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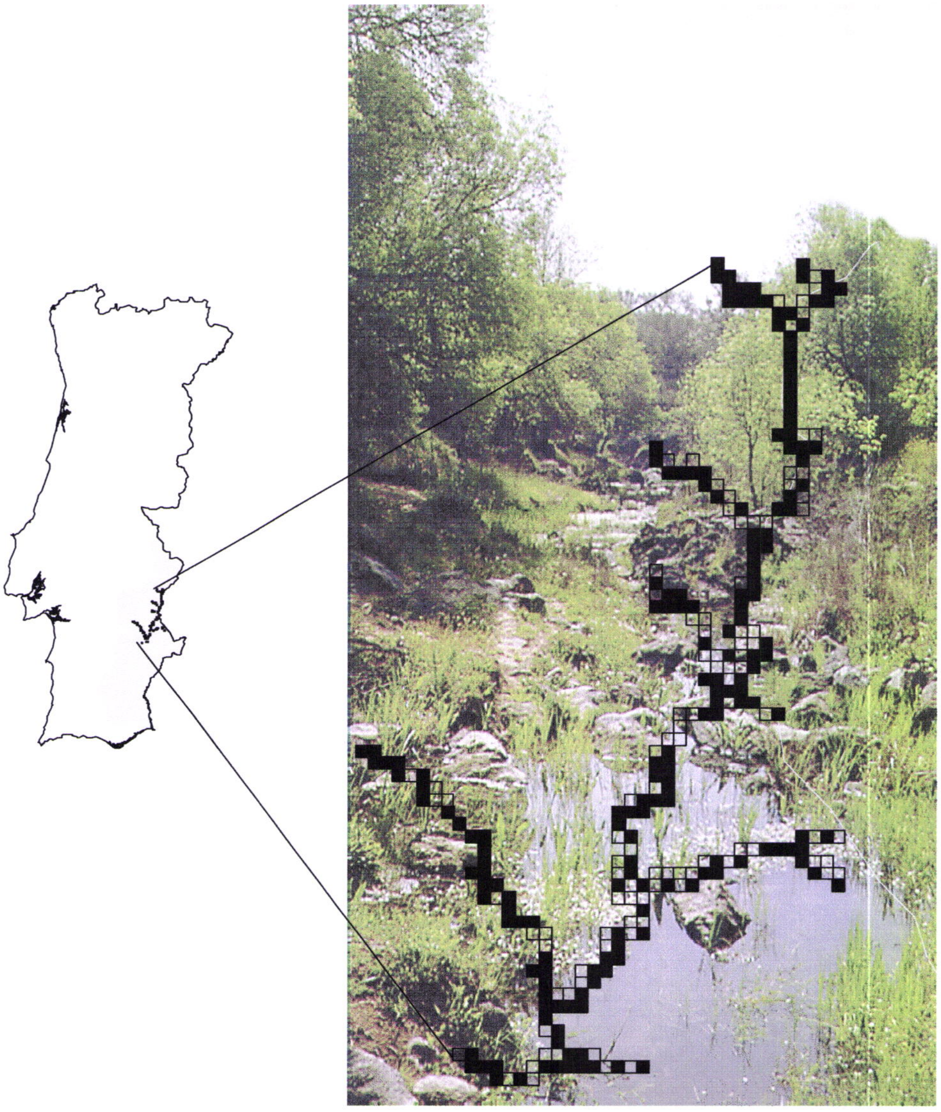
Influence area of Alqueva reservoir



Carlos António Marques Pereira Godinho

Dissertação para a Grau de Mestre em Biologia da Conservação

Orientador – Prof. Dr. João Eduardo Rabaça

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Universidade de Évora • Évora, Outubro de 2006

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Estudo das Comunidades de Aves Nidificantes na bacia Hidrográfica do Rio Guadiana – Zona de influência directa da albufeira de Alqueva

Carlos António Marques Pereira Godinho

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Resumo

Estudo das Comunidades de Aves Nidificantes na bacia Hidrográfica do Rio Guadiana – Zona de influência directa da albufeira de Alqueva

A estrutura de habitat é um dos factores mais determinantes na composição das comunidades de aves. O nosso objectivo foi procurar relações entre a estrutura de comunidades de aves nidificantes em zonas ripícolas e características particulares de habitat.

As relações entre variáveis espaciais e descritores dos cursos de água em galerias ripícolas do Sudeste de Portugal foram estudadas para dois grupos de aves (Passeriformes Florestais – PF e espécies Aquáticas/Riparias – AR). O nosso estudo decorreu em cerca de 230Km de galerias ripícolas localizadas na área inundada pela Barragem de Alqueva, antes do encerramento da barragem. No total foram realizados 190 pontos de escuta sem limite de distância.

Através de uma análise de partição de variância determinámos os efeitos independentes e de conjunto das variáveis espaciais, de leito e margem do rio nos nossos grupos de aves. A variância explicada para os PF e para as espécies AR foi de 26% e 37%, respectivamente. As variáveis que demonstraram ter maior poder discriminatório na análise reflectem a complexidade estrutural da galeria ripícola, a existência de locais com vegetação enraizada emergente e as formações rochosas naturais. O maior contributo para a variância explicada foi dado pelas variáveis referentes ao leito.

As variáveis analisadas são descritores específicos, e assim admitimos que as relações espécies – variáveis ambientais reveladas neste estudo podem ser bons indicadores para os rios Mediterrâneos.

Abstract

Study of the Breeding Bird Communities in the Hydrographical basin of Guadiana River – Influence area of Alqueva reservoir

Habitat structure is a major determinant of bird community composition and a link between riparian vegetation structure and bird communities in riparian zones, suggest that changes in bird community composition can be predicted from changes in habitats. Our study aimed at seeking for relationships between the structure of breeding bird communities and environmental drives, using fine-resolution habitat measurements

We examined two bird assemblages (Forest Passerine – FP; and Aquatic/Riparian species - AR), spatial structure and relationship to environmental stream variables in riparian galleries in Southern Portugal. Our study was conducted on the c. 230Km of riparian corridors located in the flooded area of the Alqueva reservoir, before the closure of the dam. We used data from 190 point counts of 10min. Using variation partitioning we determined the independent and join effects of stream-edge, stream-bed and spatial variables on our selected bird assemblages.

The variation captured in bird assemblages was 26% for FP and 37 for AR. The explanatory variables highlighted as important predictors for both bird groups were variables reflecting the complexity of the riparian gallery vegetation; streams with emergent rooted vegetation as a dominant habitat and riverbeds and riversides dominated by rock and scarce emergent rooted vegetation. Most of explained variation was related with the environmental variables, mainly with stream-edge.

Riparian areas can be considered a specific habitat and the variables analysed are habitat descriptors at a fine scale, we believe that the species-environment relationships revealed in this study could be good indicators for Mediterranean rivers.

Introdução

As galerias ripícolas

As zonas ripícolas englobam-se nos ecossistemas terrestres mais complexos e dinâmicos (Naiman *et al.* 1993), actuando como limite entre os ecossistemas aquático e terrestre - ecótono (Nilsson & Grelsson 1995). Comparativamente à área que ocupam, proporcionam para um elevado número de espécies animais e vegetais, maior disponibilidade de habitat, (Ward *et al.* 2002; Martin *et al.* 2006; Rodewald & Bakermans 2006). É reconhecida a sua importância enquanto local de nidificação para várias espécies de aves e a sua função como corredor durante as migrações (Mönkkönen & Reuanen 1999; Bolger *et al.* 2001). Adicionalmente, no Mediterrâneo as galerias ripícolas bem estruturadas podem ser importantes locais de nidificação para espécies associadas a ambientes florestais, principalmente quando escasseia habitat adequado nas áreas envolventes. A sua destruição é considerada a nível mundial uma das principais ameaças à redução da diversidade biológica (Boon *et al.*, 2000 *in* Rabaça, J. E., 2004).

A pressão exercida pelo Homem neste ecossistema é elevada e está a aumentar em todo o mundo (Dynesius & Nilsson 1994; Nilsson *et al.* 2005), pela alteração de usos do solo e/ou pressão urbanística. Assim, a fragmentação de habitats e a perda de áreas florestais é um facto em muitas regiões agrícolas do mundo (Rodewald & Bakermans 2006). O Mediterrâneo é um bom exemplo da influência humana nas zonas ripícolas ao longo dos tempos (Décamps *et al.* 1988; Corbacho *et al.* 2003). Muitas destas áreas estão a ser modificadas ou perdidas a um ritmo preocupante (Kaufmann *et al.* 1997; Rottenborn 1999) restando poucos locais com ecossistemas ripários naturais (Kamikaso *et al.* 2006).

Os maiores factores de ameaça a este ecossistema são a regulação dos leitos e caudais dos cursos de água, a implementação de barragens e o desenvolvimento urbano. Como consequência destas alterações ocorre frequentemente a simplificação e fragmentação de habitats, resultando num decréscimo de biodiversidade (Boulton & Lloyd 1992; Robinson *et al.* 2002; Kingsford & Thomas 2004; Smith & Wachob 2006).

A conservação da vegetação rípicola é vital para a manutenção da integridade dos cursos de água (Hancock & Froend 1996), bem como para as populações de aves em todo o mundo (Smith & Wachob 2006).

A área em estudo e a barragem de Alqueva

O nosso estudo decorreu na bacia hidrográfica do Rio Guadiana, abrangendo o seu troço médio em território nacional, nos anos que antecederam a implementação da barragem de Alqueva. Este empreendimento pela sua dimensão e vasta área alagada causou uma profunda alteração dos habitats, usos do solo e paisagem.

