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

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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.

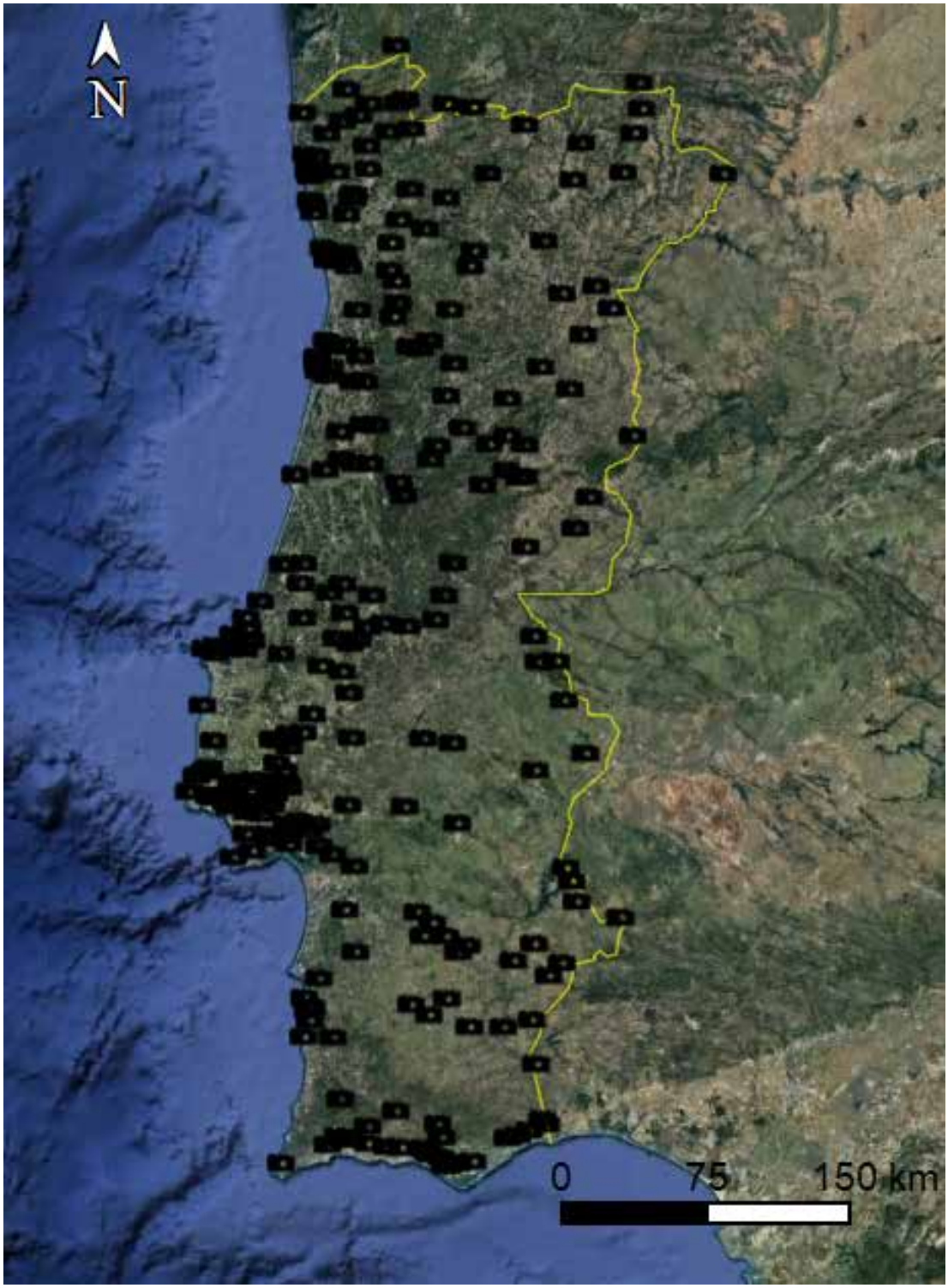


Table 1- Consumed food items detected in photographs of Portuguese birds published on the "Aves de Portugal Continental" Facebook page. For each bird species I present the proportion of food items represented by each main group (mostly at the Class taxonomic rank, but also distinguishing fruits and seeds) 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*[!], *Columba livia*[!])	*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%: P*istacia 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*[l], *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*

