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Editors
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Elisabeth Conrad and Mariella Nardi

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# INFLUENCE OF CHARACTERISTICS OF IRRIGATION CHANNELS ON THE BREEDING BIRD COMMUNITY OF A WETLAND ZONE IN SOUTHEAST OF SPAIN

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*Abstract:* The "El Hondo Nature Park" is mainly composed of a series of irrigation channels and water reservoirs, subjected to various regimes of management as well as reed and vegetation control, thus creating a great variety of habitats and situations. To determine the influence of these habitats and management regimes on the local bird community, a set of characteristics of these channels and their surrounding area were analysed with a Correspondence Analysis (CA). The degree of reed development in channels and the presence in the surroundings of orchards and other reed formations were the most decisive factors to explain the probability of occurrence of reed birds and waterbirds, as well as bird species richness and abundance. Other bird species were not directly influenced by channel variables, but only by those of surrounding land uses.

## *Introduction*

During the last decades, agriculture in the El Hondo region has experienced an important shift from traditional dry crops to irrigated crops, driven by market pressure and opportunities for greater profitability (Leal, 1969). As a result, a set of water transport and storage systems in the form of channels and ponds have been developed to cater for the increasing water demand of these new irrigated crops. Irrigation channels come in different forms, either closed or open-air, and are made of concrete or soil. These differences influence the types of habitats created and their similarity to natural fluvial systems. Previous research shows that such changes in agricultural environments may have a deep impact on biodiversity and on landscape structure (Pimm et al., 1995; Donald et al., 2001; Brotons et al., 2004).

Channels are managed by private individuals, enterprises or regional government, who all work to attain highest efficiency and profit.

Accordingly, the vegetation on the banks of watercourses is cut and sprayed, and sediments are dredged at varying frequency and intensity. Irrigation channels are semi-anthropised ecosystems that change over time with evolving requirements of agriculture. Effects of management on local fauna are not well known but probably depend both on the specific characteristics of irrigation channels and their interaction with surrounding habitats.

In wetlands, birds are a flagship group of animal species that respond quickly to environmental changes. Therefore their study can provide a test of the ecological value of this type of constructed ecosystems. This paper‘s objectives are 1) to evaluate the influence of irrigation channels and land use in their surroundings on the probability of occurrence of selected bird species, and 2) to identify characteristics of irrigation channels that influence bird species richness and their abundance.

## *Materials and methods*

### *Study area*

The study was located in Carrizales, an area between two important wetlands in Alicante (Southeast of Spain), Hondo Nature Park and Salinas de Santa Pola Natural Park. The study area is within the coordinates NW X:697104, Y:4226507; SW X:700991,Y:4222517; NE X:705182,Y:4228218; and SE X:705297,Y:4227084 (Fig. 1).

This area is included in the “Catálogo de zonas húmedas de la Comunidad Valenciana” because of its importance as a natural corridor between the aforementioned wetlands. Three hundred years ago, this area was an extensive wetland that was drained for agriculture and malaria eradication, and a web of irrigation channels were built to mantain a flow of water for agriculture.

Currently, the traditional land use in the area which extends over approximately 1649 ha is vegetable and arboreal crops (palm and pomegranate trees). The complex network of irrigation channels with their associated vegetation within the agricultural matrix and patches of natural vegetation creates a heterogeneous mosaic of land uses.

### *Bird counts*

To study the bird community associated with irrigation channels, 45 sampling points were selected, representing the various combinations of channel features (ground or cement, with or without vegetation and with or without reed). Each sampling point includes a plot which was 100m long and 6.5m wide on each side of the channel. Counting was done at the center of this plot, for five minutes in each sampling point. Countings were done always from sunrise within the 3 subsequent hours. Only birds seen within the established limits of sampling plots were recorded. In order to ensure that birds surveyed were indeed breeding, only birds which appeared in at least four of the total sampling points were included into the analysis. The point counting was carried out twice in the breeding season, in May and June of 2007.

Figure 1. Study area map. Points are bird counting points. Source: Unidad de Cartografía de los Recursos Naturales - U.A. Instituto Cartográfico Valenciano.