Os rios e ribeiras desta área encontravam-se na sua maioria em bom estado de conservação, apresentando galerias ripícolas bem estruturadas e albergando um elevado número de espécies, em particular de aves. Estas características associadas à informação obtida para este grupo taxonómico proporcionou o delineamento de uma situação de referência no contexto nacional.

Objectivos

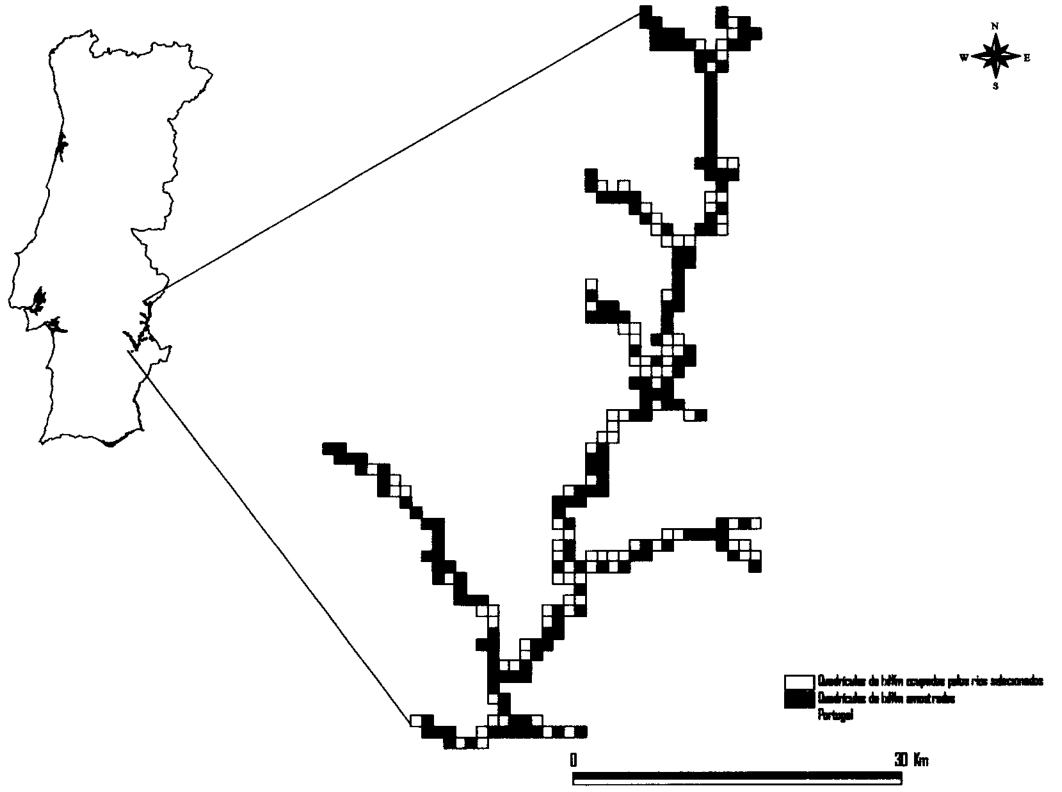
As comunidades de aves nidificantes são muitas vezes especializadas nos seus requisitos de habitat podendo reflectir a integridade dos mesmos (Sorace *et al.* 1999; Rodewald & Bakermans 2006). Desta forma, o estudo da relação entre as comunidades e o habitat são fundamentais para a compreensão dos impactos naturais e humanos na diversidade das aves (Heikkinen *et al.* 2004). O objectivo do nosso trabalho foi estudar as relações entre a comunidade de aves associadas às linhas de água e variáveis de habitat.

Área de estudo e locais de amostragem

Da bacia hidrográfica do troço médio do Rio Guadiana seleccionámos troços dos cursos de água mais representativos (Fig.1): Rio Guadiana, os seus principais afluentes (Degebe, Moures, Asseca, Azevél, Lucefecit, Cuncos, Alcarrache, Ardila) e alguns tributários de segunda ordem (Godelins and Azevelinho). Com base no número de quadrículas 1x1Km ocupadas por cada curso de água, seleccionámos aleatoriamente os locais de amostragem. O total de censos a realizar em cada troço, igual ao número de quadrículas seleccionadas, foi proporcional ao total de quadrículas ocupadas por cada linha de água. Cada local foi amostrado uma vez entre 1999 e 2001, tendo sido realizados 190 pontos de escuta de 10min sem limite de distância (e.g. Blondel et al. 1981).

Neste estudo seleccionámos dois grupos funcionais: Passeriformes Florestais (PF) (*sensu lato*) e espécies Aquáticas/Riparias (AR). Esta escolha baseia-se no pressuposto de que as espécies pertencentes a estes grupos estão relacionadas com a vegetação ripícola (Jansen & Robertson 2001).

Figura 1 – Localização da área de estudo e distribuição das quadrículas de 1x1Km com presença de troços dos rios seleccionados. Quadrículas preto – quadrículas onde foram realizados pontos de amostragem.



As variáveis e análises seleccionadas

Em cada local de amostragem foram registadas, no mesmo dia em que o censo foi realizado, quatro grupos de variáveis ambientais. Estas variáveis caracterizam: (1) leito do rio; (2) margens; (3) habitat envolvente e (4) impacto humano, representando 61 variáveis (Anexo I).

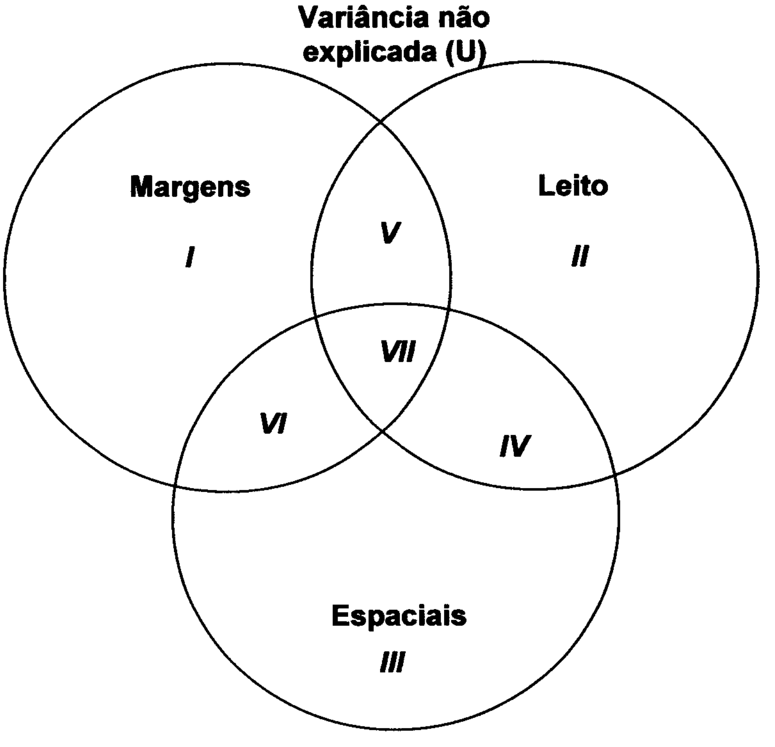
Para detectar os grupos de variáveis que melhor explicavam a variação na comunidade de aves (ter Braak 1986), efectuámos uma análise canónica de correspondência (CCA), usando o software CANOCO for Windows, versão 4.5 (ter Braak and Smilauer 2002). Inicialmente, foi realizada uma CCA com todas as variáveis e posteriormente uma a cada grupo de variáveis ambientais. As análises foram efectuadas procedendo a uma transformação logarítmica dos dados das aves para evitar a sobrevalorização de algumas espécies. Seleccionou-se a opção *Foward selection* e aplicou-se o teste de Permutações de Monte-Carlo (999), seleccionando as variáveis mais significativas (Titeux *et al.* 2004). Os grupos de variáveis que se revelaram mais importantes foram: o leito do rio e as margens.

Aos dois grupos de variáveis ambientais seleccionados foi necessário adicionar um grupo com as variáveis espaciais, com o objectivo de revelar a autocorrelação espacial nos dados das aves (Legendre 1993). As variáveis espaciais correspondem às coordenadas geográficas dos locais de amostragem x e y e aos seguintes termos: x^2, xy, y^2, x^3, x^2y, xy^2, y^3 (Legendre 1993).

Através dos 3 grupos de variáveis seleccionados efectuámos uma análise de partição de variância. De acordo com o descrito por Heikkinen *et al* (2004), decompusemos a variação dos dados das aves através de várias CCA parciais (ter Braak & Smilauer 2002).

A partição da variância origina 8 factores: *i*, efeito só das variáveis de margens; *ii*, efeito só do leito do rio; *iii*, efeito só das variáveis espaciais; variação partilhada por mais de um factor *iv*, variáveis de leito e espaciais; *v*, variáveis de margem e de leito; *vi*, variáveis de leito e de margem; *vii*, variáveis dos 3 grupos e *viii* variância não explicada (Fig.2).

