Monitoring waterbird populations in the Tejo estuary, Portugal: report for the decade 2007-2016

Monitorização de aves aquáticas no estuário do Tejo, relatório da década 2007-2016

Pedro M. Lourenço[1], Hany Alonso[2], José A. Alves[3,4], Ana T. Carvalho, Teresa Catry[1], Hélder Costa, Joana S. Costa[3], Maria P. Dias[5,6], Vítor Encarnação[7], Pedro Fernandes[8], Ana I. Leal[9,10], Ricardo C. Martins[9,11], Filipe Moniz[12], Sara Pardal[13], Afonso Rocha[13] & Carlos D. Santos[14,15]

1 Centro de Estudos do Ambiente e do Mar (CESAM)/Departamento de Biologia Animal, Faculdade de Ciências, Universidade de Lisboa, Campo Grande, 1749-016 Lisboa, Portugal. **2** Departamento de Biologia Animal, Faculdade de Ciências, Universidade de Lisboa, Campo Grande, 1749-016 Lisboa. **3** DBIO & CESAM - Centro de Estudos do Ambiente e do Mar, Universidade de Aveiro, Aveiro, Portugal. **4** South Iceland Research Centre, University of Iceland, Selfoss, IS-800, Iceland. **5** BirdLife International, The David Attenborough Building, Pembroke Street, Cambridge CB2 3QZ, UK. **6** MARE – Marine and Environmental Sciences Centre, ISPA – Instituto Universitário, Rua Jardim do Tabaco 34, 1149-041 Lisboa, Portugal. **7** Centro de Estudos de Migrações e Proteção de Aves (CEMPA), Instituto da Conservação da Natureza e das Florestas ICNF), IP, Av. Combatentes da Grande Guerra 1, 2890-015 Alcochete, Portugal. **8** Bis 29, Rue Jabal Toubkal, apt.11. Agdal, Rabat, Morocco. **9** CEABN/InBIO, Instituto Superior de Agronomia, Universidade de Lisboa, Tapada da Ajuda, 1349-017 Lisboa, Portugal. **10** cE3c – Centro de Ecologia, Evolução e Alterações Ambientais, Departamento de Biologia Animal, Faculdade de Ciências, Universidade de Lisboa, 1749-016 Lisboa, Portugal. **11** CIBIO/InBIO – Centro de Investigação em Biodiversidade e Recursos Genéticos, Universidade do Porto, Campus Agrário de Vairão, 4485-601 Vairão, Portugal. **12** Av. Professor Bento de Jesus Caraça n°25 - 3°B, 2725-032 Mem Martins, Portugal. **13** MARE - Marine and Environmental Sciences Centre, Department of Life Sciences, University of Coimbra, 3000-456 Coimbra, Portugal. **14** Núcleo de Teoria e Pesquisa do Comportamento, Universidade Federal do Pará, Rua Augusto Correa 01, Guamá, 66075-110 Belém, Brazil. **15** Department of Migration and Immuno-ecology, Max Planck Institute for Ornithology, Am Obstberg 1, 78315 Radolfzell, Germany.

*** Corresponding author:** P.M. Lourenço, email: p.m.g.lourenco@gmail.com, tel: (+351)938468585

ABSTRACT

The Tejo estuary is a key site for wintering and migratory waterbirds both at the national and international levels. Here we report the main findings of an ongoing monitoring programme of waterbirds in the main high tide roosts of the estuary. A decade of monthly counts (between 2007 and 2016) revealed peaks in waterbird abundance occurring between August and February, with monthly averages of over 28000 birds. Overall, our data highlight the importance of this wetland during winter and autumn migration, with lower but also relevant numbers during spring migration.

Despite some variation over the decade, we found some consistency in the relative importance of the several roosts, with the same five sites harbouring over 80% of all counted birds across years and waterbird groups. Three of these roosts (Samouco, Vasa Sacos and Ribeira das Enguias) are located within national protected areas, while the other two (Corroios and Alhos Vedros/Moita) have no legal protection. We also attempt to evaluate the relative importance of remote saltmarshes in the north-eastern part of the estuary, which were not part of the present monitoring effort but can harbour important numbers of several waterbird species.

In the monitored roosts, we observed different population trends for different waterbird species, ranging from strong increases (in several wildfowl species, two shorebirds and great cormorant) to strong decreases (in four shorebird species). In several cases, local population trends were dissimilar to the known trends across the flyway, but this comparison may be hindered by a temporal mismatch between our data and available flyway-wide data. Nevertheless, local trends for dunlin, redshank and ruddy turnstone may be of particular concern as these species show decreases in the Tejo estuary, in contrast with the flyway trend, suggesting that they may be facing problems locally.

Keywords: high tide roost; population trend; saltpan, saltmarsh, shorebird.

RESUMO

O estuário do Tejo é uma importante zona de invernada e passagem migratória para aves aquáticas, tanto a nível nacional como internacional. São aqui apresentados os principais resultados de um programa de monitorização em curso focado nas aves aquáticas que usam os principais refúgios de preia-mar do Tejo. Entre 2007 e 2016 observaram-se picos de abundância de aves aquáticas entre Agosto e Fevereiro, com médias mensais superiores a 28000 aves. Estes dados evidenciam a importância desta zona húmida durante a invernada e migração outonal, e em menor grau na migração primaveril.

Apesar alguma variação, a importância relativa dos diferentes refúgios manteve-se semelhante ao longo da década, com os mesmos cinco refúgios a receberem mais de 80% das aves independentemente do ano ou do grupo taxonómico. Três destes refúgios (Samouco, Vasa Sacos e Ribeira das Enguias) estão incluídos em áreas protegidas, enquanto os outros dois (Corroios e Alhos Vedros/Moita) não têm protecção legal. Tentou-se também avaliar a importância relativa dos sapais da zona nordeste do estuário, que não fizeram parte desta monitorização mas albergam importantes números de limícolas e anatídeos durante a preia-mar.

As tendências populacionais nos refúgios estudados variaram consideravelmente entre espécies, desde acentuados aumentos (em vários anatídeos, duas limícolas e no corvo-marinho-de-faces-brancas) a acentuados declínios (em quatro limícolas). Em vários casos, a tendência observada no Tejo é distinta daquela observada ao nível da rota migratória, mas esta comparação pode ter sido enviesada por discordâncias temporais entre os nossos dados e os dados internacionais disponíveis. Contudo, as tendências detectadas para pilrito-comum, perna-vermelha e rola-do-mar podem ser de especial preocupação pois estas espécies estão em declínio no Tejo mas não ao nível da rota migratória, podendo indicar que estas espécies estão a ser afectadas por problemas locais.

Palavras-chave: refúgios de preia mar; tendência populacional; salina; sapal; aves limícolas.

Introduction

Wetlands, such as estuaries and other coastal areas, play a key role in the life cycles of millions of waterbirds as wintering, breeding and migratory stopover sites (Boere et al. 2006). Due to their high productivity and typical location at the interface between oceans and rivers, coastal wetlands also attract human settlement and economic development, often leading to conflicts between human activities and the conservation of natural values (Mee 2012). Land reclamation, water and sediment regulation, fisheries, hunting, pollution (from industrial, agricultural and domestic sources) and climate change, all exert varying pressures on waterbird populations worldwide (Delany et al. 2010). Consequently, the conservation and management of coastal wetlands is an important global issue. For an informed application of conservation efforts, knowledge of the current status of different waterbird populations, as well as their annual trends, is critical. Such information will not only indicate which species are facing harsher conditions and threats, but also, when sufficiently detailed, pinpoint the sites and habitats where conservation actions are most urgently needed.

The Tejo estuary, located on the central coast of Portugal, is one of the key sites for waterbirds along the East Atlantic Flyway (EAF), particularly for migratory shorebirds. Internationally important numbers (i.e. >1% flyway population) of some species winter here, such as pied avocet *Recurvirostra avosetta*, black-tailed godwit *Limosa limosa*, grey plover *Pluvialis squatarola*, dunlin *Calidris alpina*, ringed plover *Charadrius hiaticula* and bar-tailed godwit *Limosa lapponica*, as well as over 1% of the flyway breeding population of black-winged stilt *Himantopus himantopus* (Delany et al. 2009). The Tejo estuary is also an important staging site for shorebirds migrating between high latitude breeding areas and African wintering sites. In fact, most species reach peak abundance during migratory periods (Alves et al. 2011, Catry et al. 2011), emphasizing the need to monitor bird populations not only in winter, but throughout the year.

Beside shorebirds, the Tejo estuary also holds relevant numbers of other waterbirds, such as gulls, egrets and herons, wildfowl and flamingos, highlighting the national and international importance of this wetland as a legacy of natural values for future generations. In order to improve monitoring of waterbirds populations in the Tejo estuary and provide detailed information on local population status and phenology, we started a monitoring programme in 2007 aimed at obtaining monthly waterbird counts in the main high tide roosting sites. The objective of this monitoring programme was also to detect any relevant changes occurring at roosting sites. Over the years, this effort provided accurate information on the relative importance of different roosts and documented in detail the importance of this wetland during wintering and migratory periods (Alves et al. 2010, 2011, 2012, Catry et al. 2011). After ten years of continuous monitoring, we now summarize the main findings in terms of population sizes, phenological patterns and relative importance of different roosts, and provide estimates of population trends during this decade for some of the most relevant populations wintering and breeding in the Tejo estuary.

Methods

Study area and waterbird counts

From January 2007 to December 2016, monthly counts were performed in nine key high tide roosts of the Tejo estuary (Fig. 1). The nine monitored sites cover the range of roosting conditions found by waterbirds in the Tejo: saltpans partially converted to shrimp production (Vasa Sacos, Ribeira das

Figure 1 - Map of the Tejo estuary including all monitored high tide roosts (red), the bare intertidal areas (grey) and saltmarsh areas (green). The green line indicates the limits of the Tejo Estuary Nature Reserve (RNET) and the dashed blue line shows the limits of the Tejo Estuary Special Protection Area (SPA). The saltmarshes monitored by ICNF roughly correspond to all saltmarsh areas located within the green line.

Figura 1 - Mapa do estuário do Tejo incluindo todos os refúgios de preia-mar monitorizados (vermelho), as zonas intertidais (cinzento) e os sapais (verde). A linha verde indica os limites da Reserva Natural do Estuário do Tejo (RNET) e a linha tracejada azul mostra os limites da Zona de Protecção Especial (ZPE) do estuário do Tejo. Os sapais monitorizados pelo ICNF correspondem aproximadamente aos sapais incluídos dentro da linha verde.

