Seasonal variation in avian community composition of the Sousa and Ferreira rivers, Northwest Portugal

Joel Baltasar Martins Neves

Mestrado em Ecologia e Ambiente

Departamento de Biologia

2022

Orientador

Joana Figueiredo Santana, investigadora pós-doutoramento, BIOPOLIS-CIBIO/InBIO

Coorientador

Luís Reino, investigador pós-doutoramento, BIOPOLIS-CIBIO/InBIO

Todas as correções determinadas

pelo júri, e só essas, foram efetuadas.

O Presidente do Júri,

Porto, ______/______/_________

MSc

Declaração de Honra

Eu, Joel Baltasar Martins Neves, inscrito no Mestrado em Ecologia e Ambiente da Faculdade de Ciências da Universidade do Porto declaro, nos termos do disposto na alínea a) do artigo 14.º do Código Ético de Conduta Académica da U.Porto, que o conteúdo da presente dissertação reflete as perspetivas, o trabalho de investigação e as minhas interpretações no momento da sua entrega.

Ao entregar esta dissertação, declaro, ainda, que a mesma é resultado do meu próprio trabalho de investigação e contém contributos que não foram utilizados previamente noutros trabalhos apresentados a esta ou outra instituição.

Mais declaro que todas as referências a outros autores respeitam escrupulosamente as regras da atribuição, encontrando-se devidamente citadas no corpo do texto e identificadas na secção de referências bibliográficas. Não são divulgados na presente dissertação quaisquer conteúdos cuja reprodução esteja vedada por direitos de autor.

Tenho consciência de que a prática de plágio e auto-plágio constitui um ilícito académico.

Joel Baltasar Martins Neves

Porto, 13 de outubro de 2022

Agradecimentos

A realização desta dissertação é um culminar de não só um ano de trabalho direto, como de todo um longo caminho até aqui e que não teria sido possível sem o apoio de um vasto número de pessoas, às quais aqui apresento os mais sinceros agradecimentos.

Começando pelos meus orientados, a Doutora Joana Santana e o Doutor Luís Reino, que em todos os momentos foram incansáveis por todo o auxílio prestado e toda a disponibilidade demonstrada, desde o primeiro dia. Um grande obrigado por todos os ensinamentos transmitidos e, principalmente, pelo apoio e paciência para comigo, em particular, nesta reta final.

Um especial agradecimento ao João Faria, pela sua disponibilidade, ajuda e ensinamentos referentes a tudo aquilo que envolveu o programa R, que foi essencial para o desenvolvimento deste trabalho.

Aos meus pais, irmã e tia Otília, que apesar de tudo e pelos sacrifícios passados, estiverem sempre ao meu lado, não só durante estes seis anos de percurso académico, como ao longo de toda a minha vida, permitindo e tornando-me na pessoa que sou hoje.

Aos meus tios Clarinda e Toni, por todo o apoio e confiança que me transmitiram, em particular, durante o meu percurso académico, um grande obrigado.

À direção do mestrado em Ecologia e Ambiente de 2020/21, na pessoa do Professor João Honrado, da Professora Sara Antunes e à Professora Maria Teresa Borges, pelo acompanhamento e ensinamentos no primeiro ano de mestrado e pelo auxílio prestado sempre que necessário.

Aos meus amigos de Aveiro: Miguel Conde, Miguel Vieira, João Damas, Pedro Dias, Carolina Hadden, Beatriz Vieite, Tiago Brandão e Hugo Silva, pela amizade, momentos criados nestes seis anos, pelo apoio prestado sempre que necessário e por estarem sempre ao meu lado, um grande obrigado.

À Maria, a “irmã”, e uma das melhores pessoas, que a Universidade de Aveiro me deu. Pela amizade e por todo o apoio que me tens dado ao longo destes anos, um grande obrigado cheio de gratidão e carinho. A próxima és tu!

Aos meus colegas do mestrado em Ecologia e Ambiente, em particular à Carlota, à Daniela e à Rita, por me acompanharem ao longo de todo o mestrado e com a partilha de momentos, dificuldades e de experiências das nossas aventuras académicas.

A todos os amigos de Gondomar, desde aqueles que comigo passaram a infância até às amizades mais recentes. Em particular, ao Pedro Marques e o Jorge André Sousa pela amizade e o vosso apoio.

Resumo

As alterações do uso do solo, são uma das maiores ameaças atuais sobre os ecossistemas. O Homem tem vindo a transformar paisagens naturais com várias das suas atividades, de forma a corresponder ao progressivo desenvolvimento humano. Tais alterações, afetam particularmente os habitats mais vulneráveis, como é o caso dos habitats ripícolas. Estes ecótonos são de extrema importância ecológica e para a biodiversidade, em particular para a avifauna. A ausência de estudos relativamente às comunidades ripícolas de aves no norte de Portugal, em particular na região de influência Atlântica, motivou-nos à realização deste trabalho.

O presente estudo procura caracterizar a comunidade de aves do corredor ripícola dos rios Ferreira e Sousa (Noroeste de Portugal) e determinar os efeitos dos diferentes usos do solo, nestas áreas, sobre a composição da comunidade e sobre a abundância de aves. Para tal, foram realizados censos, num total de 52 pontos, e durante três períodos do ciclo de vida das aves: migração pós-nupcial, invernada e reprodução. Posteriormente, as espécies observadas foram agrupadas em diferentes guildas consoante dieta, estrato de alimentação, fenologia e habitat preferencial. Para analisar o efeito dos usos de solo, modelamos a abundância das respetivas guildas com os gradientes de uso de solo obtidos através de PCA.

No total, detetamos 62 espécies, que na sua maioria consistiam em aves residentes (73%) e das quais 77% ocorreram no inverno, 73% no período de migração e 68% na época de nidificação. O pisco-de-peito-ruivo foi a ave mais abundante na época de migração e a mais frequente nas épocas de invernada e de migração. No inverno, o tentilhão-comum foi a ave mais abundante na área de estudo, enquanto na época de reprodução, a carriça foi a espécie mais frequente, e abundante tal como a toutinegra-de-barrete. Todas as guildas apresentaram diferenças sazonais para número de espécies com exceção granívoras, florestais, residentes, que se alimentam no solo e no sub-bosque, e para a abundância com exceção dos invertívoros, aves agrícolas e que se alimentam no estrato arbóreo. Resultados dos modelos médios demonstraram-nos relações interessantes entre guildas e usos do solo. Abundâncias de aves agrícolas, aves que se alimentam no solo e granívoros apresentaram frequentemente associações positivas com gradientes que refletiam usos de solo de caráter antropogénico, e relações negativas com usos do solo naturais. Enquanto as abundâncias de invertívoros e de espécies que se alimentam no estrato arbóreo estavam positivamente relacionadas com os usos de solo naturais e negativamente para usos de solo com influência antropogénica.

Apuramos que os corredores ripícolas dos rios Ferreira e Sousa são de particular importância para a comunidade de aves durante o inverno, havendo neste período, diferenças significativas na abundância de aves entre os rios que poderá ser explicado pelas diferenças na composição de usos de solo de cada um deles. Os nossos resultados vão ao encontro de estudos que apontam que o agrupamento de aves por características funcionais e de habitat podem servir indicadores de perturbação nas galerias ripícolas, nomeadamente aves agrícolas, florestais, granívoros, invertívoros e aves que se alimentam no solo. Determinamos ainda, os efeitos particularmente negativos de povoações de árvores exóticas na comunidade de aves e a ocorrência de efeitos de borda, provocados pelos adjacentes usos de solo, sobre os habitats ripícolas.

Palavras-chave: Corredores ripícolas; usos do solo; aves; guilda de aves; florestas; perturbação; bioindicador.

Abstract

Changes in land use are one of the greatest current threats to ecosystems. Humans have been transforming natural landscapes with several of their activities, in order to follow the progressive human development. Such changes particularly affect the most vulnerable habitats, such as the riparian areas. These ecotones are extremely important ecologically and for biodiversity, particularly for birdlife. The lack of studies on riparian bird communities in northern Portugal, particularly in the Atlantic influence region, motivated us to carry out this study.

This study aims to characterise the bird community of the riparian corridor of the Ferreira and Sousa rivers (Northwest Portugal) and to determine the effects of different land uses in these areas on community composition and bird abundance. To this end, censuses were carried out at a total of 52 points, and during three periods of the birds' life cycle: post-nuptial migration, wintering and breeding. Subsequently, the species observed were grouped into different guilds according to diet, foraging stratum, phenology and preferred habitat. To analyse the effect of land uses, we modelled the abundance of the respective guilds with the land use gradients obtained through PCA.

In total we identified 62 species,the majority consisted of resident birds (73%) and of which 77% occurred in winter, 73% in the migration period and 68% in the breeding season. The robin was the most abundant bird in the migration season and the most frequent in the wintering and migration seasons. In winter, the common chaffinch was the most abundant bird in the study area, while in the breeding season, the wren was the most frequent species, and as abundant as the blackcap. All guilds showed seasonal differences for number of species with the exception of granivores, forest species, resident, ground- and understory foragers, and for abundance with the exception of invertivores, farmland birds and tree feeders. Results from the mean models showed us interesting relationships between guilds and land uses. Abundances of farmland birds, ground-feeding birds and granivores often showed positive associations with gradients reflecting anthropogenic land uses, and negative relationships with natural land uses. While abundances of invertivores and tree foragers were positively related to natural land uses and negatively for land uses with anthropogenic influence.

We found that the riparian corridors of the Ferreira and Sousa rivers are of particular importance for the bird community during winter, with significant differences in bird abundance between rivers during this period, which can be explained by differences in land use composition of each river. Our results are consistent with studies showing that the grouping of birds by functional and habitat characteristics can serve as indicators of disturbance in riparian galleries, namely farmland birds, forest birds, granivores, invertivores and ground foragers birds. We also determined the particularly negative effects of exotic tree stands on the bird community and the occurrence of edge effects, caused by adjacent land uses, on riparian habitats.

Keywords: Riparian corridors; land use; birds; bird assemblage; forests; perturbation; bioindicator.

Index

List of tables

List of figures

Abbreviations

COS	CARTA DE OCUPAÇÃO DO SOLO
EBCC	EUROPEAN BIRD CENSUS COUNCIL
GIS	GEOGRAPHIC INFORMATION SYSTEM
GLM	GENERAL LINEAR MODEL
LULCC	LAND USE AND LAND COVER CHANGES
MI	MULTIMODEL INFERENCE
PCA	PRINCIPAL COMPONENTS ANALYSIS
QGIS	QUANTUM GEOGRAPHIC INFORMATION SYSTEM
SOW	SUM OF WEIGHTS
SD	STANDARD DEVIATION
WFD	WATER FRAMEWORK DIRETIVE

1. Introduction

Anthropogenic pressure is a major driver of degradation of ecosystems, affecting its structure and functioning by modifying biological and physicochemical processes (Vitousek *et al.*, 1997; Lu *et al*., 2015; Fierro *et al*., 2017). Highly dependent on natural resources, in response to continued development and population growth, humanity is increasingly putting pressure on the biosphere and exploiting various ecosystem services (DeFries *et al*., 2004). For centuries, humans have transformed natural landscapes into various land use activities, ranging from farmland production and forestry to urbanisation, to surpass their essential needs (DeFries *et al*., 2004). Such situation led to the intensification of land use and land cover changes (LULCC), the over explorative and intensive conversion of one cover type for another, and its consequent exploitation by human activities to acquire natural resources and fulfil human needs (Lambin & Geist, 2008; Verburg *et al*., 2012; van Asselen & Verburg *et al*., 2013).

Despite land use activities being essential for humanity, it is well-known their harmful effects on ecosystems, essentially by causing ecosystem degradation and biodiversity decline. Since the 19th century, LULCC were responsible for approximately 35% of CO2 emissions for atmosphere (Houghton *et al*., 2001), which consequently had effects on climate, from local to global scale (De Fries *et al*., 2004; Pielk *et al*., 2011; Pongratz *et al*., 2021). The transformation of natural ecosystems into agriculture or urban areas through deforestation are among the reasons for the carbon cycle modification and emissions (Houghton *et al*., 2001, Lambin and Geist, 2008). Another negative effects of LULCC includes, for example, the deterioration of water courses, caused by urbanisation or nutrients and agrochemicals pollution by agriculture intensification, infectious diseases propagation and soil degradation (Trimble & Crosson, 2000; DeFries *et al*., 2004).