Figura 2 – Exemplo da análise de partição de variância. *i*, efeito só das variáveis de margens; *ii*, efeito só do leito do rio; *iii*, efeito só das variáveis espaciais; *iv*, variáveis de leito e espaciais; *v*, variáveis de margem e de leito; *vi*, variáveis de leito e de margem; *vii*, variáveis dos 3 grupos e U variância não explicada



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Breeding birds in Mediterranean-type Rivers: relationships between avian community's parameters and environmental variables

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Abstract

Habitat structure is a major determinant of bird community composition and a link between riparian vegetation structure and bird communities in riparian zones, suggest that changes in bird community composition can be predicted from changes in habitats. Our study aimed at seeking for relationships between the structure of breeding bird communities and environmental drives, using fine-resolution habitat measurements

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The variation captured in bird assemblages was 26% for FP and 37 for AR. The explanatory variables highlighted as important predictors for both bird groups were variables reflecting the complexity of the riparian gallery vegetation; streams with emergent rooted vegetation as a dominant habitat and riverbeds and riversides dominated by rock and scarce emergent rooted vegetation. Most of explained variation was related with the environmental variables, mainly with stream-edge.

Riparian areas can be considered a specific habitat and the variables analysed are habitat descriptors at a fine scale, we believe that the species-environment relationships revealed in this study could be good indicators for Mediterranean rivers.

Introduction

Riparian areas are among the most complex, dynamic and species richness ecosystems in terrestrial biomes (e.g. Naiman et al. 1993). These complex landscapes are heterogeneous in space and time and provide habitat for a considerably large number of plant and animal species relative to pccupied surface (Ward et al. 2002; Martin et al. 2006; Rodewald and Bakermans 2006). Currently, forest loss and fragmentation has been extensive in many areas of the world (Rodewald and Bakermans 2006), where land use conversion often produces a notable pattern on the landscape: the concentration of forest remnants along waterways (Rodewald and Bakermans 2006) in narrow strips that might function as corridors and are constrained by adjacent terrestrial systems (Ferreira and Moreira 1999; Salinas et al. 2000). This is critical in maintaining biodiversity, especially in dry regions (Rottenborn 1999). Because riparian areas are dynamic boundaries between terrestrial and aquatic ecosystems (Nilsson and Grelsson 1995), the high edge to area ratio makes them vulnerable to changes in the surrounding landscape (Martin et al. 2006).

Human pressure on riparian areas is steadily increasing throughout the world (Dynesius and Nilsson 1994; Nilsson et al. 2005). Most of these areas are being lost or modified at an alarming rate (Kaufmann et al. 1997; Rottenborn 1999) remaining few natural unstressed riparian ecosystems (Kamisako et al. 2006). In Southern Europe riparian landscapes are typically characterized by a long-lasting history of intensive land use and human disturbances (Décamps et al. 1988; Corbacho et al. 2003), with major trends been related to: (1) river regulation, (2) establishment of dams and (3) urban development. As a result biodiversity tends to be reduced through habitat simplification (Boulton and

Lloyd 1992; Robinson et al. 2002; Kingsford and Thomas 2004) and/or habitat fragmentation, which normally occurs when human activities reduce contiguous forest patches into smaller isolated remains (Smith and Wachob 2006). Protecting and promoting the rehabilitation of riparian area throughout the world is crucial for maintaining the integrity of river ecosystem (Hancock and Froend 1996) and is therefore a central issue in applied ecology.

Among wildlife resources associated to riparian areas birds are of the outmost importance. As Stevens et al. (1977) (*in* Smith and Wachob) 2006pointed out, breeding grounds in riparian habitats may attract over 10x more the number of migratory birds in the spring than adjacent upland habitats and 14 times the number of birds during the fall migration. Moreover, riparian galleries often play the role of ecological corridors (Mönkkönen and Reuanen 1999; Bolger et al. 2001) providing habitat for many birds during migration (Stevens et al. 1977 *in* Smith and Wachob 2006) and dispersion of juveniles (Machtans et al. 1996). The habitat structure is a major determinant of bird community composition and many studies have shown a link between riparian vegetation structure and bird communities in riparian zones, suggesting that changes in bird community composition can be predicted from changes in habitats (Rottenborn 1999).

Relationships between birds and environmental variables have been investigated at several scales and kinds of habitats. Most studies have deal with a small-scale approach or even with a broader scale relating birds and major climatic or land use variables. Research on forest areas (e.g. Kirk and Hobson 2001; González Oreja 2003; Grand and Cushman 2003; Díaz 2006), floodplains (e.g. Jansen and Robertson 2001; Miller et al. 2004) and the influence of urbanization on riparian zones (Martin et al. 2006; Rodewald and Bakermans 2006; Smith and Wachob 2006) has been frequent, but studies conducted at an intermediate scale are less common (Heikkinen at al. 2004), specially in Mediterranean rivers.

Our study aimed at seeking for relationships between the structure of breeding bird communities and environmental drives, using fine-resolution habitat measurements. This is crucial to understand the impacts of natural and human factors in avian diversity (Heikkinen et al. 2004) as breeding bird communities might reflect the integrity of riparian habitats and are often specialized in their habitat requirements (Sorace et al. 1999; Rodewald and Bakermans 2006). Essentially, we intent to answer to the following question: which environmental variables are more accountable for the occurrence of breeding bird species associated to riverbeds and riversides? We feel that this knowledge is crucial on conservation grounds for the establishment of rehabilitation measures in riparian habitats, namely in areas where severe summer droughts highly influence the river flow regimes and water availability.

Our study was conducted on the c. 230Km of riparian corridors located in the flooded area of the Alqueva reservoir, before the closure of the dam gates that occurred in February 2002. The Alqueva dam (Guadiana River, Southern Portugal) is one of the biggest dams in the Iberian Peninsula. Its reservoir is the largest artificial lake in Europe with an inundated area of c. 250km^2 at its full storage level (152m). The impact of the dam on natural heritage was considerable and included the flooding of important habitats such as Holm and Cork oak stands, Mediterranean forests, extensive farming systems, shrubby areas and riparian galleries.

Methods

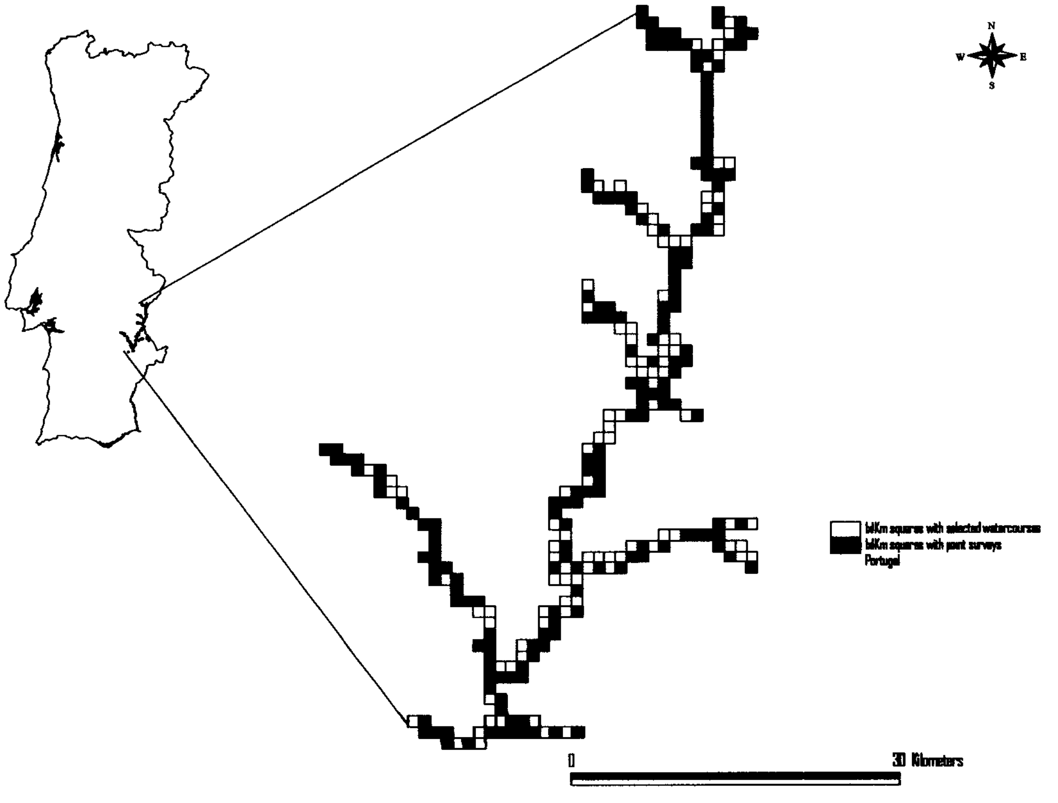
Study area

The study area covered a north–south latitudinal belt of about c. 70Km length from Juromenha (upstream) to Alqueva (7°12'W-7°29'W and 38°11'N-38°44'N) where the dam was built. Almost 90% of the altitude lies between 100m and 400m a.s.l. with an average of 237m. The climate is Mediterranean with an annual rainfall of 400-600mm and an annual average temperature of 16°C. The minimal mensal average varies from 9°C (January) to 24°C (July), with temperature records ranging from -7°C to 43°C, and insolation ranges from 2750 to 2900 hours/year (Instituto do Ambiente 1999).

Cork and Holm oaks (*Quercus suber* and *Q. rotundifolia*) parkland forested areas locally known as 'montados', are the dominant element of the landscape. Other uses included Mediterranean woodlands, cereal fields, pastures, fallow lands, vineyards, olive groves and shrubby areas dominated by Gum rockrose *Cistus ladanifer*, Narrow-leaved rockrose *C. monspeliensis*, Gorse *Ulex* sp, *Genista* sp and *Erica* sp.

Riparian vegetation is often well developed creating galleries dominated by Ashes *Fraxinus angustifolia*, Poplar *Populus alba*, Willow *Salix atrocinerea* and intermittently Common alder *Alnus* glutinosa. In rocky and driest sites Rose bay *Nerium oleander* and Tamarisk *Tamarix Africana* can be found in the riverside. Among aquatic vegetation Bulrush *Schirpus* sp and Narrow leaf cattail *Typha angustifolia* are the most significant elements, the latter often occurring in small to medium sized spots.