Enguias, Samouco, Alhos Vedros/Moita), active saltpans managed for waterbirds (Samouco), abandoned saltpans (Vale de Frades, Samouco, Sarilhos, Seixal and Alhos Vedros/Moita), and saltmarsh (Vasa-Sacos, Sarilhos, Alhos Vedros/Moita, Coina and Corroios). These conditions have remained mostly unaltered during the ten year survey period. Only the northern roosts (Vasa Sacos, Vale de Frades, Ribeira das Enguias and Samouco) are included in the local protected areas (Tejo Estuary Nature Reserve and Tejo Estuary Special Protection Area (SPA); Fig. 1).

In each count, we registered the number of individuals of each species of waterbirds, covering all species of the following orders: Anseriformes, Podicipediformes, Phoenicopteriformes, Gruiformes, Gaviiformes, Ciconiiformes, Pelecaniformes, Suliformes and Charadriiformes. Although it was not a key goal, we also recorded the number of raptors (Accipitriformes and Falconiformes) flying over the roosts during monitoring. Counts took place in a period of c. 8 days around the spring tide peak for each month, typically with high water height reaching at least 3.3 m, guaranteeing that no intertidal areas remained available for birds during high tide (Rosa et al. 2006). Counts were preferentially undertaken between 2 h prior and 2 h after the peak of high tide, when bird movements are minimal. Occasionally, some counts extended beyond this period due to logistical problems. All counts were performed by very experienced observers, so we expect no observer bias among roosts. Three roosts were not monitored over the whole ten year period: monitoring in Coina only started in 2009, Ribeira das Enguias was not covered in 2016 due to observer unavailability, and Vasa-Sacos was not monitored in 2007 as the sites was not in use as a waterbird roost at the time due to shrimp farming activities. Otherwise, counting effort was similar across roosts, with a maximum of 98.3% of all possible counts performed in Alhos Vedros/Moita and Corroios, and a minimum of 88.3% of all possible counts performed in Ribeira das Enguias.

Dealing with missing counts

During the 10 year period we carried out 991 counts in individual roosts; however, due to logistical reasons, we missed 89 monthly counts. Data on total numbers counted include all available counts, without any corrections for missing values (Table 1). Data on the relative importance of different roosts use the average count for each site/month over the ten year period, therefore, sample sizes may differ among sites and months (range: 5-10 samples per site/month), but the averages are comparable. Data on phenological patterns also use the average of each month, but in this case for all roosts combined, so any given month when not all roosts were counted was excluded from the analysis (included data ranges 5-9 samples for each month). Details on how the method for analysing population trends deals with missing data are specified below.

Grouping waterbird species according to their phenologys

Data on the phenology of individual species provide a broad picture of the relevance of the Tejo estuary for waterbird populations along the annual cycle. In order to group species according to their phenology, we used the standardized (x-mean/SD) average count for each species in each month in a UPGMA (Unweighted Pair Group Method with Arithmetic Mean Algorithm) cluster analysis (Gauch 1982). This analysis was restricted to the 40 most abundant species (see Table 1).

Population trends from 2007 to 2016

To analyse population trends, we used the TRIM-software (TRends and Indices for Monitoring data; Gregory et al. 2005, Pannekoek & Van Strien 2005) through package 'rtrim' that allows implementing TRIM within the R statistical environment (Boogart et al. 2016). TRIM is a widely used freeware program with an efficient implementation of log-linear Poisson regression models to analyse time series of count data (Gregory et al. 2005). The estimation method in TRIM uses generalized estimating equations (GEE; see Liang & Zeger 1986), thereby taking into account serial correlation and over-dispersion from Poisson distribution. The models were run for each species, and the number of birds counted in each roost was used as the dependent variable. Before calculating population trends, data from the missing counts were estimated, based on a GEE model with roost identity, year, and the interactions between these two variables. We thus estimated the population numbers for the missing counts using the average numbers within the roost when it was counted, and the trends over the years observed in other roosts. Population trends were then calculated based on this dataset with both the observed and estimated counts. Using the computed annual indices and taking into account their uncertainty, population trends were expressed as ratios of the population present in 2016 compared to 2007. The estimates of the trends are expected to be normally distributed (Gregory et al. 2005, Pannekoek & Van Strien 2005). Mean yearly change rate estimates and confidence intervals were used to classify the trends per year in six categories: "strong increase", "moderate increase", "stable", "moderate decrease", "steep decrease" and "uncertain" (Soldaat et al. 2007).

The analysis of population trends was restricted to the 40 most abundant species (Table 1). Trends were derived from January counts, as the analysis of phenological patterns showed it was the winter month when numbers were more stable (see Appendix 1) and with a smaller chance of migratory movements that may affect the results. In addition, January counts are also used by Wetlands International to analyse global population trends in waterbird populations, so using this month guarantees a straightforward easier comparison of local and global trends. Still, to confirm the trends obtained for January alone, we performed similar analysis considering the count data from December and February. Additionally, for species that use high tide roosts as breeding areas (black-winged stilt, Kentish plover *Charadrius alexandrinus* and little tern *Sternula albifrons*), we estimated trends for their breeding populations. In this case, we used May counts as the phenological patterns exhibited by these species (see Appendix 1 in the Supporting Information) suggest that numbers in this month are less likely to be affected by stochastic effects such as "late springs" or by the built up in numbers that takes place after the end of the breeding season. In the case of little tern, we could only obtain a breeding trend as this species winters in Africa.

Estimating the proportion of waterbirds in the Tejo estuary that use non-monitored roosts

The present monitoring effort covered all the key high tide roosts in the Tejo estuary that are accessible from land. However, the northeast part of the estuary comprises extensive saltmarsh areas that are also used by waterbirds during high tide and can only be accessed by boat. Coverage of those remote areas was beyond the scope of the present monitoring effort, but these areas are regularly monitored by Instituto da Conservação da Natureza e das Florestas (ICNF). We must be cautious when using these data, as monitoring of those saltmarshes areas was often not carried out according to the schedule defined for the remaining counts. In any case, we used available count data from these saltmarshes, collected in the months of January, February and December from January 2012 to January 2015 to roughly estimate the "number of birds missed" during our monitoring effort. We only present these data for shorebirds and wildfowl, as we were unable to obtain similar data for the remaining waterbird groups.

Table 1 - Monthly averages (±SD) of all waterbird species identified at the Tejo estuary during the present monitoring programme between 2007 and 2016. Species are ordered in descending order of abundance.

Tabela 1 - Médias mensais (±DP) de todas as espécies de aves aquáticas detectadas no estuário do Tejo durante o programa de monitorização em curso, entre 2007 e 2016. As espécies estão ordenadas por abundância decrescente.

SPECIES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Calidris alpina	9732 ±1930	9688 ±3177	5647 ±2437	9084 ±6618	5265 ±3169	476 ±438	3203 ±2464	7897 ±4119	5813 ±1872	7350 ±1633	9976 ±2528	8541 ±2607
Limosa limosa	3090 ±1399	2279 ±1447	1042 ±1238	584 ±381	325 ±240	1047 ±1088	3014 ±1814	4411 ±2078	5386 ±2291	5193 ±2841	5543 ±6298	5698 ±5412
Larus ridibundus	3080 ±1088	2681 ±1247	1471 ±787	679 ±369	236 ±150	783 ±523	4856 ±3207	4521 ±2131	4211 ±1889	2238 ±1043	1591 ±698	1989 ±1178
Pluvialis squatarola	2564 ±763	2650 ±639	2079 ±574	2114 ±881	390 ±325	214 ±186	295 ±228	1854 ±1271	4158 ±1574	3159 ±1516	3011 ±1262	2863 ±954
Larus fuscus	2027 ±878	1443 ±481	1512 ±575	513 ±356	375 ±598	156 ±120	774 ±775	3012 ±1315	2939 ±1483	1786 ±575	2247 ±1020	1881 ±968
Tringa totanus	1269 ±209	987 ±303	3203 ±273	35±24	21±22	187 ±160	1759 ±824	1987 ±1019	1576 ±511	1745 ±565	1430 ±393	1232 ±336
Phoenicopterus roseus	1144 ±489	1426 ±906	1266 ±1048	1091 ±987	1076 ±1609	728 ±847	947 ±646	1129 ±681	1374 ±690	1352 ±842	1081 ±923	636 ±484
Recurvirostra avosetta	1974 ±707	1717 ±764	658 ±539	144 ±120	131 ±114	80 ±102	174 ±318	29 ±42	65 ±53	324 ±270	1130 ±289	1699 ±591
Charadrius hiaticula	578 ±323	430 ±392	303 ±172	254 ±108	158 ±101	34±31	53 ±49	2103 ±1093	1876 ±1014	687 ±287	662 ±315	565 ±382
Himantopus himantopus	426 ±80	402 ±145	572 ±155	734 ±211	568 ±148	665 ±205	1061 ±518	804 ±396	617 ±180	440 ±143	430 ±117	339 ±159
Limosa lapponica	462 ±212	277 ±310	64 ±74	49 ±82	9±17	20±31	83 ±120	839 ±603	1411 ±682	935 ±843	865 ±638	332 ±235
Anas crecca	1394 ±1024	804 ±809	332 ±679	0.2±1	0.2±1	0.2±1	0.1±0.3	9±27	10±10	285 ±504	755 ±1567	932 ±834
Calidris canutus	195 ±132	240 ±288	154 ±247	228 ±393	371 ±447	38±67	58±67	397 ±290	605 ±550	527 ±583	360 ±409	308 ±340
Fulica atra	425 ±450	336 ±429	390 ±464	167 ±270	176 ±255	200 ±232	132 ±174	101 ±135	150 ±307	439 ±622	378 ±491	503 ±603
Anas platyrhynchos	307 ±211	444 ±255	408 ±241	350 ±225	384 ±278	126 ±81	87±94	334 ±632	173 ±205	175 ±127	132 ±88	164 ±132
Egretta garzetta	152 ±43	113 ±34	141 ±73	124 ±35	194 ±93	330 ±206	461 ±274	523 ±291	432 ±227	269 ±133	170 ±65	113 ±52
Anas clypeata	538 ±395	730 ±523	384 ±463	3±3	1±1	1±1	0.4 ±1	4±8	44±65	255 ±276	434 ±589	337 ±328
Numenius arquata	353 ±122	378 ±192	73 ±102	46 ±48	17±16	87±40	265 ±171	249 ±134	257 ±115	302 ±122	278 ±114	225 ±116
Calidris ferruginea	54±67	69±70	102 ±91	178 ±183	152 ±192	86±81	105 ±186	691 ±610	370 ±384	259 ±302	196 ±220	74 ±180
Charadrius alexandrinus	230 ±254	102 ±91	107 ±96	75±51	90±40	129 ±84	287 ±175	402 ±192	323 ±305	179 ±162	206 ±127	138 ±86
Arenaria interpres	299 ±106	179 ±88	295 ±189	243 ±150	73 ±102	46±43	66±48	167 ±105	156 ±75	229 ±101	249 ±101	209 ±108
Ardea cinerea	136 ±42	89±30	61 ±25	46±14	51±16	94±67	110 ±40	164 ±55	160 ±52	154 ±92	155 ±54	132 ±62
Phalacrocorax carbo	233 ±198	153 ±72	73±38	11±10	1±1	0.3±1	19±57	3±6	25 ±21	146 ±137	300 ±206	210 ±142
Tringa nebularia	102 ±26	119 ±34	133 ±38	130 ±45	9±8	11±16	31±19	123 ±70	130 ±66	131 ±43	127 ±54	93 ±29
Calidris minuta	81±68	106 ±135	129 ±95	144 ±150	44±62	0.1 ±0.3	1±2	76±72	119 ±74	136 ±71	155 ±130	58±30

