortega *et al.,* 2004).

The recent evolution of the Albuferas of Adra was analysed using 8 aerial photographs taken successively from 1957 to 2000 (the average period between two consecutive photographs was 5.6 years, varying between 2 and 15 years). The following variables were calculated for each photo, delimiting the different habitat types by means of digital planimetry used with the ArcView GIS, 3.1 program (Environmental Systems Research Institute, Inc., 1992-98) : (1) the open water, emergent vegetation, and total wetland surface area ; (2) the average area of the open water, emergent vegetation, and total wetland patches ; (3) the total perimeter length of the wetland patches all together ; (4) the perimeter-total wetland surface area relationship (perimeter divided by surface area) ; (5) the perimeter complexity of the total wetland (according to the border length divided by the circumference of a circle of equivalent area, $2\sqrt{(\pi \text{ x surface})}$; Polis & Hurd, 1996) ; and (6) the average value of the distance to the nearest wetland patch, taking into account all the present patches. For the analysis, a habitat patch was defined as independent, isolated, and at least 20 m away from the nearest patch habitat area (open water, emergent vegetation, or total wetland).

A search for information was made on the bird species sighted in the lagoons during this time interval. The data came mainly from the literature and databases from the Andalusian Government. Only works on presence/absence using systematic surveys of direct observation and identification of the species and their stay in the wetland during wintertime or breeding were used. This information was complemented with data from zoological collections from the CSIC, statements from the staff of the CSIC and the Andalusian Government, knowledgeable long-time residents of the zone, and unpublished data of the author (Appendix). Due to the systematic avian search in all the interannual stages by two or more independent authors, it was assumed that surveys were comparable among stages to simple data of presence/absence, and that when a species was not detected it was truly absent.

In the study, only the swimmer and diver waterbirds (grebes Podicipedidae, wildfowl Anatidae, and some rails Rallidae) and the marsh passerines (Passeriformes linked to wetlands) were taken into account, as these were the groups best represented in the Albuferas of Adra (Paracuellos, 1991), very dependent on their ecosystem (Perrins & Ogilvie, 1998) and sensitive to habitat patchiness (Paracuellos & Tellería, 2004 ; Paracuellos, 2006b, 2006c). The two guilds were analysed separately in relation to the biotopes to which they were mainly associated (waterbirds *vs.* open water, marsh passerines *vs.* emergent vegetation), because of the different use that they normally made of the wetlands (van der Hut, 1986 ; Owen & Black, 1990 ; Weller, 1994). Species that were hidden in the vegetation or appeared accidentally or in passing were excluded from the study.

The data were divided into 7 stages (1950-69, 1970-79, 1980-84, 1985-89, 1990-94, 1995-99, and 2000-04), separating winter (Nov.-Feb.) from the breeding season (May-Jun.). For the analysis of the evolution of the avian

Figure 1. – Aerial photographs of the Albuferas of Adra in 1957 (top) and 1992 (bottom) showing the central open water (darker) and the peripheral belts of reed-bed (greyish) habitats of the lagoons surrounded by dunes and sands in 1957 and evergreens in 1992.

composition of the wetland throughout the study period, the time from the middle of the first stage (1959.5) to the successive ones (1974.5, 1982, 1987, 1992, 1997, and 2002) were used. To discriminate the relationships between morphological features and bird-species richness of the wetland, each photo was related to a corresponding stage. The average value for each landscape variable from the photos of 1957 and 1962 was used for the stage 1950-1969 to a complete matching between the data of landscape and bird variables.

Although data on bird abundance (quantitative) were not available for the Albuferas of Adra in the majority of the study stages, complete information usually existed regarding the presence/absence (qualitative) of all the species. For the stages in which presence/absence data were not compiled on selected species, the average values (0.5) were used between the two extreme hypothetical cases : in which these species were theoretically present (1) and in which they were absent (0). Also, for each marsh passerine, estimates were made concerning its maximum time of persistence in the wetland during breeding (time from the middle of the 20th century to the last stage in which each of the marsh passerine species was detected in the Albuferas of Adra during the breeding period), and the abundance for its total Spanish breeding populations (according to Martí & del Moral, 2003).