Riparian zones are transitional areas between the terrestrial and freshwater ecosystems of such ecological importance, balancing temperature and providing organic matter and nutrients for the great diversity it harbours (Nilsson & Grelson, 1995; Dallimer *et al*., 2012). However, riparian habitats are vulnerable to perturbation and are progressively threatened, not only by water pollution, but also by land use changes and occupation by invasive alien species (Planty-Tabacchi *et al*. 1996; Allan, 2004; Poff *et al.,* 2011).

Riparian zones are particularly important for bird species, since this habitat provides trophic resources and serves as ecological corridors that favour settlement and dispersal for proximal natural areas (Litteral & Shochat, 2017). It can act as buffer zones from the effect of habitat fragmentation and mitigates the harmful impacts of exotic woody species from the surroundings (Brown *et al. 2001*; Teixido *et al.*, 2010; Rogers and Chown 2013). Riparian birds' habitats are more responsive to perturbation than other cohabitating organisms (O'Connor *et al.*, 2000; Francl & Schnell, 2002).

The current study examined the effects of modifications in riparian corridors on bird communities, which are commonly used as bioindicators since: 1) their ecology and connection with the vegetation and landscapes is, in general, well-known (Petty & Avery, 1990; Padoa-Schioppa *et al*., 2006); 2) birds are more conspicuous and easier to survey and obtain data from, than other taxa (Bibby *et al*., 2000); (3) they respond quickly to ecological changes, shifting their patterns in a spatial and temporal scale (Rabaça, 1995). We also determined the effects of different land use gradients on breeding, migrant and wintering birds' assemblages, by functional and habitat traits, of the riparian corridor and proximal upland of the Ferreira and Sousa rivers. Depending on the effect of their abundance, we obtain associations between guilds and gradients that allow us to infer that these land uses are equated with disturbance and corroborate the fact that particular bird assemblages can be considered as bioindicators of riparian integrity and to what extent different land uses affects riparian birds communities.

The objectives of the study were: i) to characterise the bird community in the riparian corridors of the Sousa and Ferreira rivers through the year (wintering season, breeding season and post-breeding migration period); ii) to understand the importance of riparian corridors as breeding, wintering and migratory stop-over habitats; iii) determining the effects of current land uses on bird community composition and birds' abundance; IV) how birds assemblage can be used to evaluate the state of riparian ecosystems. Furthermore, we tested spatial and temporal differences of the bird's community and analysed abundance of specific assemblages reflecting trophic, habitat preference, phenology and foraging substratum affinities to understand the effects of land use on them. We theorise that riparian corridors have a particular importance for migratory birds, that birds' guilds that feed on vegetal material are related to anthropogenic and perturbed landscapes, and invertivores abundance as an indicator of good ecological state of riparian areas (Larsen *et al.,* 2010; Menon *et al.*, 2019).

2. Methodology

2.1. Study area

The study was conducted in the riparian corridors of two rivers in the municipality of Gondomar, north-western Portugal (41.1396° N, 8.5291° W, Porto district) (Figure 1): the Sousa River, a tributary of one of Portugal's largest rivers, the Douro river, with a total extension of 65 km, and the Ferreira river, a tributary of the former with 43 km of extension (AMP, 2009). In the study area, both rivers are characterised by their sinuous course that lies, for the most part, in low altitude but pronounced valleys and crossing mostly schist outcrops due to the geological structures of the Xisto-Grauváquico Complex and the Valongo Anticline (Viterbo et al., 2015; Andresen et al., 2018). The climate is temperate due to Atlantic influence (Ribeiro et al., 1987), with rainy winters, persistent fogs and dry but not particularly warm summers (AMP, 2009).

In the sloping areas, the vegetation cover is dominated by scrubland of heath (*Erica* spp.), gorse (*Ulex* spp.), prickled broom (*Pterospartum tridentatum*), Portuguese broom *(Cytisus striatus)* and the tree cover is mainly composed by maritime pine (*Pinus pinaster*) and high densities of the exotic common eucalyptus (*Eucalyptus globulus*) and invasive acacia trees (*Acacia* spp.). The riparian forest, on the other hand, although fragmented and taken over by invasive alien species, such as wattle trees (*Acacia dealbata* and Acacia *melanoxylon*) or replaced by poplar (*Populus* spp.) plantations still contain typical native species in the most undisturbed areas. It consists mainly of common oak (*Quercus robur)*, black alder (*Alnus glutinosa)*, bay laurel (*Laurus nobilis)*, narrow-leaved ash (*Fraxinus angustifolia)*, elder (*Sambucus nigra*) and willows (*Salix atrocinerea* and *Salix alba)* as the most representative woody vegetation, while brambles (*Rubus* spp.) dominate the shrubby layer.

The deterioration of the riparian ecosystem at the study site is strongly linked to actual and former land uses. Agriculture and forestry activities are the current main land occupation, with corn crops, subsistence agriculture, and the production of eucalyptus, pine tree and poplar forests being common along the riverside and its proximities (AMP, 2009). Water quality is poor due to the anthropogenic pressure and in some stretches of both rivers it is visible the artificialization of the banks with the presence of schist walls made in the past by the local population in order to prevent flood damage to their farming land, as well as old trails meant to transport materials from mining activities (AMP, 2009). Moreover, the construction of infrastructures (e.g., roads and urban settlements) excessively close to the riverbanks, led to the fragmentation and deterioration of the riparian forest.

2.2. Bird sampling

Bird census was based on 52 independent sites, 29 located on the banks of the Sousa river and 23 in the Ferreira river, along 8.4 km and 6.8 km stretches, respectively (Fig. 1). Points were previously selected using Google Earth Pro by determining the closest locations to the riverbanks and delimiting a minimum distance of 200-m between them, in order to reduce the possibility of repetitive encounters (Bibby *et al.*, 1992). Then, before the beginning of the surveys, sites accessibility was checked *in situ*. Once these requirements were met, all 50 initial points were approved, with only minor rectifications being necessary. Distance between points ranged from 200 m to 665 m. Although, two locations in the Ferreira river were forcibly replaced after the first survey campaign, due to unanticipated access restrictions to the riverbanks, by two additional sites in order to maintain the same sample size throughout the study period.

For the surveys, 50-m radius bird point counts were performed within the first four hours after sunrise and under good weather conditions (absence of rain, dense fog or strong winds) to maximise the bird contacts (Bibby *et al*., 1992). During a 10-minute period, every individual from all species, visually and audibly identified within the defined radius was counted (Verner, 1988; Bibby *et al*., 1992). Birds were sampled once during the post-breeding migration period (19-23 September 2021), and twice during wintering season (2-15 December 2021 and 17-24 January 2022) and breeding season (16-21 April 2022 and mid 17-25 May 2022).

To aid interpretation of ecological effects, bird species were categorised functional traits according to their diet, phenology, habitat preference and foraging stratum affinities (See Annex 1). For the diet guilds and foraging stratum, we follow the dataset from Wilman *et al*. (2014), where we considered the highest percentage of the diet and foraging category used by a bird species. Habitat preferences were classified as farmland and forest by the EBCC species classification (PECBMS, 2022). Birds that do not belong to one of those habitats, or simply are habitat generalists are classified in the “other” category. Finally, the phenology status is based on Svensson's established classification for Portugal mainland (Svensson *et al.,* 2012), although the status of some species has been adjusted at local level. For the birds' checklist this study followed the taxonomy used by the BirdLife International (BirdLife International, 2022).

2.3. Habitat characterisation

Habitat characterization was made from a 100-m buffer around each of the survey points, using a land-use map (COS 2018) (DGT, 2018), where we mapped all the prominent land covers (Table 1). We used a buffer higher than the one used for the bird surveys (50-m) to evaluate how the adjacent upland landscape elements influence riparian bird communities. Mapping was refined with information from SIG and field work information.

We end up with 13 but only 10 land use categories were considered to further analysis: Urban areas, where we include both urban settlements and infrastructures (e.g., roads); Farmlands, that in the study area, consists mainly of corn plantations and rotative crops. Shrublands, typically of *Ulex* spp. and *Erica* spp. associations on the valley slopes; Pine forests, with little or none shrubby layer; Oak forests (*Quercus robur* and *Quercus pyrenaica*), frequently associated with a well-structured and natural understory; Natural deciduous riparian forest, majorly represented by *Salix atrocinerea*, *Salix alba*, *Alnus lusitanica* and *Fraxinus angustifolia*, with developed understory layer in undisturbed areas; Poplar plantations (hybrids of exotic *Populus* spp.), typically on riverbanks; Eucalyptus forests, either plantations or invasively established; Patches of invasive Acacia trees (principally, *Acacia dealbata* and *Acacia melanoxylon*); abandoned farmlands, former arable and cultivated areas now occupied essentially by bushes (particularly *Rubus spp*.), herbaceous species and dispersed younger stages of the most abundant tree species.

Each land use proportion per sampling point was calculated on QGIS (v3.22.7) (QGIS Development Team, 2022), a Geographic Information System (SIG) software, and used as variables for the statistical analysis.

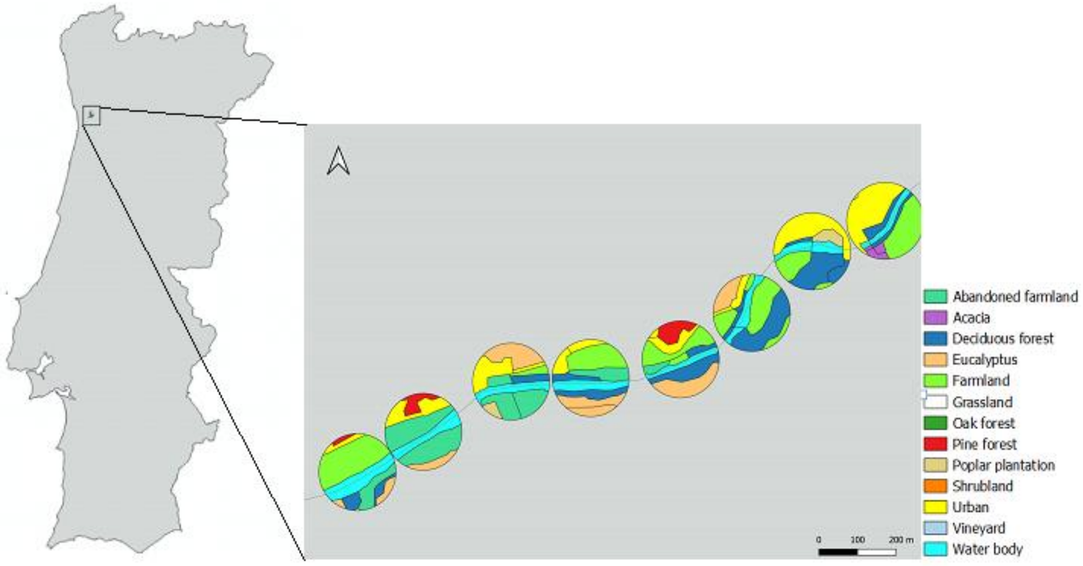

Fig. 1- Location of the study area in Northwest Portugal and examples of the land uses present in 8 of the 52 sampling points in a stretch of the Sousa River (S1 to S8).

Table 1- Percentage of occurrence of predominant land-uses from the 100-m buffer in the Ferreira and Sousa Rivers.

Land-uses	Ferreira River (%)	Sousa River (%)	Both rivers (%)
Abandoned farmland	52.2	48.3	50
Acacia	8.7	27.6	19.2
Deciduous forest	82.6	96.6	90.4
Eucalyptus	69.6	86.2	78.8
Farmland	69.6	65.5	67.3
Oak forest	39.1	31.0	34.6
Pine forest	39.1	41.4	40.4
Poplar plantation	43.5	37.9	40.4
Shrubland	52.2	31.0	42.3
Urban	91.3	55.2	71.2

2.4. Data analysis

For each season, we used the maximum numbers of each species observed during the two census campaigns. Then, we started to describe the overall patterns of bird's guilds of the Ferreira and Sousa Rivers during the principal seasons of their life cycle (breeding season, post-breeding migration period and wintering season), using species richness, occurrence, and mean abundance. These metrics were calculated for the entire community and for each bird assemblage.

We also analyse spatial differences of land-uses and species abundance using a two-sample t-test and an one-way ANOVA to examine the seasonal variations on bird´s guilds abundance and species richness. Before the spatial analysis, we excluded from the environment variables the land use referent to the water bodies, since it occurred in all the survey points which could lead to bias in the further analysis.