SPECIES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Larus melanocephalus	10±3	9±23	12 ±22	1±3	2±5	91 ±165	429 ±131	364 ±353	66±81	4±11	10±32	17±53
Numenius phaeopus	40±23	31±33	20±19	175 ±73	28±16	53±53	164 ±150	149 ±71	93±61	58±52	37±50	60 ±86
Vanellus vanellus	66±78	52±47	1±1	6±18	1±2	5±11	13 ±25	78 ±77	95±85	265 ±216	228 ±222	62 ±78
Tringa erythropus	58±47	43±28	67±38	56±36	1±1	5±9	22±21	163 ±298	78±46	75±46	67±51	58±58
Platalea leucorodia	91±33	78±42	55±45	24±24	22±19	25±32	30±58	18±19	55±50	119 ±89	80±24	84±60
Calidris alba	68 ±104	70±43	65±57	75±93	8±10	0.1 ±0.3	0.2 ±0.4	34±55	124 ±78	111 ±94	27±26	23 ±33
Sternula albifrons	0.0 ±0.0	0.3±1	0.0 ±0.0	70±49	89±46	105 ±59	137 ±99	121 ±120	15±27	0.2 ±0.4	0.0 ±0.0	0.0 ±0.0
Plegadis falcinellus	201 ±635	31±95	10±16	11±26	11±22	2±5	28±55	77 ±100	49 ±121	108 ±334	6±13	1±4
Anas penelope	90±85	156 ±231	3±6	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	1±2	73±88	105 ±173	76±90
Actitis hypoleucos	34±18	31±14	34±15	35±12	1±1	2±4	38±23	70±31	66±36	49±35	33±10	28±8
Tachybaptus ruficollis	56±42	29±29	37±85	4±6	2±3	8±13	18±18	45±48	37±34	57±49	56±61	61±53
Philomachus pugnax	5±4	12±17	64±84	22±16	0.4±1	0.2 ±0.4	15±11	151 ±259	75±42	36±39	2±2	4±7
Haematopus ostralegus	27±45	58±58	23±45	12±37	0.0 ±0.0	12±38	2±6	60±66	58±92	20±32	16±48	10±28
Bubulcus ibis	5±7	16±28	11±14	22±25	42±66	27±52	23±39	26±34	21±17	32±37	7±9	8±12
Thalasseus sandvicensis	10±7	10±12	12±9	4±7	0.2±1	13±41	10±22	49±47	59±44	27±13	23±15	14±13
Gallinago gallinago	11±12	18±15	18±29	1±1	0.1 ±0.3	2±7	0.0 ±0.0	1±2	96 ±293	5±5	9±13	9 ±10
Anas acuta	0.1 ±0.3	0.0 ±0.0	0.4±1	0.4±1	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	3±9	79 ±187	21±36	0±0.0
Larus michahellis	24±62	2±5	1±3	0.4±1	0.2 ±0.4	7±22	6±12	43±96	10±15	0.2±1	0.4±1	6±9
Pluvialis apricaria	39 ±112	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.1 ±0.3	0.1 ±0.3	16±44	43±95	1±1
Gelochelidon nilotica	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	2±3	1±2	0.4±1	89 ±128	1±1	0.0 ±0.0	1±2	0.0 ±0.0	0.0 ±0.0
Tadorna tadorna	13±23	9±12	7±6	9±9	5±4	2±3	3±3	0.3±1	4±6	7±9	3±6	13±27
Anas strepera	8±14	6±10	11±7	8±10	15±29	4±7	1±2	0.2±1	1±2	1±1	3±8	5±14
Tringa ochropus	5±5	4±5	5±5	16±36	0.0 ±0.0	0.1 ±0.3	4±4	9±18	4±4	4±5	3±3	4±4
Gallinula chloropus	5±3	5±3	5±2	5±5	5±4	3±2	2±3	2±1	1±2	4±4	3±2	13±26
Egretta alba	4±4	2±2	3±4	2±2	2±3	1±2	1±1	1±1	2±4	3±3	4±5	5±9
Anser anser	7±14	13 ±39	0.0 ±0.0	0.0 ±0.0	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	1±4	0.4±1	0.0 ±0.0
Ciconia ciconia	0.3±1	0.1 ±0.3	0.0 ±0.0	0.2±1	0.2±1	0.0 ±0.0	0.3 ±0.4	13±61	6±24	0.0 ±0.0	0.0 ±0.0	0.2±1
Netta rufina	0.0 ±0.0	1±3	2±3	4±8	4±7	1±2	0.0 ±0.0	0.2±1	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Glareola pratincola	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	2±6	2±4	7±16	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0

SPECIES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Chlidonias niger	0.0 ±0.0	0.0 ±0.0	0.3±1	1±2	3±5	1±2	0.2 ±0.4	1±1	2±6	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0
Larus minutus	0.0 ±0.0	8±24	0.2 ±0.4	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.1 ±0.3	0.1 ±0.3
Mergus serrator	2±5	2±6	2±3	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.4±1	1±2
Sterna hirundo	0.0 ±0.0	1 ±3	0.0 ±0.0	0.3 ±1	0.0 ±0.0	1 ±2	0.4 ±1	1 ±1	1 ±2	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Charadrius dubius	0.0 ±0.0	0.0 ±0.0	0.4 ±1	0.2 ±0.4	0.0 ±0.0	0.1 ±0.3	1 ±2	2 ±6	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Ardea purpurea	0.0 ±0.0	0.0 ±0.0	0.2 ±0.4	1 ±1	1 ±2	1 ±2	0.3 ±0.4	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Burhinus oedicnemus	0.0 ±0.0	0.1 ±0.3	0.2 ±1	0.3 ±1	0.1 ±0.3	2 ±4	0.0 ±0.0	0.1 ±0.3	1 ±2	0.0 ±0.0	0.1 ±0.3	0.0 ±0.0
Aythya fuligula	1±3	0.2±1	0.2±1	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	2±6	0.0 ±0.0
Hydroprogne caspia	0.1 ±0.3	1±1	0.4±1	0.3 ±0.4	0.0 ±0.0	0.2±1	0.1 ±0.3	0.1 ±0.3	0.0 ±0.0	0.4±1	0.0 ±0.0	1±2
Podiceps nigricollis	0.1 ±0.3	0.3±1	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	1±3	1±2
Chlidonias hybridus	0.0 ±0.0	0.0 ±0.0	0.1 ±0.3	0.1 ±0.3	0.1 ±0.3	2±5	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Tringa glareola	0.3±1	0.1 ±0.3	1±2	0.2 ±0.4	0.0 ±0.0	0.0 ±0.0	0.2±1	0.4±1	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Alopochen aegyptiaca	0.0 ±0.0	0.2 ±0.4	0.2±1	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.3±1	0.0 ±0.0	0.3±1	0.0 ±0.0
Marmaronetta angustirostris	0.0 ±0.0	0.0 ±0.0	0.3±1	0.3±1	0.1 ±0.3	0.3±1	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Porphyrio porphyrio	0.0 ±0.0	0.2±1	0.0 ±0.0	0.3±1	0.3±1	0.2±1	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Egretta gullaris	0.0 ±0.0	0.0 ±0.0	0.2 ±0.4	0.0 ±0.0	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.3±1	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Tadorna ferruginea	0.0 ±0.0	0.4±1	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.1 ±0.3	0.0 ±0.0
Aythya ferina	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.3±1	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.1 ±0.3
Limnodromus scolopaceus	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.1 ±0.3	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.1 ±0.3	0.1 ±0.3	0.0 ±0.0
Phalaropus fulicarius	0.0 ±0.0	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.2 ±0.4	0.0 ±0.0	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0
Tringa stagnatilis	0.0 ±0.0	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.1 ±0.3	0.0 ±0.0	0.2 ±0.4	0.0 ±0.0
Ardeola ralloides	0.0 ±0.0	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.1 ±0.3	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Calidris temminckii	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.1 ±0.3	0.0 ±0.0	0.2±1
Cygnus olor	0.0 ±0.0	0.1 ±0.3	0.1 ±0.3	0.0 ±0.0	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Larus genei	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.3±1	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Podiceps cristatus	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.2 ±1
Rallus aquaticus	0.1 ±0.3	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0
Branta canadensis	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.1 ±0.3	0.0 ±0.0	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Fulica cristata	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.2 ±0.4	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0

SPECIES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Gavia immer	0.0 ±0.0	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.1 ±0.3	0.0 ±0.0
Ixobrychus minutus	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.2±1	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Larus canus	0.0 ±0.0	0.1 ±0.3	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Phalaropus lobatus	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.1 ±0.3	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Rissa tridactyla	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.1 ±0.3
Tringa flavipes	0.0 ±0.0	0.0 ±0.0	0.1 ±0.3	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Tringa semipalmata	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Clangula hyemalis	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.1 ±0.3	0.0 ±0.0
Larus delawarensis	0.0 ±0.0	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Larus hyperboreus	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Melanitta fusca	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0. 0 ±0.0	0.0 ±0.0	0.1 ±0.3	0.0 ±0.0
Phoeniconaias minor	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0

Results

Waterbird community: composition and abundance

We identified a total of 95 waterbird species during roost counts (Table 1), the most common groups being shorebirds (36 species), followed by wildfowl (19 species), gulls and terns (17 species), and egrets and herons (8 species). We also identified five rallids, three grebes, two flamingos, one ibis, one spoonbill, one cormorant, one stork and one loon (Table 1). This list includes six species that are considered vagrants in the Western Palearctic, two originating from Africa (reef egret *Egretta gullaris* and lesser flamingo *Phoeniconaias minor*), and four from North America (lesser yellowlegs *Tringa flavipes*, willet *Tringa semipalmata,* long-billed dowitcher *Limnodromus scolopaceus* and ring-billed gull *Larus delawarensis*). Another four species are most likely escapes from captivity (Canada goose *Branta canadensis*, mute swan *Cygnus olor*, ruddy shelduck *Tadorna ferruginea* and Egyptian goose *Alopochen aegypticus*) and we cannot rule-out the possibility that this was also the case of lesser flamingo as this species is often kept in captivity.

