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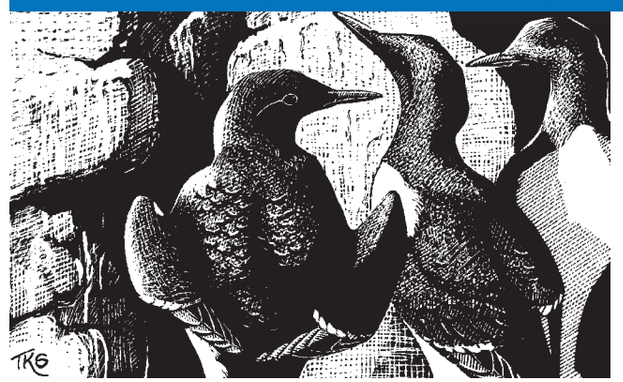

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# Subtropical Roseate Terns (*Sterna dougallii*) of Santa Maria (Azores) deliver more appropriate sized prey to their chicks than Common Terns (*Sterna hirundo*)

## Os Garajaus-rosados (*Sterna dougallii*) subtropicais de Santa Maria (Açores) entregam presas de tamanho mais adequado às suas crias do que os garajaus comuns (*Sterna hirundo*)

José C. Pereira[1] and Jaime A. Ramos[2,3]

**ABSTRACT -** We compared chick food provisioning between Roseate Tern (*Sterna dougallii*) and Common Tern (*Sterna hirundo*) on Vila, an islet offshore Santa Maria Island (36.9ºN, 25ºW), Azores in 1996. Twelve nests of each species were fenced and prey deliveries to chicks of both species were observed during three diurnal periods each day for 35 days. We identified all prey offered to chicks, registered whether chicks ingested prey or not and weighed chicks daily. Blue jack mackerel (*Trachurus picturatus*) and Atlantic sauri (*Scomberosox sauri* and *Nanicthys simulans*) were the main prey items offered to chicks by Roseate Terns, whereas Common Terns offered mainly blue jack mackerel and boarfish (*Capros aper*). The number of Atlantic sauri offered to chicks with more than 6 days old by both tern species decreased markedly, and the inverse occurred for blue jack mackerel and boarfish. Overall, non-ingested prey items were larger than those that were ingested, especially for chicks aged 1-12 days. Roseate Tern chicks showed a higher acceptance rate (frequency of prey ingested/frequency of prey offered) than did the Common Tern chicks. Acceptance rate of the chicks increased with chick age for both tern species but, overall, Roseate Tern adults made a better adjustment of prey delivered to chicks (in particular those aged 1-12 days) than did the Common Terns. The breeding strategy of the Roseate Tern might reflect a greater specialization on favourable marine fish species.

**RESUMO -** Comparou-se a entrega de alimento às crias entre Garajau-rosado (*Sterna dougallii*) e Garajau-comum (*Sterna hirundo*) no ilhéu da Vila, Santa Maria (36.9ºN, 25ºW), Açores em 1996. Doze ninhos de cada espécie forma vedados para observar a entrega de alimento em três períodos diurnos, ao longo de 35 dias. As presas oferecidas pelos progenitores às suas crias foram identificadas e registadas como ingeridas ou não ingeridas e as crias foram pesadas diariamente. As presas mais importantes para Garajau-rosado foram chicharro (*Trachurus picturatus*) e sauri (*Scomberosox sauri* e *Nanicthys simulans*), enquanto para o Garajau-comum foram chicharro e peixe-pau (*Capros aper*). O número de sauris oferecidos a crias com mais de 6 dias de idade diminuíu bastante, enquanto o inverso ocorreu para chicharros e peixe-pau. O comprimento de presas não ingeridas foi superior ao comprimento de presas ingeridas, sobretudo para crias com 1-12 dias de idade. As crias de Garajau-rosado apresentaram uma taxa de aceitação de presas (frequência de presas ingeridas/frequência de presas oferecidas)

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significativamente superior à de crias de Garajau-comum. A taxa de aceitação de presas aumentou com a idade das crias para as duas espécies de Garajaus mas, de um modo geral, o Garajau-rosado conseguiu um melhor ajuste na entrega de presas de comprimento adequado do que o Garajau-comum (em particular para crias com 1-12 dias). A estratégia reprodutora das crias de Garajau-rosado deverá reflectir uma maior especialização em presas marinhas favoráveis.

Variation in food supply around the breeding colonies has a strong impact on breeding success of small seabirds such as terns (Monaghan *et al.* 1989, 1992) because they forage close to the nest, and allocate a greater proportion of available time to foraging and carrying food items in the bill to provisioning their chicks (Pearson 1968). Therefore, terns are very vulnerable to food shortages that occur around the breeding colonies (Monaghan *et al.* 1989, Ramos 2000, Ramos *et al.* 2002). More distant foraging sites may be utilized, especially by larger species (McGinnins & Emslie 2001), if they are particularly profitable because of greater prey availability, greater prey energetic value or when the forager possesses a specific knowledge of the foraging site (Massias & Becker 1990, Lyons *et al.* 2005).

In order to ensure a normal development of their chicks parent terns must provide them with a good supply of prey of adequate quality (Massias & Becker 1990, Dahdul & Horn 2003, Martins *et al.* 2004) and, therefore, should be adapted to environmental conditions around the colonies. Diet and chick provisioning has been well studied in terns (Monaghan *et al.* 1989, Ramos *et al.* 1998a). Most studies showed that tern nestling growth, breeding success and reproductive effort is often affected by variation in food provisioning (Monaghan *et al.* 1989, Massias & Becker 1990, Monaghan *et al.* 1992, Ramos *et al.* 2002, Shealer *et al.* 2004), but, the ability of the parents to deliver prey of appropriate sizes to their growing chicks has received little attention.

This study examined in detail the characteristics of prey offered by parents and ingested by growing chicks of Common Terns (*Sterna hirundo*) and Roseate Terns (*Sterna dougallii*) breeding in mixed colonies in the Azores (Ramos & del Nevo 1995). Foraging Roseate Terns usually feed in smaller flocks over more dispersed prey (Duffy 1986), are more associated with particular physical features of the ocean such as shoals and tidal rips (Safina 1990, Monticelli & Ramos 2006), and seem to dive deeper than Common Terns (Nisbet 1981). Their foraging may be depressed when feeding within larger flocks with Common Terns (Safina & Burger 1985, Safina 1990). However, studies translating such differences in foraging habitat partitioning and feeding techniques into provisioning of chicks are lacking.

Ramos *et al.* (1998a, 1998b) and Granadeiro *et al.* (2002) showed that the diet of Roseate and Common tern chicks in the Azores overlapped to a great extent. Roseate Tern adults were obliged to avoid certain prey types for young chicks, such as boarfish (*Capros aper*) and trumpet fish (*Macroramphosus scolopax*) because they were too wide to swallow. Modelling suggests that Azores Roseate Tern chicks fed on prey with a favourable length-weight relationship, such as blue jack mackerel (*Trachurus picturatus*), have a higher growth efficiency (Martins *et al.* 2004). To understand how differently Roseate Terns and Common Terns deal with chick food provisioning, we made daily observations of the species and sizes of prey delivered by parents of both tern species to their chicks.

## METHODS

We studied chick provisioning of Roseate and Common Terns on Vila, an islet off Santa Maria Island (36.9ºN, 25ºW), Azores, in 1996. Vila is a mixed Roseate and Common Tern colony. Roseate terns nested in areas with higher relief and/or tall vegetation, and Common Terns nested immediately around the Roseate Terns in more open areas (Ramos & del Nevo 1995). In the Azores, Roseate Terns typically nest earlier than Common Terns, including on Vila Islet (Ramos & del Nevo 1995), where, in 1996, Roseate Tern chicks began hatching about one week earlier than Common Tern chicks. Both species had equal access to foraging waters

surrounding the islet.

Two portable hides were erected on the 8 June, one overlooking 35 Roseate Tern nests (0.18 nests/$m^2$) and the other, about 80 m away, overlooking 45 Common Tern nests (0.13 nests/$m^2$). Twelve nests of each species, situated 4 – 10 m away from the hides, were fenced with 0.5 m high, 2.5 cm diameter hexagonal mesh wire net, in order to avoid displacement study chicks Each fence was 1.5 m in diameter and included cover (rocks and grass) so chicks could hide and find protection from inclement weather. To keep young chicks inside, 1.5 $cm^2$ mesh plastic net 10 cm high, was added around the fence.

Fenced broods of Roseate Terns were watched from 9 June to 3 July 1996 and those of Common Terns from 22 June to 14 July. Three to 12 (median = 7) Roseate Tern chicks and two to 30 (median = 8) Common Tern chicks were watched from one to 24 days of age. For Roseate Terns, we watched only broods of one chick, which were the most common in the colony. For Common Terns, we watched six broods of two and six broods of three chicks. Common Tern chicks were designated has a, b or c according to hatching order, and were colour-marked on the head with different colours.

Prey items brought to chicks were observed daily from 7:00 - 9:30, 11:45 - 14:15 and 17:00 - 19:30 by two observers to allow simultaneous observations of both species. We used these three diurnal periods to account for the daily variation in chick provisioning (Ramos et al. 1998a). After two days training, each observer watched the same species for a whole day and observers switched between species on consecutive days. We observed all prey offered to chicks and registered whether chicks ingested the prey or not. We were familiar with the main fish species taken by terns: blue jack mackerel (*Trachurus picturatus*), trumpet fish (*Macroramphosus scolopax*), Atlantic sauri (*Scomberesox saurus saurus*) and boarfish (*Capros aper*; Ramos *et al.* 1998a; 1998b). We identified most prey species and estimated their size relative to the bill length of adult terns (in 0.5 bill units). In the Azores, bill length (mean ± SD) of Common Terns (37.54 ± 1.72 mm, n = 33) is similar to that of Roseate Terns (38.93 ± 1.56 mm, n = 30; Monteiro *et al.* 1996). We had a good view over the area with fenced nests and controlled for situations where a prey was offered multiple times (this was more frequent in Common Terns), because the adults performed small flights in the area within view, before offering the same prey.

Chicks were divided into four age groups (1-6, 7-12, 13-18, 19-22 days of age) and prey offered, ingested and not ingested by each tern species were compared among these age groups. Prey diversity index was computed using $B = 1/\sum p_i^2$, where $p_i$ is the proportion of a given species in the diet (Levins 1968). We transformed bill-length units into length of fish (L, mm) and then into mass (W, g) using the length-weight relationships for the main prey delivered (blue jack mackerel: $W = 0.00819 \times L^{3.11}$, Atlantic sauri: $W = 0.0079 \times L^{2.54}$, boarfish: $W = 0.0282 \times L^{2.81}$, trumpet fish: $W = 0.0040 \times L^{3.15}$, *Pagellus bogaraveo*: $W = 0.00819 \times L^{3.11}$; see Martins et al. 2004 and http://www.fishbase.org). The mass of unidentified prey and prey for which we had no length-weight relationship (less than 15% of all prey items) was assumed to be the same as blue jack mackerel because this was the most abundant prey species. We calculated the mean mass of each fish species, ingested and non-ingested, and compared it among chick age groups with non-parametric tests (Mann-Whitney U-test, Kruskal-Wallis and Multi-sample Q test), because variance was not homogeneous among age groups.The ratio between frequency of prey ingested and frequency of prey offered was named acceptance rate of the chicks, and compared between tern species and age groups. This can be viewed as a measure of inter-specific parental performance because this parameter reveals the capacity of the parents to match prey delivered with the need of their chicks.

Except otherwise stated data is presented as mean ± SE.