To reduce dimensionality and simplify the determination of the dominant gradients in the landscape (Legendre & Legendre, 1998) we performed a Principal Component Analysis (PCA) on the ten land-uses categories. A varimax rotation on components with eigenvalues > 1 was applied. The resulting rotated axes were further considered as variables in the modulation process. Selecting the factors with weight values higher than l0.6l, we obtained the gradients that better reflected the land-uses related patterns.

To understand the effects of the land-uses within the riparian corridor of both rivers and his proximities, on bird communities, the General Linear Model (GLM) approach was used (Bolker *et al.,* 2008). The model terms were based on the previously obtained PCA rotated axes and the river variable with the guilds parameter (abundance) and for each season.

We used a Multimodel Inference (MI) approach to assess individual variable importance, which is a method based on an estimated weighted average across all subset models containing a specific variable that takes observed model weights into account (Burnham and Anderson, 2002). We further obtain an average model, based on all model combinations generated, that contains the variables with an average estimate of all coefficients.

All the analysis were performed in R 4.2.1 software (R Development Core Team, 2022), “dplyr” package (Whickham *et al.,* 2022) for the ANOVA, “psych” package (Revelle, 2022) for the PCA, and “MuMIn” package (Barton, 2016) for the modelling process.

3. Results

3.1. Overall bird patterns

Altogether, 62 bird species were identified, of which 73% occurred in the post-breeding migration period, 77% in winter and 68% in the breeding season. From the 62 observed species, 45 (73%) were resident and 17 (27%) were either short or long migrant species (represented Annexe 1 as migrant, breeding, or non-breeding birds) (See Annexe 1). As for their habitat preferences, other than farmland or forest species, as much as habitat generalists, represented 45% of total birds. Farmland birds represented 20% and forest birds 35% of the bird's community. The invertivores (45% overall) strongly predominated, being the most represented diet group in all seasons (34% in winter, 42% and 44% in breeding and post-breeding migration seasons, respectively), while ground foragers (40%) also predominated all year-around (migration season: 38%; wintering season: 42%; breeding season: 48%) relatively to the foraging stratum classes.

In the post-breeding migration season, the most frequent and abundant species in the study area were the European robin (72%; 1.5 ± 1.4), European pied flycatcher (*Ficedula hypoleuca*) (54%; 0.8 ± 1.0) and Cettia's warbler (54%; 0.7 ± 0.7).

The European robin (*Erithacus rubecula*) was the most frequent species on the rivers riparian corridors during winter (96%) and post-breeding migration season (72%). In the winter, apart from the European robin was the most frequent species, occuring in 96% of the sampling sites, followed by the common chaffinch (*Fringilla coelebs*) (84%), the blackbird (84%), the northern wren (84%), the common chiffchaff (*Phylloscopus collybita*) (68%), the great cormorant (*Phalacrocorax carbo*) (66%), Cetti's warbler (*Cettia cetti*) (66%) and the Eurasian blackcap (64%). The most abundant species during the winter were the common chaffinch (4.8 ± 9.4), the Eurasian siskin (*Spinus spinus*) (4.7 ± 17.7), the European robin and the European serin (2.2 ± 8.9) (See Annexe 2).

During the breeding season the most frequent specie on the rivers riparian corridors was the northern wren (*Troglodytes troglodytes*) (98%), the Eurasian blackcap (*Sylvia atricapilla*) (90%), the common firecrest (*Regulus ignicapilla*) (74%), the blackbird (*Turdus merula*) (74%), the great tit (*Parus major*) (66%) and European robin (*Erithacus rubecula*) (64%). The most abundant species in the breeding season was the European robin (1.0 ± 0.9), the common firecrest (1.0 ± 0.9), the European serin (*Serinus serinus*) (1.2 ± 1.6), the blackbird (1.3 ± 1.1), the northern wren (1.9 ± 0.9) and the Eurasian blackcap (1.9 ± 1.0) (See Annex 2)

The one-way ANOVA results showed that there are significant differences in the overall bird community in Sousa and Ferreira rivers between seasons, as expected. It is noticeable that there are significant seasonal variations on species richness of all species (F = 3.42; p-value = 0.04), invertivores (F = 3.36; p-value = 0.04), omnivores (F = 3.31; p-value = 0.04), carnivores (F = 17.52; p-value < 0.001), farmland species (F = 4.35; p-value = 0.01), other species (F = 3.37; p-value = 0.04), resident species (F = 15.23; p-value < 0.001) as well as with species that feed on trees (F = 5.99; p-value < 0.001), on water (F = 14.98; p-value < 0.001) and unspecialized species (F = 9.46; p-value < 0.001) (Table 2).

In terms of abundance, all species guild showed significant differences in number of individuals (F = 18.75; p-value < 0.001), as well as omnivores (F = 22.21; p-value < 0.001), granivores (F = 4.96; p-value = 0.01), carnivores (F = 21.04; p-value < 0.001), forest species (F = 15.01; p-value < 0.001), other species (F = 6.74; p-value < 0.001), resident species (F=15.23; p-value < 0.001) as well as with species that feed on the ground (F=9.63; p-value < 0.001), on water (F = 5.50; p-value < 0.001), on understory layer (F = 20.43, p-value < 0.001) and unspecialized species (F =9.32; p-value < 0.001) (Table 2).

Spatially, differences in mean number of birds between rivers only were verified in the wintering season (See Annex 3). The Ferreira River showed higher mean numbers of farmland (Ferreira: 8.61; Sousa: 0.90; t-test = 2.10; p-value = 0.04), ground (Ferreira: 17.91; Sousa: 7.00: t-test = 2.67; p-value = 0.01) and resident species (Ferreira: 28.3; Sousa: 17.1; t-test = 2.21; p-value = 0.04) compared to the Sousa River, which according to the applied t-test, proved to be significant**.** Nevertheless, neither the migration season or the breeding season showed differences in birds' numbers between the Ferreira and the Sousa river (See Annexes 5 and 4, respectively).

Table 2- One-way ANOVA results for each guild abundance and species richness during the three different seasons.

Bird Guilds	Abundance		Species richness	
	F	p-value	F	p-value
All species	18.75	<0.001	3.42	0.04
Invertivore	2.57	0.08	3.36	0.04
Omnivore	22.21	<0.001	3.31	0.04
Granivore	4.96	0.01	1.93	0.15
Carnivore	21.04	<0.001	17.52	<0.001
Forest	15.01	<0.001	1.69	0.19
Farmland	1.60	0.21	4.35	0.01
Other	6.74	<0.001	3.37	0.04
Resident	15.23	<0.001	0.12	0.88
Tree	2.47	0.09	5.99	<0.001
Ground	9.63	<0.001	0.28	0.76
Water	5.50	<0.001	14.98	<0.001
Understory	20.43	<0.001	1.60	0.21
Unspecialized	9.32	<0.001	9.46	<0.001

3.2. Habitat patterns

The study comprises 10 main different types of land-cover (Table 1, section 2.3), showing a heterogenous riparian corridor and surrounding landscape. Urban areas were the most prevalent land-use category in the Ferreira River (91%), while farmland had the highest mean proportions (mean = 0.22). In the Sousa River, on the other hand, the deciduous riparian forest was the most recurrent type of land-use (96.6%) and had the highest proportion (mean = 0.26). We verified two land-uses with significant differences in their mean proportions between rivers, being the acacia patches (t-test = -2.08; p-value = 0.04) and the deciduous forest (t-test = -2.14; p-value = 0.04) (Table 3).

PCA on the ten variables describing land uses extracted five rotated axes (Table 4). The main gradients contrasted sites with dominant cover by deciduous riparian forests connected by upland's shrublands over farmland (RPC1; 20%), and increasing cover by oakwoods, pinewoods and poplar stands (RPC2, 20%). Other PCs included: RPC3 (15%), representing contrasting increases of cover by Eucalyptus versus urban area; RPC4 (13%), with increasing cover by abandoned farmland; and RPC5 (12%), representing increasing cover by *Acacia* spp. stands.

Table 3- Two sample t-test for means of land uses proportions in the Ferreira and Sousa Rivers.

Land-uses	Mean Ferreira	Mean Sousa	t-statistics	df	p-value	95% Conf. Int.	
Abandoned farmland	0.06	0.08	-0.50	50	0.62	-0.08	0.04
Acacia	0.00	0.03	-2.08	50	0.04	-0.04	0.00
Deciduous forest	0.17	0.26	-2.14	50	0.04	-0.17	-0.01
Eucalyptus	0.12	0.16	-1.33	50	0.19	-0.11	0.02
Farmland	0.22	0.14	1.60	50	0.12	-0.02	0.17
Oak forest	0.04	0.03	0.36	50	0.72	-0.03	0.04
Pine forest	0.06	0.05	0.63	50	0.53	-0.04	0.07
Poplar plantation	0.04	0.02	1.01	50	0.32	-0.01	0.04
Shrubland	0.07	0.05	0.89	50	0.38	-0.03	0.07
Urban	0.14	0.08	1.79	50	0.08	-0.01	0.14

Table 4- Loadings of the land-uses, as variables, on varimax rotated axes (RPC#) extracted from a principal component analysis (PCA). Values in bold indicates I factor loading I > 0.6.

(Legend: [1] Deciduous forest and shrublands to farmland; [2] Oak, pine, and poplar forests; [3] Eucalyptus to urban area; [4] Abandoned farmlands; [5] Acacia)

Variables	RPC1[1]	RPC2[2]	RPC3[3]	RPC4[4]	RPC5[5]
Abandoned farmland	0.01	-0.08	-0.05	**0.95**	0.05
Acacia	0.04	-0.02	0.00	0.04	**0.92**
Deciduous forest	**0.80**	-0.05	-0.13	-0.38	0.18
Eucalyptus	0.02	-0.11	**0.95**	0.01	-0.12
Farmland	**-0.75**	-0.33	-0.09	-0.41	-0.09
Oak forest	0.22	**0.76**	0.08	0.04	-0.01
Pine forest	-0.12	**0.85**	-0.17	-0.03	0.21
Poplar plantation	-0.03	**0.68**	0.10	-0.10	-0.37
Shrubland	**0.75**	-0.05	0.24	0.08	-0.11
Urban	-0.39	-0.33	**-0.65**	0.10	-0.29
Proportion variance	0.20	0.20	0.15	0.13	0.12

[1] RPC1: Riparian deciduous forest connected by shrublands over farmland;

[2] RPC2: Oakwood, pinewood, and poplar stands;

[3] RPC3: Eucalyptus versus urban area;

[4] RPC4: Abandoned farmland;

[5] RPC5: *Acacia* spp. stands

3.3. Bird assemblage in relation to habitats heterogeneity through different seasons

3.3.1. Post-breeding migration season

GLM results showed that the gradient of deciduous forest connected to shrublands over farmland areas (RPC1), had negative effect on the abundance of farmland species (0.75; $p = 0.039$) (Table 5), granivores (0.73; $P = 0.023$) (Table 7) and ground feeding birds (0.98; $P < 0.001$) (Table 8). This gradient was the most representative one for ground feeder.

Pinewood, oakwood and poplar stands gradient (RPC2) reflects a broader cast of associated guilds. As supposed, abundance of forest birds was highly and positively influenced by these land use types (0.98; $P < 0.001$) (Table 5), being the most relevant model for this guild. For omnivores (0.70; $P = 0.037$) (Table 7), the variable showed positive effects on abundance but was not the most important variable to represent the relation between land use and guild's abundance. A contrary effect can be seen for farmland birds (0.70; $P = 0.049$) (Table 5), granivores (0.85; $P = 0.006$) (Table 7), and ground feeding species (0.95; $P < 0.001$) (Table 8).

Increasing cover by eucalyptus (in detriment of urban cover) (RPC3) had a positive relation with omnivores (0.92; $P = 0.007$) (Table 7) and negative impact on granivores (0.98; $P < 0.001$) (Table 7), ground feeding birds (0.60; $P = 0.047$) (Table 8) and water foraging birds' abundance (0.78; $P = 0.041$) (Table 8) showing an overall pattern of negative effects of eucalyptus stands in the breeding community. This gradient was the most relevant variable that reflects the relation between guild´s abundance and type of land use for all the above described guilds.