Over the ten years of monitoring we counted nearly three million birds, the ten most abundant species being dunlin, black-tailed godwit, black-headed gull *Larus ridibundus*, grey plover, lesser black-backed gull *Larus fuscus*, greater flamingo *Phoenicopterus roseus*, common redshank *Tringa totanus*, pied avocet, common ringed plover *Charadrius hiaticula* and black-winged stilt (Table 1). Among the 40 most abundant species, which were analysed in greater detail, we mainly found shorebirds (22 species), gulls and terns (five species), ducks (four species) and herons and egrets (three species).

During the counts, we also detected 14 raptor species, the most abundant of which were marsh harrier *Circus aeruginosus*, common kestrel *Falco tinnunculus*, osprey *Pandion haliaetus*, Eurasian buzzard *Buteo buteo* and black-shouldered kite *Elanus caeruleus* (Table 2).

Table 2 - Monthly averages (±SD) of raptor species identified at the Tejo estuary during the present monitoring programme between 2007 and 2016. Species are ordered in descending order of abundance.

Tabela 2 - Médias mensais (±DP) de aves de rapina detectadas no estuário do Tejo durante o programa de monitorização em curso, entre 2007 e 2016. As espécies estão ordenadas por abundância decrescente.

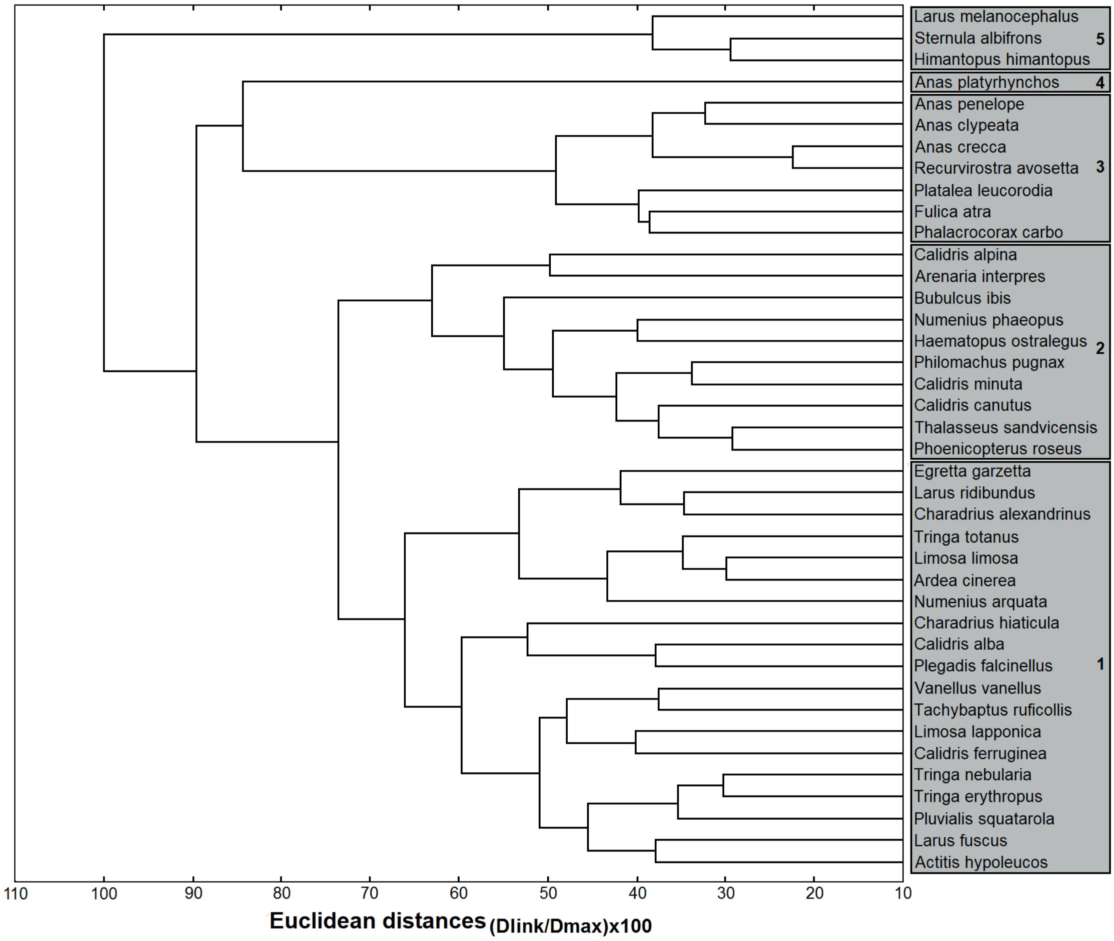
SPECIES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Circus aeruginosus	4±4	3±3	4±4	4±4	4±3	3±3	4±3	4±3	2±2	4±3	4±3	5±4
Falco tinnunculus	2±2	2±2	1±2	0.4±1	0.3 ±0.4	1±1	2±1	1±1	0.3±1	2±2	2±2	2±2
Pandion haliaetus	2±1	1±1	1±1	0.4±1	1±1	0.2 ±0.4	0.3±1	1±1	2±1	2±1	2±2	2±1
Buteo buteo	0.3±1	1±1	0.3±1	0.3±1	0.3±1	1±1	1±1	0.1 ±0.3	7±20	1±1	1±1	1±1
Elanus caeruleus	2±2	1±2	1±1	0.4±1	0.3±1	1±3	0.0 ±0.0	2±2	1±2	2±2	2±2	2±2
Falco peregrines	1±1	1±1	0.3±1	0.4±1	0.2 ±0.4	0.0 ±0.0	0.0 ±0.0	0.2±1	0.4±1	1±1	0.4±1	0.3±1
Milvus migrans	0.0 ±0.0	0.0 ±0.0	0.1 ±0.3	0.2 ±0.4	0.3±1	0.3±1	1±1	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Circus cyaneus	0.2 ±0.4	0.2 ±0.4	0.0 ±0.0	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.1 ±0.3	0.0 ±0.0	0.3±1	0.3±1	0.1 ±0.3
Aquila fasciata	0.0 ±0.0	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.1 ±0.3	0.2 ±0.4	0.1 ±0.3	0.2 ±0.4	0.1 ±0.3
Aquila pennata	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.2±1	0.2 ±0.4	0.1 ±0.3	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.3
Milvus milvus	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.1 ±0.3	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Circaetus gallicus	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Circus pygargus	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.1 ±0.3	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Falco columbarius	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.1 ±0.3

Phenological patterns

Overall, waterbird abundances in the monitored roosts peaked between August and February, when the average number of birds reached 28500-33500. By March-April numbers had dropped to roughly 18000 by March-April, reaching their lowest point in June when total numbers were on average below 6000 birds. This evidences that the vast majority of species rely on the Tejo estuary during wintering and migratory passage periods (Fig. 2; see Appendix 1 in the Supporting Information for the detailed phenological patterns of all the 40 most abundant species). Despite considerable variation among species, there were peaks associated with autumn migration for gulls and terns, occurring in July-September, and for flamingos, herons and egrets, mostly during August-October. Wildfowl did not show any evident migratory peaks, being mostly present in mid-winter from December to February (Fig. 2B). Shorebird numbers were high from August through February, with some species showing clear increases in numbers during autumn migration, others peaking during winter, and some species with a smaller but discernible peak in April associated with spring migration.

Figure 2 - Dendrogram based on Euclidean distances, representing the similarities among waterbird species with respect to phenological pattern.

Figura 2 - Dendograma baseado em distâncias euclidianas que representa as semelhanças entre espécies de aves aquáticas no que respeita aos seus padrões fenológicos.

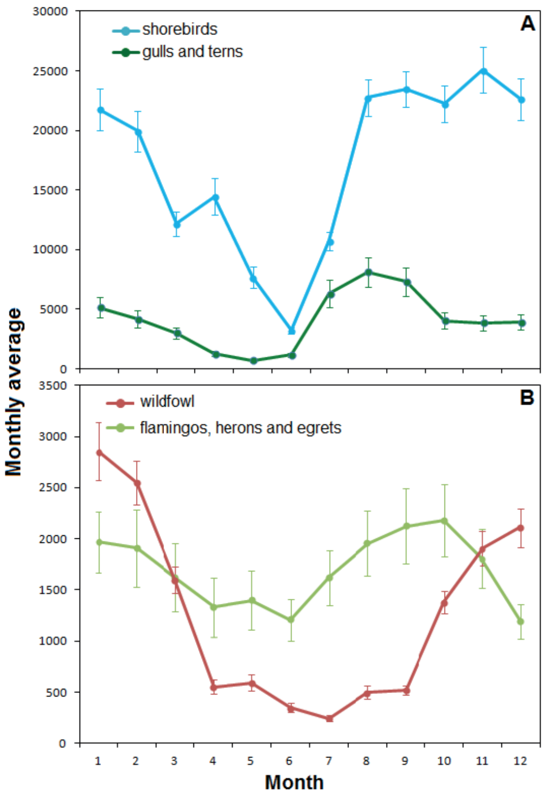


A cluster analysis allowed the identification of 5 groups of species in terms of their phenology in the Tejo estuary (Fig. 3). The larger group included 19 species, such as black-tailed godwit, black-headed gull, grey plover and lesser black-backed gull, for which counts showed a clear increase in numbers during autumn migration and in most cases remained high during mid-winter. The second group included 10 species, such as dunlin, greater flamingo and red knot *Calidris canutus*, which generally showed increases during spring migration or had peaks during both migratory periods, while remaining abundant in mid-winter. The third group was defined by a clear peak in mid-winter, generally between November and February, and included species such as pied avocet, great cormorant *Phalacrocorax carbo*, Eurasian coot *Fulica atra* and several ducks (*Anas crecca, A. clypeata* and *A. penelope*).

A fourth group included only mallard *Anas platyrhynchos* which had a particular phenological pattern with lower numbers in June-November, an increase over December and January, and a long peak in February-May (see Appendix 1 in the Supporting Information). Finally, the fifth group included the three species that peak in late spring and early summer (generally between May and August), including black-winged stilt, little tern and Mediterranean gull *Larus melanocephalus* (Fig. 3).

Figure 3 - Monthly average (±SD) of waterbirds counted in Tejo estuary's high tide roosts for the period 2007-2016. Panel A: shorebirds and gulls and terns. Panel B: wildfowl and flamingos, herons and egrets.

Figura 3 - Média mensal (±DP) de aves aquáticas contadas nos refúgios de preia-mar do estuário do Tejo no período 2007-2016. Painel A: aves limícolas (azul) e gaivotas e andorinhas do mar (verde escuro). Painel B: anatídeos (vermelho) e flamingos e garças (verde claro).