Figure 1 – Location of the study area and distribution of the 1x1 Km where the river stretches were included. Black-squares – squares where bird surveys were conducted.



Sampling sites and Bird surveys

Stretches of the 11 most important watercourses were selected: Guadiana River and the main tributaries Degebe, Moures, Asseca, Azevél, Lucefecit, Cuncus, Alcarrache, Ardila and the second order tributaries Godelins and Azevelinho. Every square (1x1Km) that included a river stretch was numbered and later on randomly selected for bird surveys. The number of sampling squares per river was proportional to the length of the river segment included in the study area. The squares were randomly selected for surveys. In each selected square only one point count census station was chosen accordingly to accessibility criteria and its location was closer to the river bed. In all, 190 stations were sampled only once from 1999 to 2001 using a point count method (e.g. Blondel et al. 1981) with a time-span of 10min.

In each year a different set of plots was surveyed just once during the breeding season: from 7 April to 14 July 1999 sixty one point counts were conducted, sixty from 16 May to 7 June 2000 and sixty nine from 11 May to 20 June 2001. Surveys were mostly carried out during early hours after sunrise but due to logistic constrain 55 point counts were conducted in late afternoon close to sunset. Windy and rainy weather was avoided and two observers with similar skills of aural and visual detection of birds were involved. Most of the birds recorded were assumed to be breeding, or at least, oversummering in the riparian corridors of the study area.

Analyses were carried out on data from 180 point counts. We excluded from data treatment species with a wider spatial use of the area than riparian belt and adjacent areas (e.g. birds of prey) (Moreira et al. 2001; Miller et al. 2004). In this study we selected two functional groups: Forest Passerines (*sensu lato*) and Aquatic/Riparian birds (afterwards referred as FP and AR). This option was base on the assumption that species from these groups were related to the riparian vegetation structure (Jansen and Robertson 2001).

Explanatory variables

Four groups of environmental variables were recorded in each sampling point (1) stream bed; (2) stream edges; (3) surrounding habitat and (4) human impact, representing 61 variables (Appendix 1). For each sampling station all variables were visual assessed in the field in the same day as the bird census was conducted.

A fifth group of predictor variables consisting of 9 spatial variables was added aiming to reveal the spatial autocorrelation structure in the bird data. These variables are the nine terms of a cubic trend surface analysis, the centered geographical coordinates of each point count (x , y) and the higher and cross-product terms x^2, xy, y^2, x^3, x^2y, xy^2 and y^3 (Legendre 1993).

Data analysis

Canonical Correspondence Analysis

We performed canonical ordination techniques for multivariate analysis using the program CANOCO for Windows, version 4.5 (ter Braak and Smilauer 2002). The bird groups selected were related to the environmental variables using Canonical Correspondence Analysis (CCA) to detect which were the sets of environmental variables that explained better the patterns of variation in bird community (ter Braak 1986).

Five initial CCA were run to define the two environmental variables data sets to use in the following analysis, using each one of the environmental groups (stream bed, stream edge, surrounding habitat and human impact) and one with all the variables. The runs were made using a logarithmic transformation on the bird data, to avoid the effect of overweighting of some species, choosing forward selection under unrestricted model with a Monte Carlo test (999 permutations). We retained the more significance variables, with stronger species-explanatory correlations (Titeux et al. 2004). For the subsequent analysis we use the environmental variables related to stream-bed and stream-edge.

Using a similar approach to Titeux (2004) rare or ubiquitous species were not analyzed because they are able to largely influence the analysis, creating a modification of the total inertia of the species data set or a distortion of the ordination. Therefore, species that occur in less than 5% of the sampling sites were omitted from the bird data set analysis and species found in more than 90% of the sampling sites were also omitted.

We submitted the geographical terms to a forward selection and then selected manually the factors on the basis of the additional variance explained (Monte Carlo test, 999 permutations).

Partition variance

According to the procedure described in Heikkinen et al. (2004), we decomposed the variation in our bird data sets among three groups of explanatory variables, stream bead (SB), stream edges (SE) and spatial (S), using a series of partial regression analysis with CCA (ter Braak & Smilauer

2002). In order to evaluate the contribution of each one of the groups separately and together, we performed seven CCA runs with a forward selection option with unrestricted model in CANOCO (999 Monte Carlo permutations tests). For each bird data set and each three variables group we performed different CCA analyses to remove variables that do not contribute significantly to the explained variation, by retaining variables with an estimate *p* value lower than 0.05.

Variation partitioning led to eight fractions: *i*, pure effect of stream edge alone; *ii*, pure effect of stream bed alone; *iii*, pure spatial fraction; combined variation due to the joint effects of *iv*, stream edge and spatial variables; *v*, stream edge and stream bed; *vi*, stream bed and spatial variables; *vii*, the three group of explanatory variables and *viii* the unexplained variation (Fig.2 and Fig.3).

Results

General results

In all, 98 species and 6744 individuals were recorded at the 180 stations analysed. The average species richness per census was 14.5±3.99, ranging from 4 to 29 species. Table 1 summarizes the distribution of census by watercourse and number of species recorded. We detected 58 species belonging to the FP group, but only 41 occurred in more than 5% of the sampling stations. The more frequent species were European Serin (71% of all sites), Barn Swallow (65%), Common Blackbird (63%), Common Nightingale (63%) and Sardinian Warbler (61%).

Nineteen aquatic and riparian species were recorded at 152 sampling points, with eleven species been present in more than 5% of the stations. We included in the analysis 8 species; 3 herons were omitted. The most frequent species were White Wagtail (49%) and Cetti's Warbler (49%), Little Ringed Plover (43%) and Kingfisher (39%).

Table 1 – Number of point counts, species and species richness by watercourse

Watercourse	Number of point counts	Number of species	Species richness
Alcarrache	10	51	14.2 ± 2.04
Ardila	7	50	18.7 ± 2.43
Asseca	12	40	13.8 ± 4.48
Azevél	10	39	13.1 ± 4.51
Azevelinho	5	21	10.2 ± 1.64
Cuncus	4	27	11.5 ± 1.73
Degebe	30	61	13.0 ± 4.33
Godelins	3	27	13.3 ± 2.52
Guadiana	83	80	15.6 ± 3.81
Lucefecit	12	40	13.7 ± 2.64
Moures	4	26	13.0 ± 4.69

Environmental groups and spatial variables

Manual selection of the explanatory variables, belonging to the 5 initial environmental groups of variables, suggests that our studied bird assemblages were more related to stream bed and edge features.

The total variation in the FP assemblage (sum of all eigenvalues) is 3.017. The 5 initial CCA runs give the following results: (1) Stream bed – 0.236; (2) Stream edge – 0.523; (3) Human impact – 0.149; (4) Surrounding habitat (<150m) – 0.195; (5) Surrounding habitat (>150m) – 0.228. Although the results from the stream bed and surrounding habitat (>150m) are similar, we opted to analyse stream bed, due to its close relationship with the features of the watercourses.

In the AR assemblages the total of variation is 2.302, and the 5 initials CCA runs give the following the results: (1) Stream bed – 0.273; (2) Stream edge – 0.623; (3) Human impact – 0.209; (4) Surrounding habitat (<150m) – 0.158; (5) Surrounding habitat (>150m) – 0.218.

A resume of the variables selected and their correlation with species axes, *F*-ratio from observed data and *p*-value from Monte Carlo test is showed in Table 2.

The following geographical terms were retained by the manual forward selections procedure ($p<0.05$) during the initial CCA:

- Passerines: $f(x,y)=b_2y + b_3 x^2 + b_4 xy + b_5y^2 + b_6x^3 + b_7x^2y + b_8xy^2 + b_9y^3$
- Riparian species: $f(x,y)= b_2y + b_4 xy + b_5y^2 + b_6x^3 + b_7x^2y + b_8xy^2 + b_9y^3$

Table 2 – Results from the CCA analysis in the environmental variables

Environmental group	Variable	Code	*F*	*p*	Axis 1	Axis 2
		Forest Passerines (FP)				
Stream Edge	Stream edge typology	STED6	1.71	0.012	0.1201	0.2457
		STED7	4.93	0.001	0.4261	-0.2492
	% Cover by vegetation strata	8+M_1	2.35	0.001	0.3917	0.0837
		8+M_2	1.98	0.003	0.0072	-0.0687
		2-8M_4	1.82	0.004	-0.0907	-0.0433
		2-8M_5	2.02	0.002	-0.2703	-0.1506
		0-0.5M_1	2.42	0.01	0.2172	-0.1248
	Dominant vegetation in the sampling point	TAMARIX	1.78	0.005	-0.2312	0.0899
		SALIX	3.33	0.001	-0.3047	-0.0992
		ARUNDO	2.57	0.002	-0.1002	0.0774
		ERV	3.53	0.001	-0.0688	0.4740
		RUBUS	3.21	0.001	-0.3106	-0.1293
		HERBACEA	1.60	0.043	0.0598	0.0164
Stream Bed	Stream width	Width	3.06	0.001	-0.0932	0.3807
	Existence river confluence	Confluence	2.25	0.001	-0.2028	0.4040
	% Cover of emergent root vegetation	ERV1	2.37	0.002	0.3036	0.1009
		ERV2	1.43	0.053*	0.1657	0.2039
	Stream substrate	Rock	5.43	0.001	0.5449	0.0694
		Aquatic/Riparian birds (AR)				
Stream Edge	Stream edge typology	STED2	2.59	0.014	-0.0141	-0.1221
		STED4	2.49	0.032	0.0361	0.0001
	% Cover by vegetation strata	8+M_3	2.18	0.037	0.1285	-0.0055
		8+M_4	1.98	0.060*	0.1391	-0.1186
		2-8M_5	6.40	0.001	0.3660	-0.2036
		0-0.5M_4	3.02	0.008	-0.2568	0.1479
	Dominant vegetation in the sampling point	FRAXINUS	3.32	0.002	0.1550	-0.1910
		TAMARIX	2.46	0.013	0.2583	-0.0562
		SECURINE	2.41	0.022	-0.1210	0.1558
		ERV	13.48	0.001	0.3348	0.6218
		RUBUS	6.11	0.001	0.4101	-0.0007
Stream Bed	Stream width	Width	2.52	0.015	0.0969	0.0129
	Aspect of river flow	ASP_2	2.06	0.046	-0.1255	-0.2013
	% Cover of emergent root vegetation	ERV4	1.95	0.069*	0.3138	0.0662
		ERV5	1.89	0.061*	0.1210	0.1521
	Stream substrate	Clay	2.45	0.024	0.2455	-0.1955
		Rock	7.54	0.001	-0.4677	0.0937

