

HABITAT SELECTION OF PASSERINE BIRDS NESTING IN THE EBRO DELTA REEDBEDS (NE SPAIN): MANAGEMENT IMPLICATIONS

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Abstract: In this study, we explored the habitat associations of the five most abundant passerine species nesting in the Ebro Delta reedbeds (NE Spain). Habitat characteristics (water depth, vegetation height and density, and plant-species composition) and abundance of all passerine species were measured at each of the 68 sampling points. The sampled area included most of the reedbeds in the Ebro Delta. Sampling points were classified according to the habitat parameters measured using cluster analysis. The resulting four habitat types differed in the composition and attributes of their passerine communities. The abundance of the great reed warbler (*Acrocephalus arundinaceus*) and reed warbler (*Acrocephalus scirpaceus*) was greatest in tall, permanently inundated and almost monospecific *Phragmites* reedbeds. In contrast, the numbers of the reed bunting (*Emberiza schoeniclus*) and Savi's warbler (*Locustella luscinioides*) were greatest in areas of drier soils and a denser basal stratum. Finally, the fan-tailed warbler (*Cisticola juncidis*) showed no clear habitat association. In the Ebro Delta, reedbed management includes freshwater inputs and burning of standing reeds. These practices promote tall, permanently inundated reedbeds with minimal detrital accumulation. Bird species richness and diversity were greater in less intensely-managed habitats, but only diversity was significant ($p < 0.001$). We conclude that, since reedbeds are important habitats for several scarce bird species, and the abundance of these species seem to be influenced by vegetation structure, bird conservation considerations should be incorporated into future reedbed management practices.

Key Words: birds, community structure, Ebro Delta, habitat associations, management, multivariate analysis, nesting passerines, reedbeds, wetlands

INTRODUCTION

As a result of human impact, wetlands are one of the fastest declining habitat types (e.g., Mitsch and Gosselink 1993). Natural wetland area has decreased 80–90% in the Mediterranean Region during the last few centuries (Fasola and Ruiz 1996). The area covered by reedbeds has decreased accordingly, becoming a scarce habitat in western Europe. In the United Kingdom, for example, the range of reedbeds has declined 40% since 1945 (Hawke and José 1996). Bird communities of reedbeds are highly specialized and include some species with great conservation value in Europe (Tucker and Heath 1994) and the Iberian Peninsula (SEO/BirdLife 1997). Thus, the study of these bird communities is especially relevant with respect to reedbed management (Bibby and Lunn 1982, Burgess and Evans 1989, Hawke and José 1996).

Habitat has long been used as a predictor of bird abundance (Cody 1985). Most of this work has been directed toward identifying associations between vegetation (structure and floristics) and the distribution and abundance of different bird species in forests (Cody 1978, Collins et al. 1982, Rice et al. 1983) and shrubby habitats (Rotenberry and Wiens 1980, Wiens and Rotenberry 1981). In spite of its limitations (Hansen et al. 1995), species-habitat relationships provide a powerful tool to predict the impact of human-driven environmental change on animal communities and have been used repeatedly to evaluate the consequences of different management practices for bird communities (e.g., Hansen et al. 1995, Díaz et al. 1998). Structural simplicity and low species richness make reedbeds particularly suitable for testing bird-habitat relationships.

Table 1. Characteristics of the coastal lagoons and brackish marshes associated with the reedbeds sampled. Enc I and EncZ12 are two different management units within the Encanyissada lagoon.

	Olles	Canal Vell	Garxal	Alfacada	Platjola	Enc I	EncZ12	Vilacoto
Type	lagoon	lagoon	lagoon	lagoon	lagoon	lagoon	marsh	marsh
Soil	mineral	mineral	mineral	mineral	mineral	mineral	peat/mineral	peat/mineral
Specific conductance ^a	low	high	low ^b	moderate	low	high	^c	^c
Standing reed burning	annual	no	no	no	annual	no	annual	no
Grazing	no	no	no	no	no	no	yes	no
Reedbed area (ha)	37.3	38.5	30.0	35.6	28.3	222.8	116.3	160
No. samples	4	4	2	10	6	30	5	7

^a Specific conductance during the period when discharge channels are functional (May to December). During this time of the year conductivity depends primarily on freshwater inputs from rice field irrigation systems: low conductance is caused by high water inputs (except in Garxal^b). Low: mean conductivity ≤ 9.34 mS cm⁻¹ (mean = 5.9 ± 2.0 mS cm⁻¹); Moderate: mean conductivity = 12.86 mS cm⁻¹; and High: mean conductivity ≥ 21.60 mS cm⁻¹ (mean = 22.7 ± 1.1 mS cm⁻¹). Conductivity data are from Comín *et al.* 1987, Curcó *et al.* 1996, E Forés (unpublished data), and A. Martínez-Vilalta (unpublished data).