Pearson's Correlation Coefficient *(r)* was usually used for the simple relationship analyses with the variables, with logarithmic transformation of the data when these presented an initial non-normal distribution (Sokal & Rohlf, 1994). Once transformed, the data persistently displaying a non-normal distribution were analyzed by the R Spearman's rank (r_s) test for its correlations (Siegel & Castellan, 1988). The program used for the analyses was Statistica 6.0 (StatSoft, Inc., 1984-01), which implicitly corrects the possible tied data for the R Spearman's rank test (assigning to each the average value of the ranks resulting if not tied ; Fowler & Cohen, 1999).

RESULTS

Evolution of the wetland

Cultivated crops progressively occupying the Albuferas of Adra significantly reduced the surface area of the wetland until the 80s. From then on, the process slowed down due to the legal protection of the wetland. This shrank in 50 years from 49 % of the landscape surface area to 32 % (Figs. 1-2, Table I). This loss did not equally affect all the different biotopes of the lagoons. While the habitat of open waters, more interior and deeper, remained similar or greater in size from the beginning to the end of the study period (varying by about 25 % of the surface area of the territory), that of emergent vegetation, more peripheral and with shallow water, underwent the greatest size loss, shrinking to less than half its initial size (from 29 % of the landscape to 12 % in 50 years, with a loss of 27 ha, Figs. 1-2, Table I). Also, progressive fragmentation occurred in the reed bed as the crops encroached (with significantly smaller vegetation patches over time ; Figs. 1-2, Table I). However, the perimeter/surface relationship of the wetland did not increase, showing a trend towards the perimeter simplification (Figs. 1-2, Table I). Over time, habitat fragments became steadily more isolated by the loss of the wetland surface area (significant increase of the distance between patches, Figs. 1-2, Table I).

TABLE I

*Morphological characteristics of the Albuferas of Adra from middle of the 20th century to beginning of the 21st century, and their relationships (*r*) with the time.* N = *8. To the habitat surface and average size of the habitat patches the values are expressed, independent, to the total wetland, open waters, and emergent vegetation.*

Morphological characteristics	1957	1962	1977	1981	1985	1992	1998	2000	*r*	*p*
Habitat surface (ha) :										
– Total wetland	80.26	76.62	68.32	59.95	59.27	57.82	53.12	53.12	-0.98	0.00001
– Open waters	32.74	32.47	32.07	32.18	32.18	32.19	32.46	32.46	-0.36	0.38
– Emergent vegetation	47.52	49.58	36.25	27.77	27.09	25.63	20.66	20.66	-0.97	0.00005
Average size of the habitat patches (ha) :										
– Total wetland	11.46	38.31	22.77	9.98	8.47	9.64	10.62	10.62	-0.55	0.15
– Open waters	5.46	8.12	10.70	8.04	8.04	8.05	10.82	10.82	0.70	0.05
– Emergent vegetation	6.79	24.79	12.08	4.63	3.87	5.13	4.13	4.13	-0.69	0.06
Perimeter-total wetland surface relationship (m/ha)	179.24	143.94	183.71	166.72	166.09	174.75	164.97	164.97	0.06	0.88
Perimetric complexity of the total wetland surface area ($2\sqrt{(\pi \text{ ha})}$)	452.99	355.43	428.35	364.15	360.70	374.84	339.17	339.17	-0.67	0.07
Average distance between wetland patches (m)	26.74	32.30	29.49	53.33	60.75	83.33	53.60	53.60	0.72	0.04