*Environmental variables*

In order to characterize the sampling points the following group of variables was recorded:

- *Physical variables*: Building material (concrete (0) or ground (1)), Channel width (m) and Distance of the counting point to the nearest wetland (m).
- *Vegetation cover*: In each sampling point, ten 6.5 m-long transects were laid out perpendicular to channel edge, five on each side of the channel and spaced 25 m apart. The occurrence of plant species or bare soil along transects was measured and its percentage of cover estimated. The maximum height of each

element was also measured. Species were grouped according to functional and morphological groups.

- *Vegetation height categories*: Vegetation height data obtained from the aforementioned vegetation transects were used to group the vegetation in 5 height categories. Without vegetation (0), from 0 to 0.3m (1), from 0.3 to 1m (2), from 1 to 2m (3) and taller to 2m (4).
- *Reed variables*: At each sampling point, we took 20 measures of reed density, 16 in the band of vegetation that borders the channels and 4 inside these channels. We used 33 cm x 33 cm quadrats to record the number of reed stems, their diameter and height and their condition (dead or live). Quadrats on the edge of channels were distributed at 0, 0.75, 1.50 and 2.25m along two perpendicular transects located 50 m apart, on each side of the channel. Reeds inside the channels were counted and measured in four 33cm x 33 cm quadrats located 25 m apart. Using these data we estimated the reed basal area and calculated a measure of reed heterogeneity as the difference in reed density between both shores of the channel at each sampling point.
- *Channel surroundings variables*: Using an official on-line GIS service (<http://orto.cth.gva.es/website/urbanismo/viewer.htm>) 50m radius circles were delimited around each sampling point. Within these circles we estimated the percentage of area occupied by the different kind of crops, semi-natural vegetation and buildings.

*Statistical analysis*

To reduce the high number of variables, a Correspondence Analysis (CA) was performed for each group of variables (except physical variables). Resulting factors, representing environmental gradients, were used as predictors in regression models. In each CA, we selected the number of factors that explained at least 80% of variance.

To model bird species occurrence, we used logistic regressions. The relation of species richness and total bird abundance to environmental gradients were analysed by means of linear regressions. In both cases we used Akaike Information Criterion (AIC) to select variables for use in the models. Models were fitted independently for each group of environmental variables, in order to detect which type of variables had a greater influence on birds. AIC was used to compare models for the same dependent variable fitted to different environmental predictors. The model with the lower AIC was considered the best model unless AIC differences between some models were less than 2, in which case they were considered equal alternative models.

## *Results*

### *Environmental variables*

A synthesis of Correspondence Analysis results is presented in Table 1. For simplicity, only variables with correlation coefficients greater than 0.5 are shown. The number of axes that explained 80% of variance ranged between 3 for vegetation height variables and reed variables and 6 for vegetation cover and surroundings variables.

### *Bird species model*

Altogether 496 birds were detected in point counts, belonging to 38 different species. The most abundant species were Common moorhen (*Gallinula chloropus*) with 79 contacts, Zitting cisticola (*Cisticola juncidis*) with 68 contacts, Barn swallow (*Hirundo rustica*) with 45 contacts, Reed warbler (*Acrocephalus scirpaceus*) with 43 contacts and Little egret (*Egretta garzetta*) with 28 contacts. Only 16 of total bird species were included in the analyses, because they appeared in at least four of the total point counts. Alternative models for species occurrence are shown in Tables 2 to 4.

Groups of bird species with similar ecology and habitat requirements tended to share environmental variables selected in their models. Within the reed passerines found in the study area, the Reed warbler (*Acrocephalus scirpaceus*) is the most closely associated to wetlands and its probability of occurrence increases with higher development of both dead and live reeds (height, diameter and basal area) and the density of reeds inside the channels. For this species it is also possible to construct a significant model with vegetation height or vegetation cover variables, but these alternative models are clearly worse than the lowest AIC model, which suggests that specific characteristics of reed vegetation play a role in the habitat selection of the Reed warbler within channels. The Cetti's warbler (*Cettia cetti*) is not so much a reed specialist and the best model for this species includes a gradient of vegetation cover that ranges from concrete-paved ground and low grasses (negative side) to reed cover (positive). The next models in AIC explain clearly less variance but are also significant and they include channel material, with greater presence of this species in concrete channels, or a positive association with reed development. Thus this species appears where vegetation cover around channels is high and this situation is attained mainly when reeds are well developed.

