AIRO 26

Sociedade Portuguesa para o Estudo das Aves

VOLUME 26 | Ano 2019

SOCIEDADE PORTUGUESA PARA O ESTUDO DAS AVES

PORTUGUESE SOCIETY FOR THE STUDY OF BIRDS

Avenida Columbano Bordalo Pinheiro, 87, 3º Andar.
1070-062 Lisboa – Portugal
T. +351 213 220 430 | F. +351 213 220 439
spea@spea.pt | www.spea.com

ILUSTRAÇÕES

ILLUSTRATIONS

PAG. 03-27-33
Birdlife International

AIRO 26

Portuguese Society for the Study of Birds

ANO / YEAR 2019

CONTENTS

ÍNDICE

Internet photography forums as sources of avian dietary data: bird diets in Continental Portugal

Fóruns de fotografia na Internet como fontes de dados de dieta de aves: dietas de aves de Portugal Continental

Pedro M. Lourenço[1]

1 Centro de Estudos do Ambiente e do Mar (CESAM) / Departamento de Biologia Animal, Faculdade de Ciências da Universidade de Lisboa, 1749-016 Lisboa, Portugal.

*** Corresponding author:** p.m.g.lourenco@gmail.com

ABSTRACT

Knowing animal diets is key ecological information, required for understanding the dynamics of ecosystems as a whole, as well as the ecology of individual species. However, for many species/regions such information is not available. Here I explore the potential use of internet photography forums to describe the diet composition of birds by analysing photographs posted on the "Aves de Portugal Continental" Facebook page.

A total of 909 photographs were found to show identifiable food items being taken by 144 different avian species. These included 78 regularly occurring species for which there were no available dietary data for Portugal according to Catry et al. (2010). The photographs were obtained in 262 different locations, covering all the 18 districts of Continental Portugal. They exhibited a total of 206 different food item categories, their taxonomic rank ranging from species (n=97) to class (n=3), as well as some non-taxonomic groupings such as unidentified berry or human refuse. The avian species with the most dietary information were European Bee-eater *Merops apiaster* (n=68), Osprey *Pandion haliaetus* (n=59) and Common Kingfisher *Alcedo atthis* (n=40).

Although this type of data are affected by several biases, namely a geographic bias in favour of areas closer to human settlements and human-altered habitats, and a possible bias favouring larger food items that are more easily identifiable in photographs, it could provide an invaluable source of avian dietary data. In the future, these data could be gathered through an open web-enabled platform which would include photographers and biologists who would provide identifications of the food items being taken.

Keywords: *Alcedo atthis*, diet composition, Facebook, *Merops apiaster*, photography, *Turdus merula*, *Upupa epops*

RESUMO

O conhecimento das dietas dos animais é essencial para compreender as dinâmicas dos ecossistemas, assim como a ecologia de espécies individuais. Contudo, para muitas espécies/regiões, esse tipo de informação não está disponível. Nesta contribuição, exploro o potencial dos fóruns de fotografia na Internet como fontes de informação sobre dietas de aves, analisando as fotografias publicadas na página de Facebook "Aves de Portugal Continental".

Um total de 909 fotografias continham imagens de aves a consumir itens alimentares identificáveis, cobrindo 144 espécies diferentes de aves. Estas incluíram 78 espécies de ocorrência regular em Portugal para as quais, segundo Catry et al. (2010), não existiam quaisquer dados publicados relativos às suas dietas no país. Estas fotografias foram obtidas em 262 locais distintos, cobrindo todos os 18 distritos de Portugal Continental. Elas apresentavam 206 categorias diferentes de alimentos que, em termos taxonómicos, iam desde o nível da espécie (n=97) até ao nível da classe (n=3). As espécies de aves para as quais foi obtida mais informação alimentar foram o Abelharuco *Merops apiaster* (n=68), a Águia-pesqueira *Pandion haliaetus* (n=59) e o Guarda-rios *Alcedo atthis* (n=40).

Embora este tipo de dados tenha alguns problemas de enviesamento, nomeadamente um enviesamento geográfico a favor de áreas mais próximas de povoações e de habitats com maior influência humana, e um provável enviesamento a favor de itens alimentares maiores que são mais facilmente identificáveis em fotografias, podendo ser uma fonte valiosa de informação ecológica. No futuro estes dados poderiam ser recolhidos através de uma plataforma online que incluiria fotógrafos e biólogos capazes de identificar os itens alimentares consumidos.

Palavras-chave: *Alcedo atthis*, dieta, Facebook, *Merops apiaster*, fotografia, *Turdus merula*, *Upupa epops*

Introduction

The diet of a species is key ecological information, required for understanding its position in trophic webs, its interactions with other species and often its habitat preferences and seasonal routines (e.g. Pimm et al. 1991, Piersma 2012). Information on the many links and interactions among prey and predators within an ecosystem is an important starting point for exploring the dynamics of ecosystems as a whole, as well as the population dynamics of individual species (Thébault & Loreau 2003, Olff et al. 2009). However, such information is often not available. Even for common and widely studied vertebrates, ecological studies frequently rely on dietary information based on observations in different geographic areas, habitats or seasons, which fails to address the issue that diet can greatly vary throughout a species range (e.g. Bojarska & Selva 2011, Terraube & Arroyo 2011).

The Portuguese avifauna is a good example of such lack of detailed dietary information. Despite its relatively small size, the geographic location and varied landscape of Portugal grants it one of the richest avifaunas in Europe with roughly 300 regularly occurring bird species in Continental Portugal (Catry et al. 2010). However, detailed ecological data is still lacking for many of these species within the Portuguese territory. In terms of dietary information, "Aves de Portugal", the most up to date monograph on Portuguese ornithology, provides diet information for 286 species. However, for 193 (67%) of these species, this diet information refers to other parts of their range. Specific dietary data for Portugal, which is some cases is only anecdotal, is only available for the remaining 93 species (33%; Catry et al. 2010). For a few species, these data have become available since the publication of that monograph, examples being Sanderling *Calidris alba* (Lourenço et al. 2015) and European Roller *Coracias garrulus* (Catry et al. 2018), but for the vast majority the situation remains the same.

In recent years, the development of web-enabled networks for citizen science and globally accessible unified databases (e.g. Sullivan et al. 2009) have allowed scientists to have access to a plethora of data on species distributions, phenological patterns, habitat associations, and even variations in numbers, productivity and survival (Greenwood 2007, Rubolini et al. 2007) that would otherwise be very difficult to collect through traditional research and monitoring endeavours. Moreover, such web-based initiatives contain information similar in quality to that from standardized monitoring programmes (Munson et al. 2010, Tiago et al. 2017a). Another potential source of valuable ecological data are internet nature photography forums, which may provide data on consumed food items, morphology (e.g. plumage variability in birds) or occurrence of specific behaviours.

Here I explore the potential value of such internet photography forums by compiling data on the diets of bird species in Continental Portugal through the analysis of photographs published on the "Aves de Portugal Continental" Facebook page, aiming to use these data to describe the diet composition of as many avian species as possible.

Method

The "Aves de Portugal Continental" Facebook page (https://www.facebook.com/groups/121307984660183/) is a large forum for bird photographers and bird enthusiasts in general, focusing on the avifauna that occurs in Continental Portugal. As of October 2018, the page has over 25000 members and its archives store over 12000 photographs, with tens of new photographs being added every week. I went through all the archived photographs, as well as monitoring the new photographs being posted (until 8 October 2018), in order to select every case where it was possible to identify a food item being taken by a given bird species (see Appendix 1 for some examples).

I only used photographs in which the bird could be unquestionably identified to specific level (the only exception being *Phylloscopus ibericus* and *P. collybita* which cannot be reliably identified based on photographs and were lumped together) and where the bird was either actively eating a food item or, in the case of raptors, was holding a prey in its talons. Photographs without information on location, date and authorship were also excluded as this information was used to exclude potential pseudo-replicates, such as two photos by the same author of the same species consuming the same food type on the same day. Finally, I also exclude photographs of birds eating food items that were likely used as lure by the photographer, such as sunflower seeds (when the birds was not actively removing the seed from the flower), canary grass seeds and mealworms, but cannot completely rule out the possibility than other prey items identified in photographs were also placed by photographers as lure.

Prey items were then identified to the lowest possible taxonomic rank, using identification keys (e.g.Chinery 1993, MacDonald & Barret 1993, Ferrand de Almeida et al. 2001) and in some cases through the help of experts (e.g. for fishes, insects, reptiles and fruits). Often the photographers also provided valuable information that helped with food item identification. Food items were then divided into groups, mostly referring to animal classes, but also to fruits, seeds and other groupings such as human refuse. For each avian species I calculated the proportion of food items from each group. I also provide information on the seasons and geographic areas in which each species was photograph, for the latter dividing Portugal in three regions (North, including the districts of Braga, Viana do Castelo, Porto, Vila Real, Bragança, Aveiro, Viseu and Guarda; Centre, including the districts of Coimbra, Castelo Branco, Leiria, Lisboa, Santarém, Portalegre and the Setúbal Peninsula; and South, including the districts of Évora, Beja, Faro and the remainder of Setúbal district). For species with over 15 photographs, diets were analysed in more detail, including the proportion of lower rank food item groups and any apparent geographic or seasonal patterns.

Results and discussion

A total of 909 photographs, covering 144 avian species and obtained between January 2003 and October 2018, were found to provide dietary information (Table 1, Appendix 1). These include 78 regularly occurring species for which there was no available dietary data for Portugal, even if anecdotal (Catry et al. 2010), for which there were 359 photographs. There were also four species that do not regularly occur in Portugal (*Falco vespertinus*, *Larus hyperboreus*, *Pluvialis dominica* and *Porphyrio martinica*). The recording of several hundred food items for such a large number of species clearly evidences the potential value of this method for obtaining data on avian diets. The number of photographs per species ranged from 1 (for 31 species) to 68 (for European Bee-eater *Merops apiaster*; Table 1).

The photographs were obtained in 262 different locations which cover all districts of Continental Portugal (Fig. 1). Lisboa (n=168 photographs), Setúbal (n=116), Porto (n=99) and Beja (n=86) were the districts with more photographs, while Viseu (n=9), Viana do Castelo (n=13), Castelo Branco (n=13) and Guarda (n=14) were the districts with fewer photographs. Overall, and despite photograph locations being more concentrated along the more densely populated coast, and around the main coastal wetlands that attract more birdwatchers, there is a wide coverage of the whole territory (Fig. 1).

It was possible to detect 206 different food item categories (Table 1), their taxonomic rank ranging from species (n=97) to class (n=3), as well as some non-taxonomic groupings such as unidentified berry or human refuse. The most commonly found food items were unidentified fishes (n=75, present in the diet of 15 species), mullets (Mugilidae, n=44, present in the diet of 10 species), unidentified insect larvae (n=40, present in the diet of 16 species), and unidentified insect (n=37, present in the diet of 28 species). Among lower rank taxonomic categories, the Red-swamp Crayfish *Procambarus clarkii* (n=28, present in the diet of 12 species), the European Eel *Anguilla anguilla* (n=18, present in the diet of 7 species), the European Mole Cricket *Gryllotalpa gryllotalpa* (n=15, present in the diet of 8 species), the Iberian Green Frog *Pelophylax perezi* (n=15, present in the diet of 8 species), and *Quercus* sp. acorns (n=15, present in the diet of 3 species) stand out as most commonly taken food items. However, the importance of the latter may results both from their importance in avian diets or from being easier to identify in photographs.

Fig. 1- Map with the 262 locations (black camera icons) where the 909 photographs used to analyse avian diets were obtained.

Fig. 1 - Mapa com os 262 locais (símbolos pretos) onde foram obtidas as 909 fotografias usadas para estudar dietas de aves.

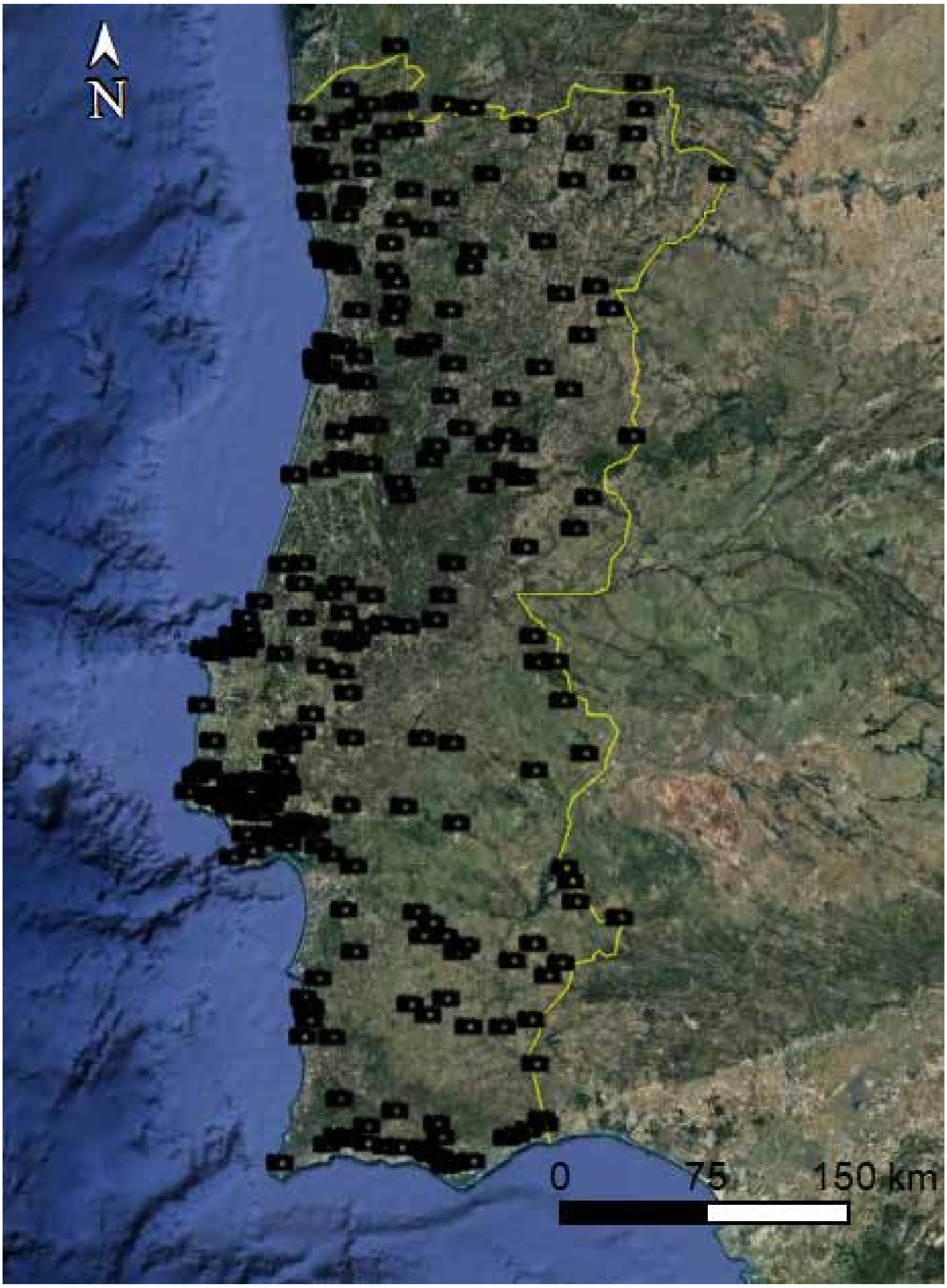


Table 1- Consumed food items detected in photographs of Portuguese birds published on the "Aves de Portugal Continental" Facebook page. For each bird species I present the proportion of food items represented by each main group (mostly at the Class taxonomic rank, but also distinguishing fruits and seeds) and within each group, between brackets, all the lower rank identifications that were possible. I also present the number of photos used (sample size), the geographic coverage dividing Continental Portugal in North (N), Centre (C) and South (S; see Methods), and the seasons when photos were taken (Wi: winter, Sp: spring, Su: summer, Au: autumn). n: necrophagy; J: juvenile or hatchling; e: egg.

Tabela 1 - Itens alimentares consumidos por aves em Portugal, de acordo com fotografias publicadas na página de Facebook "Aves de Portugal Continental". Para cada espécie de ave é apresentada a proporção de itens pertencentes a cada grupo alimentar (sobretudo ao nível taxonómico de Classe, mas também distinguindo frutos e sementes), assim como a lista de todos os itens identificados até níveis taxonómicos inferiores. É também apresentada o número de fotografias utilizadas (tamanho da amostra), a cobertura geográfica dividindo Portugal em Norte (N), Centro (C) e Sul (S; ver Métodos) e as estações do ano em que as fotografias foram obtidas (Wi: inverno, Sp: primavera, Su: verão, Au: outono). n: necrofagia; J: presa juvenil; e: ovo.