^b This marsh is flooded by the river and represents the only area in which the origin of freshwater inputs is natural.

^c Classification of freshwater inputs is not appropriate because these marshes do not have water exchange with the sea and therefore, conductivity is extremely low (mean ≤ 4.00 mS cm⁻¹).

According to Curcó *et al.* (1997), reedbeds formerly covered 52.04 km² (15% of the total area) in the Ebro Delta but in 1977 occupied only 23.76 km² (< 7%). The rate of decline has decreased since 1977, but the trend has continued (A. Martínez-Vilalta, unpublished data). Besides this quantitative change, the impact of human activities has also modified the characteristics of the remaining reedbeds. First, coastal lagoons have been increasingly used as discharge basins for freshwater from rice-field irrigation systems. Water flows in variable amounts into the lagoons during the cultivation period (April to December) and causes a decrease in salinity, an increase in water level, and acute eutrophication (Comín *et al.* 1987, Menéndez and Comín 1987, Comín *et al.* 1995). These flows have become one of the dominant factors in the hydrology of the whole delta. Second, standing reeds are burned during winter to rejuvenate stands and promote reed growth. The effects of burning include an increase in early shoot emergence and density of reeds and a reduction of litter cover (Burgess and Evans 1989, Cowie *et al.* 1992, Hawke and José 1996). Finally, year-round grazing (1.3 heads ha⁻¹) occurs in a small area in the *Encanyissada* lagoon (Table 1).

Despite the fact that the Ebro Delta was designated as a preserve (Natural Park) in 1983, there is a lack of information on the impacts of reedbed management practices on natural communities. This is particularly relevant for birds because they are the most important group from a conservation point of view (Martínez-Vilalta and Giró 1996). The objectives of our study were to (1) characterize the Ebro Delta reedbeds as habitat for passerine species, (2) determine relationships between habitat characteristics, the abundance of passerine species, and the general attributes of passer-

ine communities (richness and diversity), and (3) use these results combined with information on reedbed management to draw some conclusions that may be applicable to the conservation of reedbeds and associated bird communities.

STUDY AREA

The study was conducted in the Ebro Delta (40°36'–40°58' N, 0°31'–0°52' E), a 350 km² wetland on the Mediterranean coast of Spain (Figure 1). The reedbeds studied are associated with rheotrophic coastal lagoons or brackish-water marshes (Table 1). We sampled the reedbeds that surround all the delta lagoons, except the *Calaixos de Buda* and the *Tancada* (Figure 1). The vegetation is dominated by reeds (*Phragmites australis* (Cav.) Steudel), cattail (*Typha angustifolia* L.), and sedge (*Cladium mariscus* (L.) Pohl.).

METHODS

Bird Census

We established 68 fixed census points distributed systematically across the entire study area (Figure 1). The minimum distance between points was 350 m because the great reed warbler (*Acrocephalus arundinaceus* L.), the species with the most powerful voice, can be heard at distances of 250 m (Fouces 1995). Each sampling point was censused three times in 1995 (27 March–6 April, 24–29 April, and 29 May–8 June) to ensure that the entire nesting period of all species was sampled. During each census, all territorial males heard during a 10-minute period were counted (unlimited-distance IPAs, Bibby *et al.* 1992). Censuses were