In the case of waterbirds, habitat selection is more varied and models differ more among species. The best model for Moorhen (*Gallinula chloropus*) includes variables from the surrounding area, which is a bit surprising at first glance. According to this model, the probability of occurrence of this species increases with cover of tree orchards (palm and pomegranate trees) and decreases with reed cover and vegetable farming. A model of slightly lower significance may be constructed with a negative relationship to cover of herbaceous farming (including vegetables) for this species. Thus, short crop farming around channels negatively affects its use by the moorhen, while at least some types of tree farming favour the species. During the study moorhens were observed many times walking and looking for food in tree farms close to the channels, where they may get invertebrates in the wet ground or fallen fruits.

Four species of herons used the channels frequently enough to be modelled, but the variables influencing their use differed among species. Little egret (*Egretta garzetta*) and Squacco heron (*Ardeola ralloides*) preferred channels with low halophyte woody formations, well developed herbaceous formations and narrow channels. Except Black-crowned night-herons (*Nycticorax nycticorax*), that preferred reed formations (the only species occurring in reed taller than 2 meters) as well as vegetation of 0.3 to 1m height. In this study, Purple Heron (*Ardea purpurea*) preferred deep, narrow channels with low vegetation, built in the ground that are distant to wetlands, due to their ability for long movements in search of food.

Some generalist species, widely distributed in many habitats, were found using the channels.i.e. Serin (*Serinus serinus*) and Blackbird (*Turdus merula*). These use irrigation channels as a complementary habitat, as demonstrated in the models by the fact that they were influenced only by surrounding variables.

*Community models*

Models for species richness are shown in Table 5. Two alternative models with identical percentages of variance explained may be fitted to our data. In one of these models species richness related positively to tree farming and reeds, and negatively to herbaceous farming, low grasses and concrete pavement of channels (Figure 2). In the other model, species richness related positively to reed development and reed density inside the channels (Figure 3).

Models for total abundance are shown in Table 6. The model with variables related to the area surrounding channels was the best one. Reed formations and pomegranate farming were the most influential environments. Roads and herbaceous crops had a negative influence on total bird abundance. The highest performance model is shown in Figure 4.

Figure 2. Relation between species richness and surrounding habitat type (ranging from herbaceous crops to tree farming) represented by composite variable VC3. N=45.

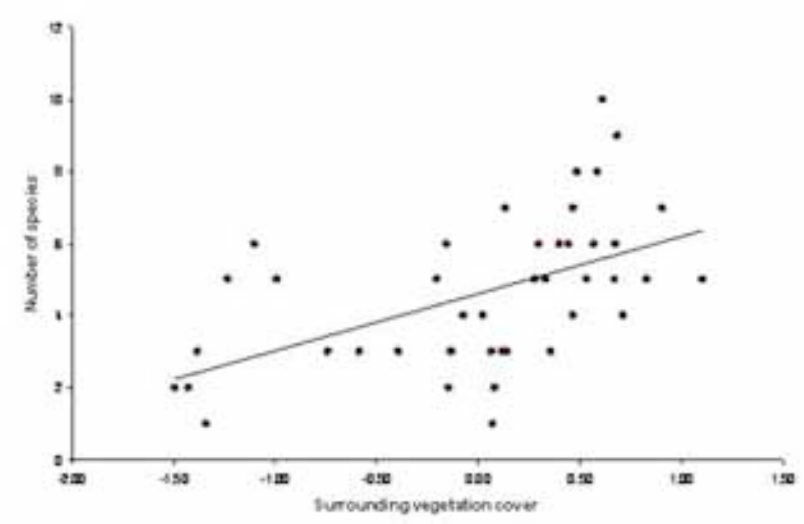



Figure 3. Relation between species richness and reed development (gradient of height of live reeds, diameter both of live and dead reeds, basal area both of live and dead reeds and symmetry degree of reed density between the two sides of the channel) represented by the composite variable 'Reed development'. N=45.

