

A comparative dietary study of Cattle Egrets (*Bubulcus ibis*) and Little Egrets (*Egretta garzetta*) in S'Albufera Natural Park, Mallorca

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The diet of cattle egrets (*Bubulcus ibis* L.) and little egrets (*Egretta garzetta* L.) was investigated by analysing their pellets while they were nesting in a mixed heronry in S'Albufera Natural Park, Mallorca. The two species are considered to compete both for nesting and roosting sites and for food. In this study the role of choice of prey type and prey size in segregating the two species' diet and reducing competition was investigated. Food niche overlaps were calculated for both the parameters of prey size and type. *B. ibis* and *E. garzetta* differ significantly in their preferences for both prey type and size. Both species opportunistically utilised the introduced resource of the exotic crayfish *Procambarus clarkii* (Girard) and there was no significant difference in choice of this prey. The calculated food niche overlap was greater for prey type than it was for prey size, implying that the egrets are more similar in the types of prey they exploit than in the size of prey taken. Little egret pellets contained remains of more large items whereas cattle egret pellets contained remains of smaller prey items. Little egrets exploited fish and orthoptera more often than cattle egrets which preferred coleoptera. Both parameters were considered important in resource partitioning for these species.

Keywords: prey size, prey type, resource partitioning, food niche overlap, *Procambarus clarkii*, diet segregation.

ESTUDI COMPARATIU DE LA DIETA DE L'ESPLUGABOUS (*Bubulcus ibis*) I L'AGRÓ BLANC (*Egretta garzetta*) AL PARC NATURAL DE S'ALBUFERA DE MALLORCA. La dieta de l'esplugabous (*Bubulcus ibis* L.) i l'agró blanc (*Egretta garzetta* L.) ha estat investigada analitzant les seves egagròpiles mentre es trobaven criant a l'agroneira mixta del P.N. de s'Albufera de Mallorca. Les dues espècies competeixen pel lloc de nidificació, els dormidors i el menjar. En aquest estudi s'analitza el paper que la mida i el tipus de preses té a l'hora de segregar les dietes i reduir la competició interespecífica. El nínxol alimentari va ser calculat per a aquests dos paràmetres (mida i tipus de preses). *B. ibis* i *E. garzetta* difereixen significativament en les seves preferències de mides i tipus de preses. Ambdues espècies aprofiten de forma oportunista l'introduït cranc de riu americà (*Procambarus clarkii* Girard), no existent diferències significatives entre elles. El solapament existent en el nínxol tròfic d'ambdues espècies és major pel que fa a tipus de preses que a mides. Les egagròpiles d'agró blanc contenen més restes de grans preses, mentre que les dels esplugabous tenen més restes de preses petites. *E. garzetta* explota més sovint peixos i ortòpters, mentre que *B. ibis* prefereix els coleòpters. Els dos paràmetres analitzats es consideren importants a l'hora d'evitar el solapament tròfic de les dues espècies.

Paraules clau: mida de presa, tipus de presa, partició dels recursos, solapament tròfic, *Procambarus clarkii*, segregació de la dieta.

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Introduction

The little egret (*Egretta garzetta*) is a widely studied species (Wong *et al.*, 2000) closely related to the cattle egret (*Bubulcus ibis*) and competing in terms of roosting and nesting habitat as well as in diet (Cramp & Simmons, 1977). The little egret's distribution spans much of Europe and Asia. The cattle egret underwent considerable expansion of range in the 20th century and is now present almost worldwide (del Hoyo *et al.* 1992). Both species roost together in S'Albufera Natural Park, Mallorca. The two species are also known to utilise similar resources in their diet having both been recorded taking insects, fish, small mammals, amphibians and crustaceans in other dietary studies (Cramp & Simmons, 1977). Food items taken by these birds vary with season, location and abundance (Cramp & Simmons, 1977) and preferences for insects in *B. ibis* and for fish in *E. garzetta* show some interspecific variation that is investigated further here. Differences in feeding behaviour of these two species will give insight into the mechanisms by which they are able to coexist, using the same nesting and feeding grounds in s'Albufera without competition becoming detrimental to the poorer competitor. In Schoener (1974) the Gause principle is stated: two species using resources too similarly cannot coexist. Differences in habit (or behaviour/preference) and morphology are stated as the mechanism by which the two species are able to segregate themselves (Schoener, 1974). In segregating species to reduce competition in diet these differences in habit and morphology may be employed in terms of varying habitat use (as a spatial dimension) or in varying behaviour such as foraging technique, preferences for food type/size or by temporal separation in feeding times (Rakocinski, 1991; Ramo & Busto, 1993; Schoener, 1974). Potential for resource partitioning of food resources in s'Albufera between *B. ibis* and *E. garzetta* was investigated for preferences of particular food types and also for prey size.