Legend: STED – Stream edge configuration; 0-0.5M – vegetation cover <0.5m (1- absent; 4- 30 to 60%); 2-8M – vegetation cover between 2 to 8m (4- 30 to 60%; 5- 60 to 100%); 8+M – vegetation cover >8m (1- absent; 2- 0 to 15%; 3-15 to 30%; 4- 30 to 60%); ERV – emergent rooted vegetation (1-absent; 2- 0 to 15%; 4- 30 to 60%; 5- 60 to 100%); ASP – aspect of river flow (2- irregular).

Variation partitioning

The amount of variation explained by the selected environmental and spatial variables for the FP group was 26.22%, and 36.69% for AR. Decomposition of variance showed that pure effect of environmental variables (9.45% and 6.17%) combined with their join effect (fraction *b* in Fig.2; 2.41%) are responsible for the largest fraction of the variability detected in FP (18.03%). All three groups of explanatory variables (fraction *d* in Fig.2; 0.88%) explain a small percentage of variation.

For the AR group the largest fraction of the explained variation (14.74%) (Fig.3) was related with the pure effect of environmental variables of Stream edge. Combined effect of variation explained by all the environmental variables is 22.27%. The combined effect of Stream edge and spatial variables (fraction *a* in Fig.3; 7.92%) was also considerable.

Figure 2 – Results of variation partitioning for the Forest Passerines group (FP) in terms of fractions of variation explained. Variation of the species data matrix is explained by three groups of explanatory variables: SB (stream bed), (SE) stream edges and S (space). U is the unexplained variation. *I*, *II* and *III* are unique effects of stream edge, bed factors and spatial autocorrelation variables, respectively. *a*, *b*, *c* and d are fractions indicating their joint effects.

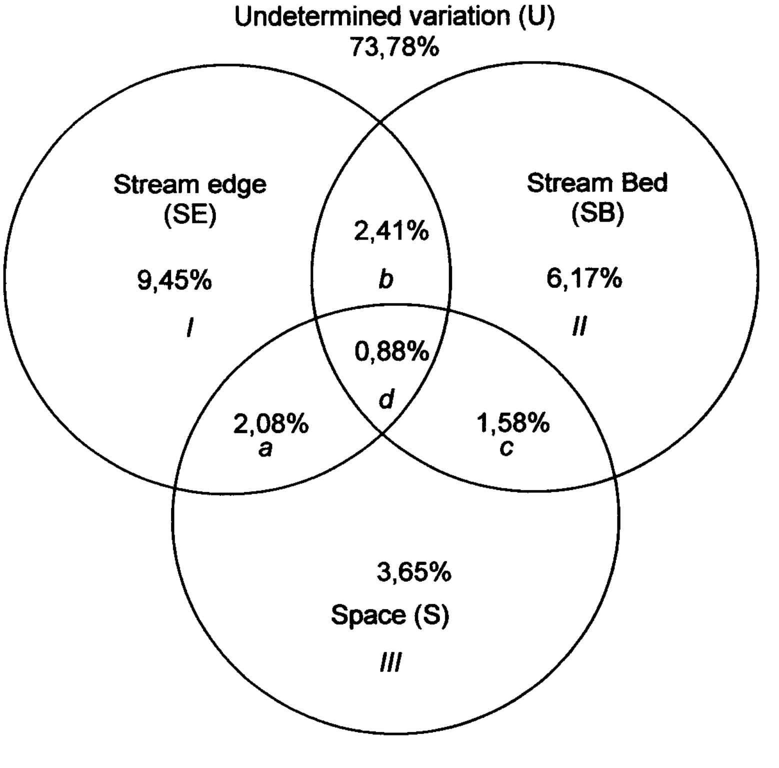
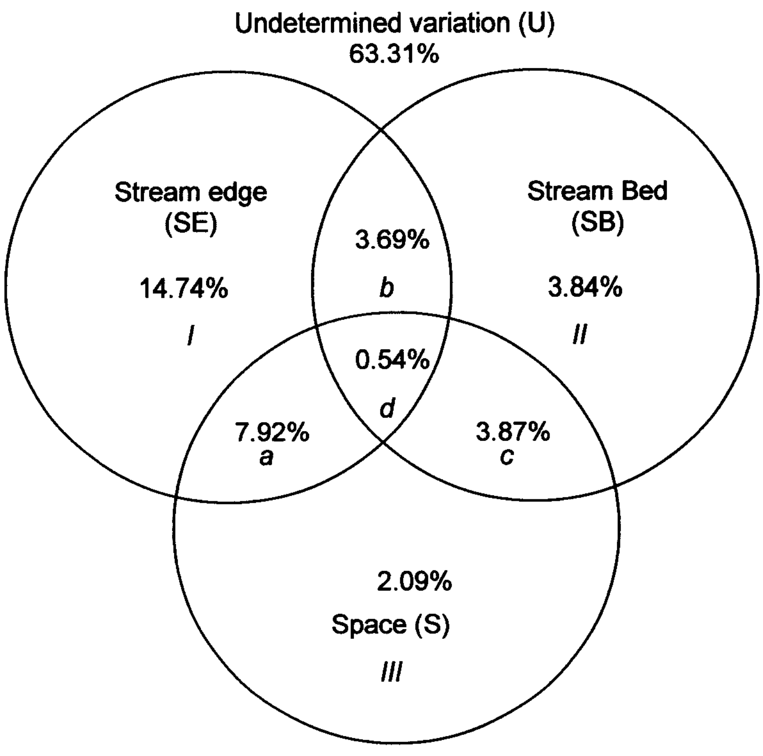


Figure 3 – Results of variation partitioning for Aquatic/Riparian bird group (AR) in terms of fractions of variation explained. See Fig.x for further details



In what species are concerned, the percentage of total and partial variance explained differs significantly from species to species (see Table 3 for FP and Table 4 for AR). Three species were analysed in the two bird data sets (White Wagtail, Cetti's Warbler and Great Reed-Warbler) and their results are slightly different depending of the assemblage.

In FP the total variance explained ranges from 10% for Common Magpie to about 54% for Cetti's Warbler. The variance explained by environmental variables ranges from 7% for European Greenfinch to 36% for Eurasian Crag-Martin. More than 66% of the species have a percentage of explained variance higher than 20%, and almost 25% of the species have an explained variance higher than 30%.

In riparian birds the total variance explained is between 11% for Common Sandpiper and 62% for Cetti's Warbler. The variance explained by environmental variables varies from 2% for Common Kingfisher to 33% for Great Reed-Warbler. Six of the species (75%) have a percentage of explained variance higher than 30% and half the species have an explained variance higher than 20%.

Table 3 - List of all recorded species with English and scientific names (taxonomic order), code (based on scientific names), total number of points detected (N) and proportion of variance explained by environmental variables (stream edge and stream bed), space and total as result of the partial Canonical Correspondence Analysis (only for passerine species present in >5% of the point counts)