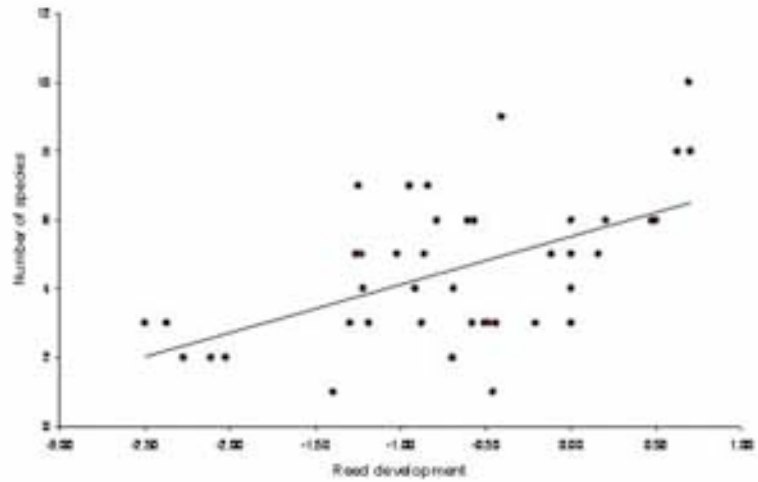
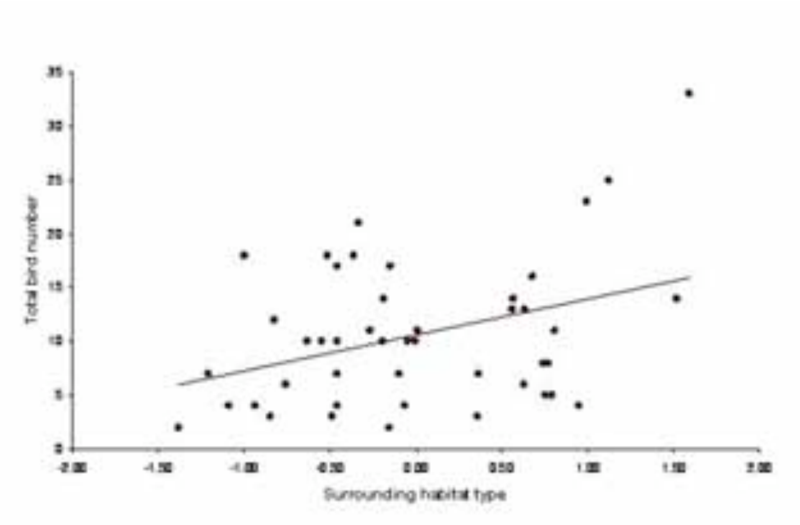


Figure 4. Relation between total bird abundance and surrounding habitat type (+ Ground irrigation channels and reed formations; – Grassy crops) represented by the composite 'Surrounding habitat type'. N=45.




*Discussion*

The study collected enough data for the probability of bird species occurrence to be modelled in relation to the characteristics of irrigation channels for all bird species, and for most species several significant alternative models were identified. Thus, bird species use of the irrigation channels is affected by sets of channel variables which in turn depend on their management.

As would be expected, different groups of bird species use irrigation channels and respond to channel characteristics differently. Some reed and aquatic birds breed and live in channels while other species use wetlands as an expansion of their typical habitats in search of food. Channels are also used by generalist species in a temporary fashion.

The models identified the channel characteristics with strongest influence on bird species richness. As indicated by their equally high predictive power, two groups of variables are worth noting. On one hand variables related to reed development, including the presence of reeds within channels affected not only species richness, but also the presence of reed specialists such as the Reed warbler. Vegetation cover variables also had an important effect on species richness, where tree farming close to the channels influenced species richness positively while herbaceous farming tended to reduce it. Thus, bird species is not only influenced by the characteristics of typical wetland vegetation that colonizes channels, but also by the type of farming in their proximity. The most appropriate model for total bird abundance included variables characterizing the area surrounding the channels and the materials they are built in. The presence of channels built in the ground and reed formations favored highest abundance.

In the study area, the diversity of managers and their management practices on channels and their associated vegetation confers a high landscape heterogeneity to the study area. This is accentuated by the important diversity of cropping patterns (herbaceous, arboreal, old fields, fallow land), the presence of salt marshes and different types of reed formations, as well as residential and farm buildings.

This study shows that recommendations for bird conservation to farmers and institutions managing irrigation channels and especially reed formations should be geared toward the specific habitat needs of groups of species. For the conservation of reed specialist species, a selective and staggered winter cut of reeds in irrigation channels is highly preferable to their complete removal on an annual basis, as it allows an appropriate development with different reed ages in the breeding season. For generalist bird species the maintenance of a heterogeneous landscape with tree and cereal crops, halophilous scrubs and reed formations could be the best conservation action.