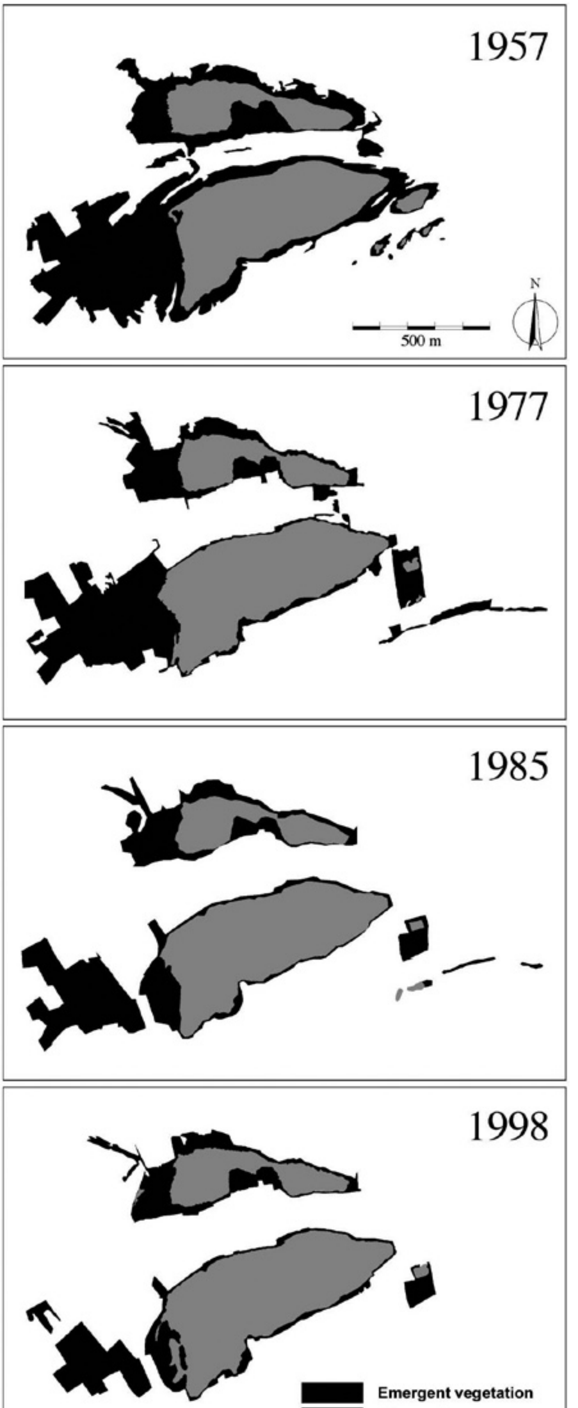

Figure 2. – Evolution of the wetland surface of the Albuferas of Adra from the middle of the 20th to the beginning of the 21st century (only four intercalated pictures are shown to represent the entire process). The image shows that the surface area of the emergent vegetation is progressively lost, fragmented and isolated, while the open-water surface area remains almost invariable over time.

Evolution of the avifauna

In the Albuferas of Adra, reliable data for 16 waterbird species were compiled over the study period (Table II). All the species appeared in winter, having consistent data about the absence of only the Greylag goose *(Anser anser)* in the last stage, and White-headed duck *(Oxyura leucocephala)* in the first two. Of all the species, only eight breeds, two of them (Great crested grebe, *Podiceps cristatus,* and White-headed duck) exclusively from the middle of the 1980s onwards.

Eight marsh passerine species were observed in Adra (Table II). Of them, six appeared in winter, without loss over time, and seven during breeding, of which three (Moustached warbler, Penduline tit *Remiz pendulinus* and Reed bunting) definitively disappeared as breeders from the middle of the 1980s onwards.

There was no significant relationship between the number of species, separately for waterbirds in both periods and marsh passerines in winter, and time from the middle of the 20th to the beginning of the 21st century (in the three cases $r \geq 0.59$, $n = 7$). However, a significant species loss was detected for marsh passerines during breeding as the time passed, approximately half of the nesting species disappearing (four extinctions *vs.* one recolonization ; Table II ; relationship between number of species and time from the middle of the 20th century : $r = -0.80$, $p = 0.03$, $n = 7$).

Relationships between landscape morphology and avifauna

A significant direct relationship was found between the number of marsh passerine breeding species and the reed-bed total surface ($r = 0.76$, $p = 0.04$, $n = 7$), while the relationship tended to be negative with the average distance between the surviving reed-bed patches ($r = -0.75$, $p = 0.05$, $n = 7$) and positive with the fragment average size ($r = 0.73$, $p = 0.06$, $n = 7$).

The relationship between the maximum time that passerine breeding species persisted in the marsh (Table II) and their abundance as breeders in Spain was analysed, revealing a positive and significant relationship between the two variables (Fig. 3). That is, very abundant species on a regional scale (currently with more than 10,000 pairs in Spain), such as Cetti's warbler *(Cettia cetti),* Fan-tailed warbler *(Cisticola juncidis),* Reed warbler *(Acrocephalus scirpaceus)* or Great reed warbler *(Acrocephalus arundinaceus),* bred in the Albuferas of Adra throughout the study period. However, scarcer species on a regional scale (actually with less than 10,000 pairs), such as Penduline tit, Moustached warbler, and Reed bunting, although they also bred during the first stages without a high habitat fragmentation, disappeared in the last stages as breeders when the loss and fragmentation level was highest in Adra.

