Short Note

Habitat selection by breeding Common Kingfishers (*Alcedo atthis* L.) in rivers from Northern Iberia

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Abstract – The relative importance of biotic and abiotic variables on the Common Kingfisher *Alcedo atthis* breeding distribution in northern Iberian rivers was quantified through surveys completed in 2007. Eight rivers were surveyed for "positive" and "negative" (control) breeding territories (PBT and NBT, respectively). PBT ($N = 9$) were 3-km river sections with breeding pairs; NBT ($N = 8$) were 3-km river sections close to PBT, where no pairs were found, with apparently similar features to the PBT and one or more cut banks suitable for nesting. Stepwise discriminant analysis (SDA) correctly classified 94.1% of territories and revealed PBT was associated with higher oxygen concentrations, a lower maximum depth and lower proportion of rockfills. Causes and consequences of these findings are discussed.

Key words: Habitat mapping / reproduction / riparian / freshwater fish / water quality

Introduction

Habitat selection has important consequences for the life history of species, but the mechanisms of selection and the relevance of the different environmental variables in the processes of selection are not fully understood for many species. This knowledge is, however, important from the ecological perspective and for initiating management and conservation actions.

The Common Kingfisher *Alcedo atthis* Linnaeus 1758 breeds across most of the Palaearctic and the Indo-Malayian region in southeastern Asia (Cramp, 1985). During the breeding period, it is strongly associated with freshwaters, including reservoirs, rivers, streams and channels that have high availability of small-sized preys (mainly fishes), perches and shallow-water areas. Therefore, changes in the habitat quality of watercourses, including water pollution and the degradation of the fluvial habitat, may have a direct impact on their population dynamics and survival (Meadows, 1972). While threatened in Europe, their populations have been stable or even increasing since 1990, although they have not recovered to the levels observed in the 1970s (Burfield and van Bommell, 2004). In Spain, their populations are still decreasing (Burfield and van Bommell, 2004) and it has thus been catalogued as "Nearly Threatened" (NT). Decreasing

habitat quality and water pollution are the chief causes of the decline (Moreno-Opo, 2003). Thus, studies on their habitat quality and habitat selection are important for evaluating their status and formulating effective management policies.

Most studies have focused on single or groups of closely related environmental factors, such as river width, depth or slope (Peris and Rodríguez, 1996; Bonnington *et al.*, 2008), the features of the riparian vegetation (Peris and Rodríguez, 1996), the availability of food (Campos *et al.*, 2000) or perches from which to fish (Bonnington *et al.*, 2008) and water quality (Meadows, 1972). Few studies have simultaneously considered all (or most of) the potential factors affecting the distribution and presence of kingfisher species along water courses (Bonnington *et al.*, 2008). In Iberia, the Common Kingfisher has been only studied in several north western streams (Peris and Rodríguez, 1996), where higher densities tended to be found at lower altitude (where rivers had a less steep slope) and in shallow zones where the vegetation was not too scarce or very abundant. Other factors that could potentially influence the occurrence of breeding Common Kingfishers have not been quantified. Thus, the aim of this study was to quantify the relative importance of the biotic (vegetation characteristics and prey availability) and abiotic factors (stream-associated physic and hydrochemical characteristics, and the presence of artificial structures) on Common