## RESULTS

### » Diet composition and prey destiny of Roseate and Common Tern chicks

The diversity of prey offered and ingested by chicks of each age-class (1-6, 7-12, 13-18, 19-24 days of age, respectively) was generally lower for Roseate Terns than for Common Terns (offered: B = 2.82, 4.45, 2.99, 3.14 and B = 3.97, 3.12, 3.92, 3.93; ingested: B = 2.35, 4.56, 3.00, 3.19 and B = 3.81, 3.42, 4.10, 4.12, for Roseate and Common

terns, respectively). Blue jack mackerel and Atlantic sauri were the main prey offered to chicks by Roseate Tern adults, whereas Common Tern adults carried mainly boarfish and blue jack mackerel (Table 1). The number of Atlantic sauri (elongated fishes easier to swallow by young chicks) offered to chicks by adults of both tern species decreased as chicks aged (Table 1). The mass of each individual ingested Atlantic saury also increased with chick age for both tern species (Table 1). The number of blue jack mackerel offered to and the % ingested by Roseate Tern chicks increased with chick age, but the mean mass of each individual blue jack mackerel ingested did not (Table 1).

Overall, the % of ingested prey items by Roseate Tern chicks was always greater than the % of non-ingested prey items. For Common Terns, the number of ingested prey items was higher than that of non-ingested items only for old chicks (Table1).

**Table 1**. Comparison of the percentage of items ingested in relation to the total number of items offered (N) per prey species, for each age class. The mean mass of individual prey item ingested and non-ingested is compared between chick age classes for both Roseate and Common Terns. Roseate Tern data is referred to a-chicks and Common Tern data is referred to a - b - and c-chicks. Kruskal-Wallis K or Mann-Whitney U tests were used to compare fish mass among age classes (rows showing different letters are significantly different, non-parametric multisample *Q* test). The all prey category includes also *Belone belone*, *Cubiceps gracilis*, *Pagellus bogaraveo*, *Ecletrona rissoi*, *Atherina presbyter*, *Argyropelecus aculeatus*, *Apogonon imberbis*, Labridae, Blenidae, Squid and Shrimps (<0.1% to 5%) and unidentified prey (5 to 17%). - = prey species not taken / ***Tabela 1***. *Comparação da percentagem de itens ingeridos em relação ao número total de itens oferecidos (N) por cada espécie de presa, e para cada classe de idade de crias. A massa média dos itens individuais ingeridos e não ingeridos foi comparada entre classes de idade das crias para Garajau-rosado e Garajau-comum. Os dados de Garajau-rosado referem-se a crias a e os dados de Garajau-comum a crias a, b e c. Os testes de Kruskal-Wallis K ou Mann-Whitney U foram utilizados para comparar a massa de peixes entre classes de idade de crias (linhas que não apresentam letras iguais são significativamente diferentes, testes múltiplos não paramétricos Q). A categoria "all prey" inclui Belone belone, Cubiceps gracilis, Pagellus bogaraveo, Ecletrona rissoi, Atherina presbyter, Argyropelecus aculeatus, Apogonon imberbis, Labridae, Blenidae, lulas e camarões (<0,1% - 5%) e presas não identificadas (5 - 17%). - = presas não consumidas.*

**Roseate Tern**

| Prey | Chick age (days) | | | | Statistic |
|---|---|---|---|---|---|
| | 1-6 | 7-12 | 13-18 | 19-24 | |
| Blue Jack Mackerel | | | | | |
| N | 46 | 69 | 90 | 56 | |
| Ingested (%) | 59 | 77 | 92 | 93 | |
| Ingested (g) | 8.5 ± 1.1 | 8.3 ± 0.8 | 8.2 ± 0.7 | 9.0 ± 0.7 | $H_{3,215} = 3.4$, P = 0.30 |
| Non-ingested (g) | 8.2 ± 1.4 | 8.8 ± 1.2 | 10.5 ± 3.3 | 10.7 ± 5.9 | $H_{3,46} = 0.6$, P = 0.90 |
| Atlantic Sauri | | | | | |
| N | 108 | 43 | 18 | 14 | |
| Ingested (%) | 83 | 88 | 88 | 100 | |
| Ingested (g) | 1.1 ± 0.1$^c$ | 2.0 ± 0.3$^b$ | 3.4 ± 0.6$^b$ | 5.1 ± 0.7$^a$ | $H_{3,158} = 46.5$, P = 0.000 |
| Non-ingested (g) | 1.5 ± 0.2 | 6.5 ± 1.8 | 2.8 ± 1.3 | - | $H_{2,25} = 6.7$, P = 0.035 |

| | | | | | |
|---|---|---|---|---|---|
| Boarfish | | | | | |
| N | 13 | 37 | 24 | 11 | |
| Ingested (%) | 15 | 76 | 88 | 91 | |
| Ingested (g) | 1.3 ± 0.0 | 1.9 ± 0.4 | 2.1 ± 0.7 | 1.8 ± 0.4 | $H_{3,61} = 2.9$, P = 0.40 |
| Non-ingested (g) | 2.7 ± 0.7 | 2.4 ± 0.9 | 1.3 ± 0.0 | 1.3 | $H_{3,24} = 1.9$, P = 0.60 |
| Trumpet fish | | | | | |
| N | 6 | 15 | - | 2 | |
| Ingested (%) | 33 | 80 | - | 100 | |
| Ingested (g) | 0.7 ± 0.4 | 2.4 ± 0.3 | - | 2.6 ± 0.0 | $H_{2,16} = 5.5$, P = 0.06 |
| Non-ingested (g) | 1.8 ± 0.4 | 2.6 ± 0.0 | - | - | U = 3, P = 0.30 |
| All prey | | | | | |
| N | 202 | 191 | 169 | 118 | |
| Ingested (%) | 73 | 81 | 92 | 94 | |
| Ingested (g) | $3.4 \pm 0.5^{c}$ | $4.7 \pm 0.4^{b}$ | $6.3 \pm 0.5^{a}$ | $6.4 \pm 0.5^{a}$ | $H_{3,568} = 84.4$, P = 0.000 |
| Non-ingested (g) | $4.5 \pm 0.7^{c}$ | $6.7 \pm 0.8^{b}$ | $6.8 \pm 2.1^{b}$ | $7.1 \pm 3.6^{ab}$ | $H_{3,112} = 8.1$, P = 0.044 |

**Common Tern**

| Prey | Chick age (days) | | | | Statistic |
|---|---|---|---|---|---|
| | 1-6 | 7-12 | 13-18 | 19-24 | |
| Blue Jack Mackerel | | | | | |
| N | 139 | 101 | 117 | 14 | |
| Ingested (%) | 27 | 39 | 69 | 79 | |
| Ingested (g) | $5.9 \pm 0.5^{b}$ | $6.8 \pm 0.5^{ba}$ | $8.9 \pm 0.6^{a}$ | $10.6 \pm 1.1^{a}$ | $H_{3,169} = 18.9$, P = 0.000 |
| Non-ingested (g) | $7.5 \pm 0.4^{b}$ | $9.5 \pm 0.6^{ba}$ | $11.8 \pm 1.1^{b}$ | $12.1 \pm 2.5^{ab}$ | $H_{3,202} = 18.8$, P = 0.000 |
| Atlantic Sauri | | | | | |
| N | 102 | 11 | - | - | |
| Ingested (%) | 83 | 36 | - | - | |
| Ingested (g) | 0.6 ± 0.1 | 2.5 ± 0.7 | - | - | U = 31.5, P = 0.006 |
| Non-ingested (g) | 2.2 ± 0.6 | 4.2 ± 0.7 | - | - | U = 34.0, P = 0.10 |

| | | | | | |
|---|---|---|---|---|---|
| Boarfish | | | | | |
| N | 86 | 168 | 123 | 42 | |
| Ingested (%) | 8 | 43 | 66 | 71 | |
| Ingested (g) | 1.6 ± 0.4 | 1.9 ± 0.3 | 2.1 ± 0.4 | 1.3 ± 0.1 | $H_{3,229} = 5.8$, P = 0.1 |
| Non-ingested (g) | 1.6 ± 0.1 | 1.8 ± 0.1 | 2.1 ± 0.6 | 1.9 ± 0.6 | $H_{3,190} = 2.1$, P = 0.6 |
| Trumpet fish | | | | | |
| N | 4 | 23 | 69 | 25 | |
| Ingested (%) | 25 | 17 | 36 | 48 | |
| Ingested (g) | 1 | 1.4 ± 0.7 | 1.3 ± 0.2 | 0.9 ± 0.2 | $H_{3,42} = 1.1$, P = 0.8 |
| Non-ingested (g) | $2.1 \pm 0.5^{a}$ | $2.5 \pm 0.4^{a}$ | $1.1 \pm 0.1^{b}$ | $0.7 \pm 0.1^{c}$ | $H_{3,79} = 24.1$, P = 0.000 |
| All prey | | | | | |
| N | 407 | 374 | 376 | 108 | |
| Ingested (%) | 45 | 47 | 65 | 73 | |
| Ingested (g) | $2.2 \pm 0.3^{c}$ | $3.1 \pm 0.3^{a}$ | $4.5 \pm 0.4^{a}$ | $2.8 \pm 0.4^{b}$ | $H_{3,683} = 60.2$, P = 0.000 |
| Non-ingested (g) | $4.6 \pm 0.3^{a}$ | $4.7 \pm 0.4^{a}$ | $4.6 \pm 0.6^{b}$ | $2.5 \pm 0.7^{b}$ | $H_{3,582} = 30.0$, P = 0.000 |

**» Differences in prey offered and ingested by chicks**

Overall, Roseate Terns parents offered longer prey (in bill-length units) to their chicks than did Common Terns (1.96 ± 0.02, N = 908 and 1.59 ± 0.02, N = 1301; Mann-Whitney test: $z = 11.6$, P = 0.000). No significant differences were found between the length of ingested (1.96 ± 0.03, N = 570 and non-ingested (2.00 ± 0.07, N = 118) prey for Roseate Terns (Mann-Whitney test: $z = -0.45$, P = 0.650). However, for Common Terns, a significant difference was found between the length of ingested (1.50 ± 0.03, N = 683) and non-ingested (1.68 ± 0.03, N = 582) prey (Mann-Whitney test: $z = 4.22$, P = 0.000). This was explained by the fact that individual prey items offered to the youngest Common Tern chicks (1-6 days) that were not ingested (mean = 4.6 g), were larger than individual ingested prey items (mean = 2.2 g; Table 1). In general, Table 1 shows that, with the exception of boarfish for Common Terns, non-ingested prey items were larger than ingested prey items. The proportion of fish stolen by kleptoparasites was negligible (1% and 2% of prey offered to Roseate and Common Tern chicks, respectively).

The acceptance rate of the chicks (frequency of prey ingested /frequency of prey offered) is presented in Figure 1 for both tern species. There was a significant difference in the acceptance rate of the chicks between age groups for both Roseate Terns (Kruskal Wallis test: $H_{3,214} = 48.1$, P = 0.000) and Common Terns (Kruskal Wallis test: $H_{3,157} = 28.5$, P = 0.000). The overall acceptance rate by the chicks was significantly higher for Roseate Terns than for Common Terns (Mann-Whitney test: $z = 9.13$, P = 0.000), but increased with age at an approximately equal rate for both species (Figure 1). Nevertheless, Common Terns showed a more marked difference between young (1-12 days) and old (>12 days) chicks than did the Roseate Terns (Figure 1).