Relative importance of different roosts

Overall, during the ten years of monitoring, the most important high tide roost for waterbirds in the Tejo estuary was Samouco, receiving on average over 30% of all counted birds (Table 3). Together with Vasa Sacos (22.4%), Ribeira das Enguias (12.3%) Corroios (10.6%) and Alhos Vedros/Moita (7.9%), these five roosting sites harboured over 85% of all birds present during our counts (Table 3). The importance of these five sites is similar for all waterbird groups. Together, these five roosts harboured 86% of shorebirds, 81% of all gulls and terns, 85% of all herons, egrets, flamingos and spoonbills (although in this case Sarilhos ranked as the fourth main roost with 10.3%) and 91% of all wildfowl (but Corroios was not particularly important for wildfowl with just 0.4%; Table 3).

These five main sites also remained the most significant throughout the annual cycle, although Samouco seems to be particularly important during autumn migration, while Vasa Sacos loses some of its relative importance during spring migration (Fig. 4). At the species level, Vasa Sacos is particularly important for black-tailed godwits during July-December, while Samouco, Ribeira das Enguias and Alhos Vedros are especially important for common redshank during autumn migration (roughly July-October; Fig. 4). Sarilhos, Samouco, Corroios and Alhos Vedros are particularly important for pied avocet in November-February. Vasa Sacos, Samouco and Ribeira das Enguias are very important for common ringed plover during autumn migration (August-September), and Samouco is virtually the only roost used by bar-tailed godwits during autumn migration (roughly August-November; Fig. 4). Samouco and Ribeira das Enguias are the two key sites for black-winged stilt throughout the year, but especially so after the breeding season in July, when the species peaks in the estuary (Fig. 4). The sites located within the Tejo SPA harbour most birds throughout the annual cycle, the main exception being pied avocet for which roosts outside the protected area receive most individuals between November and February, the period when this species peaks in the estuary.

Data from January suggest there are some temporal trends to the relative importance of difference roosts (Fig. 5). Overall, Vasa Sacos became more important over the years, in fact becoming the most important roost since 2014, while Samouco had much more birds in the first two years of monitoring after which it showed a decline and the numbers stabilized around 6000. Among the remaining roosts, numbers seem to fluctuate over the years without obvious trends, although both Alhos Vedros/Moita and Seixal seem to lose some importance over the years (Fig. 5).

Looking at different phenological and taxonomic groups (Fig. 6), the monthly averages over the years mostly followed the same trends as we observed in overall January counts, although the decline in Samouco seems to be mainly driven by shorebirds and gulls. For wildfowl, which form the bulk of phenological group 3, numbers fluctuated without a clear trend. The increase observed in Vasa Sacos is mostly explained by changes in the number of shorebirds and wildfowl, the same applying to phenological groups 1, 2 and 3 (Fig. 6)

Table 3 - Relative importance of the different high tide roosts used by waterbirds at the Tejo estuary. For each roost we present monthly averages over the ten year period as well as the average percentage (±SD) of individuals counted in that particular roost (%). Data is presented for all birds and for each of four main groups: wildfowl (including Anatidae and Rallidae), flamingos, herons and egrets (including all Phoenicopteridae and Ardeidae), gulls and terns (including all Laridae and Sternidae) and shorebirds (including all Charadriidae, Scolopacidae, Recurvirostridae, Haematopodidae and Glareolidae).

Tabela 3 - Importância relativa dos diferentes refúgios de preia-mar usados pelas aves aquáticas no estuário do Tejo. Para cada refúgio são apresentadas as médias mensais ao longo dos dez anos de monitorização, assim como a percentagem média (±DP) de indivíduos contados em cada refúgio (%). Os dados são apresentados para o conjunto de todas as aves aquáticas e para os quatro principais grupos.

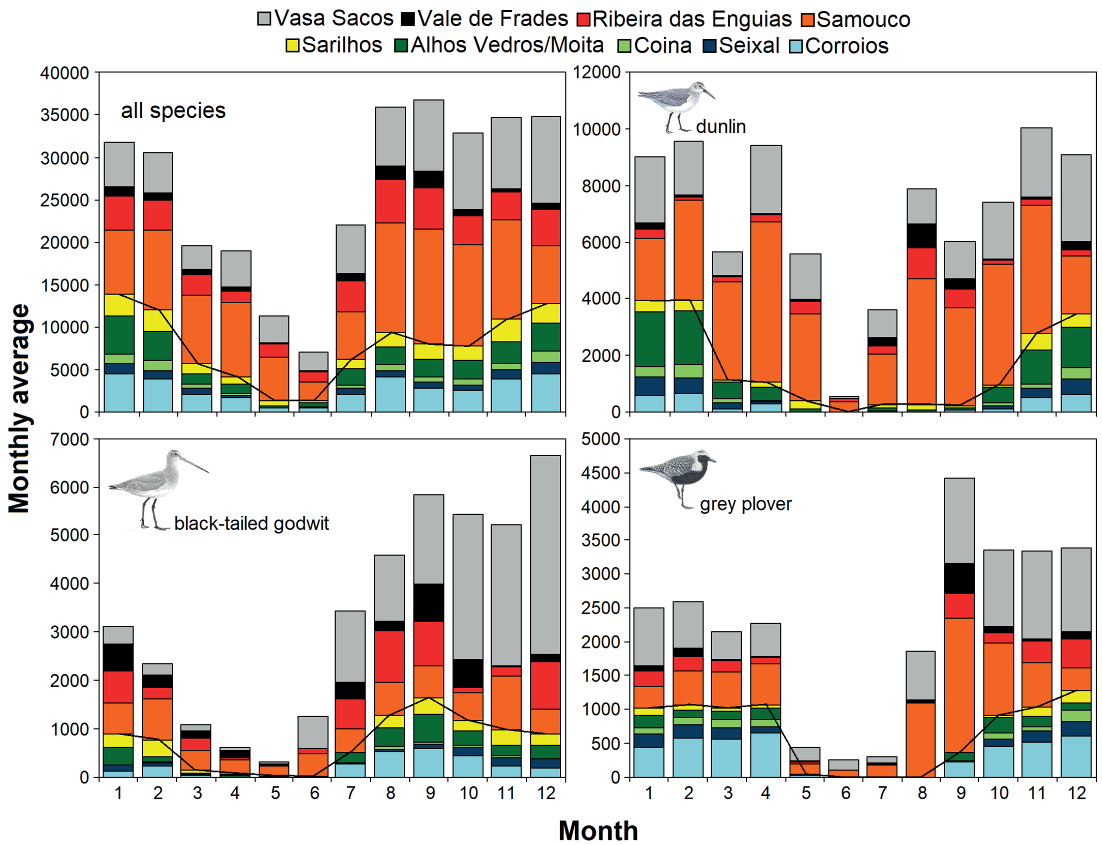
ROOST	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	%
ALL BIRDS													
Corroios	4503	4207	2140	1671	454	441	2090	4153	2862	2602	3943	4539	10.6 ±3.1
Seixal	1222	1034	651	242	20	156	671	698	672	616	1064	1295	2.6 ±1.1
Coina	1092	1406	533	273	27	43	410	747	616	736	733	1318	2.5 ±1.3
Alhos Vedros/ Moita	4493	3387	1215	1144	272	420	1929	2093	2042	2104	2601	3354	7.9 ±3.1
Sarilhos	2585	2487	1133	815	592	280	1093	1630	1799	1795	2605	2321	6.1 ±1.5
Samouco	7489	9054	8059	8738	5035	2168	5593	12906	13536	11914	11725	6715	32.5 ±8.2
Ribeira das Enguias	4059	3536	2463	1417	1604	1229	3636	5185	4890	3336	3255	4309	12.3 ±2.8
Vale de Frades	1131	855	563	410	199	116	942	1593	1908	801	378	728	3.0 ±1.3
Vasa Sacos	5250	4764	2848	4251	3182	2168	5699	6899	8384	8933	8335	10192	22.4 ±5.6
SHOREBIRDS													
Corroios	2284	2607	1006	1082	92	182	749	1159	1383	1599	1995	2454	7.4 ±2.9
Seixal	1191	983	558	204	14	6	82	129	188	497	1019	1271	2.8 ±1.1
Coina	910	1096	413	182	11	4	202	250	277	487	545	1150	2.5 ±1.7