Abandoned farmlands (RPC4) demonstrated significant and negative relations with unspecialized species (0.80; $P = 0.002$) (Table 8). Acacia tree stands (RPC5) also showed a significant and positive association with farmland birds (0.081; $P = 0.033$) (Table 5) and ground feeders (0.75; $P = 0.045$) (Table 8), but significantly negative effects on forest species abundance (0.69; $P = 0.046$) (Table 5). For farmland birds

(0.81; P = 0.033) (Table 5), the gradient that represents the presence of acacia trees (RPC5) was the most important variable, whereas for forest species (0.69; P = 0.046) (Table 5) and ground feeders (0.75; P = 0.045) (Table 8) was also relevant.

Finally, the Sousa and Ferreira rivers variable was the most important one to describe the negative association to other species (0.84; P = 0.019) (Table 5).

3.3.2. Wintering season

Contrarily to the previous season, results showed the absence of relation between the deciduous forest and shrubland over farmland gradient (RPC1) and abundance of ground feeders, that have been replaced by all species guild (0.67; P = 0.070) (Table 6) and species that foraging in trees (0.62; P = 0.059) (Table 8). All species guilds had a negative relation with riparian deciduous forests and shrublands but positive with farmland (Table 5), whereas tree foraging species had a positive relation with deciduous forests and shrublands, and negative relation with farmlands. This variable continued to be most statistically significant and relevant to represent the negative relation of this habitat gradient and the abundance of farmland (0.99; P < 0.001) (Table 5) and granivores species (0.92; P = 0.009) (Table 7), during the winter.

Also, the oakwoods, pinewoods and poplar stands gradient (RPC2) was important to explain the relation with the abundance of bird guilds that do not represent in the previous season. It demonstrated to be important to explain the negative relation with the abundance of carnivores (0.80; P = 0.038) (Table 7), was statistically significant and positively related to invertivores (0.89; P = 0.009) (Table 7) and statistically significant and negatively related to species that forage on water (0.96; P = 0.009) (Table 8). For tree species abundance, the gradient was the most representative variable (0.70; P = 0.029) and positively associated (Table 8).

The eucalyptus in detriment of urban area gradient (RPC3), continued to be reflected as the major variable for granivores (0.98; P < 0.001) (Table 7) and unspecialized foraging species (1.00; P < 0.001) (Table 8), as well to have a negative relation with the gradient. Forest (0.77; P = 0.020) (Table 5) and non-breeding birds abundance (0.99; P < 0.001) also are negatively and mainly affected by this gradient (Table 6).

The presence of abandoned farmlands gradient (RPC4) demonstrated to be the most relevant variable to represent the relation between type of land use and abundance for invertivores (0.95; P = 0.003) (Table 7) and species that forage on water (0.99; P < 0.001) (Table 8). The GLM model revealed positive relations between abandoned farmlands and invertivores and water feeding species.

The river variable is associated with distinct bird guilds compared to the post-breeding migration season. It showed significant effects and major importance for residents (0.88; P = 0.016) (Table 6) and ground foraging species (0.99; P < 0.001) (Table 8), as the most important variable for omnivores (0.62; P = 0.043) (Table 7) and high statistical significance, but not as the most representative, for farmland species (0.97; P < 0.001) (Table 5). All the guilds' abundance has a negative relation with the variable river.

3.3.3. Breeding season

The gradient associated with deciduous forest and shrubland over farmland (RPC 1) remained important for farmland species (1.00; P < 0.001) abundance (Table 6) and granivores (0.98; P < 0.001) (Table 7). The gradient was the most important variable for ground foraging species (1.00; P < 0.001) (Table 8), as it was in winter and during the post-breeding migration period. This season, the abundance of all guilds maintain the same relationship as in previous seasons: negatively related to deciduous forest and shrublands but positively related to farmlands.

For the oak, pine and poplar forests variable (RPC2), results demonstrated statistical significance for invertivores (0.77; P = 0.018) (Table 7) and understory foraging species abundance (0.83; P = 0.012) (Table 8), as well a positive relation with the gradient.

The model demonstrated that the eucalyptus versus urban area variable (RPC3) was significant and with positive effects on forest species (0.75; P = 0.035) (Table 5), omnivores (0.74, P = 0.045) (Table 7) and tree foraging species abundance (0.86; P = 0.013) (Table 8). Also, was the major explanatory variable for these guilds with exception of the tree foraging species. Although, results showed statistical significance and a negative impact for farmland species (0.93; P = 0.006) (Table 5), granivores (0.91; P < 0.001) (Table 7) and ground foraging species (0.99; P < 0.001) (Table 8). Granivores, farmland birds and ground foraging species abundance demonstrated a negative relation with eucalyptus forest and positive relation with urban areas. Omnivores, forest birds and tree foraging species showed an opposite relation, compared to the previous guilds, where the gradient positively affected these guilds' abundance.

Throughout all seasons, the abandoned farmland variable (RPC4) had a various number of guilds associated. In the breeding season this was the most important variable for tree foraging birds abundance (0.87; P = 0.008) (Table 8). For farmland birds (0.73; P = 0.032) (Table 5), granivores (0.78; P = 0.014) (Table 7) and ground foraging species (0.79; P = 0.027) (Table 8), abandoned farmlands were relevant but not statistically significant for invertivores (0.60; P = 0.065) (Table 7) during the breeding season. Invertivores, breeding birds and tree foraging species shows a positive relation with the variable and granivores, farmland birds and ground foraging species presented a negative relation.

The presence of acacia woods (RPC5) demonstrated to be the most important variable for other species (0.77; P = 0.042) (Table 5) and ground foraging birds (0.74; P = 0.041) (Table 8). Was also relevant for forest birds abundance, although was not statistically significant (0.68; P = 0.63) (Table 5). Acacia woods gradient has a negative relation with other species guild and ground foraging birds and positive towards forest birds’ abundance.

Table 5- General linear model (GLM) relating habitat preference guilds abundance and the rotated axes from PCA analysis and the river variable for each season. We present the estimate coefficients (Coef), the sum of weights (SoW) of each model, and the respective p-value (P). Both the most suitable models and significant variables (<0.05) are represented in bold. Green = significatively positive; Yellow = significatively negative;

(Legend: RPC1 - Deciduous riparian forest and shrublands to farmland; RPC2 - Oak, pine, and poplar forests; RPC3 - Eucalyptus to urban area; RPC4 - Abandoned farmlands; RPC5 – Acacia stands).

Guild	Variable	Wintering			Breeding			Migration		
		SoW	Coef	P	SoW	Coef	P	SoW	Coef	P
Farmland	RPC1	**0.99**	-0.99	**< 0.001**	**1.00**	-0.72	**< 0.001**	**0.75**	-1.04	**0.039**
	RPC2	0.32	-0.31	0.138	0.44	-0.24	0.139	**0.70**	-0.98	0.049
	RPC3	0.32	-0.27	0.245	**0.93**	-0.42	**0.006**	0.51	-0.77	0.123
	RPC4	0.23	-0.07	0.733	**0.73**	-0.34	**0.032**	0.26	-0.31	0.528
	RPC5	0.29	0.21	0.261	0.35	-0.11	0.570	**0.81**	1.13	**0.033**
	River	**0.97**	-1.70	**< 0.001**	0.22	-0.07	0.886	0.23	0.02	0.975
Forest	RPC1	0.31	-0.10	0.407	0.31	0.05	0.367	0.32	0.06	0.393
	RPC2	0.25	-0.06	0.602	0.59	0.09	0.063	**0.98**	0.17	**<0.001**
	RPC3	**0.77**	-0.26	**0.020**	**0.75**	0.11	**0.035**	0.26	0.03	0.706
	RPC4	0.24	0.04	0.677	0.43	0.07	0.161	0.34	0.06	0.295
	RPC5	0.23	-0.02	0.877	**0.68**	0.10	0.063	**0.69**	-0.13	0.046
	River	0.25	-0.11	0.653	0.39	0.13	0.432	0.31	0.11	0.38
Other	RPC1	0.23	<0.001	0.951	0.29	0.04	0.453	0.33	-0.07	0.395
	RPC2	0.24	-0.03	0.737	0.43	-0.08	0.203	0.24	-0.02	0.756
	RPC3	0.24	0.02	0.929	0.26	-0.03	0.612	0.59	-0.12	0.091
	RPC4	0.55	0.13	0.089	0.29	0.04	0.449	0.38	-0.08	0.252
	RPC5	0.24	-0.03	0.650	**0.77**	-0.14	**0.042**	0.37	0.08	0.216
	River	0.24	0.05	0.721	0.25	0.02	0.807	**0.84**	-0.33	**0.019**

Table 6**-** General linear model (GLM) relating phenological guilds abundance and the rotated axes from PCA analysis and the river variable for each season. We present the estimate coefficients (Coef), the sum of weights (SoW) of each model, and the respective p-value (P). Both the most suitable models and significant variables (<0.05) are represented in bold. Green = significatively positive; Yellow = significatively negative;

(Legend: RPC1 - Deciduous riparian forest and shrublands to farmland; RPC2 - Oak, pine, and poplar forests; RPC3 - Eucalyptus to urban area; RPC4 - Abandoned farmlands; RPC5 – Acacia stands).

Guild	Variable	Wintering			Breeding			Migration		
		SoW	Coef	P	SoW	Coef	P	SoW	Coef	P
Migrant	RPC1	-	-	-	-	-	-	0.24	0.03	0.925
	RPC2	-	-	-	-	-	-	0.23	-0.01	0.996
	RPC3	-	-	-	-	-	-	0.25	-0.08	0.651
	RPC4	-	-	-	-	-	-	0.34	0.13	0.380
	RPC5	-	-	-	-	-	-	0.26	-0.08	0.547
	River	-	-	-	-	-	-	0.24	0.08	0.729
Non Breeding	RPC1	0.31	-0.15	0.340	-	-	-	0.32	-0.27	0.380
	RPC2	0.40	-0.22	0.145	-	-	-	0.24	-0.06	0.847
	RPC3	**0.99**	-0.57	**< 0.001**	-	-	-	0.40	-0.36	0.300
	RPC4	0.23	-0.02	0.974	-	-	-	0.29	0.20	0.405
	RPC5	0.23	0.05	0.756	-	-	-	0.46	0.39	0.076
	River	0.23	0.01	0.674	-	-	-	**0.66**	-1.22	0.065
Breeding	RPC1	-	-	-	0.24	0.08	0.473	-	-	-
	RPC2	-	-	-	0.31	0.26	0.675	-	-	-
	RPC3	-	-	-	0.33	-0.54	0.321	-	-	-
	RPC4	-	-	-	0.57	0.68	0.097	-	-	-
	RPC5	-	-	-	0.33	-0.99	0.395	-	-	-
	River	-	-	-	0.26	0.54	0.482	-	-	-
All Species	RPC1	**0.67**	-0.18	0.070	0.27	-0.03	0.495	0.41	-0.09	0.152
	RPC2	0.24	-0.04	0.591	0.24	-0.01	0.884	0.23	0.01	0.840
	RPC3	0.55	-0.17	0.069	0.23	0.00	0.882	0.52	-0.11	0.096
	RPC4	0.27	0.07	0.366	0.24	0.02	0.765	0.24	-0.02	0.803
	RPC5	0.23	-0.01	0.926	0.24	-0.01	0.750	0.28	0.05	0.434
	River	0.45	-0.28	0.171	0.25	0.05	0.573	0.26	-0.07	0.668
Resident	RPC1	0.51	0.14	0.128	**0.27**	-0.03	0.481	**0.51**	-0.11	0.115
	RPC2	0.23	0.03	0.727	0.24	-0.01	0.853	0.23	0.01	0.769
	RPC3	0.23	0.02	0.836	0.23	6.1e-4	0.891	0.46	-0.11	0.146
	RPC4	0.37	0.11	0.190	0.24	0.01	0.816	0.29	-0.06	0.443
	RPC5	0.23	2.7e-3	0.961	0.24	-0.01	0.794	0.31	0.06	0.353
	River	**0.88**	-0.48	**0.016**	0.25	0.05	0.577	0.26	-0.07	0.694

Table 7- General linear model (GLM) relating diet guilds abundance and the rotated axes from PCA analysis and the river variable for each season. We present the estimate coefficients (Coef), the sum of weights (SoW) of each model, and the respective p-value (P). Both the most suitable models and significant variables (<0.05) are represented in bold. Green = significatively positive; Yellow = significatively negative;

(Legend: RPC1 - Deciduous riparian forest and shrublands to farmland; RPC2 - Oak, pine, and poplar forests; RPC3 - Eucalyptus to urban area; RPC4 - Abandoned farmlands; RPC5 – Acacia stands)