Species				% Variance explained			
English name	**Scientific name**	**Code**	**N**	**Stream Edge**	**Stream bed**	**Spatial**	**Total**
Thekla Lark	*Galerida theklae*	GALTHE	74	6.83	7.96	5.32	35.63
Wood Lark	*Lullula arborea*	LULARB	10	4.41	3.92	1.42	14.11
Sand martin	*Riparia riparia*	RIPRIP	14	6.02	5.2	5.53	33.35
Eurasian Crag-Martin	*Ptyonoprogne rupestris*	PTYRUP	21	29.33	6.49	1.01	51.91
Barn swallow	*Hirundo rustica*	HIRRUS	117	3.66	7.07	2.75	18.08
Red-rumped Swallow	*Hirundo daurica*	HIRDAU	45	5.77	5.57	3.86	22.94
Northern house-martin	*Delichon urbicum*	DELURB	10	6.81	6.63	4.38	15.55
White wagtail	*Motacilla alba**	MOTALB	74	11.82	12.1	1.68	40.65
Winter wren	*Troglodytes troglodytes*	TROTRO	39	4.4	4.15	3.84	25.13
Rufous Bush Chat	*Cercotrichas galactotes*	CERGAL	22	6.18	5.01	9.64	25.66
Common nightingale	*Luscinia megarhynchos*	LUSMEG	114	10.64	5.06	4.74	44.93
Common stonechat	*Saxicola torquata*	SAXTOR	100	13.86	5.15	2.13	26.43
Black-eared Wheatear	*Oenanthe hispanica*	OENHIS	12	20.98	3.06	2.79	33.33
Blue Rock-Thrush	*Monticola solitarius*	MONSOL	10	6.09	8.08	2.51	24.64
Common blackbird	*Turdus merula*	TURMER	114	7.65	5.14	2.81	18.31
Cetti's Warbler	*Cettia cetti**	CETCET	74	9.28	9.33	4.63	53.59
Zitting Cisticola	*Cisticola juncidis*	CISJUN	39	7.92	8.84	5.77	21.00
Great Reed-Warbler	*Acrocephalus arundinaceus**	ACRARU	16	25.83	6.94	3.5	45.11
Melodius warbler	*Hippolais polyglotta*	HIPPOL	90	9.53	4.95	6.89	36.04
Sardinian Warbler	*Sylvia melanocephala*	SYLMEL	110	15.61	3.51	4.01	22.90
Blackcap	*Sylvia atricapilla*	SYLATR	31	6.65	5.33	3.6	29.72
Long-tailed tit	*Aegithalus caudatus*	AEGCAU	26	6.31	3.72	1.19	18.91
Blue tit	*Parus caeruleus*	PARCAE	68	6.73	2.39	1.73	13.86
Great tit	*Parus major*	PARMAJ	60	8.6	9.81	1.22	24.71
Short-toed tree-creeper	*Certhia brachydactyla*	CERBRA	12	9.36	6.2	0.33	19.32
Eurasian golden-oriole	*Oriolus oriolus*	ORIORI	11	12.11	6.3	1.82	25.39
Southern Grey Shrike	*Lanius meridionalis*	LANMER	11	4.45	3.16	8.7	14.88
Woodchat Shrike	*Lanius senator*	LANSEN	23	7.33	6.22	4.77	22.68
Eurasian jay	*Garrulus glandarius*	GARGLA	10	26.8	5.55	0.36	43.19
Azure-winged Magpie	*Cyanopica cyana*	CYACYA	16	6.54	7.3	5.7	24.15
Common Magpie	*Pica pica*	PICPIC	15	2.31	6.28	1.73	10.11
Common starling	*Sturnus vulgaris*	STUUNI	44	7.54	5.57	6.65	20.92
House sparrow	*Passer domesticus*	PASDOM	33	6.41	12.18	1.78	23.95
Spanish Sparrow	*Passer hispaniolensis*	PASHIS	19	8.8	6.83	2.98	24.23
Common Waxbill	*Estrilda astrild*	ESTAST	16	7.87	3.56	3.13	21.38
Chaffinch	*Fringilla coelebs*	FRICOE	42	3.59	5.99	8.21	19.53
European serin	*Serinus serinus*	SERSER	127	4.96	3.22	5.8	18.60
European greenfinch	*Carduelis chloris*	CARCHL	53	4.13	2.83	5.38	14.76
European goldfinch	*Carduelis carduelis*	CARCAR	109	3.51	6.27	3.27	16.55
Eurasian linnet	*Carduelis cannabina*	CARCAN	77	5	3.96	1.91	13.31
Corn bunting	*Emberiza calandra*	EMBCAL	97	13.42	6.28	1.49	21.50

* Aquatic species

Table 4 - List of Aquatic/Riparian bird species (AR) with English and scientific names (taxonomic order), code (based on scientific names), total number of points detected (N) and proportion of variance explained by environmental variables (stream edge and stream bed), space and total as result of the partial Canonical Correspondence Analysis (only for species present in >5% of the point counts)

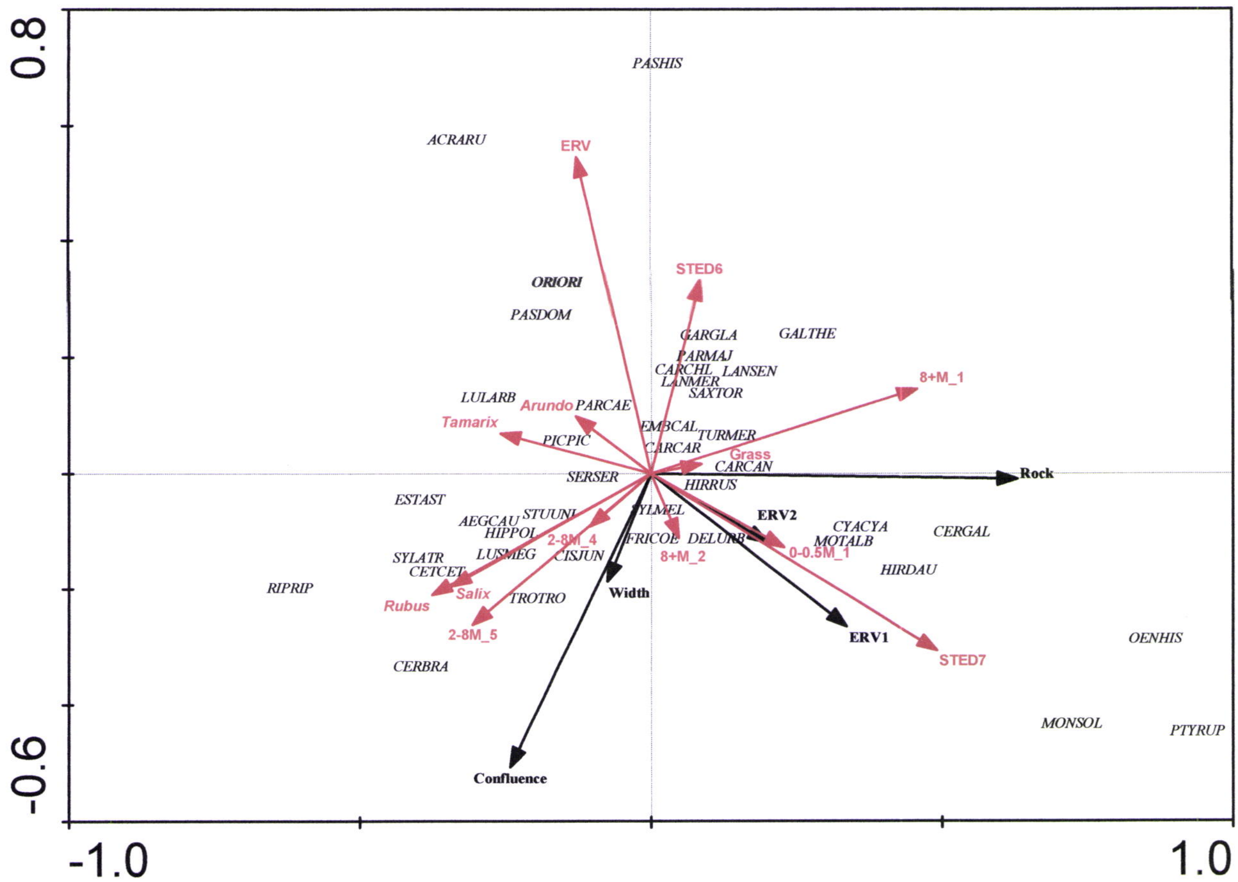
Species				% variance explain			
English name	**Scientific name**	**Code**	**N**	**Stream Edge**	**Stream bed**	**Spatial**	**Total**
Mallard	*Anas platyrhynchos*	ANAPLA	15	7.07	6.67	1.90	22.55
Common Moorhen	*Gallinula chloropus*	GALCHL	17	11.08	0.83	0.66	25.18
Little Ringed Plover	*Charadrius dubius*	CHADUB	65	12.27	2.30	1.40	32.34
Common Sandpiper	*Actitis hypoleucos*	ACTHYP	9	9.09	0.64	3.00	11.22
Common Kingfisher	*Alcedo atthis*	ALCATT	59	2.05	0.03	1.40	12.31
White wagtail	*Motacilla alba*	MOTALB	74	1.75	2.57	0.85	29.54
Cetti's Warbler	*Cettia cetti*	CETCET	74	11.10	4.34	4.82	61.75
Great Reed-Warbler	*Acrocephalus arundinaceus*	ACRARU	16	32.28	0.67	2.29	54.54

The CCA ordination results along the first two axes after variance partition, representing environmental variables, are plotted in Fig. 4 (FP group) and Fig.5 (AR group). Arrows represent the environmental variables included in the model that better represent the species distribution. The relative importance of each variable in the model is expressed by the length of the arrows. Their direction relative to the axes shows how well the environmental variable is correlated with each axis. The environmental condition associated to the presence of each species is indicated by the location of the bird species relative to the arrows.

Forest Passerine assemblage (FP)

For FP the first two axes, accounted respectively for 24.27% (eigenvalue = 0.192) and 13.15% (eigenvalue = 0.104) of the extracted variance in the species-environment relationship. Therefore, the first two canonical axes explain 37.42% of the variation of passerine community. The species-environmental correlations, indicating the ability of environmental variables to explain the variation in bird community composition, were 0.81 in the first axis and 0.75 in the second. Absence of vegetation cover higher than 8m (8+M_1), rocky stream bed (Rock), stream edge features (STED7), absence of emergent rooted vegetation (ERV1 – *Stream bed*), vegetation cover 2 to 8m between 60-100% (2-8M_5) and presence of Raspberry and Willow were the most stronger variables associated with the bird community structure (Fig.4). The first axis of the ordination plot was influenced primarily by absence of vegetation cover higher than 8m, rocky stream bed, stream edge features and absence of emergent rooted vegetation and existence of river confluence, vegetation cover 2 to 8m between 60-100% and presence of Raspberry and Willow in the opposite direction. This axis seems to separate plots with less cover of riparian vegetation and simple stream bed from more complex and structured riparian corridors. The species distribution is in accordance with this separation: those that require more complex vegetation structure are located at the negative end of this axis, while those associated with scarce environments and presence of rocky formations are located at the positive end. The second axis was affected by emergent rooted vegetation (ERV - *Stream edge*) and presence of river confluence. Most of the species negatively related with the presence of confluence, which usually contributes to a more complex vegetation structure, are species associated with more open areas. As expected from its habitat requirements, the Great Reed-Warbler is positively related with emergent rooted vegetation.