Long before s'Albufera became a natural park, the exotic crayfish *Procambarus clarkii* was introduced after failure of an attempt to farm

the species commercially. It has become established in the wetland and is considered a pest due to its effect on increasing turbidity and reducing biodiversity where it becomes established, as was the case in other areas of introduction (Correia, 2001; Rodriguez *et al.*, 2005). However, for piscivorous mammals and birds, the introduction of this species represents a new food resource. Rodriguez *et al.* (2005) found that the density of piscivorous birds increased as a result of the introduction of the Louisiana red swamp crayfish (*P. clarkii*). Therefore, as in Rodriguez *et al.* (2005) the presence of *P. clarkii* could be beneficial to one or both of our study species. However, the turbidity created by *P. clarkii* has also been shown to reduce the forage success rate of piscivorous birds by reducing visibility (Cézilly, 1992).

It is likely that *P. clarkii* has had a dramatic effect on trophic interactions within the ecosystem of s'Albufera since its introduction, as in other studies (Correia, 2001). In a previous study of the effect of *P. clarkii* introduction in Portugal, little egrets exploited the new resource whereas cattle egrets did not (Correia, 2001). Analysis of pellets gave the opportunity to investigate whether there was any evidence of cattle egrets taking crayfish in this dietary study.

The aim of this study, therefore, was to compare feeding habits of *B. ibis* and *E. garzetta* in order to develop some insight into the way their food resources are partitioned to reduce interspecific competition; and to use pellet contents to help define the limits of each species' food niche in terms of the type and size of prey each exploits to the exclusion of the other. Knowledge of the role of *P. clarkii*, as a non indigenous member of the Albufera ecosystem, in the diet of either species was also considered to be valuable in understanding its contribution to changing trophic interaction in s'Albufera.

Materials and Methods

Study area and species

Cattle egrets (*B. ibis*) and little egrets (*E. garzetta*) nest together in mixed heronries that

also include night herons (*Nycticorax nycticorax*) in S'Albufera Natural Park. The park, in the north-east of Mallorca, was established in 1988 and covers nearly 1700 ha of marshes and dunes containing both saltwater and freshwater wetlands. The dominant vegetation is the common reed *Phragmites australis*, although the park is a patchwork of habitat types supporting high biodiversity. The park is protected under the Ramsar convention for wetlands of international importance and as a designated SPA provides protection for more than 200 species of birds. *B. ibis* and *E. garzetta* are two of the 61 species that breed in the park. These two species have a variety of wet and dry habitats in which to forage, within the park and in the arable farmland outside its borders.

Pellet collection and analysis

Pellets from *B. ibis* and *E. garzetta* were collected in early May 2005 from below a mixed heronry of these two species and night heron *Nycticorax nycticorax* located alongside the *gran canal* at the entrance to S'Albufera de Mallorca Natural Park. The site was also used as a roost site by these species outside the breeding season but at the time of collection most of the birds present were breeding adults on eggs. First young for both species were seen on 10th June 2005, outside the study period (P. Vicens, pers. obs.). Only one collection was made in order to minimise disturbance. The sample taken comprised 20 pellets from *B. ibis* and 21 pellets from *E. gar-*

zetta. On return to the laboratory, pellets of the two species were identified by colour and size (those of *B. ibis* being smaller and black in colour compared with the larger and paler pellets of *E. garzetta*) and separated for analysis. Pellets of the two species were treated in the same way to determine their contents. The pellets were soaked individually, then pulled apart so that large identifiable pieces could be found. The larger pieces were removed and allowed to dry before they were assigned to orders/food type groups. The contents of the pellets were assessed visually to determine the proportions that each food type represented in each pellet. The criteria used are given in Table 1.