SPECIES	SAMPLE SIZE	FOOD ITEMS	COVERAGE	SEASON
Accipiter gentilis Northern Goshawk	2	Birds (100%: *Carduelis carduelis* and *Anas platyrhynchos*)	C,S	Su,Au
Accipiter nisus Eurasian Sparrowhawk	1	Birds (100%: *Passer domesticus*)	N	Sp
Acrocephalus arundinaceus Great Reed Warbler	2	Insects (100%: Lepidoptera larvae and Diptera)	S	Sp,Au
Aegithalus caudatus Long-tailed Tit	3	Fruits (33%: *Diospyrus kaki*); Insects (33%: Coleoptera larvae); Arachnids (33%: Araneae)	N,C	Su,Au
Alcedo atthis Common Kingfisher	40	Fishes (75%: *Anguilla anguilla*[J], *Cobitis paludica*, Cyprinidae, Mugilidae and unidentified); Crustaceans (20%: unidentified shrimp and *Procambarus clarkii*[J]); Amphibians (2.5%: *Pelophylax perezi*); Reptiles (2.5%: *Timon lepidus*[J])	N,C,S	Wi,Sp, Su,Au
Anthus campestris Tawny Pipit	3	Arachnids (67%, Araneae); Insects (33%: Lepidoptera larvae)	S	Su
Anthus petrosus Rock Pipit	1	Crustaceans (100%: *Ligia oceanica*)	C	Au
Anthus pratensis Meadow Pipit	1	Insects (100%: Lepidoptera larvae)	N	Wi
Aquila fasciata Bonelli's Eagle	2	Birds (50%: *Columba livia*); Mammals (50%: *Oryctolagus cuniculus*)	N,S	Wi,Su
Aquila pennata Booted Eagle	3	Birds (100%: *Columba livia* and *Larus fuscus*)	C	Sp,Au
Ardea cinerea Grey Heron	39	Fishes (80%: *Anguilla anguilla, Barbus barbus, Belone belone, Cyprinus carpio, Dicentrarchus labrax, Solea solea, Trachurus trachurus*, Cyprinidae, Mugilidae, Petromyzontidae and unidentified); Mammals (7.5%: *Rattus* sp.); Crustaceans (5%: *Procambarus clarkii*); Amphibians (2.5%: *Pleurodeles waltl*); Cephalopods (2.5%: *Sepia officinalis*); Insects (2.5%: Odonata)	N,C,S	Wi,Sp, Su,Au
Ardea purpurea Purple Heron	4	Amphibians (50%: *Pelophylax perezi*); Fishes (25%: unidentified); Reptiles (25%: *Natrix maura*)	N,C	Wi,Sp,Su

SPECIES	SAMPLE SIZE	FOOD ITEMS	COVERAGE	SEASON
Ardeola ralloides Squacco Heron	6	Amphibians (67%: *Pelophylax perezi*, Ranidae); Crustaceans (33%: *Procambarus clarkii*)	C	Wi,Su
Arenaria interpres Ruddy Turnstone	2	Gastropods (100%: *Patella vulgata, Phorcus lineatus*)	N,S	Sp,Su
Asio flammeus Short-eared Owl	1	Mammals (100%: *Rattus* sp.)	C	Wi
Asio flammeus Short-eared Owl	4	Mammals (100%: *Apodemus sylvaticus*, Muridae)	C	Sp,Su,Au
Athene noctua Little Owl	7	Insects (43%: *Gryllotalpa gryllotalpa,* Coleoptera, Lepidoptera larvae); Mammals (43%: Muridae); Reptiles (14%: *Lacerta schreiberi*)	N,C,S	Sp,Au
Botaurus stellaris Eurasian Bittern	2	Crustaceans (100%: *Procambarus clarkii*)	C	Wi
Bubulcus ibis Cattle Egret	12	Reptiles (25%: *Timon lepidus, Chalcides striatus*, Serpentes); Mammals (25%: *Talpa occidentalis, Rattus norvegicus*); Insects (17%: *Gryllotalpa gryllotalpa*, unidentified); Amphibians (17%: *Pelophylax perezi*); Arachnids (8%: Araneae); Crustaceans (8%: *Procambarus clarkii*)	N,C,S	Wi,Sp, Su,Au
Burhinus oedicnemus Eurasian Thick-knee	2	Insects (100%: Coleoptera, unidentified)	*S*	*Su*
Buteo buteo Eurasian Buzzard	9	Mammals (34%: *Rattus norvegicus*, Muridae, Soricidae); Amphibians (22%: Ranidae, *Hyla arborea*); Crustaceans (22%: *Procambarus clarkii*); Reptiles (11%: Serpentes); Birds (11%: *Limosa limosa*)	*N,C,S*	*Wi,Sp,Au*
Calidris alba Sanderling	*5*	Bivalves (20%: unidentified); Polychaetes (20%: unidentified); Crustaceans (20%: Amphipoda); Fishes (20%: Mugilidaen); Insects (20%: unidentified larvae)	*N,C,S*	*Wi,Sp,Su*
Calidris alpina Dunlin	*1*	Polychaetes (100%: unidentified)	*C*	*Au*
Calidris canutus Red Knot	*2*	Bivalves (50%: unidentified); Polychaetes (50%: unidentified)	*N,S*	*Wi,Sp*
Carduelis carduelis European Goldfinch	*6*	Seeds (83%: Cynareae, unidentified); Fruits (17%: *Arbutus unedo*)	*C,S*	*Wi,Sp,Au*
Carduelis chloris European Greenfinch	*4*	Seeds (50%: *Helianthus* sp., unidentified); Fruits (50%: unidentified berry)	*N,C,S*	*Wi,Sp,Au*
Carduelis spinus Eurasian Siskin	*5*	Seeds (80%: *Betula celtiberica, Platanus* sp., *Pinus pinea*); Fruits (20%: *Arbutus unedo*)	*N,C*	*Wi,Au*
Cercotrichas galactotes Rufous-tailed Scrub-robin	*2*	Insects (100%: Orthoptera)	*S*	*Sp,Su*

SPECIES	SAMPLE SIZE	FOOD ITEMS	COVERAGE	SEASON
Certhia brachydactyla Short-toed Treecreeper	*5*	Insects (80%: Forficulidae, Lepidoptera); Arachnids (20%: Araneae)	*N,C,S*	*Wi,Sp,Au*
Charadrius hiaticula Common Ringed Plover	*6*	Polychaetes (100%: unidentified)	*N,C*	*Wi,Su,Au*
Chlidonias niger Black Tern	*2*	Fishes (50%: unidentified); Insects (50%: Blattoidea)	*C*	*Su,Au*
Ciconia ciconia White Stork	*3*	Crustaceans (67%: *Procambarus clarkii*); Mammals (33%: *Oryctolagus cuniculus*)	*C,S*	*Wi,Sp,Su*
Cinclus cinclus White-throated Dipper	*13*	Insects (100%: Odonata, Odonata larvae and nymphs, Ephemeroptera, unidentified larvae)	*N,C*	*Sp*
Circaetus gallicus Short-toed Snake-eagle	*2*	Reptiles (100%: *Rhinechis scalaris*, Serpentes)	*C*	*Sp,Su*
Circus aeruginosus Western Marsh-harrier	*4*	Amphibians (50%: Anura); Birds (25%: *Anas platyrhynchos*); Insects (25%: unidentified)	*N,C*	*Sp,Au*
Circus pygargus Montagu's Harrier	*2*	Reptiles (50%: Serpentes); Mammals (50%: Muridae)	*S*	*Sp,Su*
Cisticola juncidis Zitting Cisticola	*1*	Insects (100%: Orthoptera)	*S*	*Au*
Clamator glandarius Great Spotted Cuckoo	*8*	Insects (100%: *Lymantria dispar* larvae, *Thaumetopoea pityocampa* larvae, Lepidoptera larvae, Lepidoptera, unidentified larvae	*C,S*	*Sp,Su*
Coccothraustes coccothraustes Hawfinch	*5*	Seeds (100%: unidentified)	*C*	*Sp,Su*
Coracias garrulus European Roller	*5*	Insects (60%: *Gryllotalpa gryllotalpa*, Orthoptera, Tipulidae); Centipedes (20%: Scolopendromorpha); Mammals (20%: Muridae)	*C,S*	*Sp,Su*
Corvus corone Carrion Crow	*1*	Insects (100%: Odonata)	*C*	*Su*
Corvus monedula Eurasian Jackdaw	*2*	Birds (100%: *Delichon urbicum*[J], *Columba livia*[J])	*S*	*Sp*
Cuculus canorus Common Cuckoo	*6*	Insects (100%: *Thaumetopoea pityocampa* larvae, Lepidoptera larvae, unidentified larvae)	*N,C,S*	*Sp,Su*
Cyanopica cyanus Azure-winged Magpie	*7*	Fruits (57%: *Prunus* sp., *Olea europaea*, *Eriobotrya japonica*); Insects (43%: Coleoptera, unidentified	*C,S*	*Sp*
Dendrocopus major Great Spotted Woodpecker	*3*	Insects (67%: Lepidoptera larvae, unidentified larvae); Seeds (33%: unidentified)	*C,S*	*Wi,Sp,Su*
Dendrocopus minor Lesser Spotted Woodpecker	*5*	Insects (100%: Myrmicidae, unidentified larvae)	*C,S*	*Sp,Su*

SPECIES	SAMPLE SIZE	FOOD ITEMS	COVERAGE	SEASON
Egretta alba Great White Egret	*2*	Fishes (100%: Cyprinidae, *Lepomis gibbosus*)	*C*	*Wi,Au*
Egretta garzetta Little Egret	*16*	Fishes (63%: *Anguilla anguilla, Solea solea, Lepomis gibbosus*, Gobiidae, Mugilidae, unidentified); Crustaceans (25%: *Carcinus maenas, Procambarus clarkii*); Polychaetes (6%: unidentified); Insects (6%: Odonata)	*N,C,S*	*Wi,Su,Au*
Elanus caeruleus Black-winged Kite	*13*	Mammals (92%: *Mus* sp., *Rattus* sp., *Microtus* sp., Muridae); Birds (8%: *Motacilla alba*)	*N,C,S*	*Wi,Sp, Su,Au*
Emberiza cia Rock Bunting	*2*	Insects (50%: unidentified larvae); Arachnids (50%: Araneae)	*S*	*Sp*
Emberiza cirlus Cirl Bunting	*3*	Seeds (100%: *Avena* sp., unidentified)	*C,S*	*Wi,Su,Au*
Emberiza citrinella Yellowhammer	*1*	Insects (100%: Orthoptera)	*N*	*Su*
Erithacus rubecula European Robin	*7*	Insects (29%: unidentified larvae); Oligochaetes (29%: Lumbricidae); Fruits (29%: *Pistacia lentiscus, Rubus* sp.); Polychaetes (13% unidentified)	*N,C*	*Wi,Sp,Au*
Falco columbarius Merlin	*2*	Birds (100%: *Motacilla alba*, Passeriformes)	*C*	*Wi*
Falco naumanni Lesser Kestrel	*9*	Insects (56%: Orthoptera); Mammals (22%: Muridae); Reptiles (11%: *Chalcides* sp.); Centipedes (11%: *Scolopendra cingulata*)	*S*	*Sp,Su*
Falco peregrinus Peregrine Falcon	*5*	Birds (100%: *Streptopelia decaocto, Columba livia, Calidris alpina*)	*C,S*	*Wi,Sp*
Falco subbuteo Eurasian Hobby	*2*	Birds (50%: *Passer domesticus*); Insects (50%: unidentified)	*N,C*	*Sp*
Falco tinnunculus Common Kestrel	*18*	Mammals (44%: *Mus* sp., Muridae); Amphibians (28%: *Pelophylax perezi*, Anura); Birds (22%: *Passer domesticus, Sturnus unicolor, Columba livia, Carduelis chloris*); Reptiles (6%: *Tarentola mauritanica*)	*N,C,S*	*Wi,Sp, Su,Au*
Falco vespertinus Red-footed Falcon	*1*	Insects (100%: Orthoptera)	*C*	*Sp*
Ficedula hypoleuca European Pied Flycatcher	*2*	Insects (100%: *Pararge aegeria*, Coleoptera larvae)	*N*	*Au*
Fringilla coelebs Eurasian Chaffinch	*1*	Insects (100%: Lepidoptera larvae)	*N*	*Su*
Fringilla montifringilla Brambling	*1*	Fruits (100%: unidentified berry)	*C*	*Au*

SPECIES	SAMPLE SIZE	FOOD ITEMS	COVERAGE	SEASON
Galerida cristata Crested Lark	*3*	Insects (100%: Orthoptera, unidentified)	*C,S*	*Sp*
Gallinago gallinago Common Snipe	*2*	Oligochaetes (100%: Lumbricidae)	*C*	*Wi*
Garrulus glandarius Eurasian Jay	*23*	Fruits (70%: *Quercus* sp., *Eryobotrya japonica, Juglans regia, Ficus carica*); Insects (17%: Orthoptera, Diptera, unidentified); Birds (9%: *Sylvia atricapilla*[j], *Turdus merula*[e]); Seeds (4%: unidentified)	*N,C,S*	*Wi,Sp,Au*
Gavia immer Common Loon	*2*	Fishes (50%: *Anguilla anguilla*); Crustaceans (50%: *Carcinus maenas*)	*N*	*Wi,Au*
Gelochelidon nilotica Common Gull-billed Tern	*1*	Insects (100%: Odonata)	*C*	*Su*
Glareola pratincola Collared Pratincole	*6*	Insects (100%: *Gryllotalpa gryllotalpa, Crocothemis* sp., Odonata, unidentified)	*C*	*Sp,Su*
Gyps fulvus Griffon Vulture	*6*	Mammals (100%: *Ovis aries*[n], *Bos taurus*[n])	*S*	*Wi,Su*
Haematopus ostralegus Eurasian Oystercatcher	*3*	Bivalves (67%: *Solen marginatus*, unidentified); Gastropods (33%: *Gibbula umbilicalis*)	*N,C,S*	*Wi,Au*
Hippolais polyglotta Melodious Warbler	*3*	Insects (100%: Forficulidae, Hymenoptera, unidentified)	*C*	*Sp,Su*
Hirundo rustica Barn Swallow	*3*	Insects (100%: unidentified)	*N,C,S*	*Sp.Su*
Jynx torquilla Eurasian wryneck	*5*	Insects (100%: Myrmicidae, unidentified)	*C,S*	*Sp,Su,Au*
Lanius collurio Red-backed Shrike	*3*	Insects (67%: Orthoptera, unidentified); Arachnids (33%: Araneae)	*N*	*Sp,Su*
Lanius meridionalis Iberian Grey Shrike	*5*	Insects (60%: Orthoptera, Coleoptera, Odonata); Mammals (20%: Muridae); Reptiles (20%: *Podarcis bocagei*)	*N,C,S*	*Wi,Sp*
Lanius senator Woodchat Shrike	*12*	Insects (67%: *Gryllotalpa gryllotalpa*, Orthoptera, Coleoptera, Odonata, Lepidoptera larvae, unidentified); Centipedes (16.5%: *Scolopendra* sp.); Arachnids (16.5%: Araneae)	*N,C,S*	*Wi,Sp,Su*
Larus audouinii Audouin's Gull	*1*	Crustaceans (100%: *Procambarus clarkii*)	*C*	*Wi*
Larus fuscus Lesser Black-backed Gull	*11*	Crustaceans (45.5%: *Procambarus clarkii, Carcinus maenas*, unidentified crab); Fishes (45.5%: *Mugil cephalus, Halobatrachus didactylus, Anguilla anguilla*, Mugilidae, unidentified); Birds (9%: *Columba livia*)	*N,C*	*Wi,Su,Au*

SPECIES	SAMPLE SIZE	FOOD ITEMS	COVERAGE	SEASON
Larus hyperboreus Glaucous Gull	*1*	Fishes (100%: *Merluccius merluccius*)	*N*	*Wi*
Larus michahellis Yellow-legged Gull	*8*	Birds (25%: *Columba livia, Anas platyrhynchos*[j]); Cephalopods (12.5%: *Sepia officinalis*); Barnacles (12.5%: *Pollicipes pollicipes*); Starfishes (12.5%: unidentified); Fishes (12.5%: *Scyliorhinus canicula*[j]); Mammals (12.5%: *Rattus* sp.); Human refuse (12.5%)	*N,C,S*	*Wi,Sp, Su,Au*
Larus ridibundus Black-headed Gull	*4*	Fishes (50%: *Diplodus sargus, Silurus glanis*); Polychaetes (25%: unidentified); Algae (25%: *Ulva* sp.)	*N,C,S*	*Su,Au*
Limosa lapponica Bar-tailed Godwit	*1*	Polychaetes (100%: unidentified)	*N*	*Au*
Limosa limosa Black-tailed Godwit	*2*	Polychaetes (50%: unidentified); Bivalves (50%: *Scrobicularia plana*)	*N,C*	*Wi,Su*
Loxia curvirostra Red Crossbill	*2*	Seeds (100%: *Pinus pinea*)	*N*	*Wi*
Lullula arborea Wood Lark	*2*	Insects (100%: unidentified, unidentified larvae)	*N*	*Su*
Merops apiaster European Bee-eater	*68*	Insects (99%: *Apis melifera, Bombus terrestris, Xylocopa violacea, Vespa crabro, Vespula vulgaris, Boyeria irene, Cordulegaster boltonii, Orthetrum chrysostigma, Sympetrum fonscolombii, Hippotion celerio, Papilio machaon, Maniola jurtina, Vanessa atalanta,* Vespidae, Sphingidae, Cicadidae, Coleptera, Diptera, Orthoptera, Hemiptera, Odonata, Plecoptera, unidentified); Crustaceans (1%: *Uca tangeri*)	*N,C,S*	*Sp,Su*
Miliaria calandra Corn Bunting	*5*	Insects (100%: Orthoptera, Lepidoptera larvae)	*C,S*	*Sp*
Milvus migrans Black Kite	*11*	Fishes (55%: *Micropterus salmoides*, Mugilidae, Cyprinidae, unidentified); Insects (9%: Orthoptera); Amphibians (9%: *Pelophylax perezi*); Reptiles (9%: Serpentesn); Mammals (9%: *Rattus* sp.); Birds (9%: *Tringa totanus*)	*N,C*	*Sp,Su*
Monticola saxatilis Rufous-tailed Rock-thrush	*1*	Insects (100%: *Gryllotalpa gryllotalpa*)	*N*	*Sp*
Monticola solitarius *Blue Rock-thrush*	*15*	Insects (47%: *Bombus terrestris, Gryllotalpa gryllotalpa*, Coleoptera, Hymenoptera, unidentified larvae); Centipedes (26.5%: *Scolopendra cingulata*); Reptiles (25.5%: *Psammodromus algirus, Tarentola mauritanica, Chalcides bedriagai*)	*N,C,S*	*Sp*

SPECIES	SAMPLE SIZE	FOOD ITEMS	COVERAGE	SEASON
Morus bassanus Northern Gannet	*3*	Fishes (100%: *Belone belone*, unidentified)	*N,C,S*	*Wi,Au*
Motacilla alba White Wagtail	*3*	Insects (100%: Hymenoptera, unidentified)	*N,S*	*Sp,Su,Au*
Motacilla cinerea Grey Wagtail	*6*	Insects (50%: Ephemeroptera, unidentified larvae); Fishes (33%: unidentified); Crustaceans (17%: *Palaemon* sp.)	*N,C,S*	*Wi,Sp, Su,Au*
Motacilla flava Yellow Wagtail	*4*	Insects (75%: Dytiscidae, Diptera, Lepidoptera larvae); Oligochaetes (25%: Lumbricidae)	*N*	*Sp*
Muscicapa striata Spotted Flycatcher	*1*	Insects (100%: Lepidoptera)	*C*	*Au*
Numenius arquata Eurasian Curlew	*1*	Crustaceans (100%: unidentified crab)	*N*	*Wi*
Numenius phaeopus Whimbrel	*5*	Crustaceans (80%: *Carcinus maenas, Uca tangeri*, unidentified crab); Bivalves (20%: *Cerastoderma edule*)	*N,S*	*Wi,Sp,Au*
Nycticorax nycticorax Black-crowned Night-heron	*10*	Fishes (90%: *Anguilla anguilla, Carassius auratus, Mugil cephalus, Chondrostoma* sp., Mugilidae, Cyprinidae); Reptiles (10%: *Natrix maura*)	*C*	*Sp,Su*
Oenanthe hispanica Black-eared Wheatear	*2*	Insects (100%: Orthoptera, Coleoptera)	*S*	*Sp*
Oenanthe oenanthe Northern Wheatear	*1*	Insects (100%: unidentified)	*N*	*Sp*
Oriolus oriolus Eurasian Golden Oriole	*7*	Fruits (86%: *Ficus carica, Morus alba, Prunus* sp.); Insects (14%: Cicadidae)	*N,C,S*	*Sp,Su*
Otus scops Eusarian Scops-owl	*1*	Insects (100%: Lepidoptera)	*N*	*Su*
Pandion haliaetus Osprey	*59*	Fishes (100%: *Liza ramada, Mugil cephalus, Dicentrarchus labrax, Sparus aurata, Carassius auratus, Barbus barbus, Cyprinus carpio*, Mugilidae, unidentified)	*N,C,S*	*Wi,Sp, Su,Au*
Parus ater Coal Tit	*2*	Insects (50%: Coleptera); Arachnids (50%: Araneae)	*N*	*Sp*