Guild	Variable	Wintering			Breeding			Migration		
		SoW	Coef	P	SoW	Coef	P	SoW	Coef	P
Invertivore	RPC1	0.32	-0.06	0.382	0.46	0.09	0.164	0.33	0.06	0.390
	RPC2	**0.89**	0.14	**0.009**	**0.77**	0.13	**0.018**	0.44	0.09	0.143
	RPC3	0.25	-0.03	0.718	0.33	0.06	0.382	0.39	-0.08	0.187
	RPC4	**0.95**	0.16	**0.003**	**0.60**	0.11	0.065	0.23	7.0e-4	0.991
	RPC5	0.24	-0.02	0.571	0.24	0.02	0.876	**0.67**	-0.15	0.054
	River	0.31	-0.11	0.399	0.46	0.18	0.253	0.26	0.06	0.450
Omnivore	RPC1	0.24	-0.03	0.891	0.33	0.05	0.367	0.24	-0.02	0.813
	RPC2	0.30	-0.08	0.345	0.30	-0.04	0.464	**0.70**	0.13	**0.037**
	RPC3	0.43	0.15	0.079	**0.74**	0.11	**0.045**	**0.92**	0.18	**0.007**
	RPC4	0.37	0.11	0.192	0.44	0.7	0.162	0.58	0.11	0.069
	RPC5	0.24	-0.03	0.891	0.29	0.04	0.551	0.24	0.02	0.630
	River	**0.62**	-0.34	**0.043**	0.44	0.15	0.348	0.24	-0.03	0.747
Granivore	RPC1	**0.92**	-0.59	**0.009**	**0.98**	-0.54	**< 0.001**	**0.73**	-0.59	**0.023**
	RPC2	0.22	-0.01	0.856	0.36	-0.22	0.161	**0.85**	-0.84	**0.006**
	RPC3	**0.98**	-0.73	**< 0.001**	**0.91**	-0.45	**< 0.001**	**0.98**	-1.03	**< 0.001**
	RPC4	0.23	-0.10	0.553	**0.78**	-0.40	**0.014**	**0.67**	-0.55	**0.033**
	RPC5	0.24	-0.10	0.910	0.28	-0.15	0.606	**0.70**	0.45	**0.034**
	River	0.48	-0.67	0.146	0.39	-0.43	0.239	0.25	-0.20	0.622
Carnivore	RPC1	0.24	-0.01	0.972	0.27	0.16	0.585	0.38	-0.21	0.293
	RPC2	**0.80**	-0.30	**0.038**	0.36	-0.34	0.372	0.27	0.09	0.592
	RPC3	0.24	0.00	0.999	**0.55**	-0.43	0.101	**0.53**	-0.28	0.134
	RPC4	0.26	0.05	0.607	0.37	-0.33	0.404	0.25	-0.07	0.693
	RPC5	0.30	0.08	0.403	0.24	-0.01	0.925	0.25	0.05	0.625
	River	0.24	0.00	0.826	0.38	0.6	0.314	0.49	-0.52	0.219

Table 8- General linear model (GLM) relating foraging stratum guilds abundance and the rotated axes from PCA analysis and the river variable for each season. We present the estimate coefficients (Coef), the sum of weights (SoW) of each model, and the respective p-value (P). Both the most suitable models and significant variables (<0.05) are represented in bold. Green = significatively positive; Yellow = significatively negative;

(Legend: RPC1 - Deciduous riparian forest and shrublands to farmland; RPC2 - Oak, pine, and poplar forests; RPC3 - Eucalyptus to urban area; RPC4 - Abandoned farmlands; RPC5 – Acacia stands)

Guild	Variable	Wintering			Breeding			Migration		
		SoW	Coef	P	SoW	Coef	P	SoW	Coef	P
Tree	RPC1	**0.62**	0.19	0.059	0.45	0.12	0.145	0.37	0.16	0.277
	RPC2	**0.70**	0.19	**0.029**	0.33	0.08	0.281	0.42	0.17	0.168
	RPC3	**0.67**	0.20	0.059	**0.86**	0.22	**0.013**	0.26	-0.08	0.568
	RPC4	0.30	0.09	0.371	**0.87**	0.20	**0.008**	0.40	0.15	0.210
	RPC5	0.23	0.00	0.886	0.27	0.06	0.463	0.29	-0.12	0.291
	River	0.24	0.01	0.888	0.24	0.05	0.973	0.30	0.23	0.333
Ground	RPC1	0.45	-0.17	0.160	**1.00**	-0.24	**<0.001**	**0.98**	-0.33	**<0.001**
	RPC2	0.23	-0.01	0.986	0.40	-0.08	0.216	**0.95**	-0.34	**<0.001**
	RPC3	0.23	-0.01	0.870	**0.99**	-0.19	**<0.001**	**0.60**	-0.18	**0.047**
	RPC4	0.24	0.05	0.599	**0.79**	-0.13	**0.027**	0.22	-0.02	0.822
	RPC5	0.23	0.02	0.968	**0.74**	-0.13	**0.041**	**0.75**	0.20	**0.045**
	River	**0.99**	-0.89	**<0.001**	0.24	0.04	0.679	0.33	0.23	0.337
Water	RPC1	0.25	0.05	0.724	0.34	0.42	0.303	0.26	-0.11	0.628
	RPC2	**0.96**	-0.39	**0.009**	0.39	-0.46	0.344	0.43	0.22	0.198
	RPC3	0.33	0.10	0.391	0.30	0.29	0.679	**0.78**	-0.45	**0.041**
	RPC4	**0.99**	0.28	**< 0.001**	0.24	-0.12	0.762	0.23	-0.01	0.943
	RPC5	0.25	-0.05	0.552	0.31	-0.47	0.240	0.24	0.02	0.763
	River	0.31	0.20	0.391	0.32	0.74	0.476	0.55	-0.65	0.943
Understory	RPC1	0.24	-0.03	0.872	0.57	0.12	0.087	0.30	0.09	0.327
	RPC2	0.24	-0.01	0.951	**0.83**	0.15	**0.012**	0.43	0.13	0.202
	RPC3	0.49	-3.2e-3	0.143	0.26	0.04	0.562	0.25	0.03	0.584
	RPC4	0.47	0.02	0.133	0.55	0.11	0.087	0.24	0.01	0.906
	RPC5	0.53	-0.01	0.125	0.43	0.09	0.219	0.33	0.10	0.215
	River	0.33	0.05	0.639	0.36	0.16	0.501	**0.58**	-0.37	0.050
Unspecialized	RPC1	0.48	-0.19	0.134	0.26	-0.06	0.615	0.23	-0.06	0.891
	RPC2	0.23	5.0e-4	0.932	0.24	-0.04	0.722	0.44	-0.04	0.140
	RPC3	**1.00**	-0.49	**< 0.001**	0.30	0.09	0.376	0.27	0.09	0.366
	RPC4	0.23	-0.02	0.873	0.25	0.05	0.645	0.80	-0.33	**0.002**
	RPC5	0.23	0.01	0.896	0.30	0.09	0.360	0.30	-0.13	0.521
	River	0.23	0.07	0.756	0.24	0.01	0.817	0.48	-0.39	0.169

4. Discussion

Our results showed the importance of riparian corridors of both rivers as stopover sites for autumnal migrants and, principally, as wintering ground for either short or long-distance migrants. It also confirms that different types of land uses influence bird community composition and guilds abundance in riparian landscapes, being the invasive stands the most detrimental land use for typical riparian bird's assemblage. Pine, oak and poplar tree associations had an interesting amount of positive relations with bird's assemblages abundance in different seasons namely for forest birds, omnivores, tree and understory foragers, and principally for invertivores. Counterwise to our expectations, we notice that the deciduous riparian forest connected with shrubland, had no significant positive relation with any bird guild. We also consolidate that bird's assemblage, such invertivores, forest birds, granivores, ground foragers and farmland birds can be used as bioindicators of deterioration in riparian landscapes, by observing a pattern in our results that connected these bird guilds to anthropogenic land uses and with natural land covers. Although, due to the lack of significant relations, we consider that phenological bird assemblages metric are not suitable for measure land use perturbance.

The Sousa and Ferreira rivers differed slightly in terms of the land use composition. Firstly, in both rivers all land uses are present, with the only significant differences being in the invasive acacia woodlands and in deciduous riparian forests, where the biggest proportions of these land uses are observed in the Sousa River. In addition, the Ferreira River has more urbanised areas and a higher proportion of agricultural fields along the waterline in comparison to a lower proportion of deciduous forest than the Sousa River, which also has higher average proportions of abandoned farmlands and eucalyptus in the upland areas. Therefore, Sousa river landscape is less urbanised and with more natural riparian woodlands, but connected to dense eucalyptus stands while the Ferreira river has less riparian woodland vegetation, containing larger open farmlands and urban areas, but equally connected to valley slopes taken by the invasive eucalyptus stands. Despite these differences, the avian community of the Sousa and Ferreira do not differ much, except in winter. Numbers of farmland birds, ground feeders and residents demonstrated to be significantly higher in the Ferreira river than in the Sousa River. We believe that the abundance of the referred guilds is related to the land use patterns observed in each river, principally the lower proportions of deciduous forest and higher proportions of open areas, in particular farmlands and urban areas, in the Ferreira river.

Bird assemblages in the study area were typical of riverine habitats of the Atlantic region (Ramos *et al*., 2019), with presence of species associated with other habitats (e.g., dartford warbler *Curruca undata* and rock bunting *Emberiza cia*), due to habitat heterogeneity, natural or human-induced, of adjacent land uses to the water course. Riverine specific birds, such as the common kingfisher (*Alcedo atthis*) or the grey wagtail (*Motacilla cinerea*) were observed. Although species typical of this geographic region but scarcer and with stricter habitat requirements, such as the white-throated dipper (*Cinclus cinclus*) (Ramos *et al*., 2019), were absent. The presence/absence of such species can serve as bioindicators on water and habitat quality since they occupy high trophic levels on aquatic food webs and are often sensitive to environmental changes (Meadows, 1972; Ormerod & Tyler, 1987; Sorace *et al.*, 2002).

Phenologically, the bird community of the Ferreira and Sousa rivers is predominated by resident species and migrants constituted 27% of the overall community. Species richness was higher in the wintering and post-breeding migration season than in the breeding season which may suggest a relatively impoverished breeding community, which may be linked with habitat deterioration. We found seasonal significant differences in the number of species for all guilds with exception of granivores, forest birds, residents, ground feeders and understory foragers, and in abundance with exception of invertivores, tree foragers and farmland birds. As nesting sites, both rivers host a lower number of species compared to the other two seasons. The breeding community was constituted by mostly residents and common species, with a scarcity or even absence of breeding migrants, as the Iberian chiffchaff (*Phylloscopus ibericus*). Such feature is in line with other studies in other European riparian galleries (Larsen *et al*., 2010; Godinho *et al*., 2010; Pereira *et al.*, 2014). Forest birds (e.g., firecrest, great tit, long-tailed tit and song thrush) and understory specialist birds (e.g., blackcap and wren) dominated the breeding community. The verified seasonal pattern of the community reflects the dynamics of different guilds and how they responded to the particularities of each season. Some of the species included as residents actually have short and long-distance migratory individuals in their wintering and post-breeding migratory populations. In the winter, European robin, common chaffinch, and song thrush reached their abundance peak as a result of the ingression of individuals from higher latitudes (Roché & Frochot, 2008), and exclusively wintering species, such as the chiffchaff and the siskin, were also frequent and abundant. This high influx of wintering birds occurs by the fact that such species find mild weather conditions and greater availability of resources to survive the winter in the Iberain Peninsula (Tellería, 1988; Senar & Borras, 2004). The humid and less harsh conditions of winter in this region under influence of Atlantic climate, increases ecosystem productivity and consequently increasing the availability of invertivores and seeds that are important food resources for invertivores, granívores and omnivores species (Tellería, 1988; Telleria *et al.*, 1988; Senar & Borras, 2004). Also, during the migratory passage both species from northern Europe and species returning to their African wintering grounds cohabitated the riparian corridors of both rivers. Moreover, the occurrence of more specific habitat species, such the purple heron or the common reed warbler, typically associated with wetlands and dense reedbeds, respectively (de Juana & Garcia, 2015), exemplifies the importance of riparian corridors as migratory stopover sites for birds that must fulfil the energy demands of migration (Rodewald & Matthews, 2005).