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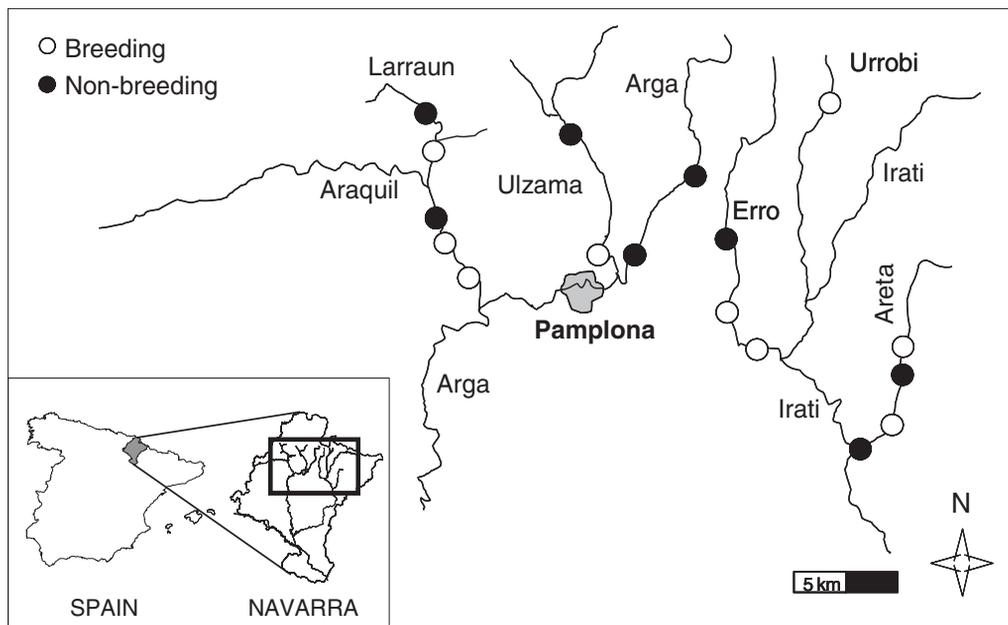*Corresponding author: antvilches@gmail.com

Fig. 1. Location of the PBT and NBT where the study was carried out, in northern Navarra. Data were collected during the spring and summer 2007. Pamplona, the main city within this area, is shown as a reference point.

Kingfisher's breeding distribution in rivers from northern Iberia.

Methods

Field data collection

During the spring and summer 2007, eight rivers in northern Iberia, covering 126.7 km (Navarra, Ebro basin; Fig. 1), were surveyed to look for what were termed "positive" and "negative" (control) breeding territories (PBT and NBT, respectively) of the Common Kingfisher. PBT ($N = 9$) were 3-km river stretches where breeding pairs were found (with a nest with either eggs or chicks detected), while NBT ($N = 8$) were 3-km river stretches where no pairs were found, but with apparent similar features to the PBT and, above all, with one or more cut banks apparently suitable for breeding, since this latter is required for the presence of a breeding pair (Cramp, 1985). A 3-km length was considered to be representative of a Kingfisher's breeding territory (Cramp, 1985). The centre of the territory was considered to be the nest for PBT and the point where the cut bank was found for NBT. In summary, 54 km of territories were studied, where no territory overlapped with another.

As their habitat is restricted to watercourses (Woodwall, 1991), all variables considered were limited to the riparian and fluvial habitats. This meant some of the measured habitat variables were restricted to lineal measures: length of lentic waters (m), riparian vegetation (yes/no), rockfills in the banks, artificial walls (parallel to the stream as rockfills, but not modifying the river course), rocky river cliffs and cut banks (presumably suitable for

breeding). All were measured in the downstream direction by recording the starting (upstream) and final (downstream) coordinates of each variable. Locations were recorded using a GPS navigator (Garmin GPSMAP 76Cx, DGPS; ± 5 m accuracy). All variables were expressed as a percentage over the territory length.

As kingfisher diet is fish-based (*e.g.* Cramp, 1985; Woodwall, 1991), food availability focused on fish abundance. Three electrofishing sampling points per PBT and NBT were selected (one point in the nest/cut bank and the other points 1 km upstream and 1 km downstream from the nest point) and used a semi-quantitative 30-min survey to provide a relative estimate of fish density (as number of fish/30 min). This provided an adequate methodological approach for comparing fish density between similar rivers (Reid *et al.*, 2009). Only fishes of 30–120 mm length were considered as these are within the size range taken by kingfishers (Campos *et al.*, 2000). Captured fish were anaesthetized (2-phenoxyethanol, 0.1–0.2 mg.L^{-1}), identified to species and measured (total body length, nearest mm). Body mass was estimated from length (Leunda *et al.*, 2006) to provide estimates of fish biomass (as g/30 min). While 14 species were captured, only those with relatively high abundances ($>5\%$ of the total number) were considered: Pyrenean gudgeon *Gobio lozanoi* Doadrio and Madeira, 2004, Ebro barbel *Barbus graellsii* (Steindachner, 1866), Ebro nase *Parachondrostoma miegii* (Steindachner, 1866) and Pyrenean minnow *Phoxinus bigerri* Kottelat, 2007.