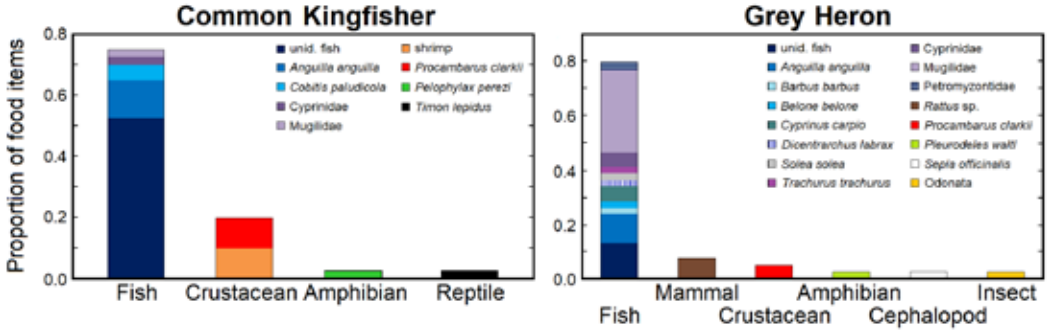
SPECIES	SAMPLE SIZE	FOOD ITEMS	COVERAGE	SEASON
Parus caeruleus Blue Tit	*12*	Insects (50%: Lepidoptera larvae, unidentified larvae, unidentified); Fruits (25%: *Diospyrus kaki*, *Prunus* sp.); Arachnids (17%: Araneae); Seeds (8%: unidentified)	*N,C,S*	*Wi,Sp*
Parus cristatus Crested Tit	*1*	Seeds (100%: *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*