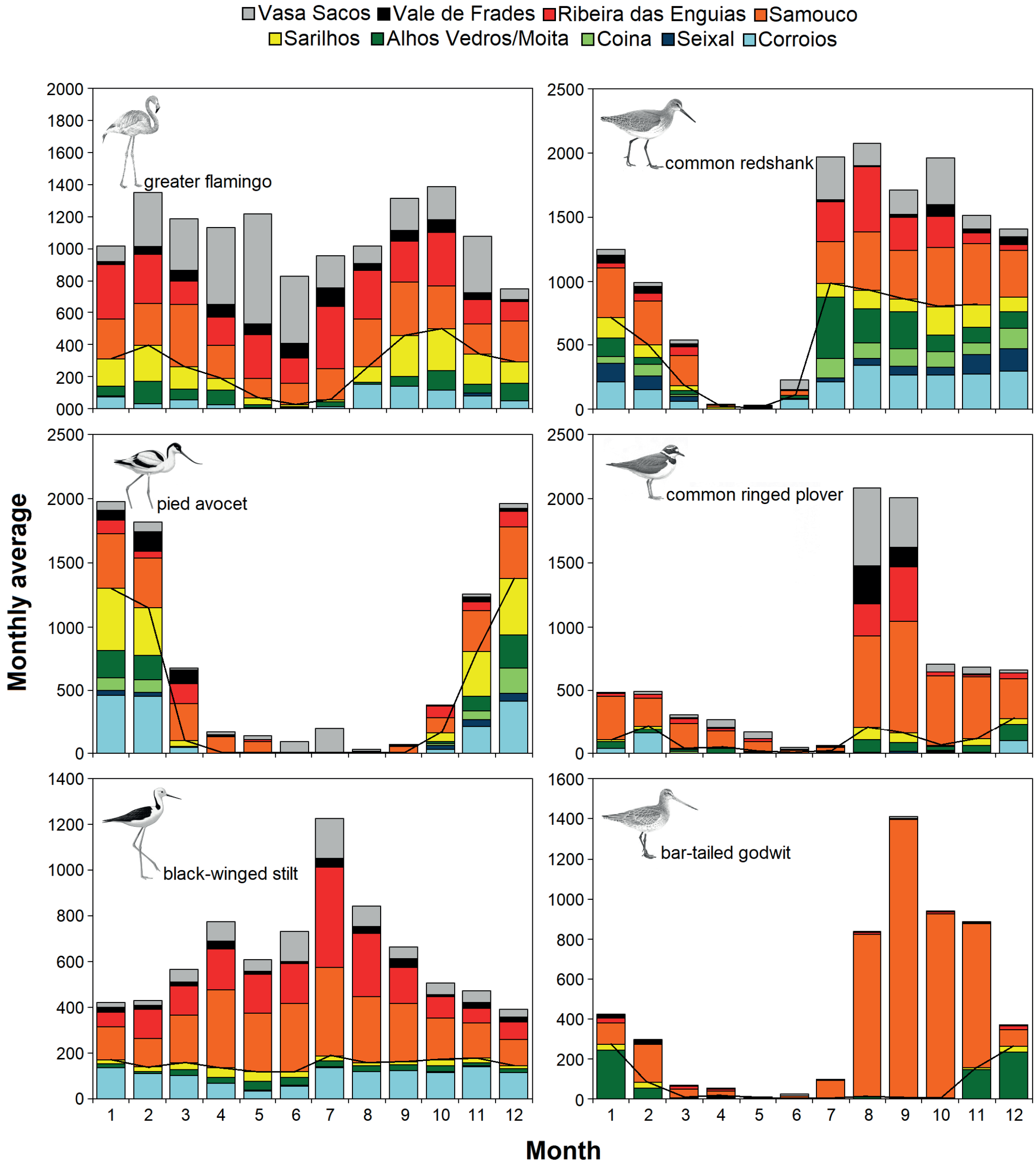
ROOST	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	%
SHOREBIRDS													
Alhos Vedros/ Moita	3356	2553	881	901	168	150	991	1154	1315	1574	2254	2701	8.1 ±3.7
Sarilhos	1645	1449	368	424	354	119	451	783	679	736	1832	1826	4.8 ±1.9
Samouco	5171	6985	6180	8075	4516	1562	3956	10464	10855	9490	9510	4704	36.5 ±10.9
Ribeira das Enguias	1913	1096	1099	699	696	408	1759	3553	3015	1105	1517	2390	8.6 ±3.4
Vale de Frades	1049	740	444	268	129	22	656	1549	1822	668	309	642	3.7 ±2.1
Vasa Sacos	4758	3746	1997	3613	2340	1327	3718	5565	6122	7806	7375	8989	25.7 ±6.4
GULLS AND TERNS													
Corroios	2011	1664	1023	534	324	203	1235	2733	1247	776	1727	1934	26.9 ±10.6
Seixal	20	51	95	48	13	265	593	562	469	124	21	15	4.0 ±4.6
Coina	49	97	133	115	29	58	294	484	332	161	59	44	3.2 ±1.9
Alhos Vedros/ Moita	1033	846	300	214	99	243	903	1000	795	449	254	548	11.7 ±3.6
Sarilhos	639	705	533	245	116	100	559	645	738	655	473	302	10.0 ±3.5
Samouco	1225	954	956	141	75	161	1066	1823	1951	1644	1395	1076	21.7 ±8.5
Ribeira das Enguias	402	774	312	166	187	276	925	761	1034	664	254	360	10.7 ±4.5
Vale de Frades	3	8	113	51	9	8	256	371	30	133	60	4	1.8 ±1.5
Vasa Sacos	71	20	22	53	29	307	1656	984	1818	341	60	405	10.1 ±8.3
WILDFOWL													
Corroios	4	3	7	7	5	8	6	2	7	6	6	4	0.4 ±0.7
Seixal	1	1	2	3	2	1	0	0	0	1	0	1	0.1 ±0.2
Coina	90	174	3	2	0	1	2	2	1	63	100	100	3.5 ±2.5
Alhos Vedros/ Moita	5	4	7	8	7	5	1	0	2	4	9	11	0.4 ±0.4
Sarilhos	103	67	53	54	47	6	3	5	7	17	38	29	2.8 ±2.6
Samouco	537	708	424	192	174	95	31	36	50	150	234	329	19.5 ±8.3
Ribeira das Enguias	882	967	759	266	385	224	211	145	269	793	758	1215	45.2 ±11.4
Vale de Frades	57	56	23	42	16	9	10	7	8	21	26	70	2.3 ±1.5
Vasa Sacos	774	461	322	22	16	33	7	68	141	473	615	1006	25.9 ±12.9

ROOST	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	%
FLAMINGOS, HERONS AND EGRETS													
Corroios	202	117	104	48	33	48	99	258	224	219	213	145	7.7 ±3.4
Seixal	14	10	5	2	3	4	6	7	14	8	26	11	0.5 ±0.3
Coina	4	3	2	3	4	6	10	9	6	5	4	6	0.3 ±0.1
Alhos Vedros/ Moita	202	193	101	106	28	29	53	56	117	186	130	164	6.1 ±3.3
Sarilhos	195	264	179	91	74	44	80	197	373	383	261	157	10.3 ±4.4
Samouco	536	492	587	341	276	351	523	570	658	609	557	543	27.2 ±5.4
Ribeira das Enguias	704	465	256	278	356	347	725	688	578	711	435	279	26.2 ±6.8
Vale de Frades	28	55	73	89	67	90	118	48	75	93	41	13	3.6 ±1.9
Vasa Sacos	134	339	348	504	712	476	318	212	253	299	376	81	18.2 ±12.5

Figure 4 - Monthly average of waterbirds counted in each high tide roost of the Tejo estuary between 2007 and 2016 for all species combined (top left) and for the nine most abundant species (excluding gulls). Black lines represent the sums for the roosts laying in the southern part of the estuary, which are outside protected areas (see also Figure 1).

Figura 4 - Média mensal de aves aquáticas contadas em cada um dos refúgios de preia-mar do estuário do Tejo entre 2007 e 2016 para todas as espécies em conjunto (canto superior esquerdo) e para cada uma das nove espécies mais abundantes (excluindo gaivotas). As linhas pretas representam a soma de aves contadas nos refúgios da parte sul do estuário, que estão fora dos limites das áreas protegidas (ver também a Figura 1).





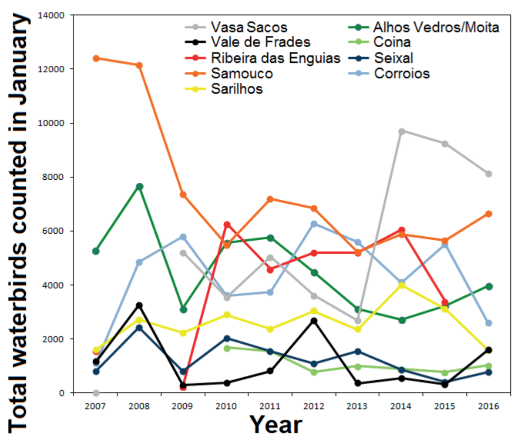
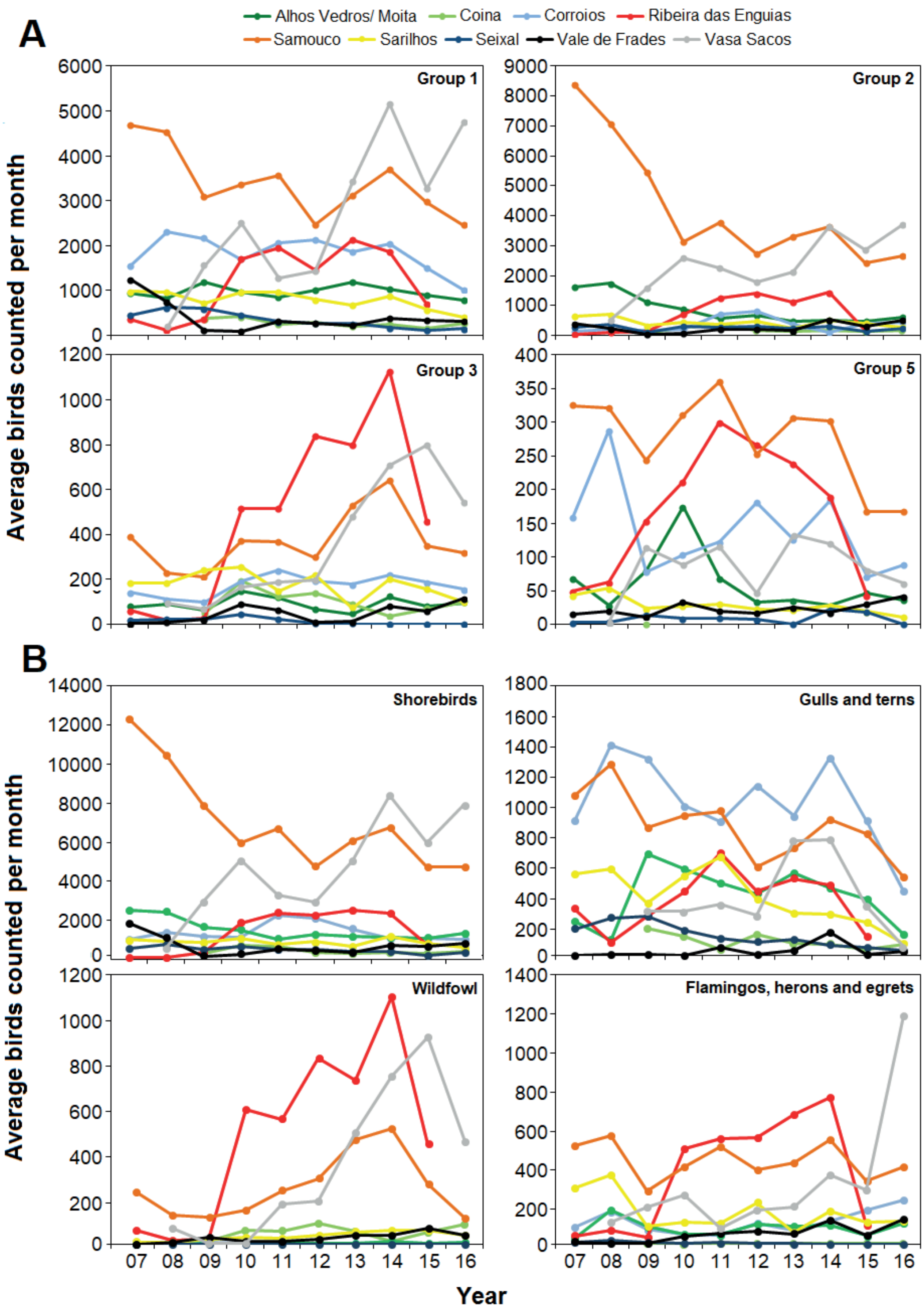


Figure 5 - Total waterbirds (all species combined) recorded in the January count of each high tide roost of the Tejo estuary between 2007 and 2016, showing changes in the relative importance of each roost over the ten year period.