Water chemistry was measured using the following hydrochemical variables in each electrofishing point: temperature ($^{\circ}$C), conductivity (μS.cm^{-1}), dissolved oxygen (mg.L^{-1}) and pH. Water speed (m.s^{-1}), river width and depth (m), substrate-type (sand, gravel, pebble,

Table 1. Mean ($\pm$ SE), median and the first and third quartiles values of biotic and abiotic variables measured in breeding ($N = 9$) and non-breeding ($N = 8$) Common Kingfisher territories during the spring and summer 2007 in Navarra, northern Iberia. Statistics (*U*-test and the corresponding *P* values) have been also included. Abbreviations: CPUE, captures (number of fishes) in a half hour; BPUE, biomass (*g*) of fishes caught in a half hour.

Variable	Unit	Breeding	Non-breeding	*U*-test	*P*
Lentic waters	%	69.5 $\pm$ 3.4 68.2 (59.5–77.6)	66.7 $\pm$ 4.0 67.2 (57.4–77.0)	32.0	0.700
Riparian vegetation	%	66.6 $\pm$ 4.9 66.0 (55.8–77.8)	64.9 $\pm$ 4.2 70.0 (53.6–73.0)	32.0	0.700
Rockfills	%	1.3 $\pm$ 0.8 0.0 (0–1.9)	4.4 $\pm$ 2.0 3.1 (0.7–4.2)	18.0	0.073
Artificial walls	%	4.5 $\pm$ 1.7 2.3 (1.0–8.7)	4.3 $\pm$ 1.4 3.5 (2.1–5.0)	31.0	0.630
Rocky river cliffs	%	3.3 $\pm$ 1.2 2.2 (0.0–5.9)	2.8 $\pm$ 0.9 2.3 (0.7–3.7)	35.5	0.961
Cut banks	%	1.8 $\pm$ 0.5 2.2 (0.5–2.4)	2.8 $\pm$ 1.0 1.7 (0.8–4.2)	27.0	0.386
QBR index	No unit	64.2 $\pm$ 7.7 59.4 (44.2–83.3)	60.8 $\pm$ 4.5 58.3 (50.8–65.8)	30.5	0.596
Dissolved oxygen	mg.L^{-1}	7.4 $\pm$ 0.3 7.3 (6.8–7.8)	6.6 $\pm$ 0.3 6.6 (5.9–7.4)	17.0	0.068
pH	No unit	8.39 $\pm$ 0.04 8.40 (8.29–8.46)	8.37 $\pm$ 0.05 8.40 (8.23–8.51)	35.0	0.923
Water conductivity	µS.cm^{-1}	434.9 $\pm$ 45.6 407.3 (340–571.5)	353.2 $\pm$ 29.8 391.5 (260.4–426.8)	27.0	0.386
Water temperature	°C	15.8 $\pm$ 0.8 15.3 (14.4–17.4)	14.9 $\pm$ 0.7 15.6 (12.8–16.7)	30.5	0.596
Width	M	11.0 $\pm$ 1.3 9.2 (7.9–14.2)	11.0 $\pm$ 1.1 10.4 (9.3–12.0)	34.0	0.847