Fig. 4 – Ordination biplot for the first two axes of the CCA for Forest Passerines group (FP). stream bed variables are represented in black and stream edge variables in red.

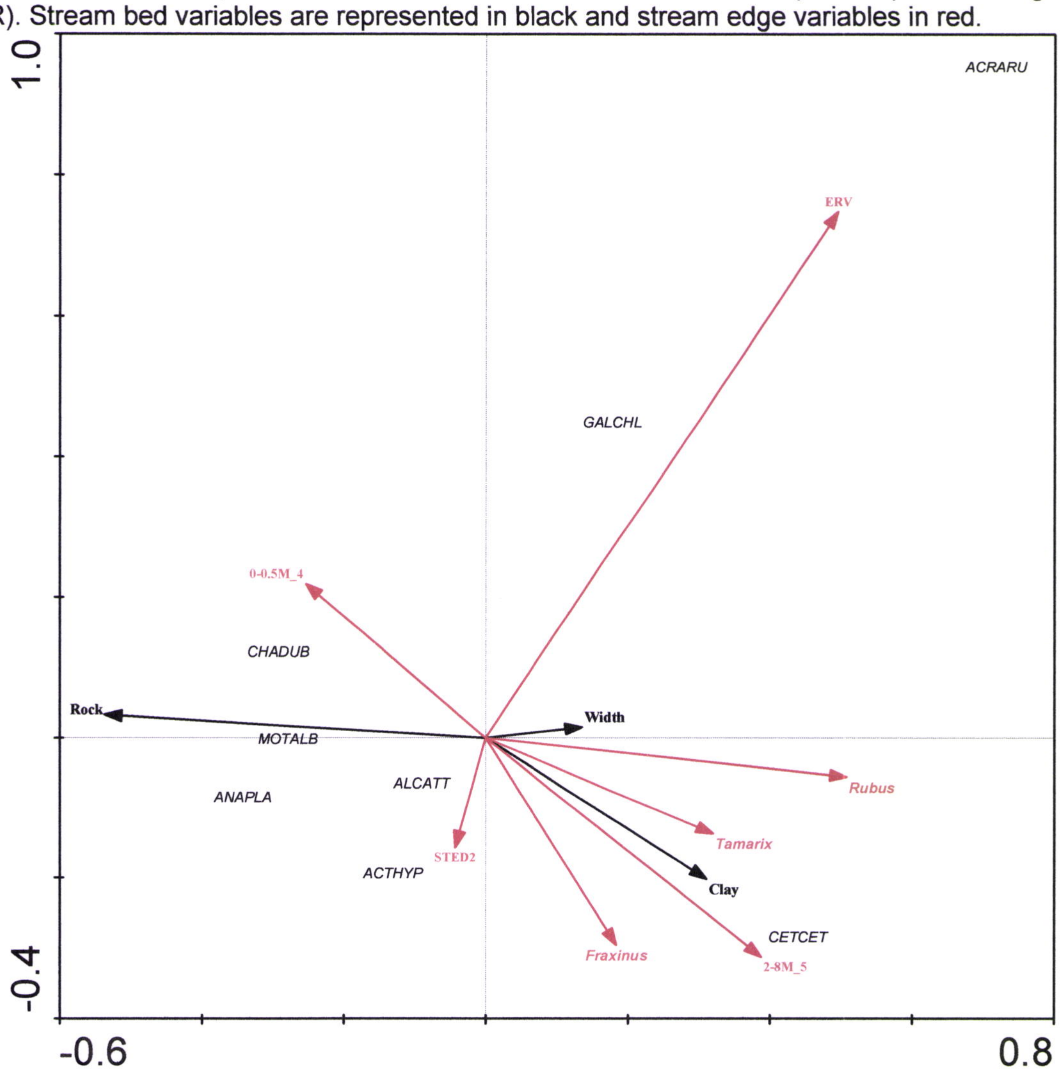


Aquatic/Riparian birds

For the AR the first two axes accounted for 37.41% (eigenvalue = 0.315) and 26.49% (eigenvalue = 0.223) respectively, meaning that almost 64% of the extracted variance is explained. The species-environmental correlations were 0.81 in the first axis and 0.79 in the second. The most strongly related variables with the riparian species in the first axis were rocky stream bed (Rock), vegetation cover <5m between 30-60% (0-0.5M_4) and presence of Raspberry and Tamarisk. This axis seems to separate plots with median-higher vegetation from lower vegetation with dense cover and rock. At the negative end of this axis are located the species associated to rock formations and lower riparian vegetation.

The second axis was affected by emergent rooted vegetation (ERV - *Stream edge*) vegetation cover 2 to 8m between 60-100% and presence of Ashes. Similarly to the CCA results obtained for FP, the species positively related to emergent rooted vegetation is typical of this habitat, while a species characteristic of well structured riparian corridors is plotted at the opposite end of the axis.

Fig. 5 – Ordination biplot for the first two axes of the CCA for the Aquatic/Riparian bird group (AR). Stream bed variables are represented in black and stream edge variables in red.



Discussion

Spatial and environmental variables

The three groups of explanatory variables considered in this study captured a variation in bird assemblage of 26% for Forest Passerine and 37% for Aquatic/Riparian species.

Most of the spatial structure of FP and AR species can be explained by stream variables, which indicates that variables and bird assemblages have a rather intercorrelated spatial structure (Heikkinen et al. 2004). About 3.65% (FP) and 2.09% (AR) of the species variation is attributed to the pure effect of the spatial variables. This fraction varies from species to species, ranging between 0.3% for Short-toed-tree-creeper *Certhia brachydactyla* and 9.6% for the Rufus-bush-chat *Cercotrichas galactotes*. This result can probably be explained to the establishment of breeding territories exhibited some aggregation, although apparently suitable habitat is available elsewhere (João Tiago Tavares com. pess.). In AR species the spatial fraction ranges from 0.7% for Common Moorhen *Gallinula chloropus* to 4.8% for Cetti's Warbler *Cettia cetti*. Nevertheless, the pure space seems to be a minor descriptor, in our study area, being the majority of the spatial distributions due to the spatial arrangement of their stream features.

Forest Passerines

Environment explains 22.57% of the variation in the species assemblage, of which 18.03% is purely environment and 4.54% is shared by the polynomial function of geographical coordinates of the sampling points. Similarly to the results of other studies (Hobson et al. 2000; Titeux et al. 2004) fraction explained suggests that species and environmental variables do not have a common spatial pattern and do not respond to similar underlying causes. Our results suggest that the main bird assemblage gradient is mainly driven by the gradient of vegetation structure and cover. The more structured riparian vegetation is characterized by a percentage of cover at the vertical strata 2 to 8m ranging between 60 and 100%, and the presence of Raspberry and Willows. In a less extent the cover at the vertical strata of 2 to 8m that varies between 30 and 60% is also an indicator of the complexity of the riparian gallery vegetation. Species associated with a more complex vegetation habitat, were *Certhia brachydactyla*, *Troglodytes troglodytes*, *Cettia cetti*, *Sylvia atricapilla*, *Luscinia megarhynchos*, *Hippolais polyglota* and *Aegithalus caudatus*, species that are commonly associated to riparian forest of Southern Portugal. In the opposite side we have more open areas, influenced by grassland and shrubs and without cover higher than 8m. Here we find species often associated to open fields with scattered trees and shrubs like *Galerida theklae*, *Lanius meridionalis* and *Saxicola torquata*. The other two major groups of stream variables associated with bird species involve: streams with riverbeds and riversides dominated by rock and scarce emergent rooted vegetation; and streams with emergent rooted vegetation as a dominant habitat. As expected based on species requirements *Acrocephalus arundinaceus* shows a direct link with the presence of emergent rooted vegetation; species associated to streams with riverbeds and riversides dominated by rock formations and scarce vegetation cover are *Motacilla alba*, *Hirundo daurica*, *Cercotrichas galactotes*, *Oenanthe hispanica*, *Monticola solitarius* and *Ptyonoprogne rupestris*. This group of species reflects particular environmental conditions in riverbeds and riversides, the presence of *Monticola* *solitarius* might indicate a correlation between the environmental variable Rock with the presence of scarps in the river side. The occurrence of *Cercotrichas galactotes* can possiblly be explained by the presence of Azalea *Rhododentrun ponticumm* that is not represented by any of the variables selected, but frequently occurs at these locations (field observations).

Aquatic/Riparian birds

Similarly to the results of passerines in variation partitioning, the pure effect of spatial variables is very low (2.09%), compared to the effect of environmental stream variables (34.6% of which 12.3% is shared with spatial – pure effect of 22.27%). The pure effect of stream edge (14.74%) is more evident than the remaining environmental effect. The species-environment relationships are quite evident in the resulting CCA biplot (Fig.5). This model also shows a separation of complex riparian galleries (high vegetation cover and presence of Ashes and Tamarisk) from more incipient environments dominated by rock formations. Species associated with rock are the *Motacilla alba* and *Charadrius dubius*. *Cettia cetti* is more related with structured habitat. *Acrocephalus arundinaceus* and *Gallinula chloropus* are highly correlated with a high cover of emergent rooted vegetation.