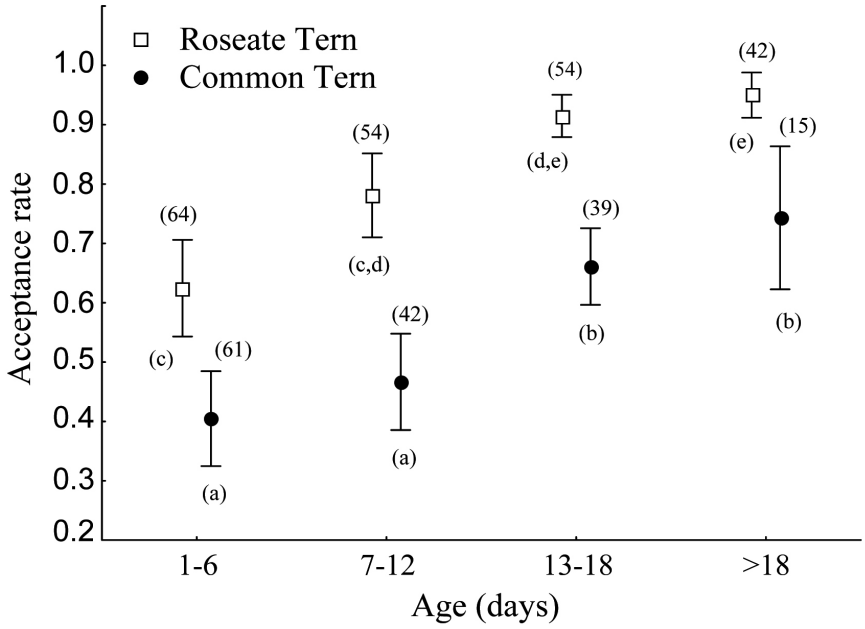


**Figure 1.** Variation in the prey acceptance rate of the chicks (prey ingested/prey offered) for both Common and Roseate Terns in relation to chick age. Age groups sharing the same latter did not differ significantly (Nemenyi test: P < 0.01). Vertical bars indicate standard error. Sample size indicated in parenthesis beside the bars. / ***Figura 1.*** *Variação na taxa de aceitação pelas crias (presas ingeridas/presas oferecidas) para Garajau-rosado e Garajau-comum, por classes de idade de crias. Os grupos de idade que apresentam a mesma letra não diferem significativamente entre si (teste Nemenyi: P < 0,01. As barras verticais indicam o erro padrão. O tamanho da amostra está indicado entre parêntesis.*

## DISCUSSION

In this study the diet of Roseate Tern chicks was less diverse than that of Common Terns, which agrees with other studies of these two species breeding in the same colony or area (Gochfeld *et al.* 1998, Nisbet 2002). However, the diversity of prey ingested by Roseate and Common terns on Vila Islet in 1996 was greater than reported for other coastal marine areas. In 1995, also in Vila islet, Trumpet fish was the main prey species delivered to Roseate Tern chicks, with a diversity index of 2.61 (calculated from table 2 of Ramos *et al.* 1998b). The prey diversity index for Roseate Tern chicks breeding in temperate regions such as Cedar Beach, U.S.A (*B* = 1.81, Safina et al. 1990) and South Africa (*B* = 2.71, Randall & Randall 1978), or tropical regions such as Puerto Rico (*B* = 2.32, Shealer 1995) was also lower than that obtained in our study. Apart from a greater diversity of fish species, the diet of Common Terns usually includes variable numbers of invertebrates (Gochfeld *et al.* 1998, Granadeiro *et al.* 2002), although these were not recorded in our study. Differences in diet composition among areas and years should reflect variation in prey availability. The subtropical geographical location of the Azores, together with important physical and oceanographic features such as seamounts and upwellings (Santos et al. 1995), may be important in explaining the higher diversity of prey taken by Roseate and Common terns in the Azores when compared with other coastal marine areas (Ramos *et al.* 1998a, 1998b, Meirinho 2000, Granadeiro *et al.* 2002, This study).

The smallest size fish available to young Roseate Tern chicks may not have been equally available to Common Tern chicks because we began observing them about two weeks later. However, this does not explain the differences in chick provisioning between both species because: (1) there were consistent differences in the prey species delivered

by Roseate and Common Terns to chicks of all age groups, and (2) non-ingested prey items were significantly larger than ingested items for young chicks (1-12 days) of both tern species. This and other studies (Shealer 1998a, Robinson *et al.* 2001) showed that chick age influenced the size and the species of fish offered by parent terns to their chicks. In particular, thin and relatively long prey items such as the Atlantic sauri were apparently targeted for the youngest chicks, which agrees with the hypothesis that seabird parents select higher quality prey for chick provisioning (Wilson *et al.* 2004, Catry *et al.* 2006). However, Roseate Terns were more efficient in delivering appropriate-sized prey than Common Terns, especially for chicks up to six days old.

The high percentage of boarfish, a wider prey species with acute dorsal fins, offered by Common Terns to their youngest chicks, explained most of the high percentage of not-ingested prey items by chicks of this tern species. Some chicks died with boarfish stuck in their mouths, a fact already reported by Ramos *et al.* (1998a). Our results suggest that some seabird species are more constrained than others in provisioning their chicks with prey of adequate quality. Most tern studies to date addressed only the impact of food shortage in chick growth and breeding success (Monaghan *et al.* 1989, Ramos 2001). This may be related to the fact that most studies were carried out in temperate coastal areas of Europe and North America, where *Ammodytes* sp are often the main prey species (Monaghan *et al.* 1989, Safina *et al.* 1990). In subtropical oceanic areas such as the Azores, prey diversity is higher and, therefore, prey quality may be increasingly important to explain chick provisioning patterns in marine terns.

Common Terns were unable to provide their young (1-12 days) chicks with appropriately-sized fish because their acceptance rate was lower than that of Roseate Tern chicks. Why did Common Terns offer such a high proportion of deep-bodied prey, such as boarfish, to young chicks, when more than 50% of these were rejected? These findings should be taken into account to explain the fact that the majority of tern chicks that die do so at ages 1-6 days (Nisbet 1978, 2002). The apparent inability of Common Terns to offer adequate prey for young chicks may be partly related to a larger brood size (Nisbet 2002). With more chicks to feed Common Terns presumably spent less time searching for fish and/or may have foraged closer to the colony. In fact, despite their larger clutch size, the overall productivity (fledgings/pair) of Common Terns is only significantly larger than that of Roseate Terns in some specific areas and years (Gochfeld *et al.* 1998, Nisbet 2002), with an apparent greater marine productivity (Rossell *et al.* 2000). The higher prey acceptance rate of Roseate Tern chicks might reflect the greater specialization of this tern species on specific foraging habitats (Safina 1990, Ramos 2000) and marine fish species (Safina *et al.* 1990, Shealer 1998b). This could be indicative of a better adaptation to a (sub)tropical marine situation, and contribute to explain the worldwide distribution of the Roseate Tern.

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# Rice field use by raptors in two Portuguese wetlands

## Utilização de arrozais por aves de rapina em duas zonas húmidas Portuguesas

Pedro M. Lourenço[1]

**ABSTRACT -** Rice plantations are internationally recognized for their importance as an agricultural habitat for birds. Despite being mostly used by aquatic birds, raptors also use this habitat. Portugal is one of the main rice producers in Europe. Despite this, little information is available regarding the bird community in these rice plantations. The present study aims to describe the abundance of wintering birds of prey in the rice plantations around the estuaries of the Tejo and Sado rivers. In the Winter 2005-2006 transepts were performed by car in several rice plantations, and comparatively high raptor densities were found. A total of nine species were identified, the most abundant being the buzzard /*Buteo buteo*/ (3.51±0.40 individuals/ 10 km), the common kestrel /*Falco tinnunculus*/ (1.88±0.32 ind./ 10 km), the marsh harrier /*Circus aeruginosus*/ (1.86±0.31 ind./ 10 km) and the black-shouldered kite /*Elanus caeruleus*/ (1.07±0.21 ind./ 10 km). Some of these species were significantly more abundant in the Tejo than in the Sado. The buzzard had a temporal trend, with densities decreasing throughout the winter.

This study underlines the importance of rice plantations as a wintering habitat for birds of prey, so the maintenance and management of these areas should be considered when planning the conservation of raptors in Portugal.

**RESUMO -** As oriziculturas são reconhecidas internacionalmente pela sua importância como habitats agrícolas para a avifauna. Apesar de serem zonas tipicamente utilizadas por aves aquáticas, também as aves de rapinam usam este habitat. Portugal é um dos principais produtores de arroz na Europa; contudo, pouca informação existe sobre a comunidade de aves destas zonas. Este estudo pretende descrever a abundância de aves de rapina invernantes nas áreas de arrozal em redor dos estuários do Tejo e do Sado.

No Inverno 2005-2006 foram realizados transeptos de automóvel em diversas zonas de arrozal, tendo sido encontradas densidades relativamente elevadas de aves de rapina. Foram identificadas um total de nove espécies, sendo as mais abundantes a águia-de-asa-redonda *Buteo buteo* (3.51±0.40 indivíduos/ 10 km), o peneireiro-comum *Falco tinnunculus* (1.88±0.32 ind./ 10 km), o tartaranhão-ruivo-dos-paúis *Circus aeruginosus* (1.86±0.31 ind./ 10 km) e o peneireiro-cinzento *Elanus caeruleus* (1.07±0.21 ind./ 10 km). Algumas destas espécies mostraram abundâncias significativamente superiores no Tejo. A águia-de-asa-redonda exibiu uma tendência temporal, com as densidades a diminuírem ao longo do Inverno. Este estudo mostra que os arrozais são um importante habitat de invernada para diversas aves de rapina, pelo que a sua manutenção e gestão devem ser consideradas no planeamento da conservação de aves de rapina em Portugal.

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Human caused changes in the world ecosystems have led to a progressive substitution of natural habitats by artificial agricultural habitats, which today represent one third of the world's ice-free land area (Elphick 2000). Accordingly, many wild species had to adapt to these new habitats in order to survive. Rice fields are currently seen as very important agricultural habitats for birds (Fasola & Ruíz 1996, Elphick & Oring 1998), in many cases functioning as substitutes for natural wetlands in places where drainage and other human developments forced birds away from their original habitats (Elphick 2000, Lawler 2001, Tourenq *et al.* 2001).

Naturally, the species most commonly associated with rice fields are waterbirds and wildfowl (Fasola & Ruíz 1996, Maeda 2001), which forage on plants, aquatic animals (e.g. Correia 2001) or even spilled rice grain (Tréca 1994; Lourenço & Piersma 2008). However, raptors have also been associated to rice fields, in areas like Panama (Petit *et al.* 1999), Maga Lake, Cameroon (Thiollay 2001) or the Po river plain, Italy (Boano & Toffoli 2002).

Although records of rice farming in Portugal go back to the Middle Ages, large scale rice production only started in the 1930's (Lains & Sousa 1998). Currently, Portugal is one of the main rice producers in Europe, with over 25000 ha being annually used for this crop. Portuguese rice fields are known to have some importance for egrets, herons and storks (Farinha & Trindade 1994), and form an important stop-over habitat for black-tailed godwits (Lourenço & Piersma 2008). Regarding raptors, marsh harriers have been reported hunting in rice field areas, in the Tejo estuary (Costa *et al.* 1993) but, in general, little is known about rice field use by raptors in Portugal.

A large portion of these rice plantations are located around the estuaries of the Tejo (38º 57' N, 8º 54' W) and Sado (38º 24' N, 8º 38' W) rivers, and along the lower parts of their basins. Field work took place in a number of areas around these two estuaries. In the Tejo I counted raptors in Ponta da Erva, Samora Correia, Ribeira de St. Estêvão and Paúl do Trejoito; in the Sado estuary I counted Zambujal, Agualva, Monte Novo da Palma, Alcácer do Sal, Batalha and Carrasqueira (Fig. 1). These areas represent a total rice field area of 2550 ha.