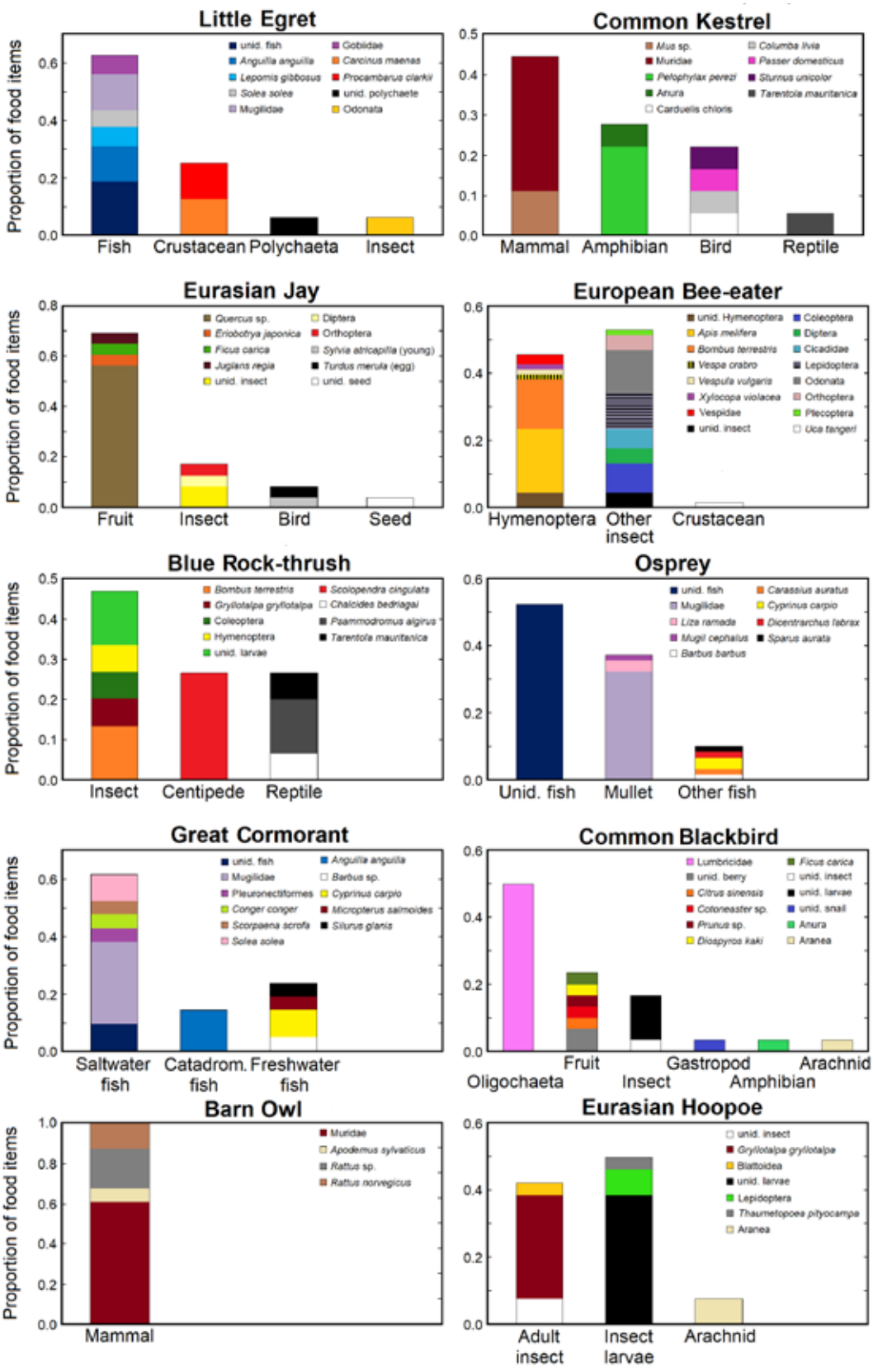
SPECIES	SAMPLE SIZE	FOOD ITEMS	COVERAGE	SEASON
Podiceps cristatus Great Crested Grebe	*3*	Fishes (100%: *Solea solea*, *Conger conger*, unidentified)	*S*	*Sp,Su*
Porphyrio martinica Americn Purple Gallinule	*1*	Amphibians (100%: *Pelophylax perezi*)	*C*	*Au*
Psittacula krameri Ring-necked Parakeet	*6*	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
unid. fish
Anguilla anguilla
Lepomis gibbosus
Solea solea
Mugilidae
Gobiidae
Carcinus maenas
Procambarus clarkii
unid. polychaete
Odonata
Fish
Crustacean
Polychaeta
Insect
Common Kestrel
Mus sp.
Muridae
Pelophylax perezi
Anura
Carduelis chloris
Columba livia
Passer domesticus
Sturnus unicolor
Tarentola mauritanica
Mammal
Amphibian
Bird
Reptile
Eurasian Jay
Quercus sp.
Eriobotrya japonica
Ficus carica
Juglans regia
unid. insect
Diptera
Orthoptera
Sylvia atricapilla (young)
Turdus merula (egg)
unid. seed
Fruit
Insect
Bird
Seed
European Bee-eater
unid. Hymenoptera
Apis mellifera
Bombus terrestris
Vespa crabro
Vespula vulgaris
Xylocopa violacea
Vespidae
unid. insect
Coleoptera
Diptera
Cicadidae
Lepidoptera
Odonata
Orthoptera
Plecoptera
Uca tangeri
Hymenoptera
Other insect
Crustacean
Blue Rock-thrush
Bombus terrestris
Gryllotalpa gryllotalpa
Coleoptera
Hymenoptera
unid. larvae
Scolopendra cingulata
Chalcides bedriagai
Psammodromus algirus
Tarentola mauritanica
Insect
Centipede
Reptile
Osprey
unid. fish
Mugilidae
Liza ramada
Mugil cephalus
Barbus barbus
Carassius auratus
Cyprinus carpio
Dicentrarchus labrax
Sparus aurata
Unid. fish
Mullet
Other fish
Great Cormorant
unid. fish
Mugilidae
Pleuronectiformes
Conger conger
Scorpaena scrofa
Solea solea
Anguilla anguilla
Barbus sp.
Cyprinus carpio
Micropterus salmoides
Silurus glanis
Saltwater fish
Catadrom. fish
Freshwater fish
Common Blackbird
Lumbricidae
unid. berry
Citrus sinensis
Cotoneaster sp.
Prunus sp.
Diospyros kaki
Ficus carica
unid. insect
unid. larvae
unid. snail
Anura
Aranea
Oligochaeta
Fruit
Insect
Gastropod
Amphibian
Arachnid
Barn Owl
Muridae
Apodemus sylvaticus
Rattus sp.
Rattus norvegicus
Mammal
Eurasian Hoopoe
unid. insect
Gryllotalpa gryllotalpa
Blattoidea
unid. larvae
Lepidoptera
Thaumetopoea pityocampa
Aranea
Adult insect
Insect larvae
Arachnid

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.

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