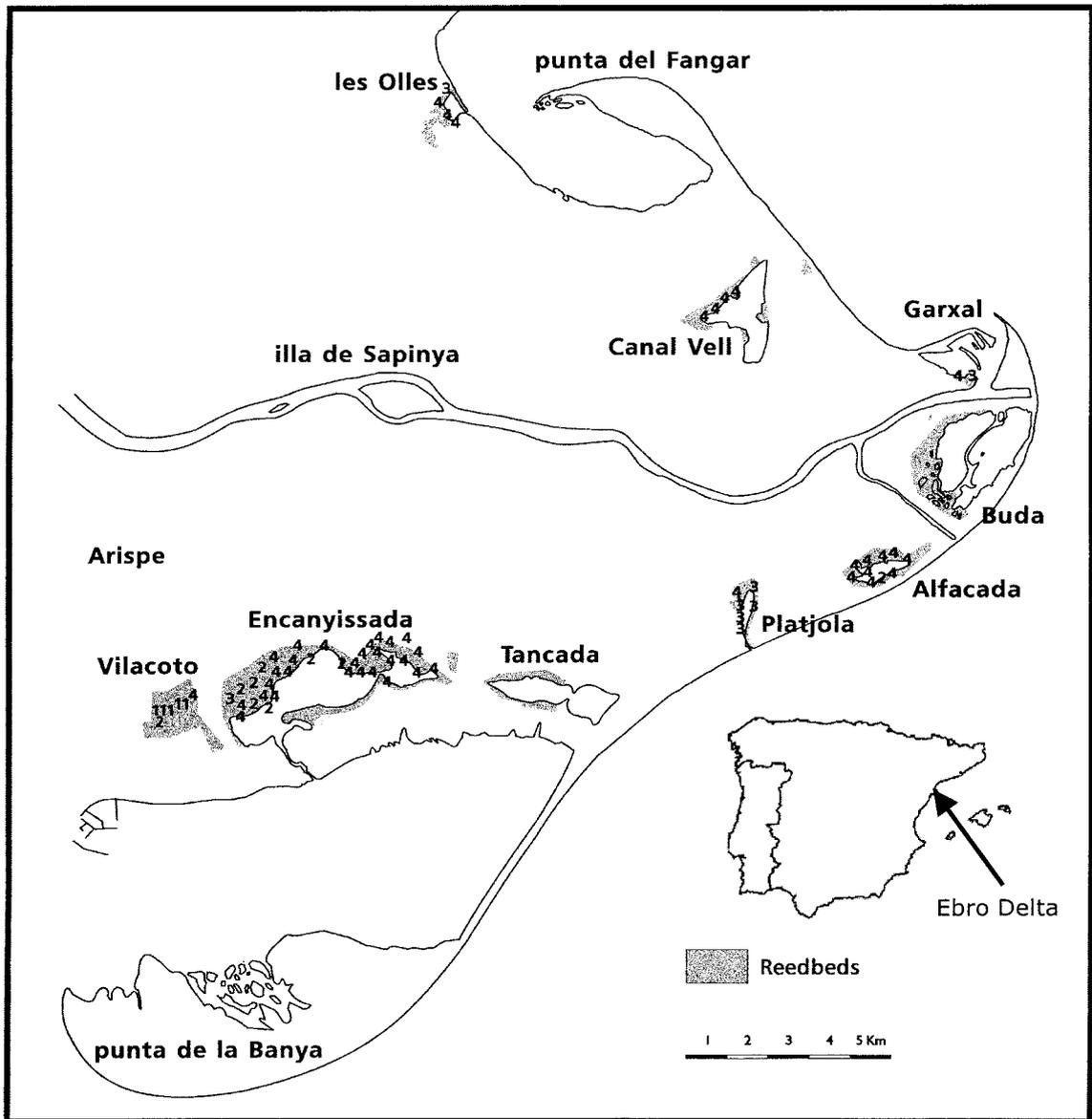


Figure 1. Distribution of sampling points in the Ebro Delta. Numerals indicate location of sampling points and habitat types defined by cluster analysis (1 = I, 2 = II, 3 = III, and 4 = IV). Shaded areas indicate the distribution of reedbeds.

performed during the three hours after sunrise. When we arrived at the sampling stations, we waited for 5 minutes prior to starting the census to allow acclimation of males to our presence. The maximum number of individuals of each bird species detected on any one of the three sampling dates was used in all analyses.