Our results are in line with other studies suggesting that invertivores and tree foragers were associated with undisturbed riparian areas and birds feeding on plant material related to altered riparian habitats (Larsen *et al.,* 2010; Menon *et al.*, 2019). We obtain associations between guilds and gradients that allow us to infer that these land uses are equated with disturbance and corroborate the fact that particular bird assemblages can be considered as bioindicators of riparian integrity and to what extent different land uses affect riparian bird communities. This is supported by the positive relation of the abundance of farmland, ground foraging and granivores species with anthropogenic land uses (farmlands, urban areas, acacia stands) and the negative relation with more natural habitats (deciduous riparian forests, shrublands, pinewood and oakwood). Contrarily, invertivores and tree foragers' abundance was positively related to natural land uses and negative in altered ones, such as farmlands, urban areas or invasive stands.

The gradient of deciduous forest connected to shrubland over farmland, negatively and significantly affected, all year round, the bird assemblages representing open habitats and anthropogenic disturbance on riparian galleries, with exception for ground foragers during the wintering season. We notice the absence of positive effects of this gradient on invertivores, known to be a good indicator of riparian integrity (Larsen *et al.*, 2010). We believe that the absence of a positive relation with this bird assemblage is related to the fact of invertivores in riparian corridors being affected by the presence of crops in the surroundings, since farmlands are frequently connected to riparian galleries in our study area. In fact, Martin *et al.*, (2006) stated that this habitat is sensitive to modification of adjacent landscapes. Also, Pereira *et al.* (2014), in their study in a Mediterranean riparian gallery, conclude that surroundings have influence on bird assemblages in the breeding season. On the other hand, our study not only suggests that these effects do occur in breeding populations, but also affects wintering and migratory populations Only tree specialists had some relation with near statistical significance, being this gradient the most important for this guild during winter. This lack of significantly positive relations can demonstrate that vertical connectivity between riparian deciduous forest and shrublands of *Erica* spp. and *Ulex* spp. do not benefit from an abundance of forest related guilds.

Forest birds and omnivore abundance was favoured by woody associations of pine, oak and poplar trees stands during migration. During winter, this gradient was particularly important for the increment in abundance of invertivores and tree foragers birds. In the breeding season, the gradient continued to influence the abundance of invertivores and was also important to understory foragers. The positive relation of understory birds during breeding season indicates that this forest association, that integrates some production stands of (mainly) native pine trees and exotic poplar trees, still contains a well-developed understory layer. Usually, forest production management removes the understory and shrublands of these stands (Veiras & Soto, 2011). When properly managed and not applying intensive control on associated vegetation, native stands for production, such as pine plantations, can provide good conditions for establishment of native species (Atauri *et al.*, 2004).

Our results reflected the harmful effects of stands of invasive species, planted or propagated, on bird communities in riparian habitats. The eucalyptus stands over urban area gradient, negatively affects the abundance of granivores in all seasons, ground foragers in the breeding season, unspecialized foragers and non breeding birds in winter, forest birds in the winter and farmland in the breeding season. Eucalyptus spread with ease and took over native woods due to high growth capacity (Fabião *et al.*, 2002; Fernandez *et al.*, 2004). Additionally, these species bloom during winter which can cause displacement of food availability and ideal habitat conditions for birds when replacing native species (Tellería & Galarza, 1990). A similar relation occurs with stands of *Acacia* spp. The increase of these invasive species was the gradient of most importance to explain the negative effects on forest birds’ abundance in the migration period and the breeding season. It also negatively impacts generalists and other habitat specialists, and ground feeders in the breeding season. Although two bird assemblages' abundance, the farmland birds and ground foragers in the migration season were positively related to this gradient. Since acacia stands were generally in the edge of farmland and, we believe such relation is result of edge effects (Reino et al., 2009). We also considered the positive effects on farmland and ground foragers' abundance as an indicator of anthropogenic disturbance.

Rural and agricultural abandonment since the mid 20th century marked substantial landscape modifications (Calvo-Iglesias *et al*., 2006; Marey-Pérez *et al*., 2006). The process of ecological succession transforms these former croplands into low-shrublands areas (Santos *et al*., 2016), with tall herbaceous plants associations and sparse younger stages of pioneer woody species. Abandonment of farmlands present in riparian corridors increases the abundance of invertivores and tree foragers in winter and in the breeding season, respectively, and negatively affects carnivores in the migration period, and granivores, ground foragers and farmland birds' abundance in the breeding season. Soil moisture and the typical mild winter climate of the region contributed to abundance of invertebrates, an important trophic resource to invertivore and omnivore species (Senar & Borras, 2004). In these habitats, in fact, we observed high densities of small arthropods, mostly arachnids, in the vegetation during the fall and winter campaigns (personal observations). Some species like the Cetti's warbler and the dunnock (*Prunella modularis*), were frequently detected in these areas.

5. Conclusion

This study adds to our understanding the dynamics of riparian bird communities in the Northwest Iberian Peninsula and supports the use of functional and habitat-preference birds' assemblages to measure and reflect the effects of disturbed landscapes. It also contributes to filling the gap in our knowledge of riparian bird communities in Portugal, especially in non-Mediterranean regions as the only studies we are aware of, have taken place in Mediterranean riparian corridors (Pereira et al., 2014; Gomes et al., 2017). At the same we provide information on the effect of invasive woody species stands, namely Eucalyptus and Acacia trees, and possible edge effects of these land uses. We are aware of only one study addressing the impact of invasive Acacia stands on local bird communities in the Iberian Peninsula (Silva, 2016), which could make our findings relevant and serve as a starting point to address the issue in future research.

For further studies, we suggest the application of environmental data that reflects structural and ecological features of riparian corridors, such as riparian width, percentage of invasive plant species and coverage of canopy, understory and herbaceous vegetation. We also consider that the determination of possible edge effects by proximal land uses in riparian corridors, would be of extreme importance for riparian landscape ecology studies and conservation.

We also emphasise the priority of conservation of riparian corridors and their adjacent natural habitats, through protection of these ecosystems or through rehabilitation of disturbed riparian areas. For this purpose, we reinforce the possibility raised by Larsen et al. (2010) of integrating riparian birds' assemblages as indicators under the Water Framework Directive (WFD), since this program uses biological measures to assess riverine ecosystems' ecological status (European Communities, 2003).

6. References

Allan, J.D. (2004). Landscapes and riverscapes: the influence of land use on stream ecosystems. Annual Review of *Ecology Evolution and Systematics,* 35, 257–284

Andresen, T., Andrade, G., Ferreira, A. N., Martins, G., Vieira, C. & Viterbo, R. (2018) Plano de Gestão do Parque das Serras do Porto - Estudos Prévios. 280 pp.

Área Metropolitana do Porto (AMP) (2009). Rede de Parques Metropolitanos na Grande Área Metropolitana do Porto. Relatório final.

Atauri, J.A., de Pablo, C.L., de Agar, P.M., Schmitz, M.F. & Pineda, F.D., (2004). Effects of management on understory diversity in the forest ecosystems of Northern Spain. *Environmental Management*, 34, 819-828

Barton, K. (2016). MuMIn: Multi-Model inference. R package version 1.15.6. https://CRAN.R-project.org/package=MuMIn.

Bibby, C. J., Burgess, N. D., & Hill, D. A. (1992). Bird census techniques. Academic Press Limited. 257 pp.

Bibby, C., M. Jones & S. Marsden. (1998). Bird surveys. Royal Society for the Protection of Birds, Sandy, Bedfordshire, United Kingdom. 137 pp.

BirdLife International (2022). Handbook of the Birds of the World and BirdLife International digital checklist of the birds of the world. Version 7. Available at: http://datazone.birdlife.org/userfiles/file/Species/Taxonomy/HBW-BirdLife_Checklist_v7_Dec22.zip

Bolker, B. M., Brooks, M. E., Clark, C. J., Geange, S. W., Poulsen, J. R., Stevens, M. H. H., & White, J. S. S. (2009). Generalized linear mixed models: a practical guide for ecology and evolution. *Trends in ecology & evolution*, *24*(3), 127-135.

Brown, J.H., Morgan, E.S.K., Parody, J.M. & Haskell, J.P. (2001). Regulation of diversity: maintenance of species richness in changing environments. *Oecologia,* 126, 321–332.

Burnham, K.P. & Anderson, D.R. (2002). Avoiding pitfalls when using information-theoretic methods. *The Journal of Wildlife Management*, 912–918.

Dallimer, M., Rouquette, J.R., Skinner, A.M., Armsworth, P.R., Maltby, L.M., Warren, P.H. & Gaston, K.J. (2012). Contrasting patterns in species richness of birds, butterflies and plants along riparian corridors in an urban landscape. *Diversity and Distributions*, 18 (8), 742–753.

DeFries, R. S., Foley, J. A., & Asner, G. P. (2004). Land-use choices: Balancing human needs and ecosystem function. *Frontiers in Ecology and the Environment*, *2*(5), 249-257.

de Juana, E., & Garcia, E. (2015). *The birds of the Iberian Peninsula*. Bloomsbury Publishing, U.K.

DGT-Direcção Geral do Território (2018). Carta de Uso e Ocupação do Solo de Portugal Continental para 2018. Direção de serviços de geodesia, cartografia e informação geográfica, Direção-Geral do Território.

European Communities (2003). Common implementation strategies for the water framework directive (2000/60/EC) guidance document No. 3. Analysis of pressures and impacts. European Union, Brussels

Fabião, A., Martins, M.C., Cerveira, C., Santos, C., Lousã, M., Madeira, M. & Correia, A., (2002). Influence of soil and organic residue management on biomass and biodiversity of understory vegetation in a Eucalyptus globulus Labill. plantation. *Forest Ecology Management,* 87–100.

Fernández, C., Vega, J.A., Gras, J.M., Fonturbel, T., Cuiñas, P., Dambrine, E. & Alonso, M. (2004). Soil erosion after Eucalyptus globulus clearcutting: differences between logging slash disposal treatments. *Forest Ecology Management*, 195, 85–95.

Fierro, P., Bertrán, C., Tapia, J., Hauenstein, E., Peña-Cortés, F., Vergara, C., Cerna, C.& Vargas-Chacoff, L. (2017). Effects of local land-use on riparian vegetation, water quality, and the functional organization of macroinvertebrate assemblages. *Science of the Total Environment*, *609*, 724-734.

Godinho, C., Rabaça, J.E. & Segurado, P. (2010). Breeding bird assemblages in riparian galleries of the Guadiana River basin (Portugal): the effect of spatial structure and habitat variables. *Ecological research*, *25*(2), 283-294.

Gomes, M., Rabaça, J. E., Godinho, C., & Ramos, J. A. (2017). Seasonal variation in bird species richness and abundance in riparian galleries in Southern Portugal. *Acta Ornithologica*, *52*(1), 69-79.

Houghton, R. A., Hackler, J. L., & Cushman, R. M. (2001). *Carbon flux to the atmosphere from land-use changes: 1850 to 1990*. Oak Ridge: Carbon Dioxide Information Center, Environmental Sciences Division, Oak Ridge National Laboratory.

Lambin, E. F., & Geist, H. J. (Eds.). (2008). *Land-use and land-cover change: local processes and global impacts*. Springer Science & Business Media.

Larsen, S., Sorace, A. & Mancini, L. (2010). Riparian bird communities as indicators of human impacts along Mediterranean streams. *Environment Management*, 45, 261–273.

Legendre, P. & Legendre, L. (1998). Numerical Ecology, second ed. Elsevier, Amsterdam.

Litteral, J. & Shochat, E. (2017). The role of landscape-scale factors in shaping urban bird communities. In: Murgui, E., Hedblom, M. (Eds.), *Ecology and Conservation of Birds in Urban Environments.* Springer, Cham, 135–159.

Lu, Y., Wang, R., Zhang, Y., Su, H., Wang, P., Jenkins, A., Ferrier, R. C., Bailey, M. & Squire, G. (2015). Ecosystem health towards sustainability. *Ecosystem Health and Sustainability*, *1*(1), 1-15.

Martin, T. G., McIntyre, S., Catterall, C. P., & Possingham, H. P. (2006). Is landscape context important for riparian conservation? Birds in grassy woodland. *Biological Conservation*, *127*(2), 201-214.Meadows, B.S., (1972). Kingfisher numbers and stream pollution. *Ibis*, 114, 443.