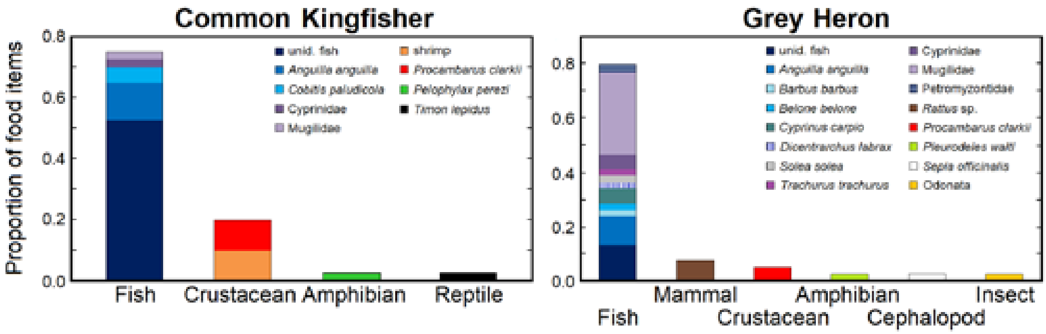
SPECIES	SAMPLE SIZE	FOOD ITEMS	COVERAGE	SEASON
Parus caeruleus Blue Tit	*12*	Insects (50%: Lepidoptera larvae, unidentified larvae, unidentified); Fruits (25%: *Diospyrus kaki*, *Prunus* sp.); Arachnids (17%: Araneae); Seeds (8%: unidentified)	*N,C,S*	*Wi,Sp*
Parus cristatus Crested Tit	*1*	Seeds (100%: *Pinus pinea*)	*C*	*Wi*
Parus major Great Tit	*9*	Insects (55%: Lepidoptera larvae, unidentified); Fruits (23%: *Quercus* sp., unidentified berry); Arachnids (11%: Araneae); Seeds (11%: unidentified)	*N,C,S*	*Sp,Au*
Passer domesticus House Sparrow	*10*	Seeds (70%: Helianthus sp., unidentified); Insects (30%: Coleptera, Hemiptera, unidentified larvae)	*N,C,S*	*Sp,Su*
Passer montanus Eurasian Tree Sparrow	*2*	Seeds (50%: unidentified); Insects (50%: unidentified larvae)	*N*	*Sp,Su*
Phalacrocorax aristotelis European Shag	*1*	Fishes (100%: Gobiidae)	*C*	*Au*
Phalacrocorax carbo Great Cormorant	*21*	Fishes (100%: *Anguilla anguilla, Solea solea, Conger conger, Scorpaena scrofa, Micropterus salmoides, Silurus glanis, Cyprinus carpio, Barbus* sp., Mugilidae, Pleuronectiformes, unidentified)	*N,C,S*	*Wi,Sp,Au*
Phoenicuros ochruros Black Redstart	*9*	Insects (89%: Tipulidae, Tettigonidae, Lepidoptera, Lepidoptera larvae, Diptera, Hymenoptera, unidentified larvae), Arachnids (11%: Araneae)	*N*	*Sp,Su,Au*
Phylloscopus collybita ibericus Common/Iberian Chiffchaff	*7*	Insects (57%: *Xanthogramma* sp., Diptera, unidentified, unidentified larvae); Fruits (29%: *Diospyrus kaki*); Nectar (*Aloe* sp.)	*C,S*	*Wi,Au*
Phylloscopus trochilus Willow Warbler	*2*	Insects (100%: unidentified)	*N*	*Su,Au*
Pica pica Eurasian Magpie	*4*	Insects (50%: Lepidoptera larvae), Birds (25%: unidentified egg); Fruits (25%: *Quercus* sp.)	*N,C,S*	*Wi,Sp,Au*
Platalea leucorodia Eurasian Spoonbill	*5*	Fishes (80%: Mugilidae, Pleuronectiformes, unidentified); Crustaceans (*Procambarus clarkii*)	*N,C*	*Wi,Sp,Au*
Plegadis falcinellus Glossy Ibis	*8*	Crustaceans (75%: *Procambarus clarkii*); Amphibians (25%: *Pelophylax perezi, Pleurodeles waltl*)	*C,S*	*Wi,Sp,Au*
Pluvialis apricaria Eurasian Golden Plover	*2*	Insects (100%: unidentified larvae)	*N,S*	*Au*
Pluvialis dominica American Golden Plover	*3*	Polychaetes (67%: unidentified); Crustaceans (33%: unidentified crab)	*N*	*Au*
Pluvialis squatarola Grey Plover	*5*	Polychaetes (100%: unidentified)	*N,C*	*Wi,Sp,Au*

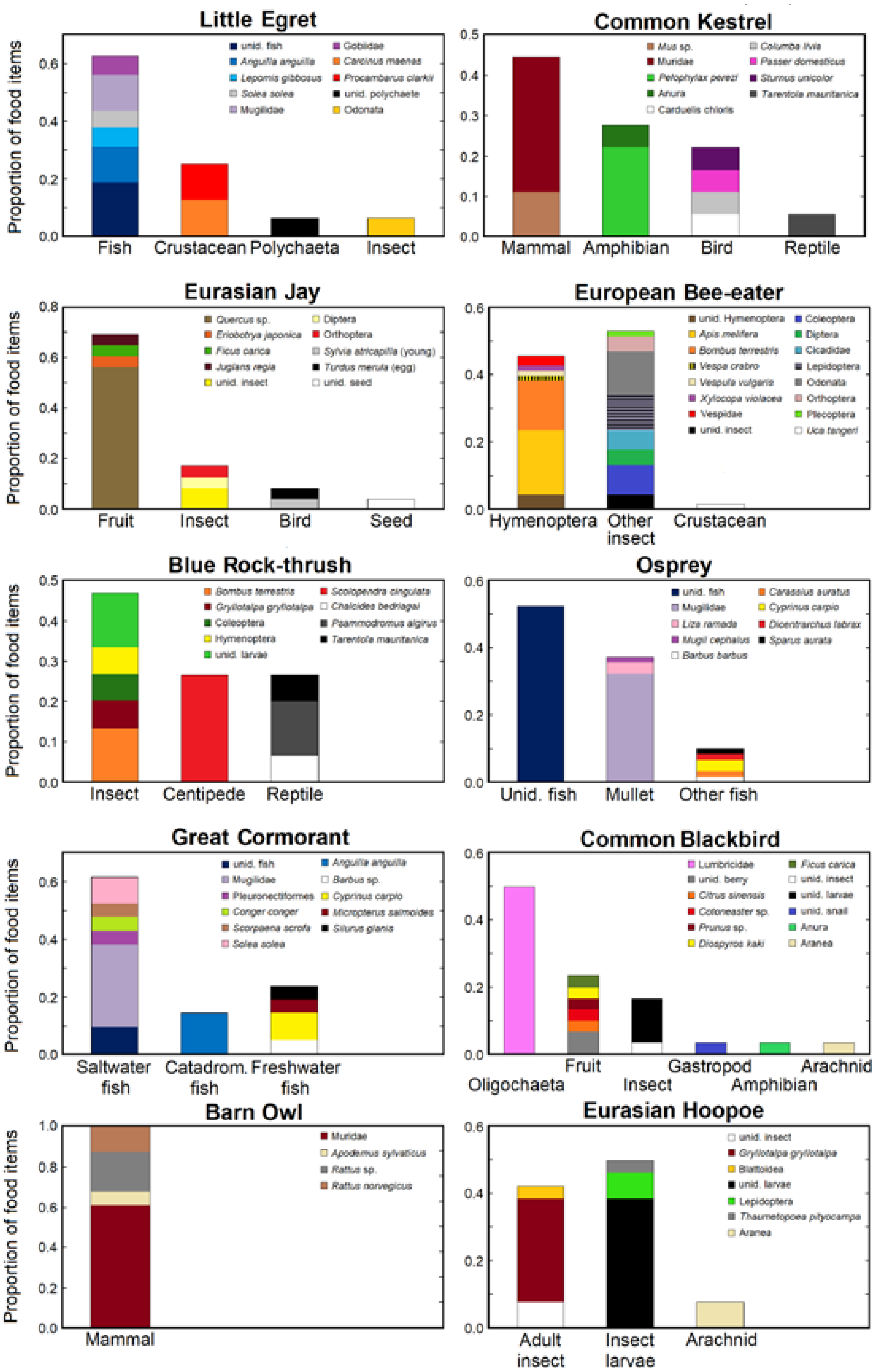
SPECIES	SAMPLE SIZE	FOOD ITEMS	COVERAGE	SEASON
Podiceps cristatus Great Crested Grebe	*3*	Fishes (100%: *Solea solea*, *Conger conger*, unidentified)	*S*	*Sp,Su*
Porphyrio martinica Americn Purple Gallinule	*1*	Amphibians (100%: *Pelophylax perezi*)	*C*	*Au*
Psittacula krameri Ring-necked Parakeet	*6*	Fruits (100%: *Celtia australis, Melia azedarach, Cupressus lusitanica, Eryobotria japonica, Morus* sp., *Acacia* sp.)	*C*	*Wi,Sp, Su,Au*
Regulus ignicapillus Firecrest	*2*	Insects (100%: Orthoptera)	*C*	*Wi,Au*
Saxicola rubicola European Stonechat	*13*	Insects (85%: Gomphidae, Odonata, Coleoptera, Orthoptera, Diptera, Lepidoptera larvae, unidentified, unidentified larvae); Centipedes (7.5%: unidentified); Reptiles (7.5%: *Podarcis* sp.)	*N,C*	*Wi,Sp, Su,Au*
Sitta europaea Wood Nuthatch	*6*	Insects (50%: Coleoptera, Lepidoptera larvae, unidentified); Seeds (50%: *Pinus pinea*, unidentified)	*N,C,S*	*Wi,Sp,Su*
Sterna albifrons Little Tern	*1*	Fishes (100%: unidentified)	*C*	*Sp*
Sterna sandvicensis Sandwich Tern	*3*	Fishes (100%: *Ammodytes tobianus*, unidentified)	*N,C,S*	*Wi,Au*
Sturnus unicolor Spotless Starling	*7*	Insects (43%: Gryllidae, Diptera, unidentified larvae); Fruits (43%: *Ficus carica, Prunus* sp., *Rubus* sp.); Oligochaetes (16%: Lumbricidae)	*N,C,S*	*Sp,Au*
Sturnus vulgaris Common Starling	*1*	Fruits (100%: *Diospyros kaki*)	*N*	*Au*
Sylvia atricapilla Blackcap	*10*	Fruits (90%: *Arbutus unedo, Eriobotrya japonica, Diospyros kaki, Pyracantha* sp., Aracacea, unidentified berry); Gastropods (10%: unidentified snail)	*N,C,S*	*Wi,Sp,Au*
Sylvia borin Garden Warbler	*1*	Fruits (100%: *Ficus carica*)	*C*	*Su*
Sylvia cantillans Subalpine Warbler	*1*	Insects (100%: Vespidae)	*S*	*Au*
Sylvia communis Common Whitethroat	*3*	Fruits (100%: *Rubus* sp., unidentified berry)	*N,S*	*Su,Au*
Sylvia melanocephala Sardinian Warbler	*6*	Fruits (50%: *Pyracantha* sp., *Rubus* sp., *Diospyros kaki*); Insects (33%: Lepidoptera larvae); Arachnids (17%: Araneae)	*N,C,S*	*Wi,Sp, Su,Au*
Sylvia undata Dartford Warbler	*3*	Insects (67%: Tipulidae, Orthoptera); Arachnids (33%: Araneae)	*N,C,S*	*Sp,Su*

SPECIES	SAMPLE SIZE	FOOD ITEMS	COVERAGE	SEASON
Tachybaptus ruficollis Little Grebe	1	Crustaceans (100%: unidentified shrimp)	C	Wi
Tringa nebularia Common Greenshank	3	Crustaceans (67%: *Carcinus maenas*, unidentified crab); Polychaetes (33%: unidentified)	N,C	Wi,Su
Tringa ochropus Green Sandpiper	1	Crustaceans (100%: *Atyaephyra desmarestii*)	S	Su
Troglodytes troglodytes Eurasian Wren	8	Insects (100%: *Clytus arietis*, Odonata, Lepidoptera, unidentified larvae, unidentified)	N,C	Wi,Sp
Turdus merula Common Blackbird	30	Oligochaetes (50%: Lumbricidae); Fruits (24%: *Ficus carica*, *Diospyros kaki*, *Citrus sinensis*, *Prunus* sp., *Cotoneaster* sp., unidentified berry); Insects (17%: unidentified insect, unidentified larvae); Gastropods (3%: unidentified snail); Amphibians (3%: Anura); Arachnids (3%: Araneae)	N,C,S	Wi,Sp, Su,Au
Turdus philomelus Song Thrush	6	Gastropods (50%: unidentified snail); Oligochaetes (33%: Lumbricidae); Fruits (17%: *Diospyros kaki*)	N,C	Wi,Sp, Su,Au
Tyto alba Barn Owl	17	Mammals (100%: *Rattus norvegicus*, *Apodemus sylvaticus*, *Rattus* sp. Muridae)	C	Wi,Su,Au
Upupa epops Common Hoopoe	26	Insects (92%: *Gryllotalpa gryllotalpa*, *Thaumetopoea pityocampa* larvae, Blattoidea, Lepidoptera larvae, unidentified larvae, unidentified), Arachnids (8%: Araneae)	N,C,S	Wi,Sp, Su,Au

Fig. 2- Diet composition of the twelve best sampled species, based on the analysis of photographs posted on the "Aves de Portugal Continental" Facebook page. Sample sizes: Common Kingfisher, n=40; Grey Heron, n=39; Little Egret, n=16; Common Kestrel, n=18; Eurasian Jay, n=23; European Bee-eater, n=68; Blue-rock Thrush, n=15; Osprey, n=59; Great Cormorant, n=21; Common Blackbird, n=30; Barn Owl, n=15; and Eurasian Hoopoe, n=26.

Fig. 2 - Composição da dieta das doze espécies melhor amostradas, de acordo com a análise de fotografias publicadas na página de Facebook "Aves de Portugal Continental". Número de amostras: Guarda-rios, n=40; Garça-real, n=39; Garça-branca-pequena, n=16; Peneireiro-comum, n=18; Gaio, n=23; Abelharuco, n=68; Melro-azul, n=15; Águia-pesqueira, n=59; Corvo-marinho-de-faces-brancas, n=21; Melro-preto, n=30; Coruja-das-torres, n=15; e Poupa, n=26.





Little Egret
Proportion of food items
0.0
0.2
0.4
0.6
Fish
Crustacean
Polychaeta
Insect
unid. fish
Anguilla anguilla
Lepomis gibbosus
Solea solea
Mugilidae
Gobiidae
Carcinus maenas
Procambarus clarkii
unid. polychaete
Odonata
Common Kestrel
0.0
0.1
0.2
0.3
0.4
0.5
Mammal
Amphibian
Bird
Reptile
Mus sp.
Muridae
Pelophylax perezi
Anura
Carduelis chloris
Columba livia
Passer domesticus
Sturnus unicolor
Tarentola mauritanica
Eurasian Jay
Proportion of food items
0.0
0.2
0.4
0.6
0.8
Fruit
Insect
Bird
Seed
Quercus sp.
Eriobotrya japonica
Ficus carica
Juglans regia
unid. insect
Diptera
Orthoptera
Sylvia atricapilla (young)
Turdus merula (egg)
unid. seed
European Bee-eater
0.0
0.2
0.4
0.6
Hymenoptera
Other insect
Crustacean
unid. Hymenoptera
Apis melifera
Bombus terrestris
Vespa crabro
Vespula vulgaris
Xylocopa violacea
Vespidae
unid. insect
Coleoptera
Diptera
Cicadidae
Lepidoptera
Odonata
Orthoptera
Plecoptera
Uca tangeri
Blue Rock-thrush
Proportion of food items
0.0
0.1
0.2
0.3
0.4
0.5
Insect
Centipede
Reptile
Bombus terrestris
Gryllotalpa gryllotalpa
Coleoptera
Hymenoptera
unid. larvae
Scolopendra cingulata
Chalcides bedriagai
Psammodromus algirus
Tarentola mauritanica
Osprey
0.0
0.2
0.4
0.6
Unid. fish
Mullet
Other fish
unid. fish
Mugilidae
Liza ramada
Mugil cephalus
Barbus barbus
Carassius auratus
Cyprinus carpio
Dicentrarchus labrax
Sparus aurata
Great Cormorant
Proportion of food items
0.0
0.2
0.4
0.6
Saltwater fish
Catadrom. fish
Freshwater fish
unid. fish
Mugilidae
Pleuronectiformes
Conger conger
Scorpaena scrofa
Solea solea
Anguilla anguilla
Barbus sp.
Cyprinus carpio
Micropterus salmoides
Silurus glanis
Common Blackbird
0.0
0.2
0.4
0.6
Oligochaeta
Fruit
Insect
Gastropod
Amphibian
Arachnid
Lumbricidae
unid. berry
Citrus sinensis
Cotoneaster sp.
Prunus sp.
Diospyros kaki
Ficus carica
unid. insect
unid. larvae
unid. snail
Anura
Aranea
Barn Owl
Proportion of food items
0.0
0.2
0.4
0.6
0.8
1.0
Mammal
Muridae
Apodemus sylvaticus
Rattus sp.
Rattus norvegicus
Eurasian Hoopoe
0.0
0.2
0.4
0.6
Adult insect
Insect larvae
Arachnid
unid. insect
Gryllotalpa gryllotalpa
Blattoidea
unid. larvae
Lepidoptera
Thaumetopoea pityocampa
Aranea

Common Kingfisher *Alcedo atthis*

Kingfishers fed mainly on fish (75%) and crustaceans (20%), with two cases of predation on amphibians and reptiles (Fig. 2). The diet of this species had not been previously studied in Portugal (Catry et al. 2010). Although kingfishers are known to routinely consume non-fish prey (e.g. Snow & Perrins 1998), the present data suggested a much higher proportion of crustaceans than that observed elsewhere in Europe (e.g. Reynolds & Hinge 1996, Vilches et al. 2012, Čech & Čech 2015), which may be related to the consumption of the introduced Red-Swamp Crayfish that has become an important prey for several mammals and birds in Portugal and southern Spain (Correia 2001).