Habitat Classification

Habitat at each sampling point was characterized based on water depth, density of basal stratum, height of vegetation, and presence/absence of the following genera of helophytes: *Typha*, *Phragmites*, *Arthrocnemum*, *Atriplex*, *Juncus*, and *Cladium*. These variables

are commonly used in the description of reedbeds (e.g., Lenssen et al. 2000). All measurements were obtained during the spring of 1995 at the same time birds were censused. Quantitative or semi-quantitative variables were measured or evaluated at three sites within a radii of 175 m around each census point, and the most frequent value was recorded. We observed low within-site variability (data not shown), suggesting that the Ebro Delta reedbeds are homogeneous at this spatial scale. This is in agreement with other studies in the same area. A. Bertolero (unpublished results) found that, within a reedbed (total sampled area = 0.25–10 ha), the coefficient of variation among 4 m² parcels for variables such as vegetation height or den-

sity ranged between 8 and 28%. Water depth was determined using a tape measure and recorded as dry, low (≤ 10 cm), or high (> 10 cm). This variable was measured in 60 of the 68 census points. Area (%) covered by litter (basal stratum) was estimated visually and recorded as absent (*i.e.*, bare stems), intermediate (1–99%), or complete (100%). Height of vegetation was determined visually and classified as low (< 1.5 m), medium (1.5–3.0 m), or high (> 3.0 m). Presence/absence of plant genera was determined by searching the entire 175-m-radius circle.

Data Analyses

Multivariate statistics were used to simplify the data and assess interactions among variables. A hierarchical and agglomerative cluster analysis (Legendre and Legendre 1997) of all habitat variables (except water depth) was performed to aggregate sampling points into groups (termed habitat types) that were similar with respect to structure and floristics. We used the complete linkage method (“percent disagreement” distance) because it permits expansion of the reference space and magnifies the discontinuities between clusters. This was a desirable characteristic because reedbeds were relatively homogeneous. A linkage distance of 0.6 was chosen to cut the dendrogram because, beyond that level, a reasonable number of relatively homogeneous groups could be identified.

In all analyses of bird counts, detection probability was assumed to be similar among census points based on habitat homogeneity. Even reedbeds that were assigned to different habitat types were similar in general habitat structure. In the same study cited above, A. Bertolero (unpublished results) characterized in detail the structure of reedbeds in two different areas of the Ebro Delta. He found vegetation height = 1.29 ± 0.10 m and density = 228 ± 51 stems m^{-2} in an Habitat IV reedbed, whereas it was 1.55 ± 0.22 m and 94 ± 39 , respectively, in an Habitat III area (see below for definition of habitat types).

G-tests (one per species) were performed to test whether occurrence of each bird species was associated with habitat type. These analyses were complemented with a factorial correspondence analysis (canonical normalization; Legendre and Legendre 1997) in which data from all species were combined to test general associations between avian species and habitat types. The contingency table was constructed counting the total number of males per species detected in each habitat type.

Three parameters were used to describe avian communities occurring within each habitat type: bird abundance (*i.e.*, the maximum number of individual birds detected at a sampling point), species richness (S), and

Shannon’s Diversity Index (H' , in nits). All variables were normally distributed (Kolmogorov-Smirnov test; $p > 0.05$). A jackknife procedure (Zahl 1977) was used to estimate the mean and standard deviation of H' , and modified t-tests (Hutcheson 1970) were used to test for differences among avian communities. A Bonferroni Correction was applied because multiple tests were performed simultaneously. Bird abundance was compared among habitats using one-way analysis of variance (ANOVA), and Scheffé multiple-comparison procedure was used to separate habitat types.

Species richness and Shannon’s Diversity depend on the area sampled (Wiens 1989). Because the total areas occupied by each habitat type differed, we standardized S with respect to sampled areas (number of sampling points in our case) by means of the rarefaction method (Krebs 1989). We considered the habitat type with the least sampled area to be the reference. We calculated $H'_{\text{standardized}}$ from $S_{\text{standardized}}$ using the following formula, which assumes a log-normal species-abundance distribution (May 1975):

$$H' = 2 \times \gamma \times \pi^{-1/2} \times \sqrt{\ln(S)} \quad (1)$$

where γ is one of the two parameters of the log-normal distribution and was obtained for each habitat type from the original data relating H' with S.