DISCUSSION

Evolution of the wetland

The loss and degradation of marsh habitat found in the Albuferas of Adra appears to be related to a generalized tendency on a regional scale, where at least 60 % of the wetland surface, mainly coastal, have been lost mainly by anthropic interference in Spain during the last 200 years (Casado & Montes, 1995).

However, in Adra, physiognomic changes in the landscape were more evident in the peripheral and shallow biotope of emergent vegetation, because this habitat was most accessible to human activity.

Spatial fragmentation causes loss and patchiness of the habitat surface area, as well as isolation between the resulting patches, while at the same time increasing their interface with the surrounding environment by increasing the perimeter/surface relationship (Andrén, 1994 ; Turner, 1996 ; McCollin, 1998 ; Tellería & Santos, 2001). Although such patterns were found mostly in the reed-bed habitat of Adra, no increase in the perimeter/surface relationship was found, because of the simplification of the shape, from natural complex contours to rectilinear ones imposed by agriculture.

TABLE II

Matrix of appearance and number of avian species in the Albuferas of Adra during winter and breeding periods of each interannual stage (indicated by "X"). Dashed lines indicate no species present. Question mark (?) signifies without available data (average value, 0.5, between the two extreme hypothetical cases : in which these species were theoretically present, 1, and in which they were absent, 0).

	1950-69	1970-79	1980-84	1985-89	1990-94	1995-99	2000-04
Winter							
Waterbirds : Nº of species	14.5	14	16	16	16	16	15
– Little grebe *Tachybaptus ruficollis*	X	X	X	X	X	X	X
– Great crested grebe *Podiceps cristatus*	X	X	X	X	X	X	X
– Black-necked grebe *Podiceps nigricollis*	?	?	X	X	X	X	X
– Greylag goose *Anser anser*	X	?	X	X	X	X	---
– Wigeon *Anas penelope*	X	X	X	X	X	X	X
– Gadwall *Anas strepera*	X	X	X	X	X	X	X
– Teal *Anas crecca*	X	X	X	X	X	X	X
– Mallard *Anas platyrhynchos*	X	X	X	X	X	X	X
– Pintail *Anas acuta*	X	X	X	X	X	X	X
– Shoveler *Anas clypeata*	X	X	X	X	X	X	X
– Red-crested pochard *Netta rufina*	X	X	X	X	X	X	X
– Pochard *Aythya ferina*	X	X	X	X	X	X	X
– Tufted duck *Aythya fuligula*	X	X	X	X	X	X	X
– White-headed duck *Oxyura leucocephala*	---	---	X	X	X	X	X
– Moorhen *Gallinula chloropus*	X	X	X	X	X	X	X
– Coot *Fulica atra*	X	X	X	X	X	X	X
Marsh passerines : Nº of species	5.5	5.5	5.5	6	6	6	6
– Bluethroat *Luscinia svecica*	X	?	?	X	X	X	X
– Cetti's warbler *Cettia cetti*	X	X	X	X	X	X	X
– Fan-tailed warbler *Cisticola juncidis*	X	X	X	X	X	X	X
– Moustached warbler *Acrocephalus melanopogon*	X	X	X	X	X	X	X
– Penduline tit *Remiz pendulinus*	?	X	X	X	X	X	X
– Reed bunting *Emberiza schoeniclus*	X	X	X	X	X	X	X
Breeding							
Waterbirds : Nº of species	5.5	5.5	6	8	8	8	8
– Little grebe *Tachybaptus ruficollis*	X	X	X	X	X	X	X
– Great crested grebe *Podiceps cristatus*	---	---	---	X	X	X	X
– Mallard *Anas platyrhynchos*	X	X	X	X	X	X	X
– Red-crested pochard *Netta rufina*	X	X	X	X	X	X	X
– Pochard *Aythya ferina*	?	?	X	X	X	X	X
– White-headed duck *Oxyura leucocephala*	---	---	---	X	X	X	X
– Moorhen *Gallinula chloropus*	X	X	X	X	X	X	X
– Coot *Fulica atra*	X	X	X	X	X	X	X
Marsh passerines : Nº of species	6.5	5.5	6	3	3	3	4
– Cetti's warbler *Cettia cetti*	X	X	X	---	---	---	X
– Fan-tailed warbler *Cisticola juncidis*	X	X	X	X	X	X	X
– Moustached warbler *Acrocephalus melanopogon*	?	?	X	---	---	---	---
– Reed warbler *Acrocephalus scirpaceus*	X	X	X	X	X	X	X
– Great reed warbler *Acrocephalus arundinaceus*	X	X	X	X	X	X	X
– Penduline tit *Remiz pendulinus*	X	---	---	---	---	---	---
– Reed bunting *Emberiza schoeniclus*	X	X	X	---	---	---	---