Grey Heron *Ardea cinerea*

Grey Herons predominantly took fish (80%), with a wide variety of secondary prey such as rats *Rattus* sp., Red-Swamp Crayfish, Iberian Ribbed Newt *Pleurodeles waltl*, Common Cuttlefish *Sepia officinalis* and dragonflies (Odonata, Fig. 2). Similarly to what had been described for the Tejo estuary (Moreira 1992) and Santo André lagoon (Catry 1993), the most common fish prey that could be identified were mullets (31%) and European Eel (10%, Fig. 2). Although the Red-Swamp Crayfish has been described as a frequent prey for Grey Herons (e.g. Catry 1993, Correia 2001), it only occurred twice in the 39 photographs that were analysed.

Little Egret *Egretta garzetta*

Little Egrets fed mainly upon fish (63%) and crustaceans (25%), with polychaetes and dragonflies as secondary prey (Fig. 2). Previous work in the Tejo estuary (Moreira 1992) and Boquilobo marsh (Cardoso 1994) also highlighted the importance of fish and crustaceans for this species. However some prey such as gobies *Pomatoschistus* sp. and Brown Shrimp *Crangon crangon*, which were described as common prey in the Tejo estuary (Moreira 1992), were seldom or never observed in the analysed photographs. Such differences could arise from a bias caused by the difficulty in identifying smaller prey in photographs.

Common Kestrel *Falco tinnunculus*

On the 18 analysed Common Kestrel photographs, the most common prey were mammals (44%), amphibians (28%) and birds (22%). Particularly, murid rodents, Iberian Green Frog and passerines represented 83% of identified prey (Fig. 2). The importance of rodents and passerines for common kestrels in Portugal had already been described (Fonseca 1994), but that study also indicated that insects, which were absent from the analysed photographs, represented 38% of prey found in pellets collected around Lisboa. Although frogs had been previously recorded as Common Kestrel prey in other parts of their range (e.g. Korpimäki 1985), they typically represent a very small proportion of the diet. The large proportion of frogs in the analysed photographs was most likely due to a geographic bias as these frogs were found exclusively on photographs taken at Ponta da Erva, an agricultural area north of the Tejo estuary where they seem to be an important prey for the Common Kestrel (71% of prey, n=7 photographs).

Eurasian Jay *Garrulus glandarius*

Eurasian Jays fed predominantly on plants, including both fruits (70%) and seeds (4%, Fig. 2). Insects (17%) and passerine eggs and nestlings (9%) were also observed in the photographs. The most frequently recorded fruits were oak *Quercus* sp. acorns (57%), but jays were also photographed taking figs *Ficus carica*, walnuts *Juglans regia* and loquats *Eriobotrya japonica*. Although there was no previous published data on their diet in Portugal (Catry et al. 2010), jays are also known to be omnivorous and rely heavily on *Quercus* sp. acorns in other parts of their range (e.g.

Patterson et al. 1991, Clayton et al. 1996), while being often reported as predators of passerine nests (e.g. Moreira & Mota 1998, Weidinger 2009).

European Bee-eater *Merops apiaster*

The diet of European Bee-eaters consisted almost exclusively of insects (99%, Fig. 2), with one case of a bird eating the claw of a Fiddler Crab *Uca tangeri*. Among insects, the most important were Hymenoptera (46%), but Honey Bees *Apis melifera* only represented 19% of prey (Fig. 2). This large relative importance of Hymenoptera had also been reported in various parts of their breeding range (Costa 1991, Inglisa et al. 1993, Kristin 1994, Galeotti & Inglisa 2001). However, this species is also reported to exhibit high diet diversity (e.g. Kristin 1994) with hundreds of different insect species listed as prey of European Bee-eater (Kristin 1994, Galeotti & Inglisa 2001). The analysed photographs evidence the consumption of at least eight insect orders, the most relevant after Hymenoptera being Odonata (13%, including *Boyeria irene*, *Cordulegaster boltonii*, *Orthetrum chrysostigma* and *Sympetrum fonscolombii*) and Lepidoptera (10%, including *Hippotion celerio*, *Maniola jurtina*, *Papilio machaon* and *Vanessa atalanta*), which differs from a previous study indicating Coleoptera and Diptera as the main secondary prey for European Bee-eaters in Portugal (Costa 1991). The importance of Honey Bees in bee-eater diet varies depending on the abundance of bee hives (e.g. Costa 1991, Galeotti & Inglisa2001), so the prevalence of this prey in the present data set was most likely related to the proportion of photographs taken in areas with and without apiculture.

Blue Rock-thrush *Monticola solitarius*

Blue Rock-thrushes fed on insects (47%), centipedes (26.5%) and reptiles (26.5%), the most important individual prey being *Scolopendra cingulata* (26.5%, Fig. 2). Although photographs range from north (Peso da Régua) to south (Tavira) of the country, the majority (87%, n=15) originate from just two areas, Peso da Régua and Arouca, so these results may be biased for prey availability in those regions. Although there was no previous published information on the diet of Blue Rock-thrush in Portugal (Catry et al. 2010), insects and other invertebrates, as well as small reptiles and amphibians are also reported in their diet in other parts of their range (Snow & Perrins 1998).

Osprey *Pandion haliaetus*

Osprey was the second most common bird species in the analysed photographs (n=59). Unsurprisingly, all photographed Ospreys were taking fish (Fig. 2). Most of the fish were not possible to identify (53%), but mullets represented at least 37% of their diet (Fig. 2) and are likely to be also a large proportion of the unidentified specimens. The importance of mullets for Ospreys had already been noted in a previous study performed along the south-western coast of Portugal (Palma et al. 1986). However, that study suggested European Carps *Cyprinus carpio* were also a key prey for Ospreys, while the present data suggested they represent less than 5% of all taken prey (Fig. 2). Such a difference may arise from the large proportion of Osprey photographs obtained in and around estuarine areas (83%, n=59), where mullets are very abundant (e.g. Costa & Bruxelas 1989). However, estuaries are in fact the most commonly used habitat by Ospreys wintering in Portugal (Torralvo et al. 2018), so the present data is likely to reflect the true importance of mullets for this piscivorous predator, at least along the Portuguese coast.

Great Cormorant *Phalacrocorax carbo*

Great Cormorants fed exclusively on fish (Fig. 2), mainly species found in salt and brackish water (62%), but also fresh water species (24%) and European Eels (14%)

which are catadromous migrants. The proportion of fresh water fishes reflects the proportion of photographs taken in inland water bodies versus those obtained in estuarine areas and along the coast. In salt and brackish water environments, Great Cormorants fed mainly on mullets (29%), eels (14%) and Common Sole *Solea solea* (10%, Fig. 2), which were also important prey in previous studies performed in the Algarve (Grade & Granadeiro 1997), Santo André lagoon (Catry 1993) and the Sado estuary (Granadeiro et al. 2013). Although this species is widely regarded as an aquaculture pest (e.g. Garcia 2000), the two most common aquaculture fishes in Portugal, European Sea Bass *Dicentrachus labrax* and Gilthead Seabream *Sparus aurata* were not observed in any of the 21 analysed photographs.

Common Blackbird *Turdus merula*

Blackbirds relied heavily on earthworms, which represented 50% of all food items observed in photographs (Fig. 2). Fruits (23%) and insects (17%) were also observed frequently, with single records of a spider, an anuran and a snail also being taken (Fig. 2). The diet of this species had not been previously studied in Portugal, but in other parts of their range they are known to feed mainly on earthworms and insects during spring and summer, with a higher frequency of fruits and berries during autumn and winter (Snow & Perrins 1998). Similarly, in the present data set fruits represented 60% of the diet in autumn and winter (n=5 photographs), but just 20% during spring and summer (n=25 photographs).

Barn Owl *Tyto alba*

The diet of this species had already been widely studied in Portugal (e.g. Buckley 1976, Tomé 1994, Catry et al. 2010, Vale-Gonçalves & Cabral 2014), evidencing the importance of small rodents and, to a lesser extent, shrews in barn owl diets. Although barn owls occasionally also take birds, amphibians and insects (Catry et al. 2010), all 15 analysed photographs exhibited rodent prey, 67% of which were rodents from the family Muridae while the remaining 33% were rats (Fig. 2). Voles and shrews were absent from the photographs, despite being important prey for barn owls in some areas (e.g. Tomé 1994, Vale-Gonçalves & Cabral 2003), but I believe this was not caused by identification issues as several photographs with murids were shown to a micromammal expert.

Eurasian Hoopoe *Upupa epops*

Photographed hoopoes were mostly eating insects, both larvae (50%) and adults (42%), as well as a few spiders (8%, Fig. 2). The most frequently recorded adult insects were European Mole Crickets (31%, Fig. 2). The majority of larvae were impossible to identify, but all identified larvae were Lepidoptera, including one individual of Pine Processionary *Thaumetopoea pityocampa*, a troublesome pest for pine plantations in Portugal (e.g. Gatto et al. 2009). Large insects and their larvae, including European Mole Crickets, also form the bulk of hoopoe diets elsewhere in Europe (e.g. Snow & Perrins 1998, Fournier & Arlettaz 2001) and they have been reported as important predators of pine processionary in Italy (Battisti et al. 2000). Although there were no previous detailed studies in Portugal, Catry et al. (2010) already mentioned anecdotal evidence for the importance of mole crickets for hoopoes in Portugal.

Biases and other issues of the method, and way forward

Although photographs posted on internet forums are clearly a valuable source of dietary data, such data also suffers from several types of biases. Despite the wide territorial coverage of the analysed photographs, they tend to be concentrated near human settlements. Also, human influenced habitats, such as urban parks, agricultural areas and beaches, are much more likely to be sampled through this method than other less accessible habitats. In fact, opportunistic data from citizen science typically suffer from such spatial biases, the most important factor being path density (Tiago et al. 2017b). This means that prey types being photographed are more often those that these avian species consume in human-altered environments. Since there is no control over where the photographs are originating from, the dataset can also be biased in favour of prey that are only common in a specific location from which there are a disproportionate number of photograph, such as the case of frogs in common kestrel diet that was discussed above. However, in a larger dataset such issues could be solved by sub-sampling photographs with a geographic stratification.

Another potential issue, especially in the case of scarce species, is that photographers may consistently photograph the same individual, because it is particularly easy to access. In that way, data may not accurately express the diet of the species, but only of that specific individual in a specific location.

Data from photographs are also more likely to be biased in favour of larger prey, which are more likely to be identifiable in a photograph. Although such prey will also likely be more important in terms of consumed biomass, it is possible that the importance of small but highly frequent prey will be underestimated. If such prey are mostly consumed in a specific season, or through a specific behaviour, such as during nest provisioning when birds are more likely to carry prey instead of consuming it on the spot, this may lead to seasonal or behavioural biases. Such biases are common to most other methods of diet analysis as there are always prey that will be less likely to be detected by any given method (e.g. Rosenberg & Cooper 1990, Pierce & Boyle 1991). Additionally, and although I excluded photographs with prey items they were likely provided as lure by photographers, it is impossible to rule out completely that some lures were still included in this analysis. This may well be the case of micromammal in the diets of European Rollers and Lesser Kestrel for although these birds do occasionally consume small mammals (Snow & Perrins 1998), they are not as widely consumed as the present data would suggest (e.g. Catry et al. 2018, Rodríguez et al. 2010).

Despite these biases, and the fact that secretive species or those that specialize in very small prey are unlike to be sampled through this method, I believe internet photography could be an invaluable source of avian dietary data. This could best work through an open web-enabled platform which would include both nature photographers and biologists. Nature photographers could post their photographs of foraging birds, and these could be later screened by biologists who would provide identifications of the prey items being taken. The development of such a platform would originate an ever increasing dataset of casuistic observations covering an increasing number of avian species. If photographs could be coupled with data on time, date, location and also habitat, the dataset would be increasingly robust against biases and provide each day a more reliable picture of avian diets in Portugal as a whole, in specific regions and also of how diets vary seasonally and spatially. This could potentially be done through existing biodiversity databases who already couple random observers and experts to obtain reliable data on the distribution and seasonal occurrence of wildlife.

Acknowledgements

I would like to thank the many photographers and nature lovers who posted the photographs that were here used to access avian diets. The full list would include 300 names, so I won't thank each photographer individually, but special thanks are due to Armando Caldas and José Frade who manage the page and together produced 59 of the photographs that were used. I would also like to thank several experts who helped identify food items, namely Filipe Ribeiro, Israel Silva, Joaquim Tapisso, Miguel Porto, Renato Barragão and Roland van Steen, as well as two reviewers who provided useful comments to an earlier version of this paper.

References

Battisti, A., Bernardi. M. & Ghiraldo, C. 2000. Predation by the hoopoe (*Upupa epops*) on pupae of *Thaumetopoea pityocampa* and the likely influence of other natural enemies. Biocontrol 45: 311-323.

Bojarska, K. & Selva, N. 2011. Spatial patterns in brown bear *Ursus arctos* diet: the role of geographic and environmental factors. Mammal Review 42: 120-143.

Buckley, J. 1976. Barn owl (*Tyto alba*) pellets from Portugal. Boletim da Sociedade Portuguesa de Ciências Naturais 16: 133-136.

Cardoso, A.C. 1994. Uso do habitat e sucesso alimentar dos ardeídeos do Paul do Boquilobo. BSc thesis. Faculty of Sciences of the University of Lisboa, Lisboa.

Catry, I., Sampaio, A., Silva, M.C., Moreira, F., Franco, A.M.A. & Catry, T. 2018. Combining stable isotope analysis and conventional techniques to improve knowledge of the diet of the European roller *Coracias garrulus*. Ibis doi 10.1111/ibi.12625.

Catry, P. 1993. A avifauna da lagoa de Santo André. Caracterização, impacto das actividades humanas e propostas de gestão. BSc thesis. Faculty of Sciences of the University of Lisboa, Lisboa.

Catry, P., Costa, H., Elias, G. & Matias, R. 2010. Aves de Portugal. Ornitologia do território continental. Assírio & Alvim, Lisboa.

Čech, M. & Čech, P. 2015. Non-fish prey in the diet of an exclusive fish-eater: the common kingfisher *Alcedo atthis*. Bird Study 62: 457-465.

Chinery, M. 1993. Insects of Britain and northern Europe. 3rd edition. Harper Collins Publishers, London.

Clayton, N.S., Mellor, R. & Jackson, A. 1996. Seasonal patterns of food storing in the jay *Garrulus glandarius*. Ibis 138: 250-255.

Correia, A.M. 2001. Seasonal and interspecific evaluation of predation by mammals and birds on the introduced red swamp crayfish Procambarus clarkii (*Crustacea, Cambaridae*) in a freshwater marsh (Portugal). Journal of Zoology 255: 533-541.

Costa, L.T. 1991. Apiculture and the diet of breeding European bee-eater *Merops apiaster*. Airo 2: 34-40.

Costa, M.J. & Bruxelas, A. 1989. The structure of fish communities in the Tagus estuary, Portugal, and its role as a nursery for commercial fish species. Scientia Marina 53: 561-566.

Ferrand de Almeida, N., Ferrand de Almeida, P., Gonçalves, H., Sequeira, F., Teixeira, J. & Ferrand de Almeida, F.. 2001. Anfíbios e répteis de Portugal. FAPAS, Porto.

Fonseca, J.P. 1994. Aspectos da ecologia trófica e da biologia da reprodução do peneireiro-de-dorso-malhado (*Falco tinnunculus*, Linnaeus, 1758). BSc thesis. Faculty of Sciences of the University of Lisboa, Lisboa.

Fournier, J. & Arlettaz, R. 2001. Food provision to nestlings in the hoopoe *Upupa epops*: implications for the conservation of a small endangered population in the Swiss Alps. Ibis 143: 2-10.

Galeotti, P. & Inglisa, M. 2001. Estimating predation impact on honeybees *Apis melifera* L. by European bee-eaters *Merops apiaster* L. Revue d'Écologie 56: 373-388.

Garcia, G.M.D. 2000. A população de corvos-marinhos-de-faces-brancas *Phalacrocorax carbo* na Reserva Natural do estuário do Sado. BSc thesis. Instituto de Conservação da Natureza, Setúbal.

Gatto, P., Zocca, A., Battisti, A., Barrento, M.J., Branco, M. & Paiva, M.R. 2009. Economic assessment of managing processionary moth in pine forests: A case-study in Portugal. Journal of Environmental Management 90: 683-691.

Grade, N. & Granadeiro, J.P. 1997. Cormorant wintering in Portugal: the case o Ria Formosa Natural Park. Supplemento alle Ricerche di biologia della Selvaggina 26: 465-468.

Granadeiro, J.P., Catry, T., Catry, P., Pereira, S. & Campos, A. 2013. Distribuição e impacto do corvo-marinho-de-faces-brancas sobre as comunidades ictiológicas do estuário do Sado. Unpublished report. Tróia-Natura S.A., Setúbal.

Greenwood, J.J.D. 2007. Citizens, science and bird conservation. Journal of Ornithology 148: Suppl.77–124.

Inglisa, M., Galeotti, P. & Taglianti, A.V. 1993. The diet of a costal population of European bee-eater *(Merops apiaster)* compared to prey availability (Tuscany, central Italy). Bolletino di Zoologia 60: 307-310.

Korpimäki, E. 1985. Diet of the kestrel *Falco tinnunculus* in the breeding season. Ornis Fennica 62: 130-137.

Kristin, A. 1994. Breeding biology and diet of the bee-eater *(Merops apiaster)* in Slovakia. Biologia, Bratislava 49: 18-23.