Menon, T., Sridhar, H., & Shahabuddin, G. (2019). Effects of extractive use on forest birds in Western Himalayas: Role of local and landscape factors. *Forest Ecology and Management*, *448*, 457-465.

Nilsson, C., & Grelsson, G. (1995). The fragility of ecosystems: a review. *Journal Applied Ecology,* 32, 677–692.

Ormerod, S. J., & Tyler, S. J. (1987). Dippers (Cinclus cinclus) and grey wagtails (Motacilla cinerea) as indicators of stream acidity in upland Wales. *The value of birds*, 191-208.

Padoa-Schioppa, E., Baietto, M., Massa, R., & Bottoni, L. (2006). Bird communities as bioindicators: The focal species concept in agricultural landscapes. *Ecological indicators*, *6*(1), 83-93.

PanEuropean Common Bird Monitoring Scheme (PECBMS) (2022). Species classification 2022. Available at: https://pecbms.info/methods/pecbms-methods/3-multispecies-indicators/species-selection-and-classification/

Pereira, P., Godinho, C., Gomes, M., & Rabaça, J. E. (2014). The importance of the surroundings: are bird communities of riparian galleries influenced by agroforestry matrices in SW Iberian Peninsula?. *Annals of forest science*, *71*(1), 33-41.

Petty, S. J., & Avery, M. I. (1990). Forest bird communities. *Forestry Commission Occasional Paper*, *26*, 1-110.

Pielke Sr, R. A., Pitman, A., Niyogi, D., Mahmood, R., McAlpine, C., Hossain, F., ... & de Noblet, N. (2011). Land use/land cover changes and climate: modeling analysis and observational evidence. *Wiley Interdisciplinary Reviews: Climate Change*, *2*(6), 828-850.

Planty-Tabacchi, A., Tabacchi, E., Naiman, R.J., Deferrari, C., & Decamps, H. (1996). The invisibility of species rich communities in riparian zones. *Conservation Biology,* 10, 598–607

Poff, B., Koestner, K.A., Neary, D.G., & Henderson, V. (2011). Threats to riparian ecosystems in Western North America: an analysis of existing literature. J. Am. Water Resources Assoc. 47, 1241–1254.

Pongratz, J., Schwingshackl, C., Bultan, S., Obermeier, W., Havermann, F., & Guo, S. (2021). Land use effects on climate: current state, recent Progress, and emerging topics. *Current Climate Change Reports*, 1-22.

QGIS Development Team (2022). QGIS Geographic Information System. Open-Source Geospatial Foundation Project. http://qgis.osgeo.org.

R Core Team (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Rabaça, J.E., (1995). Métodos de Censo de Aves: Aspectos Gerais, Pressupostos e Princípios de Aplicação. Sociedade Portuguesa para o Estudo das Aves, Lisboa, 52 pp.

Ramos, J., Godinho, C. & Encarnação, V. (2019). Aves. In Feio, M.J. & Ferreira, V. (Eds). *Rios de Portugal: comunidades, processos e alterações.* Coimbra University Press, Coimbra, Portugal. 233-249.

Reino, L., Beja, P., Osborne, P. E., Morgado, R., Fabião, A., & Rotenberry, J. T. (2009). Distance to edges, edge contrast and landscape fragmentation: interactions affecting farmland birds around forest plantations. *Biological Conservation*, *142*(4), 824-838.

Revelle, W. (2022). *psych: Procedures for Psychological, Psychometric, and Personality Research*. Northwestern University, Evanston, Illinois. R package version 2.2.5, https://CRAN.R-project.org/package=psych.

Ribeiro, O., Lautensach, H., & Daveau, S. (1987). Geografia de Portugal, vol. II. *O Ritmo Climático e a Paisagem*. Edições João Sá da Costa, Lisboa. 623 pp.

Roché, J., & Frochot, B. (2008). Riparian birds. In Arizpe, D., Mendes, A., & Rabça, J.E. (Eds.). *Sustainable riparian zones - a management guide*, 105-109. Generalitat Valenciana, España.

Rodewald, P. G., & Matthews, S. N. (2005). Landbird use of riparian and upland forest stopover habitats in an urban landscape. *The Condor*, *107*(2), 259-268.

Rogers, A.M. & Chown, S.L. (2013). Novel ecosystems support substantial avian assemblages: the case of invasive alien Acacia thickets. *Diversity and Distributions*, 20, 34-45

Santos, M., Ferreira, D., Bastos, R., Vicente, J., Honrado, J., Kueffer, C., ... & Cabral, J. A. (2016). Linking landscape futures with biodiversity conservation strategies in northwest Iberia—a simulation study combining surrogates with a spatio-temporal modelling approach. *Ecological informatics*, *33*, 85-100.

Senar, J. C., & Borras, A. (2004). Sobrevivir al invierno: estrategias de las aves invernantes en la Península Ibérica. *Ardeola*, *51*(1), 133-168.

Silva, L. F. P. (2016). A community-level approach to forest biodiversity and avian dispersal services. Doctoral dissertation. Universidade de Coimbra, Portugal.

Sorace, A., Formichetti, P., Boano, A., Andreani, P., Gramegna, C., & Mancini, L. (2002). The presence of a river bird, the dipper, in relation to water quality and biotic indices in central Italy. *Environmental Pollution*, *118*(1), 89-96.

Svensson, L., Mullarney, K. & Zetterström, D. (2012). Guia de Aves. (2ª ed.) Portugal. Assírio & Alvim, Lisboa, Portugal.

Teixido, A. L., Quintanilla, L. G., Carreno, F., & Gutierrez, D. (2010). Impacts of changes in land use and fragmentation patterns on Atlantic coastal forests in northern Spain. *Journal of Environmental Management*, *91*(4), 879-886.

Tellería, J. L. (1988). Invernada de aves en la Península Ibérica. Sociedad Española de Ornitología. Madrid.

Tellería, J.L., Santos, T., Alvaréz, G. & Sáez-Royuela, C. (1988). Avifauna de los campos de cereales del interior de España, in F. Bernis (ed.). Aves de los Medios Urbano y Agricola. Monografias SEO, 2, 173-317

Tellería, J.L., & Galarza, A. (1990). Avifauna y paisaje en el norte de España: efecto de las repoblaciones con árboles exóticos. *Ardeola,* 37, 229-245.

Trimble, S.W. & Crosson, P. (2000). Land use: U.S. soil erosion rates. Myth and reality. *Science,* 289, 248–250.

van Asselen, S., & Verburg, P.H. (2013). Land cover change or land-use intensification: simulating land system change with a global-scale land change model. *Global Change Biology*, 19, 3648–3667.

Verburg, P.H., van Asselen, S., van der Zanden, E.H., & Stehfest, E. (2012). The representation of landscapes in global scale assessments of environmental change. *Landscape Ecology*, 28, 1067–1080.

Verner, J. (1988). Optimizing the duration of point counts for monitoring trends in bird populations (Note PSW-395). US Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 4 pp.

Veiras, X. & Soto, M. A., (2011). La conflictividad de las plantaciones de eucalipto en España (y Portugal). Análisis y propuestas para solucionar la conflictividad ambiental y social de las plantaciones de eucalipto en la península Ibérica. Greenpeace, Madrid.

Vitousek, P. M., Mooney, H. A., Lubchenco, J., & Melillo, J. M. (1997). Human domination of Earth's ecosystems. *Science*, *277*(5325), 494-499.

Viterbo, R., Bessa, R., & Nunes, M. (2015) Anexo IV: Fichas de Caracterização Parque Serras do Porto.

Wickham, H., François, R., Henry, L., & Müller, K. (2022). *dplyr: A Grammar of Data Manipulation*. https://github.com/tidyverse/dplyr.

Wilman, H., Belmaker, J., Simpson, J., de la Rosa, C., Rivadeneira, M. M., & Jetz, W. (2014). EltonTraits 1.0: Species-level foraging attributes of the world's birds and mammals: Ecological Archives E095-178. *Ecology*, *95*(7), 2027-2027.

Annexes

Annex 1- List of the 62 species surveyed in the riparian corridors of the Sousa and Ferreira Rivers during the study period. Species were categorised by their phenological status in Portugal (Svensson *et al*., 2012), habitat preference following the classification used by (PECBMS, 2022) and its diet (Wilman *et al.,* 2014).

Specie	Phenology	Habitat preference	Diet	Foraging stratum
Accipiter gentilis, Northern goshawk	Resident	Forest	Carnivore	Ground
Accipiter nisus, Eurasian sparrowhawk	Resident	Forest	Carnivore	Unspecialized
Acrocephalus scirpaceus, Common reed warbler	Migrant	Other	Invertivore	Understory
Aegithalos caudatus, Long-tailed tit	Resident	Forest	Invertivore	Unspecialized
Alcedo atthis, Common kingfisher	Resident	Other	Carnivore	Water
Anas platyrhynchos, Mallard	Resident	Other	Omnivore	Water
Anthus pratensis, Meadow pipit	Non breeding	Forest	Invertivore	Ground
Anthus trivialis, Tree pipit	Migrant	Forest	Invertivore	Ground
Ardea cinerea, Grey heron	Non breeding	Other	Carnivore	Water
Ardea purpurea, Purple heron	Migrant	Other	Carnivore	Water
Buteo buteo, Common buzzard	Resident	Other	Carnivore	Ground
Carduelis carduelis, European goldfinch	Resident	Farmland	Granivore	Unspecialized
Certhia brachydactyla, Short-toed treecreeper	Resident	Forest	Invertivore	Tree
Cettia cetti, Cetti's warbler	Resident	Other	Invertivore	Ground
Chloris chloris, European greenfinch	Resident	Farmland	Granivore	Ground
Cisticola juncidis, Zitting cisticola	Resident	Farmland	Invertivore	Ground
Columba livia (feral), Feral rock dove	Resident	Other	Granivore	Ground
Columba palumbus, Common woodpigeon	Resident	Other	Granivore	Ground
Corvus corone, Carrion crow	Resident	Farmland	Carnivore	Ground
Cuculus canorus, Common cuckoo	Breeding	Other	Invertivore	Tree
Curruca communis, Common whitethroat	Migrant	Other	Invertivore	Understory
Curruca melanocephala, Sardinian warbler	Resident	Other	Omnivore	Understory
Curruca undata, Dartford warbler	Resident	Other	Invertivore	Understory
Cyanistes caeruleus, Eurasian blue tit	Resident	Forest	Omnivore	Tree
Dendrocopos major, Great spotted woodpecker	Resident	Forest	Omnivore	Tree
Emberiza cia, Rock bunting	Resident	Other	Granivore	Ground
Erithacus rubecula, European robin	Resident	Forest	Omnivore	Unspecialized
Estrilda astrild, Common waxbill	Resident	Other	Granivore	Unspecialized
Ficedula hypoleuca, European pied flycatcher	Migrant	Forest	Invertivore	Tree
Fringilla coelebs, Common chaffinch	Resident	Forest	Omnivore	Ground
Gallinula chloropus, Common moorhen	Resident	Other	Omnivore	Ground
Garrulus glandarius, Eurasian jay	Resident	Forest	Omnivore	Ground
Hippolais polyglotta, Melodious warbler	Breeding	Other	Invertivore	Understory
Lophophanes cristatus, Crested tit	Resident	Forest	Invertivore	Tree

Annex 1 (cont.)- List of the 62 species surveyed in the riparian corridors of the Sousa and Ferreira Rivers during the study period. Species were categorised by their phenological status in Portugal (Svensson *et al*., 2012), habitat preference following the classification used by (PECBMS, 2022) and its diet (Wilman *et al.,* 2014).