Figura 5 - Total de aves aquáticas (todas as espécies em conjunto) contadas em Janeiro em cada um dos refúgios de preia-mar do Tejo entre 2007 e 2016, mostrando as mudanças na importância relativa dos diferentes refúgios ao longo destes dez anos.

Figure 6 - Average waterbirds counted per month in each of the high tide roosts of the Tejo estuary between 2007 and 2006. We present data for the phenological groups defined in Figure 3 (Panel A) and for each of the main waterbird groups using the Tejo estuary's high tide roosts (Panel B).

Figura 6 - Média mensal de aves aquáticas contadas em cada refúgio de preia-mar do estuário do Tejo entre 2007 e 2016. São apresentados os dados referentes aos grupos fenológicos definidos na Figura 3 (Painel A) e para cada um dos principais grupos de aves aquáticas que usam os refúgios de preia-mar do Tejo (Painel B).



Population trends from 2007 to 2016

We were able to derive trends for 22 wintering populations, seven of which had a stable population trend, eight were increasing and seven were decreasing (Table 4). For the remaining 18 wintering population we either obtained uncertain trends or the data was not sufficient to run the models (see Appendix 2 in the Supporting Information). For the three breeding populations analysed, black-winged stilts showed a stable trend, while little terns showed a moderate decrease and Kentish plover evidenced a strong decrease (Table 4). All analysed duck species showed strong increases, the same being true for great cormorant. Eurasian spoonbill *Platalea leucorodia* showed a moderate increase, while the two gulls, greater flamingo and little egret *Egretta garzetta* all show stable trends. The grey heron *Ardea cinerea* is declining at a moderate rate. Among shorebirds, trends varied considerable, ranging from strong decreases to strong increases (Table 4).

Count data for December and February mostly confirmed the trends obtained from January counts, although there are a few cases where they differed. For December, 12 species were in the exact same trend class, five changed to an adjacent trend class (either between a stable trend and a moderate trend, or between strong and moderate trends in the same direction) and in only two cases, black-tailed godwit and greater flamingo, we observed very different trends from those observed in January (more details in Appendix 2 of the Supporting Information). Additionally, for three species with a trend for January, data from December delivered an uncertain trend (see Appendix 2 in the Supporting Information). For February, 17 species showed the exact same trend class as in January, while five changed to an adjacent trend class (see Appendix 2 in the Supporting Information). In one case, the red knot, data from January delivered an uncertain trend, but data from February indicated a strong decrease (-0.273±0.011; $p<0.001$; see Appendix 2 in the Supporting Information).

Table 4 - Trends of waterbird populations in the Tejo estuary between 2007 and 2016. For each species we present the estimated annual change ± SE, the P value indicating whether the estimated yearly change is significantly different from 0, the modelled change in numbers over the ten year period (decadal change), the population trend in the study areas (↓↓ strong decrease, ↓ moderate decrease, ➔ stable, ↑ moderate increase, ↑↑ strong increase) and the most recent available flyway trend for the population using the Tejo estuary (Delany et al. 2009, Wetlands International 2017).

Tabela 4 - Tendências populacionais das aves aquáticas do estuário do Tejo entre 2007 e 2016. Para cada espécie é apresentada a variação anual estimada ± EP, o valor-P que indica se a variação anual é significativamente diferente de 0, a variação ao longo dos dez anos obtida a partir do modelo (decadal change), a tendência populacional nas áreas de estudo (↓↓ declínio acentuado, ↓ declínio moderado, ➔ estável, ↑ crescimento moderado, ↑↑ crescimento acentuado) e a estimativa mais recente disponível para a tendência populacional ao nível da rota migratória (Delany et al. 2009, Wetlands International 2017).

SPECIES	ANNUAL CHANGE	P-VALUE	DECADAL CHANGE	TREND IN THE TEJO	FLYWAY TREND
Calidris alpina	-0.016±0.001	<0.001	-13.5%	↓	Stable (ssp. alpina, 1997-2007)
Limosa limosa	-0.080±0.003	<0.001	-52.8%	↓↓	Increasing (ssp. islandica, 1997-2007)
Larus ridibundus	0.010±0.002	n.s.	+9.4%	➔	Stable (W Europe, 1997-2007)
Pluvialis squatarola	0.059±0.003	<0.05	+67.5%	↑↑	Decreasing? (ssp. squatarola from W Siberia and Canada, 1997-2007)

SPECIES	ANNUAL CHANGE	P-VALUE	DECADAL CHANGE	TREND IN THE TEJO	FLYWAY TREND
Larus fuscus	-0.007±0.004	n.s.	-6.1%	→	Increasing (ssp. graellsii from W Europe, 1990-2000)
Phoenicopterus roseus	-0.007±0.005	n.s.	-6.1%	→	Increasing (W Mediterranean, 1994-2004)
Tringa totanus	-0.008±0.003	<0.05	-7.0%	↓	Stable (ssp. totanus from N Europe, 1987-1997)
Recurvirostra avosetta	0.006±0.003	n.s.	+5.5%	→	Stable (W Europe, 1997-2007
Charadrius hiaticula	0.076±0.012	<0.001	+93.3%	↑↑	Fluctuating (ssp. hiaticula, 1997-2007)
Himantopus himantopus (wintering)	-0.013±0.007	n.s.	-11.1%	→	Stable (SW Europe and NW Africa, 1990-2000)
Himantopus himantopus (breeding)	-0.005±0.005	n.s.	-4.4%	→	Stable (SW Europe and NW Africa, 1990-2000)
Limosa lapponica	0.044±0.010	<0.05	+47.3%	↑	Increasing (ssp. lapponica, 1997-2007)
Anas crecca	0.399±0.014	<0.001	+1953%	↑↑	Increasing (ssp. crecca form NW Europe, 1997-2007)
Anas platyrhynchos	0.149±0.013	<0.001	+249%	↑↑	Increasing (NW Europe and W Mediterranean, 1997-2007)
Egretta garzetta	-0.003±0.011	n.s.	-2.3%	→	Increasing (ssp. garzetta from W Europe, 1997-2007)
Anas clypeata	0.206±0.007	<0.001	+440%	↑↑	Increasing (NW Europe and W Siberia, 1997-2007)
Numenius arquata	-0.095±0.010	<0.05	-59.3%	↓↓	Decreasing (ssp. arquata, 1997-2007)
Charadrius alexandrinus (breeding)	-0.126±0.016	<0.05	-70.2%	↓↓	Unknown (ssp. alexandrinus from W Europe, 1996-2006)
Arenaria interpres	-0.089±0.009	<0.05	-56.8%	↓↓	Increasing? (ssp. interpres from NE Canada and Greenland, 1997-2007)
Ardea cinerea	-0.048±0.012	<0.05	-35.8%	↓	Increasing (ssp. cinerea from N and W Europe, 1997-2007)
Phalacrocorax carbo	0.110±0.021	<0.05	+156%	↑↑	Increasing (ssp. carbo from NW Europe, 1997-2007)
Tringa nebularia	-0.019±0.012	n.s.	-15.9%	→	Stable (N Europe, 1990-2000)
Calidris minuta	-0.234±0.016	<0.001	-90.9%	↓↓	Increasing? (N Europe 1997-2007)
Platalea leucorodia	0.093±0.021	<0.05	+123%	↑	Increasing (ssp. leucorodia from W Europe and Mediterranean, 1996-2006)
Sternulla albifrons (breeding)	-0.047±0.014	<0.05	-35.2%	↓	Decreasing (ssp. albifrons from W Europe and Mediterranean, 1990-2000)

Proportion of shorebirds and wildfowl using remote saltmarshes

Remote saltmarshes were very important for wildfowl, with 75-100% of individuals of all analysed species using these areas as roosting sites (Table 5). Among shorebirds, for both pied avocet and bar-tailed godwit there were on average more birds in those saltmarshes than in all the monitored roosts combined (Table 5), while for another six species numbers in remote saltmarshes represent over 30% of the average "total" number of birds using the estuary (Table 5). However, the proportion of birds using remote saltmarshes varied enormously, in cases such as bar-tailed godwit, red knot, curlew *Numenius arquata* and northern lapwing *Vanellus vanellus* ranging from 0% to nearly 100%).

Table 5 - Shorebird and waterfowl species using remote saltmarshes of the Tejo estuary not regularly surveyed within the scope of this monitoring programme, based on boat counts performed by ICNF in the months of January, February and December from January 2012 to January 2015. For each species we present an estimate of the average "total" number of individuals present in the estuary in those months (± SD), by adding the birds counted in remote saltmarshes and those counted in the present study. The average percentage (± SD) of birds using the remote saltmarshes during those months and its range is also given. Species are ordered by decreasing average percentage using the remote saltmarshes.

Tabela 5 - Espécies de limícolas e de anatídeos que usam os sapais da zona nordeste do estuário do Tejo, que não foram monitorizados no presente estudo, com base nas contagens efectuadas de barco pelo ICNF nos meses de Janeiro, Fevereiro e Dezembro entre Janeiro de 2012 e Janeiro de 2015. Para cada espécie é apresentada uma estimativa média do "total" de indivíduos que usaram o estuário nesses meses (±DP), obtida somando as aves contadas pelo ICNF nesses sapais e as aves contadas durante a presente monitorização. É também apresentada a percentagem média (±DP) de aves que usaram os sapais não monitorizados, assim como a percentagem mínima e máxima durante os meses em questão. As espécies estão ordenadas por ordem decrescente da percentagem média que usa os sapais não monitorizados.