Lourenço, P.M., Alves, J.A., Catry, T. & Granadeiro, J.P. 2015. Foraging ecology of sanderlings *Calidris alba* wintering in estuarine and non-estuarine intertidal areas. Journal of Sea Research 104: 33-40.

MacDonald, D. & Barret, P. 1993. Mammals of Britain and Europe. Harper Collins Publishers, London.

Moreira, F. 1992. Aves piscívoras em ecossistemas estuarinos: a dieta da garça-branca pequena *Egretta garzetta* e da garça-real *Ardea cinerea* num banco de vasa no estuário do Tejo. Airo 3: 9-12.

Moreira, M. & Mota, P.G. 1998. Nest predation in the serin *Serinus serinus* (Aves: Fringillidae) and predator identification using artificial nests. Acta Ethologica 1: 81-87.

Munson, M.A., Caruana, R., Fink, D., Hochachka, W.M., Iliff, M., Rosenberg, K.V., Sheldon, D., Sullivan, B.L., Wood, C. & Kelling, S. 2010. A method for measuring the relative information content of data from different monitoring protocols. Methods in Ecology and Evolution 1: 263-273.

Olff, H., Alonso, D.A., Berg, M.P., Eriksson, B.K., Loreau, M., Piersma, T. & Rooney, N. 2009. Parallel ecological networks in ecosystems. Philosophical Transactions of the Royal Society of London B 364: 1755–1779.

Palma, L., Fonseca, L. & Beja, P. 1986. A população residual de *Pandion haliaetus* em Portugal de 1979-1986 - fenologia, produtividade, regime trófico e conservação. V Conferência Internacional sobre Rapinas Mediterrâncias, Évora.

Patterson, I.J., Cavallini, P. & Rolando, A. 1991. Density, range size and diet of the European jay *Garrulus glandarius* in the

Maremma Natural Park, Tuscany, Italy, in summer and autumn. Ornis Scandinavica 22: 79-87.

Pierce, G.J. & Boyle, P.R. 1991. A review of methods for diet analysis in piscivorous marine mammals. Oceanography and Marine Biology, an Annual Review 29: 409-486.

Piersma, T. 2012. What is habitat quality? Dissecting a research portfolio on shorebirds. In: Fuller, R.J. (ed) Birds and habitat: relationships in changing landscapes. Cambridge University Press, Cambridge, pp. 383–407.

Pimm, S.L., Lawton, J.H. & Cohen, J.E. 1991. Food web patterns and their consequences. Nature 350: 669–674.

Reynolds, S.J. & Hinge, M.D.C. 1996. Foods brought to the nest by breeding kingfishers *Alcedo atthis* in the New Forest of southern Englang. Bird Study 43: 96-102.

Rodríguez, C., Tapia, L., Kieny, F. & Bustamante, J. 2010. Temporal changes in the lesser kestrel *(Falco naumanni)* diet during the breeding season in southern Spain. Journal of Raptor Research 44: 120-128.

Rosenberg, K.V. & Cooper, R.J. 1990. Approaches to avian diet analysis. Studies in Avian Biology 13: 80-90.

Rubolini, D., Møller, A.P., Rainio, K. & Lehikoinen, E. 2007. Intraspecific consistency and geographic variability in temporal trends of spring migration phenology among European bird species. Climate Research 35: 135-146.

Snow, D.W. & Perrins, C.M. 1998. The birds of the Western Palearctic. Concise Edition. Oxford University Press, London & New York.

Sulivan, B.L., Wood, C.L., Iliff, M.J., Bonney, R.E., Fink, D. & Kelling, S. 2009. eBird: a citizen-based bird observation network in the biological sciences. Biological Conservation 142: 2282-2292.

Terraube, J. &Arroyo, B. 2011. Factors influencing diet variation in a generalist predator across its range distribution. Biodiversity and Conservation 20: 2111-2131.

Thébault, E. & Loreau, M. 2003. Food-web constraints on biodiversity–ecosystem functioning relationships. Proceedings of the Natural Academy of Sciences 100: 14949–14954.

Tiago, P., Pereira, H.M. & Capinha, C. 2017a. Using citizen science data to estimate climatic niches and species distributions. Basic and Applied Ecology 20: 75-85.

Tiago, P., Ceia-Hasse, A., Marques, T.A., Capinha, C. & Pereira, H.M. 2017b. Spatial distribution of citizen science casuistic observations for different taxonomic groups. Scientific Reports 7: 12832.

Tomé, R. 1994. A coruja-das-torres *(Tyto alba)* no estuário do Tejo: fenologia, dinâmica populacional, utilização do espaço e ecologia trófica. BSc thesis. Faculty of Sciences of the University of Lisboa, Lisboa.

Torralvo, C.A., Martín, B., Elias, G., Tomás, J., Onrubia, A., González-Broco, C. & Ferrer, M. 2018. Increase of the wintering osprey population in the Iberian Peninsula. III International Congress on Bird Migration and Global Change, Tarifa.

Vale-Gonçalves, H.M. & Cabral, J.A. 2014. New records on the distribution of three rodent species in NE Portugal from barn owl *(Tyto alba)* diet analysis. Galemys 26: 100-104.

Vilches, A., Miranda, R. & Arizaga, J. 2012. Fish prey selection by the common kingfisher *Alcedo atthis* in Northern Iberia. Acta Ornithologica 47: 169-177.

Weidinger, K. 2009. Nest predators of woodland open-nesting songbirds in Central Europe. Ibis 151: 352-360.

Results from an avifaunal survey along the Corubal and Fefine rivers, Guinea-Bissau

Resultados de um censo de aves realizado ao longo dos rios Corubal e Fefine, Guiné-Bissau

Paulo Catry[1]*, Miguel Lecoq[2], Mohamed Henriques[3], Pierre Campredon[4], José Pedro Granadeiro[3]

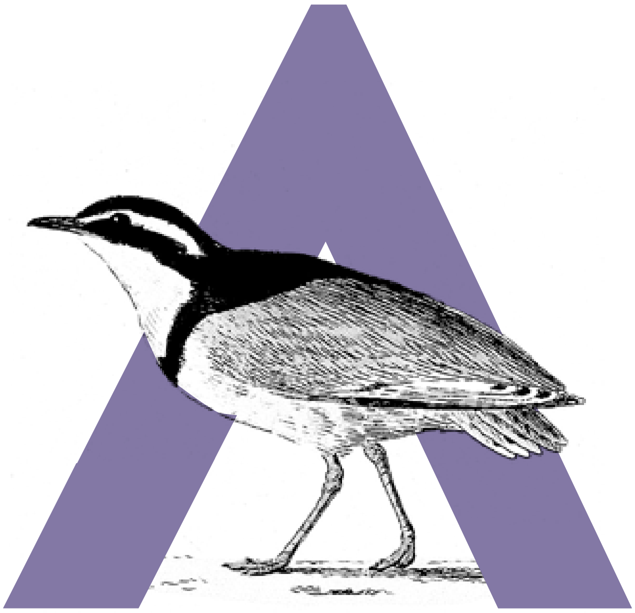
1 MARE, Marine and Environmental Sciences Centre, ISPA-Instituto Universitário, Rua Jardim do Tabaco 34, 1149-041 Lisbon, Portugal.

2 Rua Barão de Sabrosa, n.º 29 – 1.º, 1900-087 Lisbon, Portugal

3 CESAM & Departamento de Biologia Animal, Faculdade de Ciências da Universidade de Lisboa, Campo Grande, 1749-016 Lisbon, Portugal

4 53, Rua V. Costa – Bissau, Guinea-Bissau

*** Corresponding author:** paulo.catry@gmail.com



ABSTRACT

A waterbird survey was carried out along 122 km of the Corubal and Fefine rivers, eastern Guinea-Bissau, on 6-12 December 2018. Several river specialists were recorded, such as Pel's Fishing Owl *Scotopelia peli*, White-backed Night Heron *Calherodius leuconotus*, Egyptian Plover *Pluvianus aegyptius* and White-headed Lapwing *Vanellus albiceps*. Other noteworthy river species present in the area include White-crested Tiger Heron *Tigriornis leucolopha* and Rock Pratincole *Glareola nuchalis*. Some wetland and coastal birds that are common elsewhere in the country were surprisingly rare or absent (for example African Fish Eagle *Haliaeetus vocifer* and Osprey *Pandion haliaetus* were both completely absent).

Keywords: Boé, Dulombi, Guinea-Bissau, *Pluvianus, Scotopelia*

RESUMO

Foi realizado um censo de aves aquáticas ao longo de 122 quilómetros dos rios Corubal e Fefine, no leste da Guiné-Bissau, de 6 a 12 de Dezembro de 2018. Foram detetadas várias aves típicas de rios, como o Corujão-pesqueiro *Scotopelia peli*, a Garça-noturna-de-dorso-branco *Calherodius leuconotus*, a Ave-do-crocodilo *Pluvianus aegyptius* e o Abibe-de-gola-branca *Vanellus albiceps*. Outras aves especialistas de rios que ocorrem na zona incluem a Garça-tigre *Tigriornis leucolopha* e a Perdiz-do-mar-de-colar-branco *Glareola nuchalis*. Várias espécies típicas de zonas húmidas, nomeadamente de zonas costeiras, que são comuns no resto do país, revelaram-se surpreendentemente raras ou ausentes (por exemplo, não se registou a presença de qualquer exemplar de Pigargo-africano *Haliaeetus vocifer* ou de Guincho/Águia-pesqueira Osprey *Pandion haliaetus*).

Palavras-chave: Boé, Dulombi, Guiné-Bissau, *Pluvianus, Scotopelia*

Introduction

Guinea-Bissau is a small country in West Africa (36,125 km^2) but harbours some interesting ornithological values. Its coastal wetlands provide one of the major wader wintering grounds in the East Atlantic Flyway, as well as a habitat for many other waterbirds such as herons, waterfowl and migratory terns (Dodman et al. 2004, Dodman & Sá 2005, Correia et al. 2019). The country is also noted for its important populations of globally endangered vultures (Henriques et al. 2017, 2018). The avifauna of freshwater systems in the interior of Guinea-Bissau has been scarcely surveyed (but see Araújo 1994, Dodman et al. 2004), which contrasts with numerous studies for the rich coastal systems (Dodman & Sá 2005). The aim of the present study was to bring more information on the river bird fauna of two important rivers of the interior of the country.

Methods

From 6 to 12 December 2018, we navigated 90 km of the Corubal River in the regions of Cabuca and Tchetche and 32 km of the lower Fefine (a tributary of the Corubal) mostly within the Boé National Park, and also partly within the Dulombi National Park, using three small and light boats with 8CV engines (Fig. 1). Where the river was broader, we always had at least one boat sailing close to each of the two margins, to maximise the probability of detecting birds. There were always two observers fully dedicated to counting birds, while a third recorded habitat characteristics. These observers were free from tasks related to manoeuvring and navigation. Counts were carried out while sailing downstream in the Corubal and upstream in the Fefine. Sampling outside transects was opportunistic, mostly around campsites. The rainy season had occurred between mid-May and mid-November and water levels were high, with less than 0.1% of the river margins presenting sand banks or exposed rocks. Marginal vegetation was dense and tall everywhere, dominated by trees or tall bushes, with branches generally overhanging the water. Water flow was generally slow and in-water visibility between 0.5 and 1.5 m. Bird numbers were low (see Table 1), but the speed of travel (generally *c.*10 km.h^{-1}) and the dense vegetation meant that species that predominantly hide in the vegetation (most kingfishers Alcedinidae, some herons Ardeidae, African Finfoot *Podica senegalensis*) must have been largely overlooked. Birds that typically perch in the open (including on treetops or side branches) were probably efficiently surveyed.

Figure 1- Eastern Guinea-Bissau, with the surveyed sectors of the Corubal and Fefine rivers indicated in red. The Fefine runs towards the northwest, meeting the Corubal where the two red lines join.

Figura 1 - O leste da Guiné-Bissau, com os setores dos rios Corubal e Fefine que foram recenseados assinalados a vermelho. O Fefine corre em direção ao noroeste, desaguando no Corubal onde as duas linhas vermelhas se juntam.

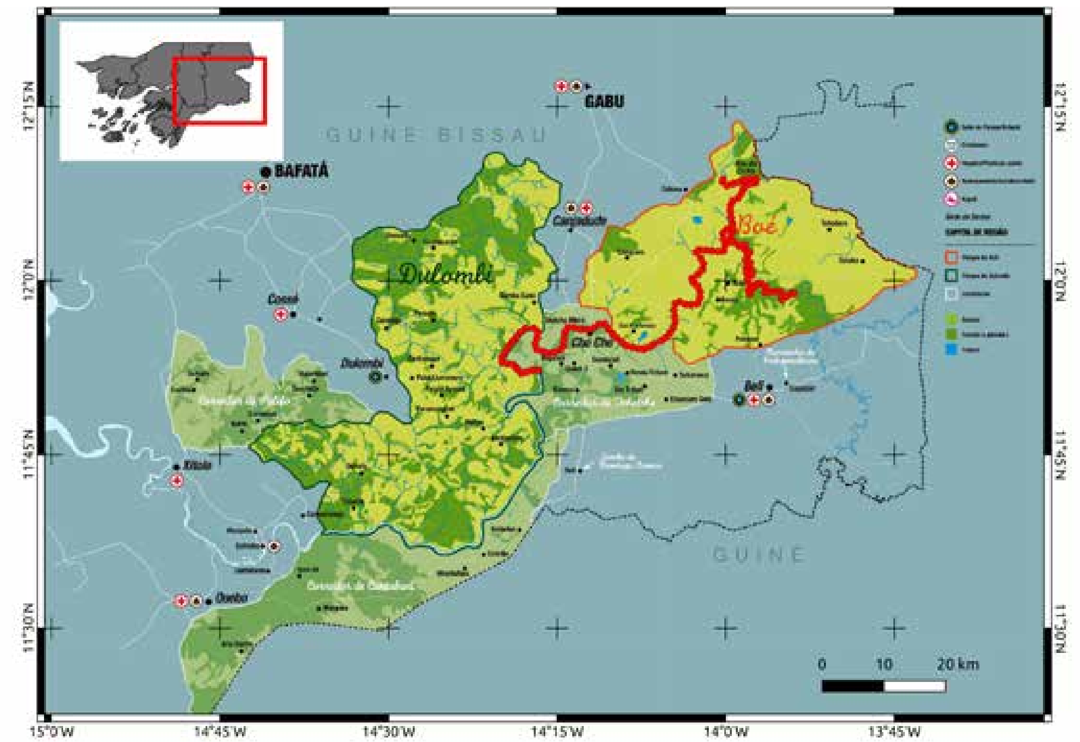


Table 1- Waterbirds recorded along the Corubal and Fefine river transects (Guinea-Bissau), 6-12 December 2018, with total numbers and, in parentheses, the number per km of surveyed river.

Tabela 1 - Aves aquáticas recenseadas ao longo dos rios Corubal e Fefine (Guiné-Bissau) entre 6 e 12 de Dezembro de 2018, com números totais e, entre parêntesis, o número por quilómetro de rio percorrido.

SPECIES	COMMON NAME	CORUBAL (90 Km)	FEFINE (32 Km)	TOTAL
Podica senegalensis	African Finfoot	3 (0.03)	3 (0.09)	6 (0.05)
Ciconia microscelis	African Woollyneck	-	1 seen outside transects	-
Bostrychia hagedash	Hadada Ibis	8 (0.09)	17 (0.5)	25 (0.20)
Calherodius leuconotus	White-backed Night Heron	2 seen outside transects	-	-

SPECIES	COMMON NAME	CORUBAL (90 Km)	FEFINE (32 Km)	TOTAL
Nycticorax nycticorax	Black-crowned Night Heron	-	3 seen outside transects	-
Ardea cinerea	Grey Heron	4 (0.04)	0 (0.00)	4 (0.03)
Ardea melanocephala	Black-headed Heron	2 (0.02)	0 (0.00)	2 (0.02)
Ardea purpurea	Purple Heron	0 (0.00)	1 (0.03)	1 (0.01)
Bubulcus ibis	Cattle Egret	17 (0.19)	4 (0.13)	21 (0.17)
Butorides striata	Green-backed Heron	1 (0.01)	0 (0.00)	1 (0.01)
Egretta gularis	Western Reef Egret	2 (0.02)	0 (0.00)	2 (0.02)
Scopus umbretta	Hamerkop	4 (0.04)	0 (0.00)	4 (0.03)
Microcarbo africanus	Long-tailed Cormorant	22 (0.24)	1 (0.03)	23 (0.19)
Anhinga rufa	African Darter	6 (0.07)	0 (0.00)	6 (0.05)
Burhinus senegalensis	Senegal Thick-knee	9 (0.10)	0 (0.00)	9 (0.07)
Pluvianus aegyptius	Egyptian Plover	5 (0.06)	0 (0.00)	5 (0.04)
Vanellus albiceps	White-headed Lapwing	7 (0.08)	0 (0.00)	7 (0.06)
Rostratula bengalensis	Greater Painted-snipe	-	1 seen outside transects	-
Actitis hypoleucos	Common Sandpiper	9 (0.1)	3 (0.09)	12 (0.10)
Tringa ochropus	Green Sandpiper	1 seen outside transects	-	-
Gypohierax angolensis	Palm-nut Vulture	16 (0.18)	0 (0.00)	16 (0.13)
Scotopelia peli	Pel's Fishing Owl	1 (0.01)	1 (0.03)	2 (0.02)
Alcedo quadribrachys	Shining-blue Kingfisher	2 (0.02)	4 (0.13)	6 (0.05)
Ceryle rudis	Pied Kingfisher	1 (0.01)	0 (0.00)	1 (0.01)
Corythornis cristatus	Malachite Kingfisher	3 (0.03)	1 (0.03)	4 (0.03)
Halcyon malimbica	Blue-breasted Kingfisher	12 (0.13)	4 (0.13)	16 (0.13)
Megaceryle maxima	Giant Kingfisher	5 (0.06)	4 (0.13)	9 (0.07)

Results

The results of our surveys are presented in Table 1.

Discussion

Although apparently not rich in numbers of species and individuals, our results revealed a bird community with some interesting features. Some specialised river species were observed, and may be more numerous than the few records suggest, as they often keep well hidden. At least four different Pel's Fishing Owls *Scotopelia peli* were found along the Fefine (three outside transects), and one other individual along the Corubal. Only two White-backed Night Herons *Calherodius leuconotu*s were seen (in the evening, outside the transect), but they must have been largely overlooked because they are nocturnal birds and may be relatively common (we have also seen them a few kilometres downstream the study area, at Saltinho). We did not detect any White-crested Tiger Herons *Tigriornis leucolopha*, another river specialist, although this inconspicuous species is known to occur near Tchetche (H. Monteiro pers. comm.).