The analyses were conducted with SPSS for Windows (Release 6.1, SPSS Inc., Chicago, IL, USA, 1995) and STATISTICA for Windows (Release 5, StatSoft Inc., Tulsa, OK, USA, 1996).

RESULTS

Three of the eight detected passerine species were found at very low frequency (Cetti’s warbler (*Cettia cetti* (Temminck)), moustached warbler (*Acrocephalus melanopogon* (Temminck)), and bearded tit (*Panurus biarmicus* (L.))), with $n < 10$ males observed. The other detected species ($n \geq 65$) were reed warbler (*Acrocephalus scirpaceus* (Hermann)), great reed warbler (*Acrocephalus arundinaceus*), Savi’s warbler (*Locustella luscinioides* (Savi)), fan-tailed warbler (*Cisticola juncidis* (Rafinesque)), and reed bunting (*Emberiza schoeniclus* (L.)). These five species were the only ones considered in the habitat-selection analysis.

The reedbeds of the Ebro Delta were classified into 4 habitat types (Figures 1 and 2). Habitat I occurred in areas with a thick organic soil horizon and was the only habitat type not dominated by *Phragmites* (Table 2). Habitat II reedbeds were characterized by plant species adapted to saline soils (*Juncus*, *Atriplex*, *Arthrocnemum*), low vegetation height, and high basal stratum density. The reedbeds of Habitat III consisted of tall and almost monospecific *Phragmites* stands with intermediate basal stratum density. Habitat IV

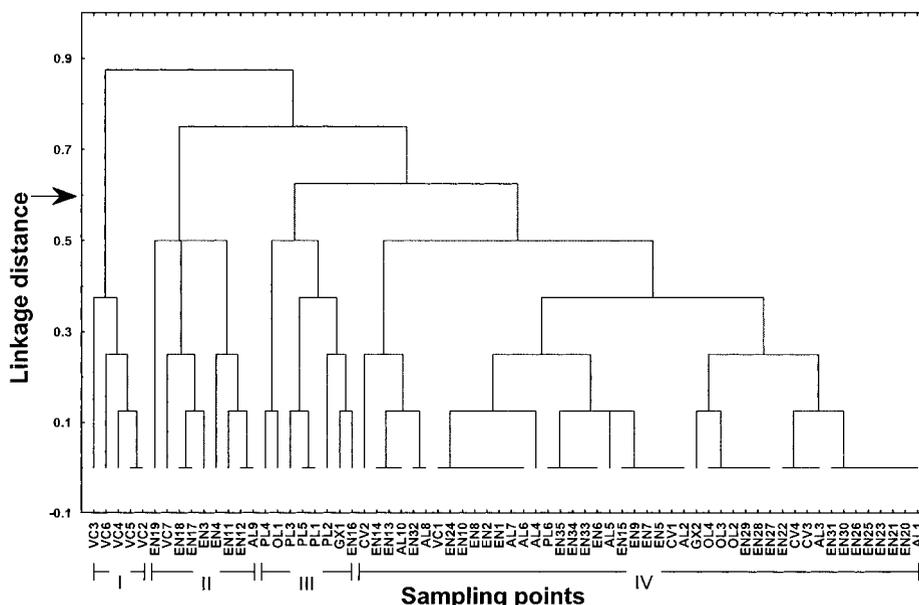


Figure 2. Classification of the sample points according to a cluster analysis of vegetation attributes. The arrow indicates the level we used to cut the dendrogram.

reedbeds showed intermediate characteristics between Habitats II and III (Table 2) and are the most representative of the Ebro Delta at present.

There was a significant association between bird species and habitat type for three of the five species analyzed (G-tests). Reed warbler was associated with Habitat III and avoided Habitat II ($\chi^2 = 13.6$, $df = 3$, $p = 0.004$), and both reed bunting and Savi's warbler were associated with Habitat I and avoided Habitat III ($\chi^2 = 13.7$, $df = 3$, $p = 0.003$; and $\chi^2 = 10.2$, $df = 3$, $p = 0.017$, respectively). Regarding the factorial correspondence analysis, only the first dimension was significant ($\chi^2 = 116.8$, $df = 6$, $p < 0.001$), but it explained 84.1% of the variance and supported our findings above (Figure 3). Basically, there were two groups of bird-habitat associations: reed bunting and Savi's warbler with Habitats I and II, and reed warbler

and great reed warbler with Habitat III. We interpreted the first axis as a gradient between permanently flooded, monospecific *Phragmites* stands (Habitat III) and reedbeds typical of irregularly flooded and more saline soils (Habitat II). The fact that this axis explained a large part of the variance seems to indicate that the communities studied are simple and structured primarily by one environmental factor.