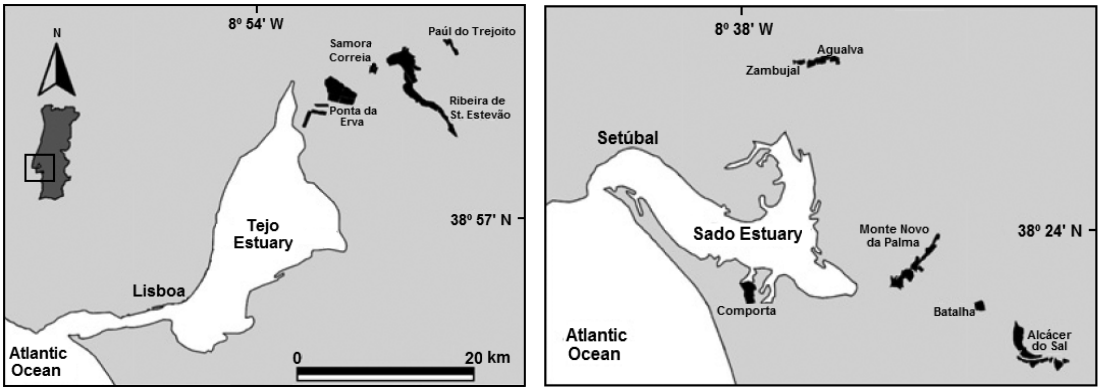


**Figure 1:** Map of the study areas, located around the estuaries of the Tejo and Sado rivers in the Portuguese western coast. The monitored rice field areas are presented in black. / ***Figura 1:*** *Mapa das áreas de estudo, localizadas em redor dos estuários do Tejo e do Sado. As zonas de arrozal monitorizadas estão representadas a preto.*

In all areas, transects were made by car, driving at a slow constant speed (Bibby *et al.* , 1992; Leitão *et al.* 2001; Boano & Toffoli 2002) along paths that run between rice paddies. All raptors seen within 500 m of the road (roughly the length of the rice fields) were included in the survey. The counts took place in the winter 2005-2006, from early November to the end of February, with every area being visited once every two weeks, always avoiding hunting days because of the disturbance hunters

cause on the bird community. Counts were always performed under dry weather conditions, with good visibility and between 10.00 a.m. and 16.00 p.m. in each day. The order in which the sites were visited changed from visit to visit so that all were counted at different times of the day. In total, 468 km were driven during the surveys.

I found a relatively diverse raptor community in the rice fields. Nine raptors species were recorded during the surveys, including five accipiterids, the buzzard *Buteo buteo*, the marsh harrier *Circus aeruginosus*, the black-shouldered kite *Elanus caeruleus*, the hen harrier *Circus cyaneus* and the booted eagle *Hieraetus pennatus*; three falconids, the common kestrel *Falco tinnunculus*, the peregrine falcon *Falco peregrinus* and the merlin *Falco columbarius*; and one strygid, the long-eared owl *Asio flameus*.

An average of 8,75±0,86 raptors /10 km was seen during the censuses, with the most abundant species being buzzard, common kestrel, marsh harrier and black-shouldered kite (Table 1). For three of these species I found significantly higher abundances in the Tejo estuary, when comparing with the Sado estuary (Fig. 2).

**Table 1:** Species overall abundance throughout this study. Results presented as mean ± SE. / ***Tabela 1:*** *Abundância total das várias espécies de rapinas estudadas. Resultados apresentados como média ± Erro Padrão.*

| Species | Individuals / 10 km |
|---|---|
| *Buteo buteo* | 3.51±0.40 |
| *Falco tinnunculus* | 1.88±0.32 |
| *Circus aeruginosus* | 1.86±0.31 |
| *Elanus caeruleus* | 1.07±0.21 |
| *Circus cyaneus* | 0.15±0.06 |
| *Hieraetus penatus* | 0.12±0.09 |
| *Asio flameus* | 0.08±0.06 |
| *Falco peregrinus* | 0.02±0.02 |
| *Falco columbarius* | 0.01±0.01 |
| unidentified raptor | 0.06±0.04 |

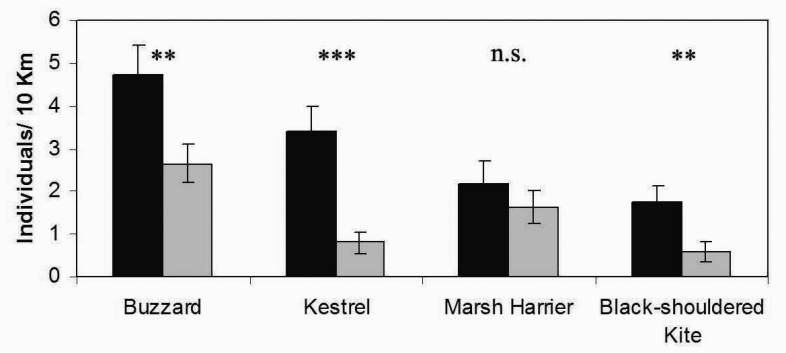


**Figure 2**: Comparative abundance of the four most common species in the two estuaries (black bars for the Tejo, grey bars for the Sado). Significance of the Mann-Whitney test (n = 7 for each estuary, with each value representing the average of all areas, in the same counting day) is presented. n.s. – $p > 0.1$, * - $p < 0.05$, ** - $p < 0.01$, *** - $p < 0.001$. / ***Figura 2:*** *Abundância comparada das quatro espécies mais comuns, em cada um dos dois estuários (barras pretas para o Tejo, cinzentas para o Sado). A significância do teste Mann-Whitney (n = 7 para cada estuário, sendo cada valor a média das contagens nos vários locais, na mesma data) é apresentada. n.s. - $p > 0.1$, * - $p < 0.05$, ** - $p < 0.01$, *** - $p < 0.001$.*

When observing temporal trends, the general pattern was one of relatively stable numbers throughout the winter. No significant temporal patterns were found for eight of the studied species. The only exception was the buzzard, which showed a significant temporal trend ($F_{(1,68)}$=19,4, $p$<0.001, $R^2$=0.27), with a decrease in densities throughout the study period (Fig. 3).

There is little quantitative data on wintering raptors in Portugal. One pioneer study made a broad scale attempt to quantify the raptor species wintering in Portugal (Leitão *et al.* 2001). Necessarily, the scope of that study was at a national level, so smaller scale conclusions where then impossible. The present

study aimed to provide quantitative data on raptors wintering in Portuguese rice fields, an agro-habitat of great significance for biodiversity (Fasola & Ruíz 1996; Elphick 2000; Lawler 2001).

Looking at the most abundant species, buzzard, common kestrel, marsh harrier and black-shouldered kite, all species showed higher abundances than the ones found by Leitão *et al.* (2001), both at the regional level of the lower Tejo and at a national level (Table 2). This suggests that rice fields are very favourable habitats for these species, housing higher numbers than the ones found in different landscapes.

The buzzard is known to use a large range of habitats, but some studies associated these birds with wetlands (Leitão *et al.* 2001) and, namely, rice fields (Boano & Toffoli 2002), while the marsh harrier is strongly associated to wetland habitats (del Hoyo *et al.* 1994; Virkkala *et al.* 2005) and been mentioned to use rice fields as hunting areas (Costa *et al.* 1993). Common kestrels and black-shouldered kites are small sized raptors commonly associated to agricultural habitats (del Hoyo *et al.* 1996; Aschwanden *et al.* 2005). No specific references regarding rice field use by these two species were found, but their densities in rice cultivated areas were roughly twice the ones found in the lower Tejo region by Leitão *et al.* (2001). Hen harrier abundance in the rice fields was only half the abundance described for the lower Tejo (Table 2), probably because this species is more associated with drier habitats, like scrubland, sand dunes and dry cereal crops (Leitão *et al.* 2001; Madders 2003).

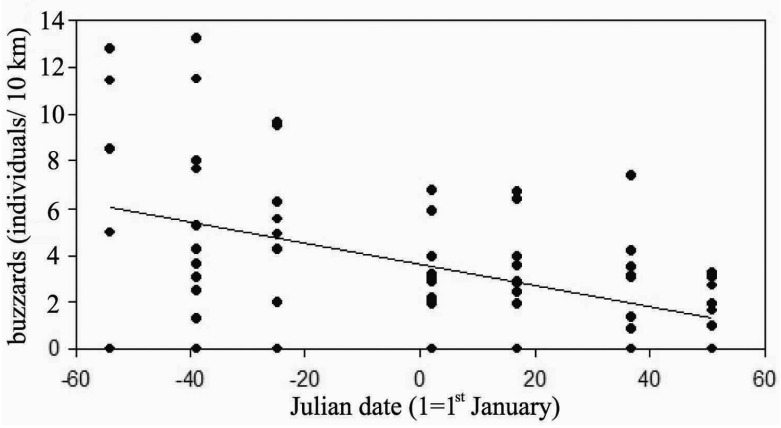


**Figure 3**: Temporal variation in buzzard abundances in the studied areas, from early November through the end of February.
***Figura 3:*** *Variação sazonal da abundância de águias-de-asa-redonda nas áreas de estudo, desde o início de Novembro até ao final de Fevereiro.*

**Table 2**: Raptor abundances (individuals/ 10 km) described by Leitão *et al.* (2001) in the lower Tejo region, that most approximates the study area of this study, and for the whole of continental Portugal. This table includes the five species found by those authors in the lower Tejo region.
***Tabela 2:*** *Abundâncias de rapinas (em indivíduos/ 10 km) registadas no censo realizado por Leitão* et al. *(2001), na região do baixo Tejo, que se aproxima da área de estudo do presente trabalho, e em Portugal Continental. Nesta tabela estão incluídas as cinco espécies registadas por esses autores na região do baixo Tejo.*

| Species | Lower Tejo | Continental Portugal |
|---|---|---|
| *Buteo buteo* | 0.78 | 0.82 |
| *Falco tinnunculus* | 1.08 | 0.65 |
| *Circus aeruginosus* | 0.49 | 0.06 |
| *Elanus caeruleus* | 0.69 | 0.19 |
| *Circus cyaneus* | 0.29 | 0.14 |

The rice fields bordering the Sado estuary had significantly lower abundances of buzzard, common kestrel and black-shouldered kite, a result that was quite unexpected has this estuary has much

less human pressure than the Tejo. The exact causes for this pattern are unclear; however, one might speculate that two factors favour the Tejo rice fields as habitat for raptors. Many rice areas in the Sado are located at the bottom of relatively narrow valleys, while the Tejo rice fields cover larger open areas, the type of landscape favoured by most of these raptor species (del Hoyo *et al.* 1994). Also, there is much more hunting in the Sado rice fields (*pers. obs.*) which, despite not being directed at the raptors and occurring only two days per week, will cause a great deal of disturbance to the entire bird community.

In general, the specific abundances remained stable throughout the winter, an expected pattern has the censuses were performed outside the main migratory periods. The buzzard stands alone as the exception to this pattern. Buzzard abundances decreased steadily during the study period, from an average density of 6 individuals/ 10 km in early November, to just under 2 individuals/ 10 km by the end of February. Buzzards are one of the latest paleartic migrants (Kjellen 1992), and there are still migrants passing through Portugal as late as mid-November (Strix 2005), so the higher numbers in November might include birds migrating through these areas. However, decreasing numbers until February can hardly be related to migratory movements. A much more likely explanation is the post-breeding dispersion of juveniles during the winter. A very similar pattern is found in barn owls (Tomé & Valkama 2001), where juveniles leave the breeding areas during the winter, in search for new nest locations. Since buzzards also breed in their first year (del Hoyo *et al.* 1994) it seems likely that it also happens in this species.

Overall I found an abundant and diverse raptor community using the rice fields bordering the estuaries of the Tejo and Sado rivers. These areas, which are mostly outside the limits of the local nature reserves, seem to be important for these raptor species and should be given greater attention, both in terms of reducing disturbance by hunting and by assuring a proper management that guarantees their continuing existence as good habitat for raptors and other animals.