Depth (mean)	cm	33.7 $\pm$ 2.7 29.7 (27.7–41.4)	35.4 $\pm$ 3.3 32.6 (28.4–41.6)	31.0	0.630
Depth (maximum)	cm	59.2 $\pm$ 4.5 56.7 (46.4–70.5)	68.8 $\pm$ 5.8 65.0 (53.5–85.2)	23.0	0.211
Velocity	m.s^{-1}	0.46 $\pm$ 0.03 0.52 (0.35–0.53)	0.40 $\pm$ 0.03 0.42 (0.33–0.47)	20.5	0.134
Sand (< 2 mm Ø)	%	7.1 $\pm$ 1.5 7.4 (3.8–8.7)	6.6 $\pm$ 2.8 4.9 (0.8–7.9)	27.0	0.384
Gravel (2–64 mm)	%	20.8 $\pm$ 3.7 19.7 (8.6–31.7)	14.7 $\pm$ 3.6 12.2 (5.8–25.6)	24.0	0.247
Pebble (65–255 mm)	%	43.3 $\pm$ 6.4 46.1 (23.5–58)	37.3 $\pm$ 7.0 31.4 (27.8–52.5)	30.0	0.564
Boulders (> 256 mm)	%	23.2 $\pm$ 5.1 20.8 (12.2–35.1)	24.7 $\pm$ 5.3 24.1 (10.6–31.5)	31.0	0.630
Rock	%	31.7 $\pm$ 8.5 31.3 (6.7–56.7)	32 $\pm$ 7.5 32.4 (14.3–46.9)	36.0	0.999
Shadow	%	39.0 $\pm$ 1.6 44.4 (25.6–49.4)	38.8 $\pm$ 2.8 41.1 (14.0–61.7)	35.5	0.962
Gobio lozanoi	CPUE	10.8 $\pm$ 3.2 10.6 (1.0–19.5)	10.8 $\pm$ 6.0 4.2 (0.3–17.8)	31.5	0.663
Larus graellsii	CPUE	12.9 $\pm$ 4.5 8.5 (1.5–22.4)	23.7 $\pm$ 15.7 6.5 (1.6–25.8)	35.5	0.962
Phoxinus bigerri	CPUE	119.2 $\pm$ 29.3 77.5 (48.2–181.0)	101.1 $\pm$ 22.9 113.2 (36.3–126.6)	33.0	0.773
Parachondrostoma miegii	CPUE	39.5 $\pm$ 12.3 22.3 (9.0–71.8)	49.6 $\pm$ 17.6 39.7 (5.6–88.5)	34.0	0.847
G. lozanoi	BPUE	57.3 $\pm$ 18.2 40.8 (9.2–92.5)	64.3 $\pm$ 32.8 22.8 (3.0–147.8)	31.0	0.628
L. graellsii	BPUE	47.5 $\pm$ 16.3 16 (8.6–91.5)	59.5 $\pm$ 30.3 15.3 (9.9–129.9)	33.0	0.773
P. bigerri	BPUE	337.8 $\pm$ 78.9 288.3 (129.1–523.9)	296.4 $\pm$ 73.3 251.7 (124.8–525.3)	30.0	0.564
P. miegii	BPUE	105.0 $\pm$ 30.3 99.6 (20.0–188.3)	159.7 $\pm$ 65.9 68.2 (11.9–304.2)	31.0	0.630

Table 2. Scores of the canonical discriminant function, prognosticate group (breeding + and non-breeding −) and the associated probability (*P*) of a territory to be classified into the original group (breeding or non-breeding). Centroids (average discriminant scores) are given for each group.