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Table 1. List of correlated factors identified in correspondence analysis of channel characteristics.

| Variable | Code | Negative correlation (r < -0.5) | Positive correlation (r >0.5) |
|---|---|---|---|
| **Surrounding area** | **SA1** | Halophyte plant formations | Grassy crops |
| | **SA2** | Reed formations | Palm tree and pomegranate farming |
| | **SA3** | Grasses crops | Ground irrigation channels and reed formations |
| | **SA4** | Houses | Herbaceous crops |
| | **SA5** | Palm tree farming | Fallow land |
| | **SA6** | | Roads |
| **Vegetation height categories** | **VH1** | Height of vegetation between 0 and 0.3m | Height of vegetation higher than 2m |
| | **VH2** | Without vegetation and height of vegetation between 1 and 2m | Height of vegetation between 0.3 and 1m |
| | **VH3** | Height of vegetation between 1 and 2m | Height of vegetation between 0 and 0.3m |
| **Vegetation cover** | **VC1** | Roads and low size grasses | Other channels and reed formations |
| | **VC2** | Other channels and reed formations | Halophyte plant formations |
| | **VC3** | Herbaceous crops | Tree farming |
| | **VC4** | Halophyte plant formations and creeping plants | Tree farming |
| | **VC5** | | Bare soil |
| | **VC6** | Medium and high size herbaceous plants | |
| **Reed development** | **RD1** | Reed’s density heterogeneous in the two sides of the channel | Height of alive reeds, diameter both of alive and dead reeds and basal area both of alive and dead reeds |
| | **RD2** | Presence of reed inside the channel and density of dead reeds | Number of channel edges with reed |
| | **RD3** | Presence of reed inside the channel | Difference in reed density between the two sides of the channel |

Table 2. Logistic regression models relating species occurrence to reed development variables. Regression coefficients are shown for reed gradients selected in the models. N=45; <0.1 n.s. (not significant), * <0.05, ** <0.01, *** <0.005; AIC: Akaike Criterion Information of the final model. Models considered the best for a species (minimum AIC) are typed in bold. Models with difference AIC<2 with respect to the best model appear underlined.

| Reed development | | | | | |
|---|---|---|---|---|---|
| | **RD1** | **RD2** | **RD3** | **R2** | **AIC** |
| Ardeidae | | | | | |
| *Ardea purpurea* | | | | 0 | 33,395 |
| *Ardeola ralloides* | | | | 0 | 28,996 |
| *Egretta garzetta* | | -0,869 ★ | | 0,115 | 48,278 |
| *Nycticorax nycticorax* | 4,807 ★ | | -1,851 ★ | 0,435 | 23,736 |
| Rallidae | | | | | |
| *Gallinula chloropus* | | | -1,354 ★ | 0,116 | 55,754 |
| Laridae | | | | | |
| *Larus ridibundus* | | | | 0 | 28,996 |
| Sternidae | | | | | |
| *Chlydonias hybridus* | | | | 0 | 33,395 |
| Hirundinidae | | | | | |
| *Delichron urbica* | | | | 0 | 28,996 |
| *Hirundo rustica* | | | | 0 | 54,192 |
| Turdidae | | | | | |
| *Turdus merula* | 1,298 ★ | | | 0,127 | 49,571 |
| Sylvidae | | | | | |
| *Acrocephalus scirpaceus* | **3,575 ★★** | **-1,949 ★** | | **0,496** | **32,284** |
| *Cettia cetti* | 1,043 • | | | 0,082 | 42,658 |
| *Cisticola juncidis* | | | 0,730 • | 0,073 | 57,078 |
| *Sylvia melanocephala* | | | | 0 | 49,674 |
| Fringilidae | | | | | |
| *Carduelis chloris* | | | | 0 | 47,036 |
| *Serinus serinus* | | | | 0 | 33,395 |

Table 3. Logistic regression models relating species ocurrence to vegetation height categories and vegetation cover variables. N=45; <0.1 n.s. (not significant), * <0.05, ** <0.01, *** <0.005. R2: Explained variability percentage; AIC: Akaike Criterion Information of the final model. Models considered the best for a species (minimum AIC) are typed in bold. Models with difference AIC<2 with respect to the best model appear underlined.