Palm-nut Vultures *Gypohierax angolensis*, which are very common elsewhere in the country (Carneiro et al. 2017, Henriques et al. 2017) were scarce (but nests and nest building were observed), which might be linked to the very low density of palms *Elaeis guineensis* (estimated at <1 per ha). Nevertheless, as transects were often carried out in the middle of the day, we may have missed some individuals hidden in the canopy and actual densities may be slightly higher. Waders were very scarce, which is not surprising given the almost complete absence of exposed rock, sand or mud. Possibly some increase in number later in the season. For example, we have seen Egyptian Plovers *Pluvianus aegyptius* at the Tchetche ferry landing point previously, but none were recorded there this time. Herons and egrets were similarly scarce, and may increase in numbers before the following raining season. Of note was the complete

Figure 2- Pel's Fishing Owl *Scotopelia peli*, lower Fefine, Guinea-Bissau, 7 December 2018 (credits Paulo Catry).

Figura 2 - Corujão-pesqueiro *Scotopelia peli* no baixo Fefine, Guiné-Bissau, em 7 de Dezembro de 2018 (crédito Paulo Catry).

absence of African Fish Eagles *Haliaeetus vocifer* and Ospreys *Pandion haliaetus*, which are common along the coast (Henriques et al. 2017) and also occur at some freshwater lakes. Another river species that was not detected is the Rock Pratincole *Glareola nuchalis*, which regularly breeds further down the Corubal, in the Saltinho–Cusselinta area (pers. obs.).

Despite extensive signs of slash-and-burn agriculture and fishing activities, the surveyed sections of the river are still relatively wild and well conserved, and seven species of primates were detected, including 3-4 groups of chimpanzees *Pan troglodytes*, numerous baboons *Papio papio* and colobus *Piliocolobus badius* and *Colobus polykomos*. Therefore, human presence or habitat degradation are presumably not responsible for the low number of birds recorded. More studies are needed, with counts along the annual cycle (and perhaps different methodologies, such as nocturnal listening stations), to further clarify to what extent the scarcity of birds reported in our study is typical of these ecosystems, and the true status of the most interesting river specialists.

Acknowledgements

We thank Instituto da Biodiversidade e das Áreas Protegidas, namely Justino Biai (Director), Abílio Rachid Said (Coordinator of the Program) and Aissa Regalla (Coordinator of the Department for the Conservation of Biodiversity) for permits and encouragement. Laurent Durris and his team are thanked for the logistical support and for sharing his expertise on the river.

References

Araújo, A. 1994. A importância ornitológica da Região da Cufada na Guiné-Bissau. Report. Lisbon: Instituto para a Conservação da Natureza.

Carneiro, C., Henriques, M., Barbosa, C., Tchantchalam, Q., Regalla, A., Patrício, A. R. & Catry, P. 2017. Ecology and behaviour of palm-nut vultures *Gypohierax angolensis* in the Bijagós Archipelago, Guinea-Bissau. Ostrich 88: 113–121.

Correia E, Granadeiro JP, Mata VA, Regalla A, Catry P 2019. Trophic interactions between migratory seabirds, predatory fishes and small pelagics in Coastal West Africa. Marine Ecology Progress Series 622: 177-189.

Dodman, T., Barlow, C., Sá, J. & Robertson, P. 2004. Important Bird Areas in Guinea-Bissau. Dakar: Wetlands International & Bissau: Gabinete de Planificação Costeira.

Dodman, T. & Sá, J. 2005. Monitorização de aves aquáticas no Arquipélago dos Bijagós, Guiné-Bissau. Dakar: Wetlands International & Bissau: Gabinete de Planificação Costeira.

Henriques, M., Lecoq, M., Monteiro, H., Regalla, A., Granadeiro, J. P. & Catry, P. 2017. Status of birds of prey in Guinea-Bissau: first assessment based on road surveys. Ostrich 88: 101–111.

Henriques M, Granadeiro JP, Monteiro H, Nuno A, Lecoq M, Cardoso P, Regalla A, Catry P 2018. Not in wilderness: African vulture strongholds remain in areas with high human density. PLoS ONE 13(1): e0190594.

Diet of the White Stork *(Ciconia ciconia)* in a heterogeneous Mediterranean landscape: the importance of the invasive Red Swamp Crayfish *(Procambarus clarkii)*

Dieta da Cegonha-branca *(Ciconia ciconia)* numa paisagem Mediterrânica heterogénea: a importância de uma espécie invasora, o Lagostim-vermelho-do-Louisiana *(Procambarus clarkii)*

Eduardo M. Ferreira[1*], Filipa Grilo[2], Raquel C. Mendes[2], Rui Lourenço[3], Sara M. Santos[1], Francisco Petrucci-Fonseca[2]

1 UBC – Conservation Biology Lab, Department of Biology, University of Évora, Núcleo da Mitra, Apartado 94, 7002-554, Évora, Portugal

2 Centre for Ecology, Evolution and Environmental Changes (cE3c), Faculdade de Ciências, Universidade de Lisboa, 1749-016 Lisboa, Portugal

3 Instituto de Ciências Agrárias e Ambientais Mediterrânicas, Laboratório de Ornitologia, Universidade de Évora, Núcleo da Mitra, Apartado 94, 7002-554, Évora, Portugal

*** Corresponding author:**
ferreiraeduardo.mr@gmail.com

ABSTRACT

Limited quantitative data are available on food habits of the White Stork *(Ciconia ciconia)* in Mediterranean environments, particularly in ricefields where a relatively new food resource, the invasive Red Swamp Crayfish *(Procambarus clarkii)*, is abundant. We studied the diet of the White Stork in a heterogeneous landscape (Central Portugal) in order to compare the importance of the Red Swamp Crayfish as a food resource in a dominant agricultural/ricefield area in relation to a predominant woodland/agricultural area. White Storks´ diet was analysed spatially (two sites) and seasonally (winter, spring, summer) using pellets (n = 122) collected between December 2012 and July 2013. Overall, from 1570 prey items identified, crayfish was the second most frequent and abundant prey in the diet (frequency of occurrence, FO = 79.5%; numerical frequency, NF = 22.9%, respectively), only surpassed by coleopterans (FO = 94.3%; NF = 57.7%). However, in terms of consumed biomass (global PB) crayfish dominated the diet (PB = 44.0%), representing 1.8 times the consumed biomass of coleopterans (PB = 24.2%). Consumption of crayfish was higher in the site with highest abundance of ricefields (NF: 32.0% vs. 17.7%; PB: 51.3% vs. 38.4%). Although no significant seasonal variations were detected in terms of the number of crayfish consumed by storks, consumed crayfish biomass was significantly higher in summer in relation to other seasons. Our findings suggest that in Mediterranean heterogeneous areas the White Stork feeds upon a wide range of prey taxa though, when available, coleopterans along with Red Swamp Crayfish dominate the diet.

Keywords: Feeding ecology, Mediterranean, pellet analysis, Red Swamp Crayfish, White Stork

RESUMO

O estudo dos hábitos alimentares da Cegonha-branca *(Ciconia ciconia)* em ambientes mediterrânicos carece de informação quantitativa, particularmente em áreas de arrozais onde um recurso alimentar relativamente novo, o Lagostim-vermelho-do-Louisiana *(Procambarus clarkii)*, é abundante. Analisámos a dieta da Cegonha-branca numa paisagem heterogénea no centro de Portugal com o intuito de comparar a importância desta espécie de lagostim invasor como recurso alimentar numa área dominada por culturas agrícolas e arrozais em relação a uma área predominantemente florestal/agrícola. A dieta da Cegonha-branca foi analisada espacialmente (dois locais) e sazonalmente (inverno, primavera e verão) a partir da análise de regurgitações (n = 122) recolhidas entre Dezembro de 2012 e Julho de 2013. De um total de 1570 presas identificadas, o Lagostim-vermelho-do-Louisiana foi o segundo recurso alimentar mais frequente e abundante na dieta (frequência de ocorrência, FO = 79.5%; frequência numérica, NF = 22.9%, respectivamente), unicamente excedido pelos coleópteros (FO = 94.3%; NF = 57.7%). Contudo, em termos de biomassa o lagostim dominou a dieta (PB = 44.0%) representando 1.8 vezes a biomassa consumida dos coleópteros (PB = 24.2%). O consumo de Lagostim-vermelho-do-Louisiana foi significativamente maior no local com maior percentagem de cobertura de arrozais (NF: 32.0% vs. 17.7%; PB: 51.3% vs. 38.4%). Embora não tenham sido detectadas variações sazonais significativas no consumo do lagostim em termos numéricos, o lagostim teve uma contribuição para a biomassa consumida significativamente maior no verão face às outras estações. Os resultados deste trabalho sugerem que nesta área mediterrânica heterógena, a Cegonha-branca alimenta-se de um vasto leque de presas, porém, quando disponíveis, os coleópteros e o Lagostim-vermelho-do-Louisiana dominam a dieta.

Palavras-chave: regurgitações, Cegonha-branca, ecologia alimentar, Lagostim-vermelho-do-Louisiana, Mediterrâneo

Introduction

The White Stork *(Ciconia ciconia)* is a large migratory species, being widely distributed and inhabiting a variety of open and agricultural habitats (Alonso et al. 1991, Hancock et al. 1992). This species is considered a generalist and opportunistic predator and its diet has been well documented throughout its distributional range in Europe (Mužinić & Rašajski 1992, Antczak et al. 2002, Tsachalidis & Goutner 2002). Several studies revealed that the White Stork feeds upon a wide range of prey including invertebrate and vertebrate species (Melendro et al. 1978, Antczak et al. 2002, Kosicki et al. 2006, Cheriak et al. 2014). Earthworms, orthopterans, coleopterans, and small mammals (predominantly voles in Eastern Europe) seem to be primary food resources throughout the breeding range of the White Stork. On the other hand, small fish, birds, reptiles, amphibians, and molluscs are sporadically consumed, being referred as complementary food resources (Antczak et al. 2002, Tsachalidis & Goutner 2002, Vrezec 2009, Catry et al. 2010). The diet of White Storks seems to be shaped by landscape use, prey availability and climatic conditions of each geographical region (Johst et al. 2001, Tsachalidis & Goutner 2002, Ciach & Kruszyk 2010, Chenchouni et al. 2015, Chenchouni 2017).

Recently, the appearance of new food resources, such as rubbish dumps, has produced considerable shifts in the feeding habits (e.g. foraging behaviour; Tortosa et al. 2002, Ciach & Kruszyk 2010, Gilbert et al. 2016) and diet composition of White Storks (Peris 2003). Likewise, the spread of the invasive Red Swamp Crayfish (*Procambarus clarkii*; hereafter referred as “crayfish”) has been suggested to be an important driver of observed dietary changes of the White Stork (Correia 2001, Tablado et al. 2010), as well as a major cause for the establishment and increase of White Stork wintering populations in the Iberian Peninsula (Tablado et al. 2010, Catry et al. 2017). This invasive crayfish was introduced in southwestern Europe from North America in the 1970s, and is now widespread in wetlands (e.g. ricefields) across Portugal and Spain, where it became an abundant new food resource exploited by White Storks. For example, in Portugal, in a freshwater marsh located in the Tagus river basin, White Storks show a high consumption of crayfish, which is available all over the year (Correia 2001). In Spain, the crayfish is also an important prey item in White Storks’ diet in ricefield areas (Negro et al. 2000, Tablado et al. 2010, Sanz-Aguilar et al. 2015), a typical habitat where this invasive species is often abundant (Anastácio et al. 2009). However, available information is still insufficient to fully understand the relationship between White Storks and crayfish, namely concerning a quantitative assessment of crayfish contribution to White Stork’s diet considering simultaneously the contribution of other food resources.

Here, we aimed to describe and compare the diet of the White Stork at two sites within a Mediterranean area characterized by a heterogeneous landscape: one site dominated by woodland with agricultural patches, and the other dominated by mixed agricultural habitats, with a high percentage occupied by ricefields (another site). Specifically, we aimed to (1) quantify the proportion and biomass contribution of crayfish in the diet of White Storks in relation to other food resources and (2) evaluate possible spatial-seasonal variations of crayfish consumption by White Storks.

Methods

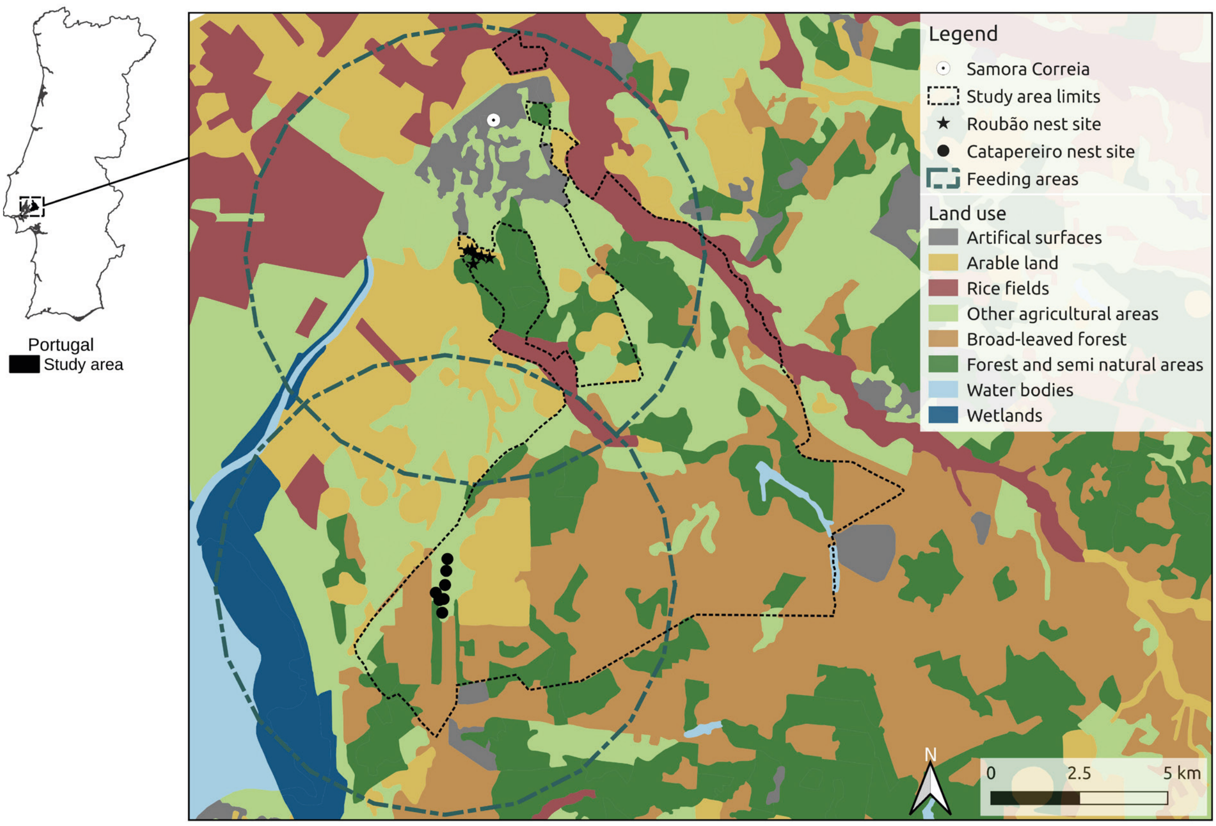
Study area

The study was carried out in Charneca do Infantado (Figure 1), within the estate “Companhia das Lezírias S.A”, which is the largest Portuguese agroforestry farmstead (38° 52’ N, 08° 51’ W; Central Portugal), located on the left margin of the Tagus River. The area is characterized by a landscape mosaic with high abundance of cork oak woodlands, pine forests and agricultural lands, such as ricefields and pastures.

The diet of the White Stork was assessed by analysing pellets collected underneath nests in two sites, Catapereiro and Roubão, separated by 8.4 km (Figure 1). The nests were located on the top of transmission electricity pylons: 18 nests in seven pylons at Catapereiro and 12 nests in six pylons at Roubão. Land use around nest sites was assessed and characterized in a buffer of 6.5 km (maximum distance of a foraging flight recorded in the area by visual estimation; E. Ferreira unpubl. data) around each nest site centroid by using the Corine land cover 2006 information (Caetano et al. 2009). In Catapereiro, the predominant land use comprises broad-leaved forest (25.9%) – mainly cork oak woodland – mixed agricultural areas (21.9%), forest and semi natural areas (18.2%) and arable land (18.1%). Here, the percentage of ricefields is low (3.6%). The Roubão nest site is mainly characterized by arable land (30.9%), mixed agricultural areas (29.0%) and ricefields (20.3%). Here, the percentages of broad-leaved forest (2.3%) and forest and semi natural areas (10.4%) are low. The remaining land use types (artificial surfaces, wetlands and water bodies) accounted individually for less than 10% of the land use at each nest site.

Figure 1 - Study area ("Charneca do Infantado") in Central Portugal showing details on the location of the sampled nest sites, feeding areas and main land use types.

Figura 1 - Localização da área de estudo ("Charneca do Infantado") em Portugal com destaque para a localização dos locais de ninhos amostrados, áreas de alimentação e principais classes de uso do solo.



Pellet Collection and Prey Identification

During the first visit to the study area we surveyed both nest sites and removed old pellets, which were not included in diet analyses. Afterwards, pellet collection took place once a month, from December 2012 to July 2013 (except March 2013), covering the presence of the White Stork in nesting areas during the whole breeding period. Only intact and fresh pellets found under the pylons with nests were collected. In the laboratory, pellets were soaked in water and washed through a 2 mm mesh sieve to disaggregate their content. Afterwards, food remains were identified using a binocular stereomicroscope with the help of identification keys, reference collections, and specialist consultation. Mammals were identified through microscopic hair analysis (Pinto 1978, Teerink 1991) and reptiles by the presence of scales and bone remains. Bird identification was based on microscopic analysis of feathers (Brom 1986) and insects from the presence of different body parts (e.g. heads, mandibles, legs, elytra and thorax) according to Chinery (1997). The crayfish – the only malacostraca species detected – was identified through fragments of body parts, namely grastroliths, uropods, rostrum and propodites of the chelae (Beja 1996, Correia 2001). Prey item remains were identified to the lowest possible taxonomic level and then the minimum number of individuals (MNI) was quantified for each prey taxa. We estimated MNI by counting the number of fragments/items recovered in each pellet corresponding to different individuals of a same given prey taxa (Chenchouni et al. 2015).