All attributes of the avian community differed among habitat types (Table 3). Bird abundance was greater in Habitat I than in Habitats II and IV. Habitat III values were intermediate, and although they were not significantly different from those in any other habitat type, they were closer to those in Habitats II and IV (Table 3). Standardized richness was greatest in Habitats I and II and lower in Habitat III. Shannon's Diversity was similar in Habitats I, II, and IV but was

Table 2. Abiotic characteristics of the four habitat types defined based on cluster analysis. Categories are in brackets when the mode corresponds to <50% of values and without them when it corresponds to >50%.

Habitat type	Vegetation height ^a	Basal stratum density ^b	Water depth ^{c,d}	Dominant species	Number of plant sp. (range)
I (n = 5)	medium	complete	low	<i>Cladium</i>	1-3
II (n = 9)	low	complete	dry	<i>Phragmites</i> +halophytes	2-5
III (n = 8)	high	intermediate	high	<i>Phragmites</i>	1-2
IV (n = 46)	medium	complete	(high)	<i>Phragmites</i>	1-4

^a Low: <1.5 m, medium: 1.5-3.0 m, and high: >3.0 m.

^b Intermediate: 1-99% coverage by litter, and complete: 100% coverage.

^c Dry, low: ≤10 cm, and high: >10 cm.

^d Since water depth was not measured in all census points sample size is slightly lower for this variable: n = 7 for Habitat III and n = 39 for Habitat IV.

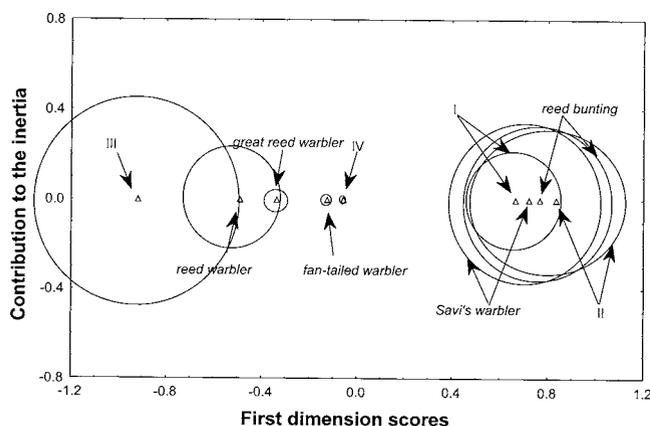


Figure 3. Ordination of the habitat types and bird species according to a factorial correspondence analysis. The radii of the circles around the points indicate the contribution of each one to the inertia of the dimension.

lower in Habitat III. None of the three additional species detected but not included in the habitat-selection analysis because of small sample size were present in Habitat III areas (Table 3).

DISCUSSION

The abundance of the reed warbler, great reed warbler, reed bunting, and Savi's warbler was associated with the habitat types we defined, suggesting that these species responded either to the habitat attributes we measured or to other variables highly correlated with them (Rotenberry and Wiens 1980). The bird-habitat relationships we identified are consistent with those reported in previous studies and can be interpreted based on the natural history of the birds. The abundance of the great reed warbler and reed warbler was

greatest in tall, permanently inundated and almost monospecific *Phragmites* reedbeds (Tables 2 and 3). These two species have very similar habitat requirements and engage in interspecific competition for habitats (Hoi *et al.* 1991, Honza *et al.* 1999). Their preference for tall reeds in water has been related to climbing techniques and associated morphological traits (Winkler and Leisler 1985, Leisler *et al.* 1989). In addition, the great reed warbler may prefer tall *Phragmites* stands because their nests are too heavy to survive on any but the strongest stems (Cramp 1992). In contrast, the abundance of the reed bunting and Savi's warbler was greatest in areas of drier soils and a denser basal stratum. These species are also adept at climbing reeds but are primarily walking species, which explains their preference for thicker beds of *Cladium* or *Juncus* (Cramp and Perrins 1994). Their feeding habits, with less preference for mobile prey than reed warblers (Cramp and Perrins 1994), may also be related to habitat selection. Finally, the fan-tailed warbler showed no clear habitat association (Figure 3). This species is not restricted to reedbeds and is more of a generalist than the other four species (Cramp 1992).