Same species – two different assemblages

There are three species simultaneously present in the two bird groups analysed: *Motacilla alba*, *Cettia cetti* and *Acrocephalus arundinaceus*. The results obtained in the two different approaches are similar for the two last species. The total variation explained is higher when these species are considered in the AR assemblage. This result may be explained by the lesser interference of non significant environmental variables. An increase of the pure stream edge effects and a decrease of the importance of stream bed and spatial variables are also observed for this species when they are grouped within the AR assemblage. *Motacilla alba*, however, reveals a reduction in the total variation explained (about 11%). Different sets of variables were selected in the two CCA analyses and therefore it is possible that important explanatory variables for this species did not contribute significantly to explain the structure of the Aquatic/Riparian assemblage.

Unexplained variation interpretation

In both analyses the unexplained variation of species assemblages is high (about 74% for PF and 63% for AR species). In ecological studies is not uncommon to observe a low percentage of explained variation because species occurrence or abundance data are often very noisy (ter Braak 1986; Guisan et al. 1999). This could be attributed to stochastic space-time fluctuations of the communities, to the presence of some species that do not occupy the most suitable habitat (Titeux et al. 2004) or to unmeasured environmental variables. Nevertheless, an ordination graphic explaining a low percentage of species-environmental relationships may still be very informative (Guisan et al. 1999; Titeux et al. 2004).

Conservation

Although the total of variation explained for the communities analysed is not high, when we focus on individual species this values raise. From the 41 species included in the FP group, 9 are commonly associated to river habitats and for those the total of variation explained is higher than 25% (for 5 species the explained variation is higher than 40%). Among the 8 riparian species, 5 have explained variation higher than 25%.

As Miller et al. (2004) referred, there are inherent dangers in the extrapolation of habitat affinities with given species, as such affinities may be specific to a particular region or landscape. Nevertheless, since riparian areas can be considered a specific habitat and the variables analysed are habitat descriptors at a fine scale, we believe that the species-environment relationships revealed in this study could be good indicators for Mediterranean rivers.

The need to preserve the natural features of the watercourses is highlighted in our results. Well-structured riparian galleries along with the presence of a natural rock formation and the maintenance of natural vegetation inside the stream are important elements for the long-term persistence of a healthy riparian bird community.

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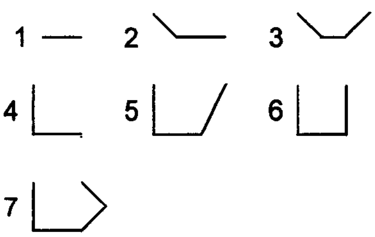
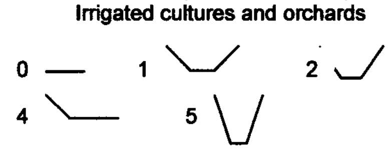
Appendix 1 – The four groups of environmental variables recorded at hitch one of the 190 sampling points. Description of the variables belonging to River bed, River edge, Surrounding habitat and Human impact

Environmental Group		Acronym		Description
River bed		LARG		Width of the water stream
		ILHO		Presence / absence of islet in stream
		CASCA		Presence / absence of waterfall
		CONF		Presence / absence of confluences
		ENSE		Presence / absence of cove
		ALGA		Presence / absence of algae
		ERV		Emergent rooted vegetation 1 - Absence 2 -]0-15%[3 - [15-30%[4 - [30-60%[5 - [60-100%]
		SUDO		Dominant substrate Sand, Silt, Clay Gravel, Rock, Other
Stream edge		STED		 Stream edge typology
	Vegetation	High	<0,5m 0.5-2m 2-8m > 8m	Vegetation cover 1 - Absence 2 -]0-15%[3 -[15-30%[4 - [30-60%[5 - [60-100%]
Surroundin habitat	Dominant habitat in two categories: >150m and >150m from the samplins point	Dominant species		Name of dominant species
		MONT		Cork and holm forest
		MATO		Shrubs areas
		OLIV		Olive forest
		EUCA		Eucalypt forest
		PINH		Pine forest
		ROCK		Rock formations
		PPSE		Set-a-side, pastures and crops
		CIPO		Irrigated cultures and orchards
		Vale typology		
Human impact	Impact	DIST		Distance to sampling station
			BARR	Presence of dam
			MOIN	Presence of mill
			BRIG	Presence of bridge
			PASS	Cross over the river
			CAIS	Presence Isolated house
			ALDE	Near by village
			VILA	Near by town
			FISH	Presence / absence of fisherman
		FOPO		Type of pollution if observed

Considerações finais

Os grupos de variáveis seleccionados neste trabalho explicam 26% e 37% da variação nos grupos de aves seleccionados, PF e AR respectivamente. As variáveis ambientais explicam em ambas as análises a maioria da variabilidade, sendo pouco influenciada pelos descritores espaciais. Semelhante aos resultados obtidos em outros estudos (Hobson et al. 2000; Titeux et al. 2004) a fracção explicada sugere que espécies e variáveis ambientais não partilham um padrão espacial.

Nos Passeriformes Florestais as variáveis ambientais explicam c. 23% da variabilidade, dos quais 18% é devido apenas ao seu efeito e 5% é partilhado com a função polinomial das coordenadas geográficas. Os nossos resultados sugerem que este grupo é principalmente determinado pelo gradiente da estrutura e cobertura da vegetação, sendo as galerias ripícolas mais estruturadas caracterizadas por uma percentagem de cobertura entre os 60-100% no estrato entre os 2 e os 8m de altura (ex. Salgueiros). No lado oposto encontramos as áreas mais abertas, influenciadas pela presença de herbáceas e arbustos, e ausência de cobertura arbórea. Os restantes grupos de variáveis com maior associação à comunidade de aves caracterizam rios com margens e leito dominados por formações rochosas e cursos de água com vegetação enraizada emergente. Resultados semelhantes foram obtidos para as espécies Aquáticas/Riparias, existindo também a separação entre galerias ripícolas complexas e locais dominados pelas formações rochosas.

Os valores de variância não explicada são elevados (c. 74% para PF e c.63% para AR), contudo em estudos de ecologia é frequente os valores explicados serem baixos devido ao ruído existente nas matrizes biológicas (ter Braak 1986; Guisan *et al.* 1999). Este facto pode ser atribuído a flutuações espacio-temporais estocásticas nas comunidades ou ao facto de algumas espécies não ocuparem todo o seu habitat potencial.

Apesar de a variância explicada para a comunidade não ser elevada, quando analisamos individualmente as espécies este valor aumenta. Das 41 espécies englobadas nos PF, nove são frequentemente associadas a habitats ripários e a variância explicada é superior a 25% (para 5 espécies é superior a 40%). No grupo AR, 5 espécies apresentam uma explicação da variância superior a 25%.

Como referido por Miller *et al.* (2004) existem riscos inerentes à extrapolação de afinidades entre espécies e habitats, uma vez que essas afinidades podem ser especificas de uma região em particular. Contudo, como as galerias ripícolas podem ser consideradas um habitat específico e as variáveis analisadas são descritores de pormenor, achamos que as relações espécies/variáveis ambientais reveladas neste estudo podem ser bons indicadores para os rios Mediterrâneos.

A necessidade de preservar as características naturais dos cursos de água é salientada nos nossos resultados. A existência de galerias ripícolas bem estruturadas, de formações rochosas naturais e a manutenção da vegetação natural do leito do rio são elementos chave para a conservação de comunidades avifaunísticas a longo termo.

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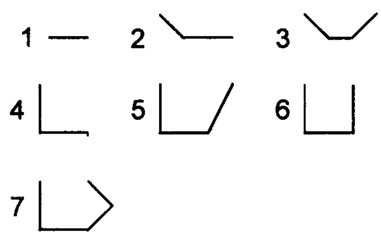
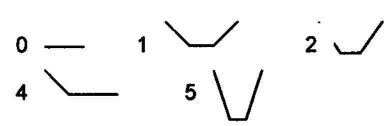
ANEXO I

Tabela 1 – Variáveis de habitat medidas nos 180 locais onde foram realizados pontos de escuta.

Grupo Ambiental	Variáveis		Descrição	
Leito	Largura		Descriminar	
	Ilhotas Cascatas Confluência Enseada Algas		Presença/Ausência	
	Vegetação enraizada emergente		Ausência]0-15%[[15-30%[	[30-60%[[60-100%]
	Substrato dominante		Areia Lodo Argila	Cascalho Rocha Outro
Margens	Perfil			
	Vegetação	> 8m 2-8m 0,5-2m <0,5m	Ausência]0-15%[[15-30%[	[30-60%[[60-100%]
		Espécies mais abundantes	Descrição	
Paisagem	Tipo dominante envolvente (<150m)	Habitat dominante Presença/Ausência	Pousio/Pastagens /Searas Culturas irrigadas/Pomares Matos Montados	Olival Eucaliptal Pinhal Afloramentos rochosos
		Outro	Descriminar	
	Tipo dominante distante (>150m)	Habitat dominante Presença/Ausência	Pousio/Pastagens /Searas Culturas irrigadas/Pomares Matos Montados	Olival Eucaliptal Pinhal Afloramentos rochosos
		Outro	Descriminar	
		Perfil do Vale		
Impacto humano	Distância à estação		Descriminar	
	Factores de impacto Presença/Ausência		Barragem Moinho Ponte Passagem	Casa isolada Aldeia Vila Pescadores
	Outros		Descriminar	
	Fonte de Poluição		Presença/Ausência Tipo	