Data Analysis

Prey items were grouped into the following eight main prey categories: crayfish, orthopterans, coleopterans, other insects, reptiles, birds, small mammals, and lagomorphs. Diet composition was expressed as the frequency of occurrence (FO), numerical frequency (NF) and the percentage of consumed biomass (PB). FO was calculated for each main prey category as the number of pellets containing a prey item i / total number of pellets × 100 – being only determined for the global data set (data from the two sites across the three seasons combined). NF was calculated for each prey item identified as the minimum number of individuals (MNI) of a given prey item i / total number of prey items N × 100 (Chenchouni et al. 2015). PB was calculated for each prey item identified as the mean biomass of a given prey item i / total consumed biomass of all prey items × 100 – using mean individual live weights of the consumed prey as a proxy for ingested biomass (Supporting information, Table S1). NF and PB were determined for the global data set and then by site (Catapereiro and Roubão) and season (winter: from December to February; spring: from April to May; summer: from late June to July), wherein seasons represent different phases of a single breeding season. Considering the relatively low number of pellets per site (Table 1), we carried out seasonal analyses combining data from both sites. Chi-square tests for independence (x^2) with Bonferroni correction for multiple comparisons were used to test the significance of NF and PB differences in each consumed prey category between sites and seasons. Diet diversity was determined using the Shannon index (H' = – Σpixlog pi where pi represents the proportion of each prey taxa in the diet; Shannon & Weaver 1949) at the family level, i.e. the most precise taxonomic level, since not all prey items could be identified to species level. All statistical analyses were performed in the software R 3.4.3 (R Core Development Team 2017).

Table 1- Diet composition of the White Stork *(Ciconia ciconia)* in the two study sites (Catapereiro and Roubão) throughout the study period (winter, spring and summer). N: number of individuals; NF (%): numerical frequency of prey in diet; PB (%): percentage of consumed biomass; N total: total number of individuals; N pellets: number of pellets collected from each site and per season; H': diet diversity according to Shannon index.

Tabela 1 - Composição da dieta da Cegonha-branca *(Ciconia ciconia)* descrita por local de estudo (Catapereiro e Roubão) e por estação do ano (inverno, primavera, verão). N: número de indivíduos; NF (%): frequência numérica de presas na dieta; PB (%): percentagem de biomassa consumida; N total: somatório do número de indivíduos; N pellets: número de regurgitações recolhidas por local de amostragem e estação do ano; H': valor do nicho trófico (índice de Shannon).

PREY TAXA	CATAPEREIRO									ROUBÃO								
	winter			spring			summer			winter			spring			summer		
	N	NF (%)	PB (%)	Nv	NF (%)	PB (%)	N	NF (%)	PB (%)	N	NF (%)	PB (%)	N	NF (%)	PB (%)	N	NF (%)	PB (%)
Class Malacostraca		21.8	28.9		13.6	34.9		20.9	45.3		32.6	68.9		37.3	46.5		28.5	53.7
Order Decapoda																		
Procambarus clarkii	24	21.8	28.9	62	13.6	34.9	91	20.9	45.3	15	32.6	68.9	76	37.3	46.5	91	28.5	53.7
Class Insecta		71.8	23.2		84.4	48.0		78.2	47.8		67.4	31.1		59.3	17.7		69.9	38.4
Order Odonata					0.2	0.2												
Odonatata NI				1	0.2	0.2												
Order Orthoptera		10.9	5.5		0.4	0.4		28.7	23.8					7.4	3.5		31.4	22.5
Gryllotalpa gryllotalpa	12	10.9	5.5				1	0.2	0.2							1	0.3	0.2
Orthoptera NI				2	0.4	0.4	124	28.4	23.6				15	7.4	3.5	99	31.0	22.3
Order Hemiptera					0.4	0.4								0.5	0.2			
Hemniptera NI				2	0.4	0.4							1	0.5	0.2			
Order Coleoptera		60.9	17.6		82.0	45.9		47.5	22.5		67.4	31.1		51.5	14.0		38.6	15.8
Carabidae																		
Calosoma maderae	6	5.5	1.6															
Carabus lusitanicus				1	0.2	0.1												
Carabus melancholicus				8	1.8	1.0	4	0.9	0.4							2	0.6	0.3
Carabus sp.				5	1.1	0.6	1	0.2	0.1				1	0.5	0.1			
Chlaenius olivieri				1	0.2	0.1	1	0.2	0.1				1	0.5	0.1	1	0.3	0.1
Cicindela campestris				3	0.7	0.4							1	0.5	0.1			
Poecilus kugelanni				1	0.2	0.1												
Scarites cyclops				5	1.1	0.6	2	0.5	0.2				2	1.0	0.3	1	0.3	0.1
Carabidae NI	3	2.7	0.8	64	14.1	7.9				1	2.2	1.0	13	6.4	1.7	17	5.3	2.2
Dytiscidae							31	7.1	3.4									
Dytiscidae NI	1	0.9	0.3	46	10.1	5.7	24	5.5	2.6	1	2.2	1.0	25	12.3	3.3	17	5.3	2.2
Histeridae																		
Histeridae NI	1	0.9	0.3	4	0.9	0.5	2	0.5	0.2				2	1.0	0.3	1	0.3	0.1

PREY TAXA	CATAPEREIRO									ROUBÃO								
	winter			spring			summer			winter			spring			summer		
	N	NF (%)	PB (%)	Nv	NF (%)	PB (%)	N	NF (%)	PB (%)	N	NF (%)	PB (%)	N	NF (%)	PB (%)	N	NF (%)	PB (%)
Silphidae																		
Silpha puncticollis				3	0.7	0.4										1	0.3	0.1
Silphidae NI	30	27.3	7.9	30	6.6	3.7	4	0.9	0.4				7	3.4	0.9	7	2.1	0.9
Dynastidae																		
Oryctes nasicornis	3	2.7	0.8															
Scarabaeidae																		
Bubas bison	2	1.8	0.5							4	8.7	4.0						
Bubas sp.				3	0.7	0.4												
Copris hispanus										1	2.2	1.0						
Onthophagus sp.										1	2.2	1.0						
Scarabaeidae NI										9	19.6	9.0						
Melolonthidae																		
Melolontha papposa							1	0.2	0.1	9	19.6	9.0	12	5.9	1.6			
Tenebrionidae																		
Akis sp.							1	0.2	0.1							13	4.1	1.7
Blaps sp.				1	0.2	0.1										1	0.3	0.1
Erodius sp.							2	0.5	0.2									
Pimelia sp.							3	0.7	0.3									
Sepidium sp.				6	1.3	0.7	7	1.6	0.8							4	1.3	0.5
Tenebrionidae NI				43	9.5	5.3	73	16.7	7.9				4	2.0	0.5	47	14.7	6.1
Chrysomelidae																		
Chrysomela sp.				3	0.7	0.4	2	0.5	0.2				2	1.0	0.3	1	0.3	0.1
Chrysomelidae NI				1	0.2	0.1	2	0.5	0.2									
Curculionidae																		
Curculionidae NI				2	0.4	0.2										3	0.9	0.4
Coleoptera NI	21	19.1	5.5	143	31.4	17.6	47	10.8	5.1	5	10.9	5.0	35	17.2	4.7	7	2.2	0.9
Insect larvae NI				6	1.3	1.1	9	2.1	1.5									
Class Reptilia		0.9	0.7		1.8	15.5		0.5	2.5								1.3	
Order Squamata		0.9	0.7		1.8	15.5		0.5	1.2								1.3	
Chalcides striatus				4	0.9	5.6	1	0.2	1.2							2	0.6	2.9
Psammodromus sp.	1	0.9	0.7															
Colubridae NI				4	0.9	9.8												
Reptilia NI							1	0.2	1.2							2	0.6	2.9

PREY TAXA	CATAPEREIRO									ROUBÃO								
	winter			spring			summer			winter			spring			summer		
	N	NF (%)	PB (%)	Nv	NF (%)	PB (%)	N	NF (%)	PB (%)	N	NF (%)	PB (%)	N	NF (%)	PB (%)	N	NF (%)	PB (%)
Class Aves														1.0	20.0			
Order Anseriformes														1.0				
Anatidae NI													2	1.0	20.0			
Class Mammalia		5.5	47.1		0.2	1.6		0.5	4.4					2.5	15.7		0.3	2.1
Order Insectivora		0.9	1.4					0.5	4.4					1.0	2.8			
Crocidura russula	1	0.9	1.4										1	0.5	0.7			
Talpa occidentalis							1	0.2	2.7									
Insectivora NI							1	0.2	1.7				1	0.5	2.1			
Order Rodentia		3.6	12.8		0.2	1.6								1.5	12.9		0.3	2.1
Microtus sp.													1	0.5	2.1	1	0.3	2.1
Mus sp.	1	0.9	2.5															
Rattus sp.													1	0.5	9.1			
Rodentia NI	3	2.7	10.3	1	0.2	1.6							1	0.5	1.7			
Order Lagomorpha		0.9	32.9															
Lagomorpha NI	1	0.9	32.9															
N total	110			455			436			46			204			319		
N pellets	10			33			33			5			18			23		
Shannon index (H')	1.97			1.97			1.9			1.46			1.99			1.74		

Results

From a total of 122 White Stork pellets analysed, we identified and quantified 1570 prey items comprising 46 taxa belonging to 5 classes, 10 orders and 21 families (Table 1). Coleopterans (FO = 94.3%), crayfish (FO = 79.5%) and orthopterans (FO = 27.9%) were the prey categories more frequently found in pellets. Other prey categories, namely reptiles (FO = 11.5%), small mammals (FO = 8.2%), and other insects (FO = 4.9%) had a moderate frequency in pellets. Birds (FO = 1.6%) and lagomorphs (FO = 0.8%) were the least represented prey in pellets. Regarding the numerical frequency of prey in diet (global NF %), the crayfish was the second most consumed prey category (NF = 22.9%), only surpassed by coleopterans (NF = 57.7%). Indeed, the crayfish represented 1.4 times the consumption of orthopterans (NF = 16.2%) and 6.9 times the sum of other insects (NF = 1.2%), reptiles (NF = 1.0%), small mammals (NF = 0.9%), birds (NF = 0.1%) and lagomorphs (NF = 0.1%) together. In terms of biomass (global PB), crayfish (PB = 44.0%) dominated the diet of White Storks representing 1.8 times the PB of coleopterans (PB = 24.2%), 3.7 times the PB of orthopterans (PB = 11.9%) and 2.2 times the sum of PB of small mammals (PB = 6.5%), reptiles (PB = 5.3 %), birds (PB = 4.0 %), lagomorphs (PB = 3.3%), and other insects (PB = 0.8%) together.

Spatial Analysis

The crayfish was the second most consumed prey taxa (NF) at both sites, accounting for 32.0% of all prey consumed at Roubão and 17.7% at Catapereiro (Figure 2). The coleopterans dominated the diet at both sites, ranging from 45.5% at Roubão to 64.6% at Catapereiro, whereas the orthopterans, the third most important prey category, represented 20.2% of the diet at Roubão and 13.9% at Catapereiro. However, in terms of biomass (PB), crayfish represented the most important prey category at both sites (PB = 51.3% at Roubão; PB = 38.4% at Catapereiro), while coleopterans were ranked second (PB = 30.6% at Catapereiro; PB = 15.9% at Roubão), followed by orthopterans (PB = 12.4% at Roubão; PB = 11.5% at Catapereiro; Figure 2). The proportion of the other prey categories (other insects, reptiles, birds, small mammals and lagomorphs) varied among sites, however, together represented a low fraction of the diet: less than 5% of NF at each site; and, individually, each prey category accounted for less than 10% of PB at each site. We found significant between-site differences both on NF and PB mainly for the most consumed prey categories, with crayfish being significantly more consumed and represented in terms of biomass at Roubão, while coleopterans and other insects were more consumed and had a larger contribution to the consumed biomass at Catapereiro (Chi-square pairwise tests with Bonferroni correction significance at $P < 0.006$; Table 2). For the orthopterans, only significant spatial differences in terms of NF were detected, wherein this prey was more common in the diet at Roubão. No significant between-site differences on NF were found for reptiles, birds, small mammals, and lagomorphs. Nevertheless, the contribution of these prey (evidenced as secondary and occasional food items by NF) to the consumed biomass varied significantly between sites (Table 2). Diet diversity was higher at Catapereiro (H' = 2.20) than at Roubão (H' = 2.07), with species richness values of 43 and 34 prey taxa, respectively (Table 1).

Table 2- Comparison of the main prey consumed by White Storks (*Ciconia ciconia)* between study sites and seasons. Results refer to the chi-square tests (X^2) with Bonferroni correction for multiple comparisons testing the differences in numerical frequency and percentage of consumed biomass of each consumed prey category (*: significant results ($p < 0.006$); NA: Not applicable.

Tabela 2 - Comparação do consumo das principais categorias de presas encontradas em regurgitações de Cegonha-branca *(Ciconia ciconia)* entre locais de estudo e estações do ano. São apresentados os resultados dos testes de qui-quadrado (X^2) com correcção de Bonferroni para comparações múltiplas para a frequência numérica e percentagem de biomassa consumida. *: diferenças significativas ($p < 0.006$); NA: Não aplicável.

PREY CATEGORY	Catapereiro vs. Roubão				winter vs. spring				winter vs.summer				spring vs. summer			
	NF		PB		NF		PB		NF		PB		NF		PB	
	X^2	*p*	X^2	*p*	X^2	*p*	X^2	*p*	X^2	*p*	X^2	*p*	X^2	*p*	X^2	*p*
Crayfish	42.1	<0.001*	124.5	<0.001*	1.2	0.269	3.3	0.071	0.1	0.813	42.8	<0.001*	2.0	0.156	49.4	<0.001*
Orthopterans	10.7	0.001*	1.3	0.249	9.6	0.002*	18.2	<0.001*	32.8	<0.001*	172.1	<0.001*	183.8	<0.001*	652.2	<0.001*
Coleopterans	54.3	<0.001*	216.0	<0.001*	5.7	0.017	37.6	<0.001*	19.0	<0.001*	0.5	0.503	119.4	<0.001*	108.5	<0.001*
Other insects	8.0	0.005*	34.0	<0.001*	2.4	0.122	9.3	0.002*	1.9	0.171	7.7	0.006	0.3	0.596	0.5	0.476
Reptiles	0.6	0.438	69.8	<0.001*	0.4	0.538	68.3	<0.001*	0.04	0.841	27.4	<0.001*	0.6	0.427	46.5	<0.001*
Birds	3.5	0.061	406.3	<0.001*	0.5	0.491	94.5	<0.001*	NA	NA	NA	NA	2.3	0.130	341.6	<0.001*
Small mammals	0.3	0.605	30.2	<0.001*	5.0	0.026	7.3	0.007	11.7	<0.001*	97.5	<0.001*	1.5	0.226	76.6	<0.001*
Lagomorphs	0.6	0.451	199.0	<0.001*	4.2	0.040	867.0	<0.001*	4.9	0.028	938.0	<0.001*	NA	NA	NA	NA

Figure 2 - Proportion of the main prey categories in the diet of the White Stork *(Ciconia ciconia)* by site, expressed as the numerical frequency of prey in diet (NF) and percentage of consumed biomass (PB). Dark grey: Catapereiro; light grey: Roubão.

Figura 2 - Contribuição dos principais grupos de presas para a dieta da Cegonha-branca *(Ciconia ciconia)* nos dois locais de estudo, em termos da frequência numérica de presas na dieta (NF) e percentagem de biomassa consumida (PB). Cinzento-escuro: Catapereiro; cinzento-claro: Roubão.

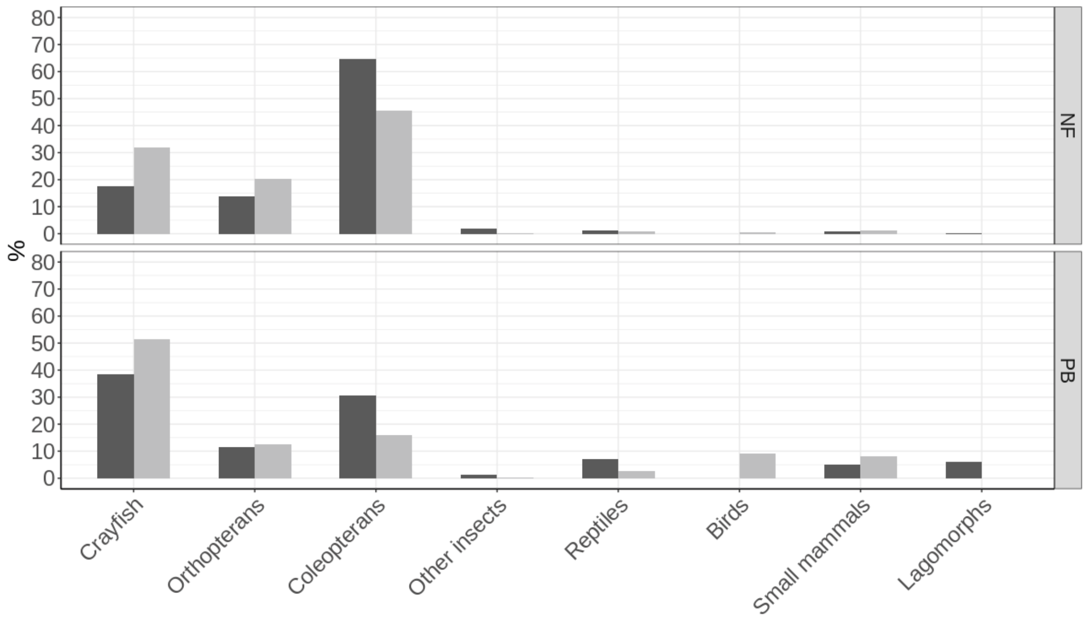
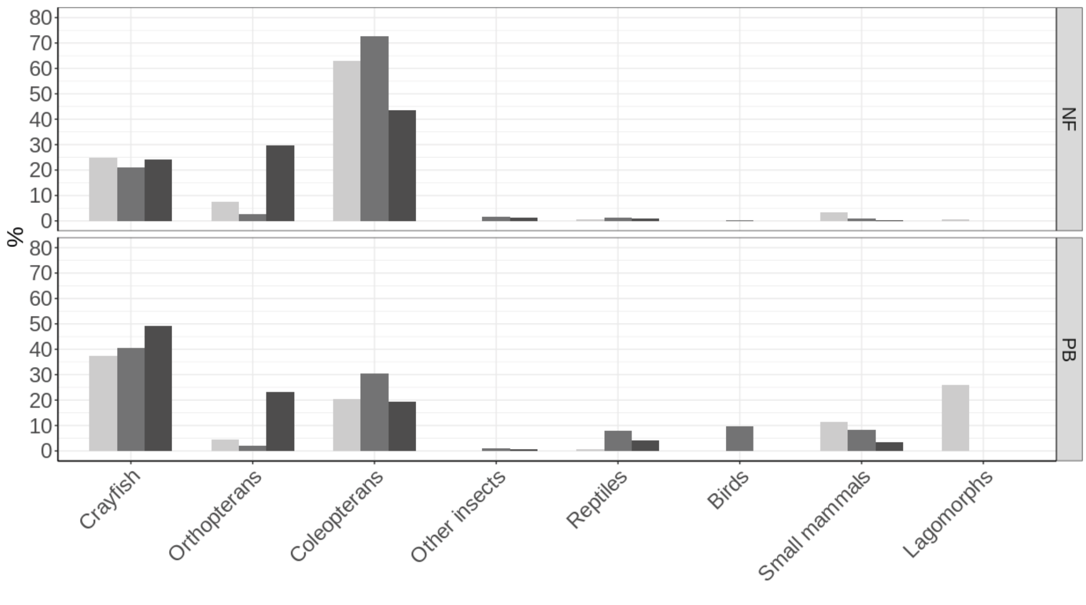


Figure 3 - Proportion of the main prey categories in the diet of the White Stork *(Ciconia ciconia)* by season, expressed as the numerical frequency of prey in diet (NF) and percentage of consumed biomass (PB). The three levels of grey (from light to dark) represent winter, spring and summer, respectively.