The present distribution of reedbed types in the Ebro Delta can be interpreted as the combined effect of physical factors and human management. Typical reedbeds (Habitat IV) are replaced by other reedbed types in areas with specific soil types: Habitat I in areas with organic soils and Habitat II in more saline areas. Human management by means of freshwater inputs and standing reed burning favors high water levels and the development of tall, dense vegetation with minimal litter accumulation (Habitat III). These effects and the encouragement of reed at the expense of other plants are widely documented (Burgess and Evans

Table 3. Attributes (mean \pm SD) of the avian community for each habitat type. Nonstandardized richness (S) is shown in parentheses. Different superscripts within rows indicate significant differences ($p < 0.05$). Abundances are the average of the maximum number of individuals observed per sampling point.

Attribute	Habitat I (n = 5)	Habitat II (n = 9)	Habitat III (n = 8)	Habitat IV (n = 46)
S _{standardized}	7 (7)	6.56 (7)	4.80 (5)	5.95 (8)
Abundance	11.40 \pm 1.14 ^a	6.22 \pm 2.44 ^b	8.13 \pm 1.13 ^{ab}	7.78 \pm 2.68 ^b
H' _{standardized}	1.71 \pm 0.20 ^a	1.66 \pm 0.20 ^a	1.27 \pm 0.20 ^b	1.54 \pm 0.21 ^a
Species list	Abundance			
Cetti's warbler (n = 2)	0.2	—	—	0.0
Reed warbler (n = 107)	2.0	0.4	2.4	1.6
Great reed warbler (n = 80)	1.0	0.6	1.4	1.3
Moustached warbler (n = 9)	0.2	0.2	—	0.1
Savi's warbler (n = 77)	2.2	1.4	0.4	1.1
Fan-tailed warbler (n = 190)	3.4	2.3	3.8	2.7
Bearded tit (n = 6)	—	0.2	—	0.1
Reed bunting (n = 65)	2.4	1.0	0.3	0.9

1989, Cowie et al. 1992, Hawke and José 1996). It is thus very likely that these management practices are related to the development of Habitat III areas at the expense of the other habitat types. In fact, Habitat III is present only in the three reedbed areas where high freshwater inputs cause low specific conductance and annual burning is used as a management practice (plus *el Garxal*, where freshwater inputs from the river naturally occur) (Table 1).

The characteristics of bird communities reflected the differences in habitat type. Habitat III proved to be the one with the least rich and diverse bird community. This habitat type is also characterized by low vegetation diversity (Table 2). The other communities were similar, with Habitat IV showing mostly intermediate characteristics between the richer and more diverse communities of Habitats I and II and the ones of Habitat III (Table 3). Therefore, it appears that management by means of freshwater inputs and standing reed burning results in an impoverished passerine community. Savi's warbler, the moustached warbler, and bearded tit, all scarce or absent in Habitat III, are catalogued as endangered in Spain (SEO/Birdlife 1997) and thus have high conservation value. In addition, the reed bunting population of the Ebro Delta belongs to the subspecies *whitterbyi*, which is endemic to Spain and the Balearic Islands (Byers et al. 1995). It is considered very scarce, localized, and decreasing in Spain (SEO/Birdlife 1997). The abundance of this subspecies is at least three times lower in Habitat III than in any other habitat (Table 3).

In conclusion, our results show that reedbed management can have an important impact on associated passerine communities. Some practices (water inputs and burning) that are commonly used for conservation purposes (Ditlhogo et al. 1992) are associated with increased abundance of reed warblers. However, the change is at the expense of other species with higher conservation value in the Iberian Peninsula and results in a general impoverishment of the passerine community. It is apparent from these results that the conservation implications of management actions must be evaluated for each particular case and decisions made according to the conservation priorities in the particular area under consideration.

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