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# The rice fields around the estuaries of the Tejo and Sado are a critical stopover area for the globally near-threatened Black-tailed Godwit *Limosa l. limosa*: Site description, international importance and conservation proposals

## Os arrozais adjacentes aos estuários do Tejo e Sado como zonas críticas de "stopover" para o Milherango *Limosa l. limosa*: descrição dos sítios, importância internacional e propostas de conservação

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**SUMMARY -** Rice fields are a globally important habitat for waterbirds. Portugal is one of the main rice producers in Europe, but little is known about how these rizicultures are used by the avifauna. The continental Black-tailed Godwit *Limosa l. limosa* is likely the most important avian population using Portuguese rice fields during the Winter and here we describe the main rice plantation areas used by these birds, report their international importance and propose some conservation measures for these areas. The plantations around the Tejo, Sado and Mondego lower basins were surveyed for three winters and peak counts reach roughly 45 000 birds each year. We define eleven areas, all around the Tejo and Sado estuaries as most important for this population, almost all holding over 1% of the population at some point during the surveys. Three areas, Paúl do Trejoito, Paúl de Belmonte and Samora Correia harboured, at least once, over 15% of the population during peak counts, and overall the eleven areas harbored over one third of the population each year. Despite this, most of these rice plantations are outside the local Special Protection Areas, and some of the most important ones lay at close distance from the proposed site for the new international airport of Lisboa. We propose some management guidelines for this areas, in terms of banning hunting during key periods, and of ideal farming pratices to maximize Black-tailed Godwit habitat availability. We also believe the international importance of these areas for this near-threatened species, as well as the potential risk of colisions, should be taken into serious consideration when deciding the location of the new airport.

**RESUMO -** As riziculturas são actualmente um importante habitat para aves aquáticas. Portugal é um dos principais produtores de arroz na Europa, mas pouca informação existe relativa ao uso dos arrozais Portugueses pela avifauna. A subespécie continental do Maçarico-de-bico-direito *Limosa l. limosa* é possivelmente a mais importante população a usar estas riziculturas durante o Inverno e o presente estudo pretende descrever as principais áreas de arrozal usadas por estas aves, avaliar a sua importância

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a nível internacional e propor algumas medidas de gestão em prol da conservação da espécie. Os arrozais nas zonas inferiores das bacias do Tejo, Sado e Mondego foram visitadas ao longo de três Invernos e foi contado em cada ano um máximo de cerca de 45 000 maçaricos. Definimos onze áreas, todas em redor dos estuários do Tejo e do Sado, como as mais importantes para esta população, quase todas recebendo em determinado ponto mais de 1% da população. Três áreas, o Paúl do Trejoito, o Paúl de Belmonte e Samora Correia albergaram, em alguma contagem, mais de 15% da população e o conjunto destas onze áreas recebeu mais de um terço da população em todos os três anos. Contudo, a maioria destas áreas estão fora das Zonas de Protecção Especial (ZPEs) locais e algumas das mais importantes estão muito próximas da localização proposta para o novo aeroporto internacional de Lisboa. Propomos um conjunto de medidas de gestão para a conservação destas riziculturas, em termos de proibição da caça durante o período crítico de passagem migratório e de adopção de regimes agrícolas que maximizem a disponibilidade de habitat para o Maçarico-de-bico-direito. Pensamos também que a importância internacional destas zonas, assim como o potencial risco de colisões, deveriam ser seriamente considerados na decisão da localização do novo aeroporto.

Rice fields are globally considered a very important agro-habitat for the conservation of biodiversity (Lawler 2001). Studies in all continents have proven their importance, particularly for waterbirds, which often use rice cultures as a substitute for natural wetlands lost to human development (e.g. Trèca 1994, Elphick 2000, Maeda 2001, Richardson & Taylor 2003, *Blanco et al.* 2006, Lourenço & Piersma 2009). Portugal is one of the main rice producers in Europe, with over 25000 ha annually devoted to this crop, mostly located in the lower basins of the Tejo, Sado and Mondego rivers (Lains & Sousa 1998).

Despite this, little information is available about the significance of these rice cultivations for either resident or migratory bird species in Portugal. Portuguese rice fields are known to harbour important numbers of egrets, herons and storks (Farinha & Trindade 1994, Lourenço & Piersma 2009), and are used by raptors, namely in the winter (Costa *et al.* 1993, Lourenço *in press*). However, the most important bird population using these rice fields may well be the continental Black-tailed Godwit *Limosa l. limosa*.

The global conservation status of this population has recently been changed to near-threatened due to a serious ongoing population decline (IUCN 2008). These birds use the rice fields around the Tejo and Sado estuaries as stopover habitat during the northward migration between their Western African wintering grounds and their breeding areas in North-western Europe. Yearly, from mid December -until early March, rice fields around the estuaries of the Tejo and the Sado are visited by the breathtaking sight of tens of thousands of godwits, either flying or frenetically foraging on rice kernels spilled in the ground during the previous harvest (Kuijper *et al.* 2006; Lourenço & Piersma 2008). Previous work showed that these godwits select rice fields that remain flooded throughout the winter, preferably shortly after they are ploughed by the farmers, which increases the availability of rice, their key food source during stopover (Lourenço & Piersma 2008).

There is, nevertheless, a slight twist to this story. Two subspecies of Black-tailed Godwit co-occur in Europe, the continental *L.l. limosa* and the Icelandic *L.l.islandica*. They currently have contrasting trends, and while the first is currently facing a drastic population decline, the latter is on the rise (Gill *et al.* 2007). Sightings of colour-ringed individuals from both subspecies prove they mix to some extent in the Portuguese rice fields, but calculations based on the density of ringed birds from either subspecies showed that over 90% of the individuals present in the rice fields belong to the most threatened *L.l. limosa* population (*unpub. data*), thus confirming the critical importance of the Portuguese rice

plantations for this declining subspecies.

The present contribution aims to: (1) give a detailed description of the main rice cultivations where godwits are found; (2) present updated data on local abundances and how significant those are at an international level; and (3) provide some proposals to ensure the conservation of these critical stopover sites.

## SITE DESCRIPTIONS

The rice plantations around the Tejo and Sado, and to a lesser extent around the Mondego rivers have been surveyed for Black-tailed Godwit presence, each winter from 2005-06 to 2007-08 between early December and mid-March. The Mondego was only visited 2-3 times per year. In the Tejo and Sado all sites were visited at least 2-3 times per week, each visit included counting all sites within an estuary in the same day to avoid over-estimations due to movements. Movements did occur between areas even within the same week, and when this happened the counts were not used to calculate an estimate for the whole area. No godwits were found in the rice fields bordering the Mondego river. Around the Tejo and Sado, peak numbers were similar every year, reaching 45 500 ± 1 060 individuals for the total area; however, these are mostly concentrated at a few locations. Based on field observations, we can define eleven areas, all having had, at least once, groups of over 1 000 godwits during this study. Paúl do Trejoito, Ribeira de St. Estevão/Paúl de Belmonte and Samora Correia are located around the Tejo estuary (Fig. 1 (a)), Zambujal, Agualva, Marateca, Ribeira de S. Martinho/Palma, Alcácer do Sal, Montevil, Monte Novo and Comporta are around the Sado estuary (Figs. 1 (b) and 1 (c)). A few other locations are also known to have been used by Black-tailed Godwits in the past, namely Ponta da Erva, Paúl das Lavouras and Barroca d'Alva, all around the Tejo estuary (N. Cidraes-Vieira, *pers. comm.*). In the first two sites no godwits were ever detected, and the latter occasionally had small groups of just a few hundreds. Here follows a short description of each of the eleven rice field sites (Table 1):

**Table 1**: Summary of the 11 rice field sites, including site area (ha) and proportion included in the local Special Protection Area and maximum count in each of the three winters (and % of the population, assuming the maximum estimate of 119200 birds, when above 1000 birds). / ***Tabela 1:*** *Resumo das onze áreas de arrozal incluindo: superfície (ha) e percentagem dentro da ZPE local; maior em cada um dos três Invernos (e % da população, assumindo a estimativa máxima de 119 200 aves, quando mais de 1 000).*

| Site | Area (% inside SPAs) | 2005/06 | 2006/07 | 2007/08 |
|---|---|---|---|---|
| Paúl do Trejoito | 202 (0%) | 1 100 (0.9%) | 18 000 (15.1%) | <1 000 |
| Paúl de Belmonte | 496 (0%) | 3 370 (2.8%) | 38 000 (31.9%) | 0 |
| Samora Correia | 532 (0%) | 23 000 (19.2%) | 0 | 22 000 (18.5%) |
| Zambujal | 50 (100%) | <1 000 | 4 590 (3.9%) | 7 500 (6.3%) |
| Agualva | 44 (13%) | 3 000 (2.5%) | 1 700 (1.4%) | 1 800 (1.5%) |
| Marateca | 8 (0%) | 0 | 3 250 (2.7%) | 0 |
| Palma | 216 (0%) | 9 700 (8.1%) | 11 000 (9.2%) | 9 400 (7.9%) |
| Alcácer do Sal | 145 (59%) | 2 500 (2.1%) | 2 790 (2.3%) | 0 |
| Montevil | 98 (100%) | 0 | 8 000 (6.7%) | 19 000 (15.9%) |
| Monte Novo | 60 (100%) | <1 000 | 1 150 (1.0%) | 0 |
| Comporta | 117 (39%) | 10 000 (8.4%) | 3 050 (2.6%) | 4 310 (3.6%) |
| All rice fields | 1968 (18%) | 44 700 (37.5%) | 46 700 (39.2%) | 45 100 (37.8%) |

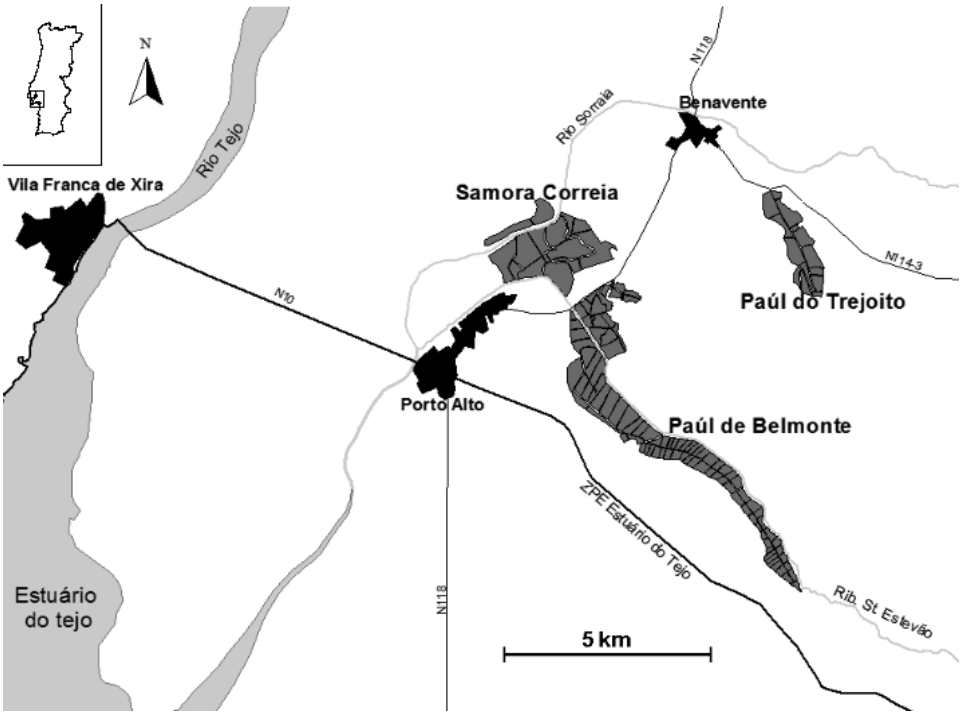
N
Vila Franca de Xira
Rio Tejo
Rio Sorraia
N118
Benavente
Samora Correia
N114-3
Paúl do Trejoito
N10
Porto Alto
Paúl de Belmonte
ZPE Estuário do Tejo
Rib. St Estevão
Estuário
do tejo
N118
5 km

Fig. 1 (a)