| | Vegetation height categories | | | | |
|---|---|---|---|---|---|
| | **VH1** | **VH2** | **VH3** | **$R^2$** | **AIC** |
| Ardeidae | | | | | |
| *Ardea purpurea* | | | | 0 | 33,395 |
| *Ardeola ralloides* | | | | 0 | 28,996 |
| *Egretta garzetta* | -1,344 • | | | 0,085 | 49,779 |
| *Nycticorax nycticorax* | **0,069** | **0,094 •** | | **0,762** | **13,480** |
| Rallidae | | | | | |
| *Gallinula chloropus* | | | | 0 | 60,574 |
| Laridae | | | | | |
| *Larus ridibundus* | | | -2,151 • | 0,129 | 27,524 |
| Sternidae | | | | | |
| *Chlydonias hybridus* | -3,743 | -3,035 • | | 0,589 | 18,906 |
| Hirundinidae | | | | | |
| *Delichron urbica* | | | | 0 | 28,996 |
| *Hirundo rustica* | **1,155** | **1,882 •** | **-3,019 *** | **0,219** | **48,766** |
| Turdidae | | | | | |
| *Turdus merula* | 1,539 ** | | | 0,198 | 45,873 |
| Sylvidae | | | | | |
| *Acrocephalus scirpaceus* | 2,354 ** | 1,595 | | 0,334 | 40,771 |
| *Cettia cetti* | 0,816 • | | | 0,069 | 43,230 |
| *Cisticola juncidis* | | | | 0 | 59,286 |
| *Sylvia melanocephala* | | | | 0 | 49,674 |
| Fringilidae | | | | | |
| *Carduelis chloris* | | | | 0 | 47,036 |
| *Serinus serinus* | | | | 0 | 33,395 |

Table 3b.

| Vegetation cover | | | | | | | |
|---|---|---|---|---|---|---|---|
| VC1 | VC2 | VC3 | VC4 | VC5 | VC6 | $R^2$ | AIC |
| | | 2,900 • | | | | 0,191 | 29,386 |
| | **1,813** | | | | **-2,338 ⋆** | **0,337** | **23,887** |
| **–0,796** | | | **-3,781 ⋆** | **-1,067** | **3,711 ⋆** | **0,419** | **39,06** |
| 0,097 ⋆⋆ | 0,037 ⋆ | | | | | 0,501 | 21,663 |
| | | 1,460 ⋆⋆ | | | | 0,154 | 53,558 |
| | | | | | 2,417 • | 0,142 | 27,151 |
| -2,097 | | | | | | 0,353 | 24,317 |
| 2,323 | | | | | 3,270 • | 0,219 | 27,062 |
| | | | 1,541 ⋆ | | | 0,140 | 48,883 |
| | | **2,689 ⋆** | **1,583 ⋆** | | | **0,379** | **38,381** |
| 3,247 ⋆ | | | -1,441 • | | | 0,281 | 43,500 |
| **2,180 ⋆** | | | | | | **0,159** | **39,432** |
| 0,978 • | | -0,895 | | | | 0,122 | 56,274 |
| -0,668 | | | -0,945 | | | 0,108 | 48,523 |
| | | | | | | 0 | 47,036 |
| | | | **1,313 •** | | | **0,105** | **32,093** |

Table 4. Logistic regression models relating species ocurrence to physical and surrounding area variables. N=45; <0.1 n.s. (not significant), * <0.05, ** <0.01, *** <0.005, R2: Explained variability percentage; AIC: Akaike Criterion Information of the final model. Models considered the best for a species (minimum AIC) are typed in bold. Models with difference AIC<2 with respect to the best model appear underlined.

| | **Physical variables** | | | | |
|---|---|---|---|---|---|
| | **Width** | **Material** | **Distance** | **R2** | **AIC** |
| Ardeidae | | | | | |
| *Ardea purpurea* | **-0,947 •** | | **0,003 *** | **0,257** | **29,317** |
| *Ardeola ralloides* | | | | 0 | 28,996 |
| *Egretta garzetta* | | | | 0 | 52,053 |
| *Nycticorax nycticorax* | | | | 0 | 33,395 |
| Rallidae | | | | | |
| *Gallinula chloropus* | 0,530 * | | | 0,132 | 54,842 |
| Laridae | | | | | |
| *Larus ridibundus* | | | -0,001 | 0,092 | 28,512 |
| Sternidae | | | | | |
| *Chlydonias hybridus* | | | **-0,016** | **0,799** | **10,288** |
| Hirundinidae | | | | | |
| *Delichron urbica* | **2,150 *** | | | **0,459** | **18,589** |
| *Hirundo rustica* | | | | 0 | 54,192 |
| Turdidae | | | | | |
| *Turdus merula* | | | | 0 | 54,192 |
| Sylvidae | | | | | |
| *Acrocephalus scirpaceus* | -0,342 • | | | 0,059 | 53,061 |
| *Cettia cetti* | | -1,504 • | | 0,084 | 42,6 |
| *Cisticola juncidis* | | | | 0 | 59,286 |
| *Sylvia melanocephala* | | | <u>-0,001 •</u> | <u>0,065</u> | <u>48,578</u> |
| Fringilidae | | | | | |
| *Carduelis chloris* | -0,319 | | | 0,051 | 46,741 |
| *Serinus serinus* | | | | 0 | 33,395 |