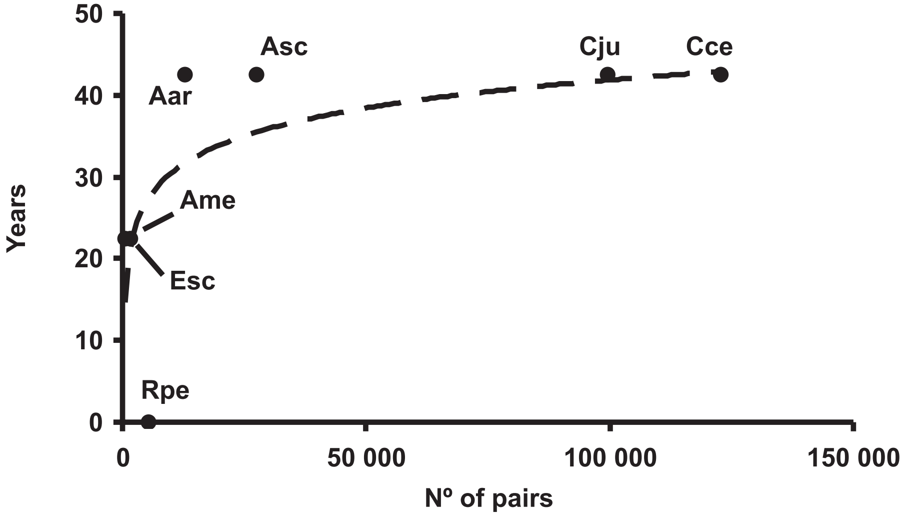

Figure 3. – Statistical relationship between the time of persistence of the marsh passerine breeding species (Years), as the time from the middle of the 20th century to the last stage in which each of the marsh passerine species was detected in the Albuferas of Adra during the breeding period, and its Spanish breeding population (Nº of pairs) according to Martí & del Moral (2003) ($r_s = 0.78$, $p = 0.04$). For a better visualization of the relationship between the two variables, the trend line is represented : scarcer species on a regional scale were extinct as breeders in Adra before more abundant species, which persisted even in the last stages, when the loss and fragmentation level was higher. Cce, Cetti's warbler *(Cettia cetti)* ; Cju, Fan-tailed warbler *(Cisticola juncidis)* ; Ame, Moustached warbler *(Acrocephalus melanopogon)* ; Asc, Reed warbler *(Acrocephalus scirpaceus)* ; Aar, Great reed warbler *(Acrocephalus arundinaceus)* ; Rpe, Penduline tit *(Remiz pendulinus)* ; Esc, Reed bunting *(Emberiza schoeniclus)*.

Repercussions on the avifauna

In the study area, having a relatively stable or greater open-water surface area over the years, with reed beds consistently present around its banks, most waterbirds would not have noted the restriction of the space over time (Paracuellos & Tellería, 2004 ; Paracuellos, 2006c). This apparently favoured (aided by the legal protection of the area in the late 1980's) the persistence of a similar, and even greater, number of these species throughout the study period (Aguirre *et al.,* 1995-96).

In agreement with various authors (see Andrén, 1994 ; Turner, 1996 ; Tellería & Santos, 2001 ; Paracuellos, 2006d), progressive fragmentation (in this case, the temporal habitat loss and patchiness, and increased isolation between patches over time) could have reduced biodiversity in the emergent vegetation of the Albuferas of Adra, such as marsh passerine species. However, during the study period, this process appeared to affect the species richness only of the nesting passerines in the reed beds. This could have been because, during the breeding, these species are more sensitive to habitat alterations owing to the nesting requirements, in comparison to other seasons of the year (van der Hut, 1986 ; Aidley & Wilkinson, 1987 ; Tellería & Santos, 1995 ; Paracuellos, 2006b).