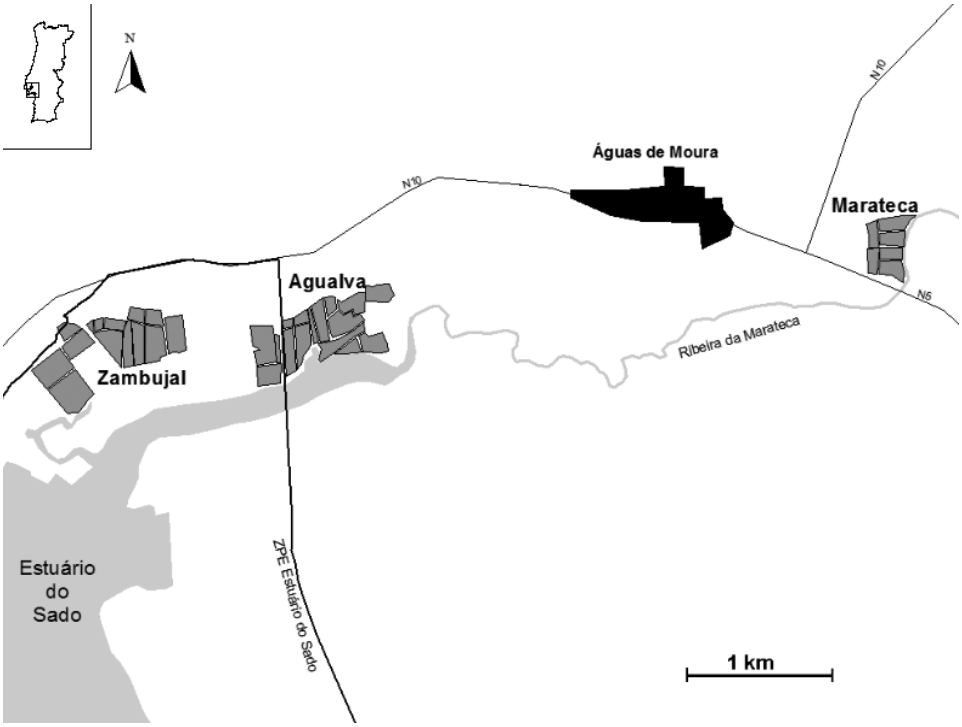
N
N10
Águas de Moura
N10
Marateca
Agualva
N6
Ribeira da Marateca
Zambujal
Estuário
do
Sado
ZPE Estuário do Sado
1 km

Fig. 1 (b)

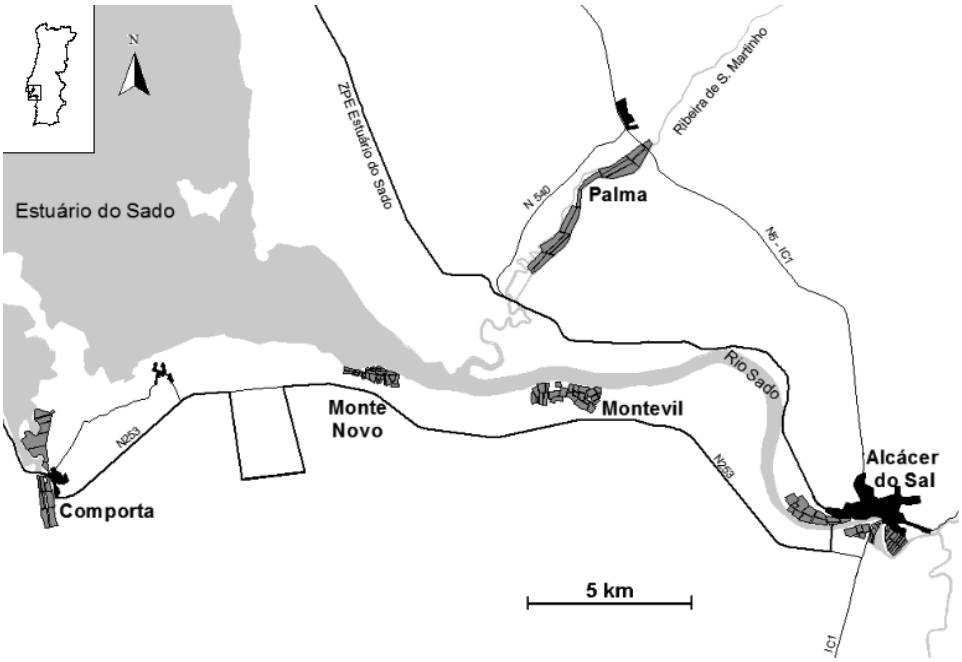


**Fig. 1 (c)**

**Figs. 1 (a), (b), (c):** Maps of the rice field sites north of the Tejo estuary (a), in the northern part of the Sado estuary (b) and in the southern part of the Sado estuary (c). The important rice fields are presented in dark grey. The nearby towns are presented in black. Main roads and rivers are also included, as is the limit of the local Special Protection Areas (ZPE do estuário do Tejo e ZPE do estuário do Sado). / ***Figs. 1 (a), (b), (c):*** *Mapa das plantações de arroz a norte do estuário do Tejo (a), na parte norte do estuário do Sado (b) e na parte sul do estuário do Sado (c). Os arrozais importantes estão representados a cinzento-escuro. As localidades estão representadas a preto. As principais estradas e rios estão também indicados, assim como o limite das Zonas de Protecção Especial (ZPE) do estuário do Tejo e do estuário do Sado.*

**» Paúl do Trejoito (38º 57' N, 8º 46' W, Fig. 1a)**

Located near Benavente, theses rice fields are crossed by the N114-3, but only the fields south of this road show the presence of Black-tailed Godwits. The latter fields cover a total of 202 ha all located outside protected areas. The maximum godwit count for this site was of 18 000 on 26 February 2007.

**» Paúl de Belmonte/Ribeira St. Estevão (38º 52' N, 8º 47' W, Fig. 1a)**

The long and narrow valey of the Ribeira de St. Estevão is mostly used for rice production between Samora Correia and Santo Estevão. These 496 ha of rice fields are completely outside any protected area. Although many fields are usually dry, and thus of little interest for godwits, in several occasions some fields retained water throughout the winter harbouring some of the highest concentrations of Black-tailed Godwits sighted during our study. The maximum godwit count at this site was of 38 000 on 13 February 2007.

**» Samora Correia (38º 57' N, 8º 50' W, Fig. 1a)**

Between the Sorraia river and the Ribeira de St. Estevão, with just two paddies on the right bank of the Sorraia, these rice fields are adjacent to the town of Samora Correia. Covering a total of 532 ha, the site is also outside the Tejo Estuary special protection area. The maximum godwit count at Samora Correia was of 23 000 on 22 February 2006.

**» Zambujal (38º 34' N, 8º 44' W, Fig. 1b)**

Located near the old bridge over the Ribeira da Marateca, near Zambujal, these rice fields had important numbers of godwits every winter. The

50 ha of paddies are inside the Sado estuary special protection area, and adjacent to mudflats that are also used by the godwits. The highest count at this site was of 7 500 on 31 January 2008.

**» Agualva (38º 34' N, 8º 43' W, Fig. 1b)**

Almost adjacent to the Zambujal rice paddies, the Agualva fields were separated both because they are accessed by a different road and because only 5.7 of the total 44 ha are inside the Sado estuary special protection area. The maximum count here was of 3 000 birds on 7 February 2006.

**» Marateca (38º 40' N, 8º 40' W, Fig. 1b)**

This small stretch of paddies is roughly 2 km east of Águas de Moura, next to the N5-IC1 road. With just 8 ha, these fields located outside any protected area harboured important numbers of godwits in 2007. The maximum count was of 3 250 on 8 February 2007.

**» Palma/Ribeira S. Martinho (38º 27' N, 8º 36' W, Fig. 1c)**

Along the Ribeira de S. Martinho, between Palma and Monte Novo da Palma span 216 ha of rice fields used by large numbers of Black-tailed Godwits in all three winters. The whole area is outside the local protected area. The highest count registered at this site was of 11 000 on 2 February 2007.

**» Alcácer do Sal (38º 21' N, 8º 30' W, Fig. 1c)**

Located between the town of Alcácer do Sal and the Sado river, some of these paddies are just next to the urban area. They cover 145 ha of which only 86 ha are inside the Sado estuary special protection area. The highest count was of 2 790 godwits on 29 January 2007

**» Montevil (38º 24' N, 8º 36' W, Fig. 1c)**

These paddies are located north of the N253, by the left bank of the Sado river, just adjacent to the Montevil rice processing plant. These 98 ha of rice plantations are inside the Sado estuary special protection area and had a maximum count of 19 000 Black-tailed Godwits on 27 February 2008.

**» Monte Novo (38º 24' N, 8º 40' W, Fig. 1c)**

Near the small village of Monte Novo do Sul, between the N253 and the Sado river, these fields span for 60 ha of special protection area. The maximum count at this small site was of 1 150 godwits on 18 December 2007.

**» Comporta (38º 23' N, 8º 47' W, Fig. 1c)**

These rice fields cover 117 ha, west and north of the town of Comporta. The site is crossed by the N253, and although most godwit flocks were recorded on the fields north from the road, which are inside the Sado estuary special protection area, the ones south from the road which are outside the protected area also had godwit flocks on a few occasions. The maximum godwit count at this site was of 10 000 on 22 February 2006.

## INTERNATIONAL IMPORTANCE

Black-tailed Godwit numbers in the rice fields around the Tejo and Sado rivers are clearly of international importance. The overall population estimate of *L. l. limosa* is between 80000-120000 breeding pairs (Thorup 2006). However, only the western part of this subspecies migrates through Iberia, as demonstrated by the ring recoveries which involved birds from The Netherlands, Germany, Belgium, France, Sweden, Denmark and the U.K., (Haverschmidt 1963; Beintema & Drost 1986). This part of the population accounts for 53 200-59 600 breeding pairs (Thorup 2006). We decided to compare the numbers in the rice fields with this western population, of which these birds are part. For each year we compared the highest count at each area to the maximum population estimate of 119 200 birds. All eleven sites received at some point over 1% of this migratory population, and could thus be of international importance under Criterion 6 of the Ramsar Convention (Ramsar 2006). Of course, not all are used every year, as defined under the convention criteria, but these group of sites probably function as one large and scattered stop-over site, with movements between different locations within a year (unpub. data) and with slight differences in use between years, due to varying management and rainfall patterns (Lourenço & Piersma 2008). Still, three of the sites, Paúl do Trejoito, Paúl de Belmonte and Samora Correia, each received over 15% of the population at some point, and when considering the maximum

counts for the whole region, we find it accounts for nearly 40% of the population (Table 1). Of course, these numbers are but underestimations of the importance of the areas, as we considered only maximum counts, and not the total volume of birds that migrate through the Portuguese rice fields. Previous work showed that when turn-over is taken into account the total volume of Black-tailed Godwits migrating through the Tejo and Sado rice fields is close to 60 000 individuals, or roughly 50% of the western breeding population (P.M. Lourenço *unpub. data*). On the other hand, the population estimate does not include birds that migrate north but never breed, namely second calendar year birds as well a proportion of adults that skip breeding each year. This underestimates the real number of birds that can potentially migrate through the Portuguese rice fields. Overall it seems reasonable that the figures summarized in Table 1 show a good picture of the true international significance of the areas.

## CONSERVATION GUIDELINES

Over one third of this near-threatened population uses rice fields around the Tejo and Sado estuaries as a migratory stopover that lasts between late December and early March (Kuijper *et al.* 2006). Despite the clear importance of these sites, 82% of their area is outside the local protected areas. In the Tejo estuary all three sites, totalizing 1 230 ha, are outside the local protected area. In the Sado the situation is considerably different, and 47% (346 ha) of the area covered by the sites is included in the local special protection area.

In many of the studied sites hunting is allowed. Although godwit hunting is prohibited, the rice fields are visited by many hunters looking for snipes, frequently causing significant disturbance to the foraging godwit flocks (European Communities 2007). It is also possible that some poaching takes place when hunters are presented with large flocks of godwits while searching for other birds. Also, for most of the area there is no management plan, and no guarantee that the current farming scheme, which is favourable for the birds by maintaining flooded fields and with ploughing starting early in the winter (Lourenço & Piersma 2008), will remain unchanged in the future. Finally, the two most important sites, Paúl de Belmonte and Samora Correia are respectively within 7 and 13km of the possible location for the new international airport of Lisboa, which is under planning at the moment. Not only are the sites close to the possible future airport, but the flight route of the birds when moving from these locations to their nocturnal roost in the saltmarshes bordering the Tejo estuary, are likely to come even closer to the airport site with potentially dire consequences for both godwits and air traffic.