	Scores	Prognosticate group	*P*
Non-breeding territories			
Araquil −	2.963	−	0.999
Areta 1−	1.514	−	0.972
Areta 2−	0.525	−	0.753
Arga 1−	1.196	−	0.941
Arga 2−	0.898	−	0.884
Erro −	− 0.434	+	0.224
Larraun −	2.124	−	0.994
Ulzama −	1.632	−	0.979
Centroid	1.302		
Breeding territories			
Araquil 1+	− 0.584	+	0.834
Araquil 2+	− 1.858	+	0.991
Areta 1+	− 2.937	+	0.999
Areta 2+	− 0.762	+	0.886
Erro 1+	− 0.431	+	0.775
Erro 2+	− 2.370	+	0.998
Larraun +	− 0.298	+	0.713
Ulzama +	− 0.371	+	0.749
Urrobi +	− 0.808	+	0.897
Centroid	− 1.158		

boulders or rock) and the presence/absence of shadow over the free water surface was also measured in four bank-to-bank transects per electrofishing point (Bain and Stevenson, 1999). The QBR (Qualitat del Bosc de Ribera, in English: Riparian Forest Quality index) index was used to assess the riparian habitat quality (Munne *et al.*, 2003). For further analyses, the mean value of each variable was calculated for each territory (PBT and NBT). Overall, more than 37 linear km were fished and 52 electrofishing surveys (PBT: 28, NBT: 24) performed.

Data analysis

Initially, data from PBT and NBT were compared with univariate, non-parametric *U*-tests due to the relatively low sample sizes. The variables with lowest probability values (i.e. most significantly different) were then selected. Their number of selected variables was six, providing a 3:1 ratio of observations to variables, recommended for reasonable stability and reliability of multivariate analyses of ecological data (King and Jackson, 1999). Pearson's correlation matrix was performed among selected variables using Bartlett's sphericity test to detect correlated variables (*e.g.* Grossman *et al.*, 1991).

A stepwise discriminant analysis (SDA) was then completed with these selected variables to detect those with a major discriminating capacity between PBT and NBT. The physical data were log-transformed, while frequency variables were arcsine-transformed. The

Table 3. Variables selected by the SDA, standardized coefficients, Wilks λ statistics and associated probability (*P*). Absolute values of the standardized coefficients are related with their relative weight in the function and, therefore, in the discriminating capacity.

	Standardized coefficients	Wilks λ	*P*
Dissolved oxygen (mg.L^{-1})	0.871	0.766	0.049
Rockfills (%)	0.979	0.557	0.017
Maximum depth (cm)	− 0.721	0.423	0.009

absolute values of the standardized *B* parameters of the discriminating function were used to evaluate the relative weight of the variables included in this function. Finally, a principal component analysis (PCA) was carried out using only those variables selected by the SDA to visualize the multivariate spatial distribution of each variable and the territories (PBT and NBT). All statistical analyses were performed using XLSTAT 7.5.2, G-Power 3.0.10 and SPSS 15.0 programs.

Results

The univariate analyses revealed that none of the 29 variables varied between PBT and NBT (Table 1). According to these results and the probability differences between territories, six variables were selected for SDA: dissolved oxygen, rockfills, maximum depth, water velocity, gravel and sand proportion.

The SDA provided a function that significantly discriminated between PBT and NBT (Table 2). A total of three variables were included in the function (Table 3), and the percentage of territories correctly classified was 94.1% (Table 2). Only one of the NBT (Erro river) was incorrectly classified as a PBT by the SDA (Table 2). According to the standardized coefficients of the function, PBT showed higher oxygen concentrations, a lower maximum depth and lower proportion of rockfills (Table 3). Of these three variables, the proportion of rockfills in the territory was the variable with a major discriminating weight. The first and second principal components of the PCA performed with the three variables which were selected by the SDA accounted for 75.7% of the variance. The relationship between the spatial distribution of the territories and the variables is shown in Figure 2. It can be seen that analysed territories become clustered (NBT and PBT) over the bi-dimensional space, only one (NBT in the Erro River) is separated from its cluster. First principal component showed high, positive values for maximum depth, and negative for rockfills, whereas second axis showed positive values for oxygen concentrations in the water.