Four of the *B. ibis* pellets were not used in the analysis as they contained no distinguishable parts. For the remainder, once the larger parts had been assigned to orders or food types they were assessed to determine the size of prey included in each pellet. These prey items were given a size rank of small, intermediate or large according to the criteria given in Table 2. The amount of prey belonging to each size group per pellet was also assessed visually as in Table 1.

Data analysis

The niche overlap of the two species for parameters of food type and for prey size was estimated as in Pianka (1973) with the equation:

$$O = \sum p_i q_i / (\sum p_i^2 \sum q_i^2)^{1/2}$$

Where O denotes dietary overlap, p_i is

Contribution rank	Criteria
0	Absent
1	Present \leq 25% of remains
2	Present $>$ 25% \leq 50% of remains
3	Present $>$ 50% \leq 75% of remains
4	Present $>$ 75% of remains

Table 1. Criteria for determining contribution rank of remains for calculating an estimate proportion of pellet. *Taula 1.* Criteri emprat per determinar el rang de contribució de les restes segons el seu percentatge de presència.

Size rank	Criteria
Small	≤ 1 cm total prey length
Intermediate	> 1 cm ≤ 2 cm total prey length
Large	> 2 cm total prey length

Table 2. Criteria for determination of size ranks of food item remains.

Taula 2. Criteri emprat per determinar el rang de mida de les restes de menjar trobats.

the proportional use of food type i by species p and q_i is the proportional use of food type i by species q . This equation gives values between 0 and 1 which signify no overlap and complete overlap respectively.

The difference between the two species in their use of food types was tested using a two-way ANOVA and for each individual food type using a Kruskal Wallis test of difference. For prey size data was tested using a two-way ANOVA to discover the difference between the two species overall and then again using a Kruskal Wallis test when considering the difference between species for each in their use of each prey size group.

Microscope analysis of hair

Hair was an unexpected component of the pellets of both *B. ibis* and *E. garzetta*. This material was compared with hair collected from cattle, horses and 'fur' from moths. The analysis of these hair samples was completed according to the method described in Strachan (1995) by preparing gelatine print slides of each hair type so that the patterns of the guard hairs could be compared using a high power microscope with diagrams also found in Strachan (1995).

Once hair samples from cattle, horses and moths failed to compare well with the hair found in pellets another sample of hair was taken from the pellet of a barn owl (*Tyto alba*) and analysed in the same way. As this sample compared well with the samples from egret pellets the species was identified by analysing the skull also contained in the barn owl pellet. The method for identifying rodent skulls is also described in

Strachan (1995). A tooth was removed from the owl pellet skull and the roots counted using a low power microscope so that the mammal, a mouse, could be identified to species.

Results

The overlap in food type choice between *B. ibis* and *E. garzetta* was calculated as $O = 0.64$ where a figure of 1 would denote full (identical) overlap and 0 would signify no overlap whatsoever. *B. ibis* and *E. garzetta* clearly utilise some of the same resources but there are also differences in their food type choices. The difference between the species for the proportions of each food type used was significant for Orthoptera ($p < 0.05$, $df = 1$), Coleoptera ($p < 0.001$, $df = 1$) and for fish ($p < 0.001$, $df = 1$) though not for Diptera, Hemiptera or for crayfish ($p = 0.69$, $df = 1$, $p = 0.63$, $df = 1$ and $p = 0.35$, $df = 1$ respectively). When the difference between species for all food types was considered together the result was also significant ($p < 0.001$, $df = 5$). The significant difference in food type choices between *B. ibis* and *E. garzetta* is illustrated in Fig. 1 where, in particular, *B. ibis* shows a preference for Coleoptera and *E. garzetta* shows partiality towards Orthoptera and fish.

When the difference between *B. ibis* and *E. garzetta* in their choice of prey size was considered the result was significant ($p < 0.001$, $df = 2$). The prey size niche overlap calculated supports the significant difference found between the two species in prey size choice ($O = 0.55$). Overlap between the species for prey size is less than it is for food type choice. Fig. 2 demonstrates the difference between *B. ibis* and *E. garzetta* in their choice of prey size. *B. ibis* is more

reliant on small prey items whereas *E. garzetta* prefers prey from the large size rank.