In order to maintain this key stopover site for Black-tailed godwits, we believe a set of measures should be put in action. Ideally, all or most of these rice fields should be made part of the local protected areas, but whether inside a protected area or not, there are a few guidelines that should be brought to the attention of the local land managers and relevant government agencies:

- Hunting should be banned in all of these sites between the 15 December and 1 March.
- Farmers should be encouraged not to drain their fields during the winter, in order to maintain plenty of flooded fields.
- The ploughing of these rice fields should start in the second half of December and be spread along the season.
- The current discussion about the location of the new Lisbon international airport should take into very serious consideration the ecological importance of the rice field areas, and the potential risk of collision between aeroplanes and godwit flocks, as well as other bird species occurring in the area.

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*Airo* 19: 27-34 (2009)

# Do diurnal migrants follow the Guadiana River when crossing dry sectors of SW Iberia?

## Será que os migradores diurnos seguem o rio Guadiana enquanto atravessam sectores áridos do sudoeste da Península Ibérica?

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**ABSTRACT -** Little is known on the importance of water courses as migratory corridors. Here, we present the results of an investigation on the movements of diurnal migrants associated with the Guadiana River when crossing dry and inhospitable regions of southern Iberia. Direct observations were carried out along the river and at control sites away from it, in late August-November 2006. The number of birds seen was extremely small (<< 1 individual per hour for most species) and most records probably involved individuals in local movements, as indicated from similar rates of birds moving up and downriver. The only exceptions were hirundines which, within our study area, were strongly associated with the Guadiana both when foraging and when engaged in medium to long-distance daily movements. House Martins *Delichon urbicum* were particularly numerous, and 98.7% of the birds seen in directed movement (n = 4122) were flying above the river. However, passing hirundines (mostly Barn Swallow *Hirundo rustica* and Sand Martins *Riparia riparia*) were scarce and did not show the same degree of association with the Guadiana. Our results suggest that there is no significant migratory corridor along the lower Guadiana during summer-autumn, but hirundines strongly associate with this river when foraging and when commuting between foraging grounds and roosts.
Key-words: Migration; Leading lines; *Delichon*; *Hirundo*; *Merops*.

**RESUMO -** O conhecimento sobre a importância dos rios ou ribeiros enquanto estruturas físicas subjacentes a corredores migratórios é muito escasso. Neste artigo, apresentam-se resultados de um estudo dos movimentos de migradores diurnos associados ao rio Guadiana durante a passagem por sectores áridos do sul da Península Ibérica. Foram realizadas, de finais de Agosto a Novembro de 2006, observações directas ao longo do rio e em sítios-controle apartados do mesmo. O número de aves registado foi extremamente reduzido (<<1 indivíduos por hora, para a maioria das espécies) e a maior parte das observações provavelmente envolveu indivíduos em movimentos locais, o que é sugerido por haver pouca diferença entre os movimentos para montante e para jusante. As únicas excepções foram as andorinhas, que na nossa área de estudo se associaram fortemente ao Guadiana tanto durante a actividade de alimentação como quando realizando movimentos de carácter local. Os registos de andorinhas-dos-beirais *Delichon urbicum* foram particularmente numerosos e 98,7% das aves vistas em movimento orientado (n = 4122) encontravam-se a voar sobre o rio. Contudo, as poucas andorinhas vistas em aparente migração (sobretudo andorinhas-das-chaminés

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*Hirundo rustica* e andorinhas-das-barreiras *Riparia riparia*) não apresentaram o mesmo grau de associação com o Guadiana. Os nossos resultados sugerem que não existe qualquer corredor migratório importante no troço terminal do Guadiana no Verão ou no Outono, mas que as andorinhas têm uma forte associação com este rio quando se alimentam e quando se deslocam entre as zonas de alimentação e os seus dormitórios.

Migrant birds are known to, at medium to large geographical scales, select migratory routes that minimise the difficulties of overcoming ecological and physical barriers, such as deserts, oceans or mountain ranges. Coasts, isthmuses, island chains and mountain passes are well-known as features favoured by a diversity of migrant birds (Alerstam 1990, Berthold 1993). However, relatively little is known about the importance of water courses as migratory corridors. Birds might associate with rivers because water courses and their margins provide suitable resting and refuelling habitats for a wide range of species (e.g. Skagen *et al.* 1998, Izhaki *et al.* 2002). Furthermore, rivers can function as leading lines, helping the orientation of migrants, as long as their course runs approximately in the appropriate direction (Bingman *et al.* 1982, Lensink 1994, see also Åkesson 1993 for the use of coasts as leading lines).

The south-western sector of the Iberian Peninsula is used by large numbers of migrants in transit, particularly during the summer and autumn (e.g. Moreau & Monk 1957, Finlayson 1998). Both Iberian breeding birds that winter in Africa and European birds from higher latitudes cross this area in relatively large numbers (e.g. Catry *et al.* 2004). At the end of summer, however, southern Iberia is, in some areas away from the coast, extremely dry and relatively inhospitable, something that becomes evident when one considers the scarcity of migrants seen stopping over in those regions. One such area is the south-eastern part of Portugal, in the Baixo Alentejo and adjacent inland hills of the Algarve (pers. observation). This area, however, is crossed by the Guadiana river, a large watercourse that runs broadly North-South in this sector, and at the mouth of which important wetlands for waterbirds are found (Rabaça 2004).

To test the hypothesis that migratory birds associate with the lower Guadiana when crossing the above-mentioned region, we have conducted observations of diurnal migrants in late summer and autumn, at several points along the river and in nearby dry areas. We considered not only birds obviously in transit, but also individuals that forage mostly on the wing, or from the air, such as swallows, martins, bee-eaters and terns.

## METHODS

This study was carried out in summer-autumn 2006. Ten observation points were chosen along the lower ca. 100 km of the Guadiana River (but with no points located less than 20 km from the river mouth – see Fig. 1). Observations were split between those 10 points (with very little geographical bias of observation effort) and carried out in 30-minute blocks. These sampling units were paired with similar 30-minute blocks of simultaneous observations at locations 5-20 km from the river (on < 20% of the cases, simultaneous observations were not possible and observations away from the river started 20-35 min before or after the paired observation block by the Guadiana). All observations were made by single experienced observers, using 10× binoculars, placed on open sites with unobstructed views, generally covered by low scrub or dry pastures with scattered trees.

Observations were conducted between 25 August and 20 November 2006. From 25 August until 20 September observations were made on a daily basis; a total of 92 30-minute pairs of observations were carried out during this period, plus an extra 6 hours by the river only. In October and November, we carried out a total of 73 hours of observation (all by the river) on 9 different dates. Overall, we watched for visible migration by the river for a total of 125 hours, approximately 10% of the overall available daylight and on 38% of the available dates, from late August until the end of November. Observations covered the entire daylight period, but the effort was uneven, with a greater coverage of the morning periods (Fig. 2).

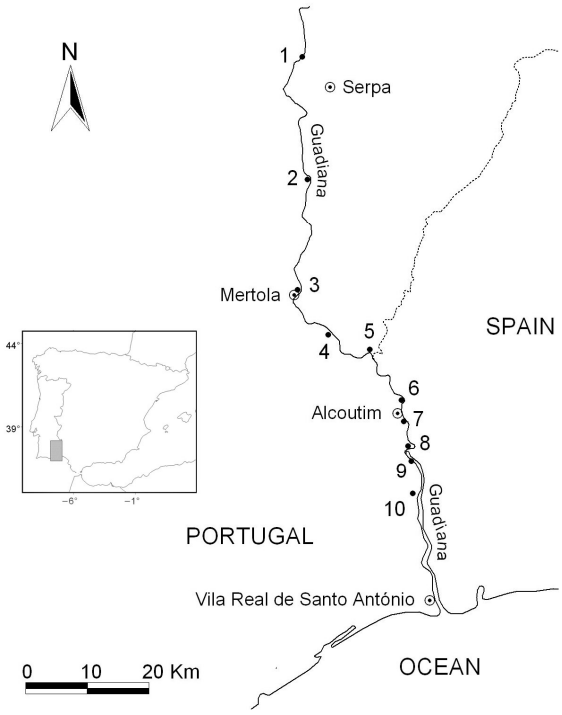


**Figure 1:** Study area in the lower Guadiana River, with locations of observation stations by the river.

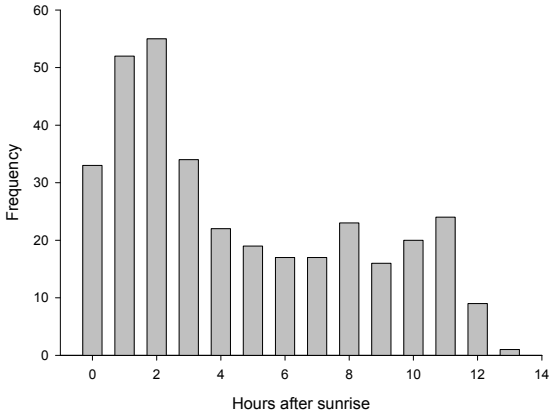


**Figure 2:** Distribution of starting times of half-hour observation periods.

Paired observations (by the river and away from it) were used to assess the degree of association of different species with the river. Supplementary observations (unpaired - by the river only) were carried out with the objective of better assessing the absolute magnitude of the visible (water) bird migration above the river.

During observation periods, we recorded all avian movements within visual range (maximum distance allowing safe identification), excluding apparent local movements. Birds were classified as being on local movements when the observed flight was seen to have started or finished within the visual range of the observers or when the individuals were seen inverting flight direction during the observation, disappearing on the same bearing where they had come from. When watching from the river margins, we noted if birds appeared to follow the river course or were clearly diverging from it. Whenever possible, directions of flight were visually determined using a compass. It was not always possible to get exact bearings for the movements of individuals or flocks. When not exactly measured, during fieldwork and throughout this paper, movements were said to be towards the south whenever they were towards 180 ± 45º. The same broad definition applies to other main geographic bearings (North, East and West).

Weather conditions were noted and wind direction and strength were measured (using a portable anemometer) at an unobstructed point during observations or immediately after they took place. Virtually all paired observations were carried out (in August and September) under clear skies with relatively light winds (mean speed 7.5 $km.h^{-1}$, range: 0-16 $km.h^{-1}$) mostly from the northern sector. In October/November weather conditions were very variable, ranging from clear skies and no wind to light rain and 45 $km.h^{-1}$ winds from the south.

To compare the incidence of foraging or passing migrants along the river with control sites away from it, we used paired non-parametric Wilcoxon rank test, for the 92 pairs of (nearly) simultaneous 30-minute observation periods. It should be noted that this involves a certain degree of pseudo-replication, as we had only 10 observation sites by the river. However, we opt to present the analyses as they are, as we believe the observation sites to be representative of the study area, there were no important bias in area coverage and between-site variance was not clearly larger than within-site variance (see Leger & Didrichsons 1994 for a detailed discussion of this type of approach). Nevertheless, we treat marginally significant results cautiously.

## RESULTS

### *Cormorants*

Cormorants *Phalacrocorax carbo* were absent in August, rare in September, but frequently seen (groups of 1-3) foraging on the river in October/November. Excluding obvious local movements, numbers moving up and downstream were similar (a total of respectively, 8 and 15) and probably also involved mostly local birds. One flock of 7 individuals moving south may have been an exception. No cormorants were seen away from the river.