Figura 3 - Contribuição dos principais grupos de presas para a dieta da Cegonha-branca *(Ciconia ciconia)* por estação do ano, em termos da frequência numérica de presas na dieta (NF) e percentagem de biomassa consumida (PB). Os três níveis de cinzento (do mais claro para o mais escuro) representam o inverno, a primavera e o verão, respectivamente.



Seasonal analysis

Crayfish was regularly consumed by the White Stork throughout the study period (Figure 3), being the second most important prey taxa in winter (NF = 25.0%) and spring (NF = 20.9%), and the third in summer (NF = 24.1%). Coleopterans were the most consumed prey across the three periods (NF ranging between 43.7% in summer to 72.5% in spring), while orthopterans were the second most important prey in summer (NF = 29.8%) and the third in winter and spring (NF = 7.7% and 2.6% respectively). Regarding the consumed biomass, crayfish was the most representative prey category across all studied seasons (PB ranging from 37.3% in winter to 49.2% in summer; Figure 3). Coleopterans and orthopterans were the second most important prey categories in spring (PB = 30.6%) and summer (PB = 23.2%), respectively. Lagomorphs and small mammals recorded noteworthy PB values during the winter (PB = 26.1% and PB = 11.3%, respectively). The remaining prey categories (other insects, reptiles, and birds) were not consumed across all seasons and represented a low fraction of the diet: together, accounted for less than 5% of NF in each season; and individually, each prey category accounted for less than 10% of PB in each season. No significant differences were detected on crayfish consumption (NF) among seasons (Chi-square pairwise tests with Bonferroni correction significance at $P < 0.006$; Table 2). There were, however, significant seasonal differences in terms of PB, with crayfish having a larger contribution to the consumed biomass in summer in relation to spring and winter. The proportion of orthopterans in diet and its contribution to the bulk of biomass was significantly different among all seasons, peaking in summer. For coleopterans, a significantly higher consumption occurred in winter and spring in relation to summer, while in terms of PB a significant higher contribution to the diet was detected in spring in relation to winter and summer. The proportion on diet of small mammals (both NF and PB) was significantly higher in winter than in summer, and, additionally, a higher contribution in terms of PB was detected in spring than in summer. No significant seasonal variations regarding NF were found for other insects, reptiles, birds and lagomorphs. However, the contribution of these prey (secondary and occasional prey in terms of NF) to the bulk of consumed biomass varied significantly among seasons (Table 2). The diversity of diet seasonally decreased (H' = 2.11, H' = 2.10 and H' = 1.86 for winter, spring and summer, respectively), while species richness showed no seasonal trend (19, 34 and 29 prey taxa, respectively for winter, spring and summer; Table 1).

Discussion

White Storks in our study area feed upon a relatively wide range of prey, though a few specific food resources constitute the bulk of the diet. Regardless of the study site and season, coleopterans, crayfish, and orthopterans were the most consumed prey categories. Our results are similar to those from other dietary studies (based on pellet analysis) conducted in Europe, where insects (primarily coleopterans and orthopterans) were found to be the most frequent consumed prey (>80%), whereas vertebrates constituted only a small fraction (<10%) of the diet (Antczak et al. 2002, Tsachalidis & Goutner 2002, Miraglia et al. 2008, Vrezec 2009). On the other hand, in terms of consumed biomass, crayfish turn out to be the most representative prey among sites and across the studied seasons, whereas insects became less prominent on diet.

Following the introduction in Spain in the 1970s, craysfishes quickly spread across wetlands in the Iberian Peninsula, including ricefields (Geiger et al. 2005), becoming an abundant new food resource exploited by White Storks (Negro et al. 2000, Correia 2001). The consumption of this new prey promoted not only dietary changes but it also shaped the foraging behaviour of the White Stork in southwestern Europe (Correia 2001, Barbraud et al. 2002, Tablado et al. 2010, Sanz-Aguilar et al. 2015). In our study area, the crayfish was the second most important prey category for the White Stork in terms of number of individuals consumed and the most predominant in terms of biomass, being regularly consumed throughout the year. This is consistent with previously studies, suggesting that crayfish, where available, is an important dietary prey for White Storks.

Linking prey consumption with abundance and availability of prey is key to deepen on spatial-temporal diet variations and how predators exploit the available prey (e.g. Beja 1996, Correia 2001). Regrettably, in this study, diet analysis was not complemented with the assessment of ecological factors most likely to influence the diet of the White Stork, particularly the abundance and availability of prey (e.g. Correia 2001), which hinder and limit the extension of interpretations of the results. Nevertheless, the differences detected on crayfish consumption between sites, as well as its regular seasonal use by White Storks may be related to landscape structure and composition at each sampled site, though further investigation is required to test the potential effects of abundance and availability of prey on spatial-temporal diet variations. For instance, spatially, crayfish consumption is likely to be linked with the presence of ricefields, a major habitat for crayfish (Anastácio et al. 2009, Ramalho & Anastácio 2015). Specifically, the highest consumption of crayfish was recorded at Roubão, which is the site with higher abundance of ricefields nearby (20.3%), against 3.6% of ricefields at Catapereiro. Similar results were found by Tablado et al. (2010) in Guadalquivir marshes, in southwestern Spain. Accordingly, a greater presence of crayfish in the White Stork´s diet (expressed as percentage of crayfish in dietary samples) was recorded in areas mainly occupied by ricefields, rather than in natural marshland areas (Tablado et al. 2010). Although the White Stork is a generalist predator that can explore a variety of freshwater habitats, it tends to forage crayfish mainly in ricefields areas (Sanz-Aguilar et al. 2015). The spatial exploitation of the crayfish may also be influenced by the availability of other important prey in accordance to land use types. Specifically, coleopterans and orthopterans are abundant in arable land, mixed agricultural areas and broad-leaved forests, mainly cork oak woodland (Alonso et al. 1991, Galante et al. 1995, Tsachalidis & Goutner 2002, Silva et al. 2008). In fact, these habitats, which are also used by storks (Alonso et al. 1991, Johst et al. 2001, Catry et al. 2010), presented the highest difference in terms of land cover abundance between the two sites.

Regarding the seasonal consumption of crayfish by the White Stork, the continuous exploitation of this prey throughout all studied seasons is consistent with the few studies conducted in the Iberian Peninsula (Correia 2001, Tablado et al. 2010). Results of prey biomass consumption suggest that crayfish had a more important role in summer in relation to other seasons. However, in terms of numerical frequency our results indicate a regular seasonal pattern of consumption of crayfish, contrasting with the results from Correia (2001), which found seasonal differences on crayfish consumption by storks, with a lower predation intensity in winter and higher in summer. These patterns probably depend on crayfish abundance and availability to predators in accordance to hydrological cycle and water temperature of habitat types, which may be different between natural marshlands (found in Correia 2001) and ricefields – such as the case of this study – (Correia 1998, Anastácio et al. 2009, Ramalho & Anastácio 2015). Additionally, crayfish consumption may also be driven by the cost-benefit relation of foraging on other highly available food, particularly insects (as evidenced by the seasonal consumption of this prey). Notice, for example, that the White Stork apparently shifted from a diet mostly comprised by coleopterans in spring to a combined consumption of coleopterans and orthopterans in summer, which may be associated with peak density of these two prey taxa (Loureiro et al. 2009).

The establishment of crayfish populations has influenced the diet of several species of predators (e.g. *Lutra lutra*; Beja 1996, Barrientos et al. 2014), including the White Stork, resulting in dietary changes (Correia 2001, Tablado 2010), behavioural changes (e.g. increase of wintering population of storks; Catry et al. 2017) and demographic shifts (e.g. increase of local abundance of storks; Tablado et al. 2010). Moreover, the response of crayfish predators in relation to crayfish availability will likely continue to be strong in the absence of restrictive factors (e.g. nesting-site areas; Tablado et al. 2010). Thus, it is of great relevance to increase our knowledge on the potentially key role of the crayfish, considering the paradox trade-off of its positive effects vs. negative impacts on ecosystems (e.g. as a predator of amphibians and vector of diseases), as well as the driver of complex cascading effects on foods webs (Geiger et al. 2005). Specifically, broad-scale studies on this interaction, which assess the availability of prey species, may help to evaluate to which degree crayfish availability can lead to significant changes on populations of White Stork and other predators.

Acknowledgements

We would like to thank administration of Companhia das Lezírias for providing us facilities and for allowing us to work in the study area. We also would like to thank Sandra Alcobia, André Silva and Bruno Silva for their technical help.

References

Alonso, J.C., Alonso, J.A. & Carrascal, L.M. 1991. Habitat selection by foraging White Storks, *Ciconia ciconia*, during the breeding season. Canadian Journal of Zoology 69: 1957-1962.

Anastácio, P.M., Leitão, S.A., Boavida M.J. & Correia, A.M. 2009. Population dynamics of the invasive crayfish (*Procambarus clarkii* Girard, 1852) at two marshes with differing hydroperiods. Annales de Limnologie - International Journal of Limnology 45: 247-256.

Antczak, M., Konwerski, S., Grobelny, S. & Tryjanowski, P. 2002. The food composition of immature and non-breeding White Storks in Poland. Waterbirds 25: 424-428.

Barbraud, C., National, F. & Karine, D. 2002. Recent changes in the feeding diet of White Stork (*Ciconia ciconia*) chicks in Charente Maritime (West France). Alauda 70: 437-444.

Barrientos, R., Merino-Aguirre, R., Fletcher, D.H. & Almeida, D. 2014. Eurasian otters modify their trophic niche after the introduction of non-native prey in Mediterranean fresh waters. Biological Invasions 16: 1573-1579.

Beja, P.R. 1996. An analysis of otter *Lutra lutra* predation on introduced American crayfish *Procambarus clarkii* in Iberian streams. Journal of Applied Ecology 33: 1156-1170.

Brom, T.G. 1986. Microscopic identification of feathers and feather fragments of palearctic birds. Bijdragen Tot de Dierkunde 56: 181-204.

Caetano, M., Nunes, V. & Nunes, A. 2009. CORINE Land Cover 2006 for Continental Portugal. Technical Report, Instituto Geográfico Português, Lisboa.

Catry, I., Encarnação, V., Pacheco, C., Catry, T., Tenreiro, P., da Silva, L.P., Leão, F., Bally, F., Roda, S., Lopes, S., Capela, C., Alonso, H., Saldanha, S., Urbano, O., Saraiva, J., Encarnacao, P., Sequeira, N., Mendes, M., Monteiro, P., Elias, G. & Moreira, F. 2017. Recent changes on migratory behaviour of the White stork (*Ciconia ciconia*) in Portugal: towards the end of migration? Airo 24: 28-35.

Catry, P., Costa, H., Elias, G. & Matias, R. 2010. Aves de Portugal. Ornitologia do território continental. Assírio & Alvim, Lisboa.

Chenchouni, H. 2017. Variation in White Stork (*Ciconia ciconia*) diet along a climatic gradient and across rural-to-urban landscapes in North Africa. International Journal of Biometeorology 61: 549-564.

Chenchouni, H., Si Bachir, A. & AlRashidi, M. 2015. Trophic niche and feeding strategy of the White Stork (*Ciconia ciconia*) during different phases of the breeding season. Avian Biology Research 8: 1-13.

Cheriak, L., Barbraud, C., Doumandji, S. & Bouguessa, S. 2014. Diet variability in the White Stork *Ciconia ciconia* in eastern Algeria. Ostrich - Journal of African Ornithology 85: 201-204.

Chinery, M. 1997. Guía de campo de los insectos de España y de Europa. Ediciones Omega 5ª, Barcelona.

Ciach, M. & Kruszyk, R. 2010. Foraging of White Storks on rubbish dumps on non-breeding grounds. Waterbirds 33: 101–104.

Correia, A.M. 1998. Seasonal and circadian foraging activity of *Procambarus clarkii* (Decapoda, Cambaridae) in Portugal. Crustaceana 71: 158-166.

Correia, A.M. 2001. Seasonal and interspecific evaluation of predation by mammals and birds on the introduced red swamp crayfish *Procambarus clarkii* (Crustacea, Cambaridae) in a freshwater marsh (Portugal). Journal of Zoology 255: 533-541.

Galante, E., Mena, J. & Lumbreras, C. 1995. Dung beetles (Coleoptera: Scarabaeidae, Geotrupidae) attracted to fresh cattle dung in wooded and open pasture. Environmental Entomology 24: 1063-1068.

Geiger, W., Alcorlo, P., Baltanás, A. & Montes, C. 2005. Impact of an introduced Crustacean on the trophic webs of Mediterranean wetlands. Biological Invasions 7: 49-73.

Gilbert, N.I., Correia, R.A., Silva, J.P., Pacheco, C., Catry, I., Atkinson, P.W., Gill, J.A. & Franco, A.M.A. 2016. Are white storks addicted to junk food? Impacts of landfill use on the movement and behaviour of resident white storks (*Ciconia ciconia*) from a partially migratory population. Movement Ecology 4: 7.

Hancock, J., Kushlan, J.A., Kahl, P., Harris, A & Quinn, D. 1992. Storks, Ibises and Spoonbills of the World. Academic Press Limited, London.

Johst, K., Brandl, R. & Pfeifer, R. 2001. Foraging in a patchy and dynamic landscape: human land use and the White Stork. Ecological Applications 11: 60-69.

Kosicki, J. Z., Profus, P., Dolata, P.T. & Tobółka, M. 2006. Food composition and energy demand of the White Stork *Ciconia ciconia* breeding population. Literature survey and preliminary results from Poland. In: Tryjanowski, P., Sparks, T.H. & Jerzak, L. (eds) The White Stork in Poland: studies in biology, ecology and conservation, pp. 169-183. Poznań: Bogucki Wydawnictwo Naukowe.

Loureiro, F., Bissonette, J.A., Macdonald, D.W. & Santos-Reis, M. 2009. Temporal variation in the availability of Mediterranean food resources: do badgers Meles meles track them? Wildlife Biology 15: 197-206.

Melendro, J., Gisbert, J. & Rodríguez, A. 1978. Datos sobre la alimentación de *Ciconia ciconia*. Ardeola 24: 207-209.

Miraglia, G., Aloise, G., Godino, G., Santopaolo, R. & Gustin, M. 2008. New data on the diet of White Stork *Ciconia ciconia* in Calabria (southern Italy). Acrocephalus 29: 185-186.

Mužinić, J. & Rašajski, J. 1992. On food and feeding habits of the White Stork, *Ciconia c. ciconia*, in the Central Balkans. Ecology of Birds 14: 211-223.

Negro, J.J., Tella, J.L., Blanco, G., Forero, M,G. & Garrido-Fernández, J. 2000. Diet explains interpopulation variation of plasma carotenoids and skin pigmentation in nestling White Storks. Physiological and Biochemical Zoology 73: 97-101.

Peris, S. J. 2003. Feeding in urban refuse dumps: ingestion of plastic objects by the White Stork (*Ciconia ciconia*). Ardeola 50: 81-84.

Pinto, M. V. 1978. Estudo morfológico dos pêlos dos mamíferos portugueses: chaves para a sua determinação. Unpublished report, University of Lisbon, Lisbon.

R Develeopment Core Team. 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Ramalho, R.O. & Anastácio, P.M. 2015. Factors inducing overland movement of invasive crayfish (*Procambarus clarkii*) in a ricefield habitat. Hydrobiologia 746: 135-146.

Sanz-aguilar, A., Jovani, R., Melián, C.J., Pradel, R. & Tella, J.L. 2015. Multi-event capture– recapture analysis reveals individual foraging specialization in a generalist species. Ecology 96: 1650-1660.

Shannon, C.E. & Weaver, W. 1949. The mathematical theory of communication. Univ. Illinois Press, Urbana, IL.

Silva, P.M., Aguiar, C.A.S., Niemelä, J., Sousa, J.P. & Serrano, A.R.M. 2008. Diversity patterns of ground-beetles (Coleoptera: Carabidae) along a gradient of land-use disturbance. Agriculture, Ecosystems & Environment 124: 270-274.

Tablado, Z., Tella, J.L., Sanchez-Zapata, J.A. & Hiraldo, F. 2010. The paradox of the long-term positive effects of a North American crayfish on a European community of predators. Conservation Biology 24: 1230-1238.

Teerink, B. J. 1991. Hair of West-European mammals: atlas and identification key. Cambridge University Press, Cambridge.

Tortosa, F. S., Caballero, J.M. & Reyes-López, J. 2002. Effect of rubbish dumps on breeding success in the White Stork in southern Spain. Waterbirds 25: 39-43.

Tsachalidis, E.P. & Goutner, V. 2002. Diet of the White Stork in Greece in relation to habitat. Waterbirds 25: 417-423.

Vrezec, A. 2009. Insects in the White Stork *Ciconia ciconia* diet as indicators of its feeding conditions: the first diet study in Slovenia. Acrocephalus 30: 25-29.

spea
Sociedade Portuguesa
para o Estudo das Aves

BirdLife
INTERNATIONAL
PARTNER