The relationship between the extinction of nesting passerines in Adra and their abundance on a wider regional range confirms a fundamental pattern in ecology, i.e. the positive interspecific occupancy-abundance relationship, which could be regulated by different artefacts or biological mechanisms potentially applicable in the present case (see reviews in Gaston *et al.,* 1997, 2000 ; Holt *et al.,* 2002). For this, very abundant passerines must occupy better fragmented habitats than scarcer species, while only the latter group of species would reach critical thresholds in the last reed beds of Adra, this presumably explaining their extinction as breeders in the zone (see also Foppen, 2001). In this group, the Moustached warbler and Reed bunting had importance as threatened birds because these are included, as vulnerable and endangered breeder species, respectively, in the Red List of the Birds of Spain (Madroño *et al.,* 2004), the first of them also being of special interest for conservation in Europe (Annex I, Birds Directive 79/409/EEC). This situation found for both species is equivalent to their population trend on a regional scale. Thus, of all the marsh breeding passerine species located in Adra, only Moustached warbler and Reed bunting are in a clear decline in Spain. For the Moustached warbler a loss of somewhat more of 10 % of its national population has been estimated in the last decade (even more than 50 % in several of its main wetlands), while for Reed bunting the loss reaches more than 80 % in different Spanish Mediterranean zones (Martí & del Moral, 2003 ; Madroño *et al.,* 2004).

IMPLICATIONS FOR CONSERVATION

The following major conclusions may be drawn with regard to this case study : (1) a loss and fragmentation of the emergent vegetation habitat occurred throughout the second half of the 20th century in Albuferas of Adra, where the reed-bed patches became progressively smaller and more isolated because of the human action ; (2) this habitat loss and fragmentation appeared to affect the marsh passerines, with a major extinction of breeding species with the passage of time ; (3) the loss of species was related to their regional populations, the more abundant marsh passerines persisting as breeders and the scarcer species tending to disappear at the time of maximum degradation of the reed beds.

Thus, the current status of threat of the wetlands and their importance for the global biodiversity conservation argues for the restoration of lost reed-bed surface area in degraded but internationally important wetlands. In this scenario, the expansion and interconnection of the survival emergent vegetation habitat could favour the recolonization of currently absent nesting marsh passerines, some of them threatened and of special interest for their conservation, such as the Moustached warbler and the Reed bunting, extinct as breeders in Adra from the beginnings of the 1980s, and in a clear decline on a national scale.

Such management is of high priority in the Albuferas of Adra, since it is one of the most valuable wetlands in Almería (Paracuellos, 2002). This concern can be generalized to the rest of the wetlands of south-eastern Spain, since the marsh habitats in this semi-arid context are currently in a process of destruction and alteration by human activities, as 30 % of the natural wetlands of the province have disappeared from the mid-20th century (Paracuellos, in press), mainly by the invasion of the territory by greenhouses and coastal urbanization (Paracuellos *et al.,* 2007).

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APPENDIX

Sources of data about the presence of bird species observed in Albuferas of Adra during each stage of time considered.

Interannual stage	Sources
1950-69	Araújo & García Rúa (1972), Bernis & Valverde (1972), Delibes *et al.* (1978), zoological collections of the Biological Station of Doñana and the Experimental Station of Arid Zones (CSIC), L. García (pers. com., Experimental Station of Arid Zones, CSIC), F. Hiraldo (pers. com., Biological Station of Doñana, CSIC), F. Delgado (pers. com., long-time resident of the zone)
1970-79	Bernis (1972), Araújo (1977), Valera *et al.* (1993), zoological collection of the Experimental Station of Arid Zones (CSIC), L. García (pers. com., Experimental Station of Arid Zones, CSIC), F. Hiraldo (com. pers., Biological Station of Doñana, CSIC), F. Delgado (pers. com., long-time resident of the zone)
1980-84	Salas *et al.* (1985), Jiménez *et al.* (1986), Martínez Vidal & Castro (1990), Pleguezuelos (1992), Valera *et al.* (1993), Castro *et al.* (1994), Aguirre *et al.* (1995-96), own data
1985-89	Martínez Vidal & Castro (1990), Paracuellos (1991), Valera *et al.* (1993), Castro *et al.* (1994), Aguirre *et al.* (1995-96), own data
1990-94	Valera *et al.* (1993), Castro *et al.* (1994), Paracuellos (1996), Aguirre *et al.* (1995-96), data from the Environmental Council (Andalusian Government), own data
1995-99	Aguirre *et al.* (1995-96), Paracuellos & Tellería (2004), data from the Environmental Council (Andalusian Government), E. González Miras (pers. com., Environmental Council, Andalusian Government), own data
2000-04	Data from the Environmental Council (Andalusian Government), own data