Specie	Phenology	Habitat preference	Diet	Foraging stratum
Motacilla alba, White wagtail	Resident	Farmland	Invertivore	Ground
Motacilla cinerea, Grey wagtail	Resident	Other	Invertivore	Ground
Muscicapa striata, Spotted flycatcher	Migrant	Forest	Invertivore	Unspecialized
Parus major, Great tit	Resident	Forest	Omnivore	Tree
Passer domesticus, House sparrow	Resident	Farmland	Granivore	Unspecialized
Periparus ater, Coal tit	Resident	Forest	Omnivore	Unspecialized
Phalacrocorax carbo, Great cormorant	Non breeding	Other	Carnivore	Water
Phoenicurus ochruros, Black redstart	Resident	Other	Invertivore	Ground
Phylloscopus collybita, Common chiffchaff	Non breeding	Forest	Invertivore	Unspecialized
Phylloscopus trochilus, Willow warbler	Migrant	Other	Invertivore	Tree
Picus sharpei, Iberian green woodpecker	Resident	Forest	Invertivore	Ground
Prunella modularis, Dunnock	Resident	Other	Omnivore	Understory
Pyrrhula pyrrhula, Eurasain bullfinch	Resident	Forest	Granivore	Unspecialized
Regulus ignicapilla, Common firecrest	Resident	Forest	Invertivore	Tree
Saxicola rubicola, Common stonechat	Resident	Farmland	Invertivore	Ground
Serinus serinus, European serin	Resident	Farmland	Granivore	Ground
Spinus spinus, Eurasian siskin	Non breeding	Forest	Granivore	Unspecialized
Streptopelia decaocto, Eurasian collared-dove	Resident	Other	Granivore	Ground
Sturnus unicolor, Spotless starling	Resident	Farmland	Omnivore	Unspecialized
Sylvia atricapilla, Eurasian blackcap	Resident	Other	Omnivore	Understory
Sylvia borin, Garden warbler	Migrant	Forest	Omnivore	Understory
Tachybaptus ruficollis, Little grebe	Resident	Other	Invertivore	Water
Troglodytes troglodytes, Northern wren	Resident	Forest	Invertivore	Understory
Turdus iliacus, Redwing	Non breeding	Other	Omnivore	Unspecialized
Turdus merula, Eurasian blackbird	Resident	Other	Omnivore	Ground
Turdus philomelos, Song Thrush	Resident	Forest	Omnivore	Ground
Turdus viscivorus Mistle Thrush	Resident	Forest	Omnivore	Ground
Upupa epops, Eurasian hoopoe	Breeding	Farmland	Invertivore	Ground

Annex 2- Percentage of occurrence and mean abundance (with associated standard deviation) of all species observed during post-breeding migration, wintering and breeding season.

	Post-breeding Migration		Wintering		Breeding	
Specie	Occurrence (%)	Mean (±SD)	Occurrence (%)	Mean (±SD)	Occurrence (%)	Mean (±SD)
Accipiter gentilis	0	0	2	0.0 (0.1)	0	0
Accipiter nisus	2	0.0 ± (0.1)	4	0.0 (0.2)	0	0
Acrocephalus scirpaceus	2	0.0 ± (0.1)	0	0	0	0
Aegithalos caudatus	22	0.4 (0.8)	20	0.7 (1.8)	30	0.6 (1.1)
Alcedo atthis	20	0.3 (0.6)	14	0.1 (0.4)	20	0.2 (0.5)
Anas platyrhynchos	0	0	10	0.5 (2.0)	12	0.6 (2.5)
Anthus pratensis	0	0	2	0.0 (0.1)	0	0
Anthus trivialis	18	0.3 (0.7)	0	0	0	0
Ardea cinerea	20	0.3 (0.6)	24	0.2 (0.4)	2	0.0 (0.1)
Ardea purpurea	2	0.0 (0.1)	0	0	0	0
Buteo buteo	10	0.1 (0.3)	12	0.1 (0.3)	2	0.0 (0.3)
Carduelis carduelis	0	0	2	0.0 (0.3)	0	0
Certhia brachydactyla	26	0.3 (0.5)	34	0.4 (0.5)	28	0.3 (0.5)
Cettia cetti	54	0.7 (0.7)	66	0.9 (0.8)	60	0.8 (0.7)
Chloris chloris	20	0.7 (1.9)	22	0.6 (1.3)	24	0.3 (0.7)
Ciconia ciconia	0	0	0	0	2	0.0 (0.1)
Cisticola juncidis	4	0.0 (0.2)	6	0.1 (0.2)	4	0.0 (0.2)
Columba livia (feral)	0	0	2	0.0 (0.6)	4	0.4 (2.0)
Columba palumbus	10	0.2 (0.5)	14	0.4 (2.0)	26	0.3 (0.5)
Corvus corone	4	0.1 (0.3)	0	0	2	0.0 (0.3)
Cuculus canorus	2	0.0 (0.1)	0	0	0	0
Curruca communis	8	0.1 (0.3)	0	0	0	0
Curruca melanocephala	10	0.1 (0.4)	32	0.3 (0.5)	22	0.3 (0.6)
Curruca undata	6	0.1 (0.4)	4	0.1 (0.3)	4	0.0 (0.2)
Cyanistes caeruleus	34	0.5 (0.9)	32	0.4 (0.6)	16	0.2 (0.4)
Dendrocopos major	16	0.2 (0.5)	18	0.2 (0.4)	10	0.3 (0.5)
Emberiza cia	0	0	2	0.0 ± (0.3)	0	0
Erithacus rubecula	72	1.5 (1.4)	96	2.5 (1.3)	64	1.0 (0.9)
Estrilda astrild	6	0.5 (2.7)	4	0.1 (0.8)	2	0.1 (0.8)
Ficedula hypoleuca	54	0.8 (1.0)	0	0	0	0
Fringilla coelebs	6	0.1 (0.5)	84	4.8 (9.4)	46	0.5 (0.6)
Gallinula chloropus	2	0.0 (0.1)	0	0	0	0
Garrulus glandarius	20	0.2 (0.5)	22	0.2 (0.5)	20	0.3 (0.6)
Hippolais polyglotta	4	0.0 (0.2)	0	0	4	0.0 (0.2)

	Post-breeding Migration		Wintering		Breeding	
Specie	Occurrence (%)	Mean (±SD)	Occurrence (%)	Mean (±SD)	Occurrence (%)	Mean (±SD)
Lophophanes cristatus	2	0.0 (0.1)	10	0.1 (0.4)	4	0.0 (0.2)
Motacilla alba	0	0	14	0.3 (0.9)	10	0.1 (0.4)
Motacilla cinerea	18	0.2 (0.4)	42	0.5 (0.6)	20	0.3 (0.6)
Muscicapa striata	2	0.0 (0.1)	0	0	0	0
Parus major	20	0.3 (0.6)	60	0.9 (1.0)	66	0.9 (0.9)
Passer domesticus	2	0.0 (0.3)	10	1.9 (5.8)	8	0.2 (0.9)
Periparus ater	14	0.2 (0.6)	16	0.2 (0.4)	30	0.4 (0.9)
Phalacrocorax carbo	0	0	66	1.0 (1.0)	0	0
Phoenicurus ochruros	6	0.1 (0.2)	6	0.1 (0.4)	4	0.0 (0.2)
Phylloscopus collybita	0	0	68	1.3 (1.3)	0	0
Phylloscopus trochilus	32	0.3 (0.5)	0	0	0	0
Picus sharpei	32	0.2 (0.4)	4	0.0 (0.2)	14	0.1 (0.3)
Prunella modularis	0	0	28	0.4 (0.6)	12	0.1 (0.4)
Pyrrhula pyrrhula	0	0	16	0.3 (0.7)	10	0.1 (0.4)
Regulus ignicapilla	10	0.3 (1.3)	30	0.4 (0.7)	74	1.0 (0.9)
Saxicola rubicola	0	0	6	0.1 (0.3)	2	0.0 (0.1)
Serinus serinus	18	1.1 (2.9)	18	2.2 (8.9)	54	1.2 (1.6)
Spinus spinus	0	0	54	4.7 (17.7)	0	0
Streptopelia decaocto	10	0.1 (0.4)	14	0.2 (0.5)	20	0.2 (0.5)
Sturnus unicolor	4	0.0 (0.2)	2	0.1 (0.7)	2	0.0 (0.1)
Sylvia atricapilla	48	0.9 (1.2)	64	1.0 (1.0)	90	1.8 (1.0)
Sylvia borin	2	0.0 (0.1)	0	0	0	0
Tachybaptus ruficollis	0	0	2	0.0 (0.1)	0	0
Troglodytes troglodytes	54	0.6 (0.6)	76	1.2 (0.9)	98	1.8 (0.9)
Turdus iliacus	0	0	16	0.2 (0.7)	0	0
Turdus merula	46	0.7 (0.8	84	1.1 (0.8)	74	1.3 (1.1)
Turdus philomelos	4	0.0 (0.2)	40	0.4 (0.6)	40	0.4 (0.5)
Turdus viscivorus	0	0	6	0.1 (0.3)	4	0.1 (0.6)
Upupa epops	0	0	0	0	2	0.0 (0.1)

Annex 3- Two sample t-test for guilds abundance during the wintering season.

Guild	Mean Ferreira	Mean Sousa	t-statistics	df	p-value	95% Conf. Int.	
All species	34.39	25.28	1.33	50	0.19	-4.66	22.89
Invertivore	5.78	5.10	0.79	50	0.44	-1.06	2.41
Omnivore	15.13	11.14	1.34	50	0.19	-2.10	10.08
Granivore	11.96	7.45	0.76	50	0.45	-7.44	16.46
Carnivore	1.52	1.59	-0.17	50	0.86	-0.82	0.69
Forest	18.78	16.97	0.34	50	0.73	-9.08	12.72
Farmland	8.61	0.90	2.10	50	0.04	0.09	15.33
Other	7.00	7.41	-0.34	50	0.73	-2.83	2.01
Resident	28.30	17.10	2.21	50	0.04	0.73	21.67
Non breeding	6.09	8.17	-0.46	50	0.65	-11.35	7.18
Tree	1.83	1.93	-0.25	50	0.81	-0.96	0.75
Ground	17.91	7.00	2.67	24.33	0.01	2.49	19.34
Water	1.57	2.03	-0.69	40.19	0.49	-1.84	0.91
Understory	2.52	3.14	-1.21	50	0.23	-1.63	0.40
Unspecialized	10.57	11,17	-0.12	38.86	0.90	-10.78	9.57

Annex 4- Two sample t-test for guilds abundance during the breeding season.

Guild	Mean Ferreira	Mean Sousa	t-statistics	df	p-value	95% Conf. Int.	
All species	15.65	16.34	-0.41	34.04	0.68	-4.13	2.74
Invertivore	4.61	5.52	-1.45	50	0.15	-2.17	0.35
Omnivore	7.04	8.41	-1.37	50	0.18	-3.38	0.64
Granivore	3.78	2.03	1.56	30.27	0.13	-0.54	4.04
Carnivore	0.22	0.38	-1.06	47.60	0.30	-0.47	0.15
Forest	7.04	8.44	-1.44	50	0.16	-3.37	0.56
Farmland	2.21	1.72	0.73	50	0.47	-0.86	1.85
Other	6.39	6.17	0.19	50	0.85	-2.10	2.54
Resident	15.57	16.28	-0.42	34.39	0.67	-4,12	2.70
Breeding	0.04	0.07	-0.38	50	0.70	-0.16	0.11
Tree	2.39	2.76	-0.70	50	0.49	-1.42	0.69
Ground	6.87	5.83	0.76	32.67	0.45	-1.75	3.83
Water	0.43	1.03	-0.96	32.67	0.35	-1.88	0.68
Understory	3.57	4.24	-1.45	50	0.15	-1.61	0.26
Unspecialized	2.39	2.48	-0.17	50	0.87	-1.18	1.00

Annex 5- Two sample t-test for guilds abundance in the post-breeding migration season.

Guild	Mean Ferreira	Mean Sousa	t-statistics	df	p-value	95% Conf. Int.	
All species	12.70	11.66	0.66	50	0.51	-2.10	4.18
Invertivore	4.30	4.24	0.09	50	0.93	-1.38	1.50
Omnivore	4.65	4.72	-0.09	50	0.93	-1.76	1.62
Granivore	2.83	2.17	0.48	35.40	0.64	-2.14	3.44
Carnivore	0.91	0.52	1.49	50	0.14	-0.14	0.93
Forest	5.52	5.62	-0.11	50	0.92	-1.98	1.78
Farmland	1.91	2.28	-0.34	50	0.74	-2.51	1.79
Other	5.26	3.76	1.48	33.76	0.15	-0.55	3.56
Resident	10.78	9.86	0.60	36.59	0.55	-2.21	4.05
Migrant	1.48	1.59	-0.22	50	0.83	-1.09	0.88
Tree	2.35	2.93	-0.84	50	0.41	-1.98	0.82
Ground	4.17	4.69	-0.45	50	0.66	-2.83	1.80
Water	0.74	0.34	1.85	50	0.07	-0.03	0.82
Understory	2.13	1.52	1.35	50	0.18	-0.30	1.52
Unspecialized	3.30	2.17	1.28	29.83	0.21	-0.67	2.94