### *Herons and related species*

We recorded one single flock of 6 Spoonbills *Platalea leucorodia*, flying high above the Guadiana, but moving clearly to the SE (160º), not following the river course. Grey Herons *Ardea cinerea* were regularly seen feeding along the river. Counting only birds not known to be feeding locally, 4 movements were upriver, 5 were downriver and 1 did not follow the river course. A similar pattern was found for Little Egrets *Egretta garzetta* with 5 birds upriver and 3 birds downriver. No other Ardeidae were observed. The very few White *Ciconia ciconia* and Black Storks *C. nigra* observed were on local movements. No egrets, herons or storks were seen away from the river.

### *Waterfowl*

The only species observed was the Mallard *Anas platyrhynchos*, and it was uncommon. A total of 69 mallards were seen flying near the Guadiana, divided by 5 flocks. The largest flock (40 individuals) was not following the river. Of the remaining 29 individuals, 19 were flying upriver and 10 were flying downriver.

### *Birds of prey*

In August-September, we saw very few birds of prey that were not either resting or hunting/commuting between perches. Short-toed Eagles *Circaetus gallicus* were the only species frequently encountered, generally hunting. We recorded only 5 individuals that showed an orientated behaviour (3 moving south and 2 moving north); 1 out of 5 individuals was seen above the river. The only other migratory raptor observed that showed a behaviour suggesting a migratory movement was the Montagu's Harrier *Circus pygargus*. Two juveniles were seen moving together over a distance of several kilometres, flying high (flight direction approximately 125º) and maybe following the course of the river from a distance.

In October / November, when observations targeted waterbirds moving along the river only, we saw Ospreys *Pandion haliaetus* twice (once up and once downriver), possibly involving one or two birds wintering locally.

### *Waders*

Excluding waders foraging or in obvious local movements, we only recorded Common Sandpipers *Actitis hypoleucos* once (heard moving south, high above the river) and Green Sandpipers *Tringa ochropus* on another occasion (2 individuals moving north).

### *Gulls and terns*

Gulls and terns (mostly *Larus michahellis*, *L. ridibundus*, *Sterna sandvicensis*, *S. albifrons* and *S. caspia*) were frequently recorded, but only in the lower sectors (observation points 6-10 in Fig. 1). Movements up and down-stream were equally frequent (results not shown) and clearly represented foraging movements of birds that roosted by the estuary. No terns or gulls were recorded up-stream from Alcoutim (where 93 hours of observation were carried out by the river), except for a flock of 18 *Larus fuscus* flying south (apparently migrating) near Mértola in November, 2 *L. ridibundus* and 1 *Sterna sandvicensis* flying north, also near Mértola, in October. No gulls or terns were seen away from the river.

### *Bee-eaters*

Of 19 flocks of passing Bee-eaters *Merops apiaster* seen, 18 were recorded in the last 7 days of August and the last was on 3 September. Furthermore, stationary (foraging) bee-eaters were all recorded in August. Considering only flocks for which numbers could be properly assessed, mean flock size was 13.7 ± 8.5 birds (range: 2-30; n = 13). Passing flocks were recorded at all times of the day, from just before sunrise to sunset. For a similar observation effort along the river and at other sites, 6 flocks were detected by the Guadiana and 13 others were away from it. Even birds seen at observation points by the river did not always, as far as we could assess, follow it. All flocks except one (seen at sunset and

maybe moving to a roost) were clearly orientated towards the south or southeast (Fig. 3). In 10 flocks for which direction could be visually assessed using a compass, mean direction (μ) was 150º, vector length (r) was 0.77, Rayleigh test p = 0.001. Excluding the flock moving towards the north, flight direction varied between 130º and 190º, and μ = 154º, r = 0.94, Rayleigh test p < 0.001.

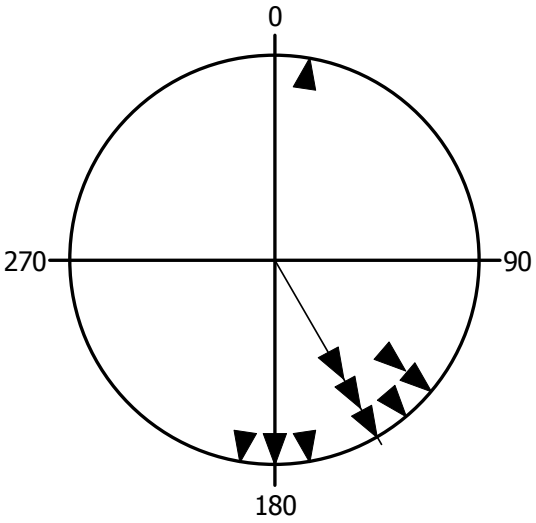


**Figure 3 -** Flight directions of 10 Bee-eater Merops apiaster flocks in late August and early September, in SE Portugal.

### *Wagtails*

Pied and Grey wagtails *Motacilla alba* and *M. cinerea* were often seen foraging or on local movements, particularly in October and November, but there were no records of flocks apparently on migration. Yellow Wagtails *M. flava* were never recorded.

### *Swallows and martins*

Different hirundine species tended to be recorded predominantly moving in different directions (Table 1). Only Barn Swallows *Hirundo rustica* and Sand Martins *Riparia riparia* were moving predominantly in the seasonally appropriate migratory direction (south). Other species must have been mostly engaged in daily movements linked to foraging.

For an equal observation effort by the river and away from it, the vast majority of Crag Martins *Ptyonoprogne rupestris*, House Martins *Delichon urbicum*, Sand Martins and Red-rumped Swallows *Hirundo daurica* were seen by the river (Table 2). Note however, that results for Sand Martins are of dubious significance as most individuals were seen on one single occasion. For Barn Swallows the sample size is relatively small but, at least for moving individuals, results seem to be considerably different from other species in that this swallow was seen as frequently away from the river as above it. It is interesting to note, as a comparison, that Common/Pallid Swifts *Apus apus/pallidus* displayed a markedly different pattern from most hirundines, with only 27.7% (n = 112) of the birds seen (including birds clearly foraging) being associated with the river. On the other hand, all 9 White-rumped Swifts *Apus caffer* seen (on 3 different locations) were by the river side.

**Table 1 -** Percentage of hirundines of different species recorded moving in the seasonally appropriate migratory direction in the lower Guadiana region. Note that these results are indicative, as many birds moved in flocks or as a continuous stream and individuals cannot be taken as independent data points.

| **Species** | **Crag martin** ***Ptyonoprogne rupestris*** | **House martin** ***Delichon urbicum*** | **Red-rumped swallow** ***Hirundo daurica*** | **Barn swallow** ***Hirundo rustica*** | **Sand martin** ***Riparia riparia*** |
|---|---|---|---|---|---|
| % moving south | 10.8 | 24.8 | 55.5 | 75.0 | 100 |
| Number of birds | 65 | 4137 | 400 | 56 | 55 |

**Table 2 -** Percentage of stationary and moving hirundines that were seen by the Guadiana river for an equal observation effort on the river and away from it and Wilcoxon rank tests comparing numbers (stationary and moving) seen in paired periods (n = 92 pairs) of observation by the river and at control sites (see methods for more details).

| Species | *Crag martin* | *House martin* | *Red-rumped swallow* | *Barn swallow* | *Sand martin* |
|---|---|---|---|---|---|
| % stationary birds seen by the river | 98.7<br>n = 158 | 89.1<br>n = 158 | 82.9<br>n = 281 | 80.0<br>n = 20 | No records |
| Comparison stationary | Z = 3.52<br>P < 0.001 | Z = 5.72<br>P < 0.001 | Z = 5.49<br>P < 0.001 | Z = 1.78<br>P = 0.076 | No records |
| % moving birds seen by the river | 98.5<br>n = 65 | 98.7<br>n = 4122 | 86.3<br>n = 388 | 56.4<br>n = 55 | 89.1<br>n = 55 |
| Comparison Moving | Z = 2.12<br>P = 0.03 | Z = 5.23<br>P < 0.001 | Z = 4.11<br>P < 0.001 | Z = 0.84<br>P = 0.40 | Z = 1.25<br>P = 0.21 |

## DISCUSSION

Despite its limited temporal coverage, this study clearly shows that the magnitude of diurnal visible migration above the lower Guadiana is extremely reduced. Even if we multiply by 10 the number of birds seen (accounting for the fact that we covered only about 10% of the available daylight hours from late August to the end of November), the net flux of birds moving south (presumably migrating) is negligible. The overall coverage was reasonably even, with a slight bias towards early morning. As there were no noticeable time effects in migrant movements, such bias is unlikely to affect our results (but see discussion on hirundines below). This study was carried out at a time of the year when huge numbers of predominantly diurnal migrants, including both terrestrial and aquatic *taxa* (such as herons, egrets, cormorants, raptors, some waders, gulls, terns, bee-eaters, wagtails and hirundines), are known to migrate along the western part of Iberia, to winter in Africa, the Mediterranean or the southern coast of Portugal and Spain (*e.g.* Alertam 1990, Finlayson 1992, 1998). Our results suggest that those migrants make virtually no use of the Guadiana as a corridor of favourable habitat to cross the arid landscapes of SE Portugal. However, we should point out that our observations may have missed high flying migrants, as they may be virtually invisible from ground level.

Studies of nocturnal migrants landed in riparian vegetation when crossing arid habitats in Southeast Arizona also failed to find an association of migratory passerines with riparian corridors, as opposed to isolated oasis, which was attributed to the fact that most migrants follow routes that are predominantly influenced by wind patterns (Skagen *et al.* 1998).

The scarcity of waterbirds moving along the Guadiana may also be due to the fact that most migrants strongly associate with the coast when moving through SW Iberia.

Movements of bee-eaters were interesting in that, contrasting with hirundines (see below), they were not associated with the river. The general SE direction of movement probably indicates an orientation towards the strait of Gibraltar, where very large numbers of Bee-eaters are usually recorded crossing to Africa (Finlayson 1992), and contrasts with the regional orientation of nocturnal passerines migrants, that is more to the SW (e.g. Hilgerloh 1988). It is interesting to note, however, that while the main Bee-eater migration in Gibraltar is in the first half of September, in southern Portugal most birds generally leave until the end of August (this study and other pers. obs.).

Contrasting with other migratory birds (excluding waterbirds), the three most numerous hirundines were strongly associated with the Guadiana within

our study area. Such association was obvious for both foraging birds and for birds (generally in flocks) in directed flight. There was an obvious pattern of daily movement of House Martins and Red-rumped Swallows from large roosting sites (mostly located in small towns, such as Mértola or Alcoutim) to unknown foraging areas, in early to mid-morning, and in the reverse direction, in mid to late afternoon. At Pulo do Lobo (observation point number 2), up to one thousand house martins were seen flying north in one hour of observation, from 08.45h, in mid September. Those birds were almost certainly coming from Mértola, located almost 20km to the south. A similar pattern was observed in other occasions at this same site. Birds always followed a very narrow corridor above the river, at most 500m wide. Reverse movements were noted in the evening and, in particular towards dusk, many of those flights were directed, fast and involved little or no foraging. River following occurred not only in sections of the river orientated North-South but also on NW-SE directions (for example, at observation point number 4). Furthermore, river following also took place on windless days, suggesting that birds were not taking advantage of shelter provided by the river valley or of local air currents. From these and other observations, it was clear that hirundines followed the river in their daily local medium-distance movements.

In arid areas of North America, the association of migratory hirudines with riparian corridors has been noted and northern Rough-winged Swallows *Stelgidopteryx serripennis*, unlike the majority of other migrants, were found to be far more numerous in continuous corridors than in isolated oases (Skagen *et al.* 1998). It is still not very clear if hirundines engaged in long-distance migratory movements associate with the Guadiana. This is difficult to evaluate because of the paucity of observations of birds known/suspected to be migrating over long-distances. However, observations of barn swallows suggest that migrating individuals were as frequent above the river as at control sites. Sand Martins, on the other hand, may have been more numerous above the river and in late September were recorded moving south in mixed flocks with House Martins and Red-rumped Swallows. More research is needed to assess if hirundines follow the Guadiana and other rivers when engaged in long-distance migration.

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