SPECIES	ESTUARY "TOTAL"	PERCENTAGE IN REMOTE SALTMARSHES
Anas acuta	7117±9047	100±0 (100-100)
Netta rufina	7±8	100±0 (100-100)
Anser anser	2528±2016	98.9±2.9 (91-100)
Anas penelope	4471±1996	94.8±7.4 (77-100)
Tadorna tadorna	285±186	94.3±8.7 (78-100)
Anas platyrhynchos	7684±5199	87.6±13.1 (65-99)
Anas strepera	108±50	86.5±13.5 (67-100)
Aythya fuligula	13±14	86.2±30.9 (31-100)
Anas clypeata	8581±6335	79.9±25.5 (32-97)
Anas crecca	7023±3132	76.0±12.1 (59-98)

SPECIES	ESTUARY “TOTAL”	PERCENTAGE IN REMOTE SALTMARSHES
Recurvirostra avosetta	5370±1984	64.4±16.1 (31-83)
Limosa lapponica	949±923	53.2±35.1 (0-100)
Numenius phaeopus	98±82	48.9±37.5 (0-93)
Calidris alpina	12595±2762	42.4±9.2 (26-55)
Calidris canutus	662±691	34.9±42.9 (0-98)
Numenius arquata	565±153	34.1±24.0 (2-69)
Vanellus vanellus	80±102	31.1±46.8 (0-100)
Pluvialis squatarola	4340±1992	30.3±18.8 (11-61)
Calidris alba	127±129	28.4±32.5 (0-87)
Tringa totanus	1721±571	26.1±13.6 (14-55)
Limosa limosa	3499±2104	20.6±31.0 (0-87)
Arenaria interpres	244±102	17.4±12.9 (0-36)
Charadrius hiaticula	793±503	16.0±24.4 (0-59)
Tringa nebularia	105±20	10.7±16.1 (0-42)
Actitis hypoleucos	34±11	7.1±4.7 (0-14)
Charadrius alexandrinus	236±271	7.0±15.0 (0-43)
Himantopus himantopus	476±80	0.2-0.4 (0-1)
Calidris minuta	70±58	0.0-0.0 (0-0)
Calidris ferruginea	57±63	0.0-0.0 (0-0)
Tringa erythropus	50±29	0.0-0.0 (0-0)
Gallinago gallinago	19±12	0.0-0.0 (0-0)
Haematopus ostralegus	12±14	0.0-0.0 (0-0)
Tringa ochropus	8±5	0.0-0.0 (0-0)
Philomachus pugnax	4±7	0.0-0.0 (0-0)

Discussion

Phenological patterns of the waterbird community in the Tejo estuary

The present study confirms the international importance of the Tejo estuary for waterbirds both as a wintering area and as a refuelling site during migratory periods (e.g. Alves et al. 2011, Catry et al. 2011, Rocha et al. 2017). In fact, most species show clear peaks associated with migratory periods, particularly in autumn as previously described (Alves et al. 2011, Catry et al. 2011).

The five phenological groups defined through the cluster analysis also corroborate these trends, with the largest group being associated with species for which the counts from months in late summer and autumn rank among the highest. Smaller groups of species were associated with higher counts in mid-winter and during spring. Species that breed in the estuary or use it during post-breeding movements were also grouped separately, but Kentish plover, which breeds in some of the studied high tide roosts (Rocha et al. 2016), was included among the group of species with a clear autumnal migratory peak. This species peaks in July-September and in October-January numbers remain higher than those observed during the breeding season (see Appendix 1 in the Supporting Information). This pattern is similar to that observed in other Portuguese wetlands (e.g. Batty 1992, Lopes et al. 2005) and suggests that most Kentish plovers using the estuary do not belong to the local breeding population. Still, we cannot rule out that the more cryptic behaviour exhibited by Kentish plovers during the breeding season may influence our ability to accurately estimate their numbers when nesting.

Overall, it is quite clear that besides being a critical wintering area for many waterbirds, many species strongly depend on the Tejo estuary during migratory passage, highlighting the key role of this wetland for the migratory fluxes linking northern Europe and Africa in spring and, especially, in autumn. Although there is considerable variation among different species, at least for shorebirds this trend for higher counts during autumn migration is also observed in several other wetlands along the flyway (e.g. Batty 1992, Le Drean Quenec'hdu et al. 1995, Scheiffarth & Becker 2008, El Hamoumi & Dakki, 2010). Despite some exceptions (e.g. Lopes et al. 2005, Lourenço 2006), this pattern is most likely explained by the fact that in spring migrants are expected to be more time-stressed in order to arrive early at their breeding areas, thus making fewer and shorter stops along the way (Lindström & Alerstam 1992, Farmer & Wiens 1998), meaning that monthly counts performed in spring are more likely to miss very short migratory peaks that can last just a few days. In fact, counts performed at shorter intervals in the Tejo evidenced the occurrence of such short migratory peaks during spring (Catry et al. 2017, Catry et al. unpub. data).

Relative importance of different roosts

Despite some variation over the years, it is clear that a small number of roosts support the vast majority of waterbirds using the Tejo estuary throughout the annual cycle. Together, Samouco, Vasa Sacos, Ribeira das Enguias, Corroios and Alhos Vedros/Moita support over 80% of all counted individuals, and this is true across all waterbird groups. The first three roosts are located within the local protected areas, but only Samouco is partially managed for waterbird conservation. As for the other two key roosts (Corroios and Alhos Vedros/Moita), they lie outside the protected areas and therefore have no legal protection. The fact that roughly 30% of waterbirds in the Tejo estuary use roosts with no legal protection (Table 3) raises concern, as these areas are likely more vulnerable to urban and industrial development. In fact, for species such as curlew (82%), whimbrel *Numenius phaeopus* (66%), lesser black-backed gull (62%), pied avocet (57%), black-headed gull (53%) and common redshank (50%) over half the population is found in roosts with no legal protection. Furthermore, although there is evidence that waterbirds can switch roosts when facing local changes (e.g. Burton et al. 1996, Rocha 2015), all of these unprotected sites are clustered around the southern part of the estuary, where there are no nearby alternative roosts. Since shorebirds prefer to forage near roosting sites (e.g. Dias et al. 2006), any anthropogenic pressure to these unprotected roosts could jeopardize the availability of the southern part of the estuary as a suitable foraging area for shorebirds.

Overall we can divide the studied roosts in two main categories, saltpans and saltmarshes, and the current trends point for a decline in the use of saltpans and an increase in the use of saltmarshes. Even in Vasa Sacos, which showed an increase in bird numbers in the last years, most birds now use the adjacent saltmarsh and not the saltpans. This mainly results from the fact that saltpans are no longer used for salt production, becoming either abandoned and increasingly encroached by vegetation, or flooded when converted to shrimp farms, both of which are less likely to provide favourable roosting condition for shorebirds.

In fact, saltmarshes were likely the main roosting option for shorebird before man-made saltpans became available. With few exceptions, most shorebird species also use the remote saltmarshes in the north-eastern area of the estuary as roosting sites during winter. In fact, these few exceptions can in most cases be attributed to the difficulties of identifying birds while doing counts from a boat. Good examples are little stint *Calidris minuta* and curlew sandpiper *C. ferruginea* which can easily be missed within large flocks of dunlin. As previously mentioned, these boat count data are difficult to interpret, since they are very rough estimates based on information that may not be directly comparable with our counts, and the proportion of birds that use these remote saltmarshes varies greatly over time. In any case, based on the information gathered by ICNF counts, it is clear that a significant proportion of shorebirds, and a much larger proportion of wildfowl were not fully covered during our land counts. However, if we assume that the use of remote saltmarshes, despite its apparent fluctuations, remains mostly similar over time, this issue should not affect our main findings regarding shorebird phenological patterns, relative use of different (monitored) roosts and population trends over the studied decade.

Waterbird population trend in the Tejo estuary

Available data suggests that different waterbird species and groups are facing distinct population trends in the East Atlantic Flyway. Whereas wildfowl, gulls and terns mostly show favourable trends, a large proportion of shorebird populations are currently declining (Davidson & Stroud 2006, Stroud et al. 2006, van Roomen et al. 2015). Previous data from the Tejo estuary, referring to the period between 1975 and 2006, indicated that three of the five most abundant shorebirds: dunlin, grey plover and redshank, were declining locally (Catry et al. 2011). At least to some extent, these declines are believed to be driven by local factors as the same trends were neither observed in other Portuguese wetlands nor at the flyway scale (Catry et al. 2011).

Our present data, referring to the last ten years, confirm the local declining trend for dunlin and redshank, while grey plover now exhibited a strong increase. These data also confirm a stable trend for pied avocet, but black-tailed godwit, which until 2006 had a stable trend (Catry et al. 2011), is now in strong decline. This change in the local trend for black-tailed godwit may in part result from an increasing proportion of the estuarine population, which is mostly composed of Icelandic godwits (*L. l. islandica*), using nearby rice fields more regularly (Alves et al. 2010). These rice fields represent the main feeding grounds for Continental godwits (*L. l. limosa*), which winter in West Africa and start migrating through the Iberian Peninsula in January (Alves et al. 2010, Lourenço et al. 2010), but in recent years observation of colour-marked birds evidenced that the number of Icelandic godwits using this alternative habitat has increased (J.A. Alves unpub. data). Furthermore, some of these rice fields are kept flooded during winter to benefit birds, so they may also receive higher number of other species, such as dabbling ducks and flamingos, than in the past.

Globally, the present shorebird trends in the Tejo estuary suggest that high-Arctic breeders are doing better than species that breed at lower latitudes. Among the species from the high-Arctic, ringed plover and grey plover both showed strong increases and bar-tailed godwit showed a moderate increase, but ruddy turnstone *Arenaria interpres* and little stint both showed strong decreases. Among the species that breed at lower latitudes, black-tailed godwit and curlew showed strong decreases; dunlin and common redshank showed moderate decreases, while only pied avocet, black-winged stilt and common greenshank evidenced stable trends.

For most of the analysed populations, the trend we observed in the monitored high tide roosts fits with the available data on flyway trends (Table 4). However, there are nine cases in which local trends differ from flyway trends. In part, these different trends can result from a temporal mismatch between different data sources, as the most recent available flyway trends at best refer to the decade immediately preceding the collection of our data and may thus not be directly comparable. Still, other factors may be at play here. Lesser black-backed gull, greater flamingo and little egret evidenced a stable trend in the Tejo, whereas at the flyway scale these populations are believed to be increasing. Grey plover and common ringed plover, which increased strongly in the Tejo, appear to be fluctuating or even decreasing at the flyway scale. Dunlin and common redshank, which showed a moderate decrease in the Tejo, are considered stable at the flyway scale, whereas black-tailed godwit and ruddy turnstone, which showed strong decreases within the Tejo estuary, and grey heron with a moderate decrease, are all believed to be increasing at the flyway scale (Table 3). These mismatches between local and global trends are also observed in other wintering and staging sites across Europe (e.g. Austin et al. 2000, Eybert et al. 2003, Lopes et al. 2005, Meltofte et al. 2006) and may result from local and regional processes (like the black-tailed godwit example mentioned above), from local changes in food availability (e.g. Austin et al. 2000), human disturbance (Eybert et al. 2003), or from large-scale changes in the overall distribution of wintering and migratory populations along the flyway (e.g. Austin & Rehfisch 2005, Rakhimberdiev et al. 2010). Although unlikely, we can also not rule out the possibility that changes in the proportion of birds using the saltmarshes that were not monitored in this study may influence the observed population trends. The cases of dunlin, redshank and ruddy turnstone may be of particular concern as the decreases in the Tejo go against the global trend and may indicate these species are facing problems locally, as had been previously described for the first two species since the 70s (Catry et al. 2011).

Such difficulties in interpreting and reconciling local and global trends evidently reinforces the need for having reliable and up-to-date information on the status of waterbird populations across the flyway, which can only be obtained through long-term monitoring programmes such as the one described here for the Tejo estuary.

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