Discussion

From 29 biotic and abiotic variables related with the riparian and fluvial habitats, only three clearly
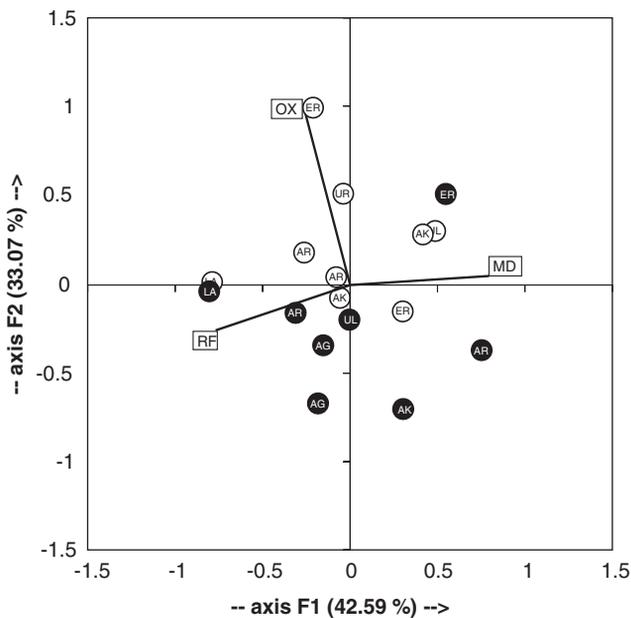
Fig. 2. Bi-plot of the first and second principal components derived from a PCA including the three variables included in the SDA. This bi-plot represents the spatial distribution the territories (white: breeding; black: non-breeding) and the discriminating variables. Variables: OX, dissolved oxygen; MD, maximum depth; RF, rockfills. Rivers: AK, Araquil; AR, Areta; AG, Arga; ER, Erro; LA, Larraun; UL, Ulzama; UR, Urrobi.

discriminated between PBT and NBT: rockfills, river depth and dissolved oxygen. Moreover, another three variables (proportion of gravel and sand in the bottom and flow velocity) also tended (though to a lesser extent) to vary between territories. It was likely that the kingfishers avoided areas with higher proportion of rockfills due to three reasons: (1) vegetation, in particular shrubs and trees, were absent from these areas and, therefore, the availability of perching sites from which to fish is lower; (2) rockfills destroy the natural cut banks, reducing thus the availability of potential breeding sites, and (3) rockfills are often built in zones with a higher human population density, which probably is associated with increasing disturbance for breeding pairs. Thus, to improve the habitat quality for kingfishers, the amount and length of rockfills along the river should be either minimized or mitigated for by providing alternative perching areas. This does not, however, solve the problem associated with the disappearance of the natural cut banks, where the building of artificial nests could be the mitigation measure (Wechsler, 2007).

Breeding pairs tended to avoid territories with higher depths, showing preferences for shallow waters. Bonnington *et al.* (2008) reported that kingfishers of *Alcedo* genus perch close to the water surface and, therefore, shallow waters are needed to full submersion – a determining factor for successful fish capture. Maximum diving depth of kingfishers is approximately 30 cm (Whitfield and Blaber, 1978) and higher depths are

unsuitable for their fishing. Supporting this, Kasahara and Katoh (2008) observed that Greater Pied Kingfishers *Ceryle lugubris* (Temminck) used perches at a higher height and fished in deeper waters than Common Kingfishers. Oxygen had higher concentrations in those river zones where breeding pairs were found, with this likely to be associated with water quality and the availability of food. Notwithstanding, food availability was similar between PBT and NBT in this study, despite fish being a limiting factor for kingfishers in other studies (Woodwall, 1991; Peris and Rodríguez, 1996). This suggests that fish availability in our rivers was not a limiting factor for the species, with habitat more important. Nevertheless, the tendency of breeding pairs to be found in zones with a higher proportion of gravel and sand in the bottom may be linked with the fact that it is in this type of substrate where preferred preys, such as Pyrenean minnow, tend to be more abundant (Campos *et al.*, 2000; Leunda *et al.*, in press).

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