Table 4b.

| Surrounding area | | | | | | | |
|---|---|---|---|---|---|---|---|
| **SA1** | **SA2** | **SA3** | **SA4** | **SA5** | **SA6** | **R2** | **AIC** |
| | | | | | | 0 | 33,395 |
| | | | -1,669 | | | 0,112 | 27,985 |
| -0,795 • | | 0,781 | | | | 0,099 | 51,067 |
| -0,015 • | -0,037 ** | | | | | 0,343 | 26,616 |
| | **1,729 **** | | **-0,799** | | | **0,208** | **52,396** |
| | | **2,075 *** | | **1,434** | | **0,357** | **23,351** |
| | | | | | | 0 | 33,395 |
| | | | 0,998 • | 1,479 • | | 0,195 | 27,394 |
| | 0,985 * | | | | | 0,102 | 50,874 |
| | 0,772 • | | | | -1,653 | 0,128 | 51,503 |
| | -1,309 * | | | | -1,112 | 0,173 | 49,166 |
| 0,976 | | 0,754 | | | | 0,113 | 43,366 |
| | | **-1,043 *** | **1,357 •** | | | **0,142** | **55,18** |
| **-0,735** | | **1,089 •** | | | | **0,113** | **48,295** |
| | **0,714** | **1,358 *** | | | **-2,829 *** | **0,258** | **41,4** |
| 1,129 | | | | | | 0,073 | 33,089 |

Table 5. Linear regression models relating species richness to each set of variables independently. N=45; <0.1 n.s.. (not significant), * <0.05, ** <0.01, *** <0.005, R2: Explained variability percentage; AIC: Akaike Criterion Information of the final model. Models considered the best for a species (minimum AIC) are typed in bold. Models with difference AIC<2 with respect to the best model appear underlined.

| **Physical variables** | **Width** | **Building** | **Distance** | | | | **R2** | **AIC** |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | 0 | 192.37 |
| **CA gradients** | **Axis1** | **Axis2** | **Axis3** | **Axis4** | **Axis5** | **Axis6** | **R2** | **AIC** |
| **Surrounding area** | | | 0.224 * | | | -0.209 | 0.199 | 188.05 |
| **Vegetation height** | 0.292 *** | | | | | | 0.279 | 182.68 |
| **Vegetation cover** | **0.174** | | **0.375 ***** | | | | **0.366** | **181.07** |
| **Reed development** | **0.337 ***** | **-0.115** | | | | | **0.365** | **181.10** |

Table 6. Linear regression models relating total bird abundance to each set of variables independently. N=45; <0.1 n.s. (not significant), * <0.05, ** <0.01, *** <0.005, R2: Explained variability percentage; AIC: Akaike Criterion Information of the final model. Models considered the best for a species (minimum AIC) are typed in bold. Models with difference AIC<2 with respect to the best model appear underlined.

| **Physical variables** | **Width** | **Building** | **Distance** | | | | **R2** | **AIC** |
|---|---|---|---|---|---|---|---|---|
| | | | -0.033 ** | | | | 0.04 | 356.63 |
| **CA gradients** | **Axis1** | **Axis2** | **Axis3** | **Axis4** | **Axis5** | **Axis6** | **R2** | **AIC** |
| **Surrounding area** | **0.001 •** | | **0.006 ***** | **-0.001** | | **-0.002 *** | **0.349** | **307.27** |
| **Vegetation height** | 0.003 *** | 0.003 ** | -0.002 | | | | 0.157 | 339.64 |
| **Vegetation cover** | 0.001 | -0.003 *** | | | -0.003 ** | -0.003 * | 0.202 | 333.6 |
| **Reed development** | 0.003 *** | | | | | | 0.153 | 336.50 |