The hair samples in the pellets were identified as belonging to the house mouse *Mus musculus* (L.).

Discussion

Limitations of pellet analysis

Both species regurgitate pellets of partially digested food that can be analysed to discover the contents. Pellets do not represent the food of a single meal and therefore there may be

discrepancies between findings of diet determined by pellet analysis compared with studies using direct observation or by analysing stomach contents (Casaux *et al.*, 1997; Casaux, 2003). However, pellet analysis has the advantage of being non-invasive and minimising disturbance to the birds, which was important here as both species were nesting when the pellets were collected (Casaux, 2003).

Collecting at the very beginning of the breeding season ensured that the samples were all derived from adults. It was not an intention of the study to differentiate between breeding and non breeding adults though it seems reasonable

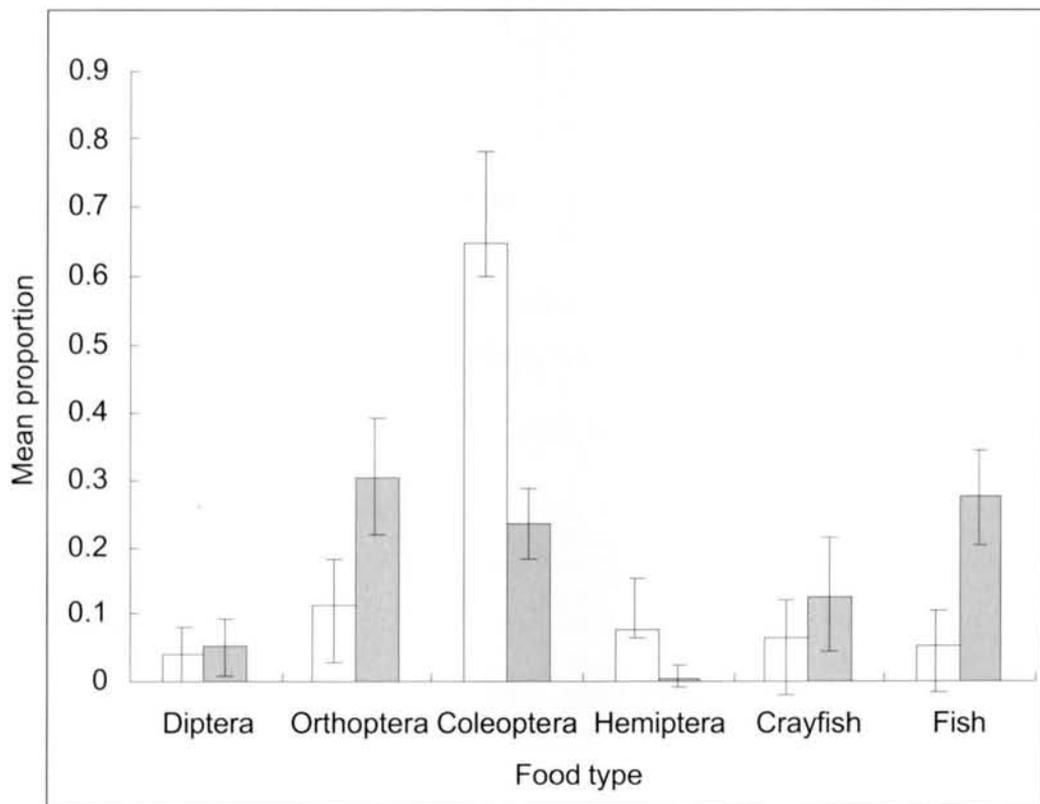


Fig. 1. The mean proportion of each food type in pellets of *B. ibis* (white bars) and *E. garzetta* (grey bars) collected at S'Albufera de Mallorca in May 2005.

Note: Error bars show 95% confidence intervals of the mean values.

Fig. 1. Proporción mitjana de cada tipus de menjar a les egagròpiles de *B. ibis* (barres blanques) i d'*E. garzetta* (barres grises) col·lectades a s'Albufera de Mallorca el maig de 2005.

Nota: les barres d'error mostrades marquen els intervals de confiança del 95% respecte als valors mitjans.

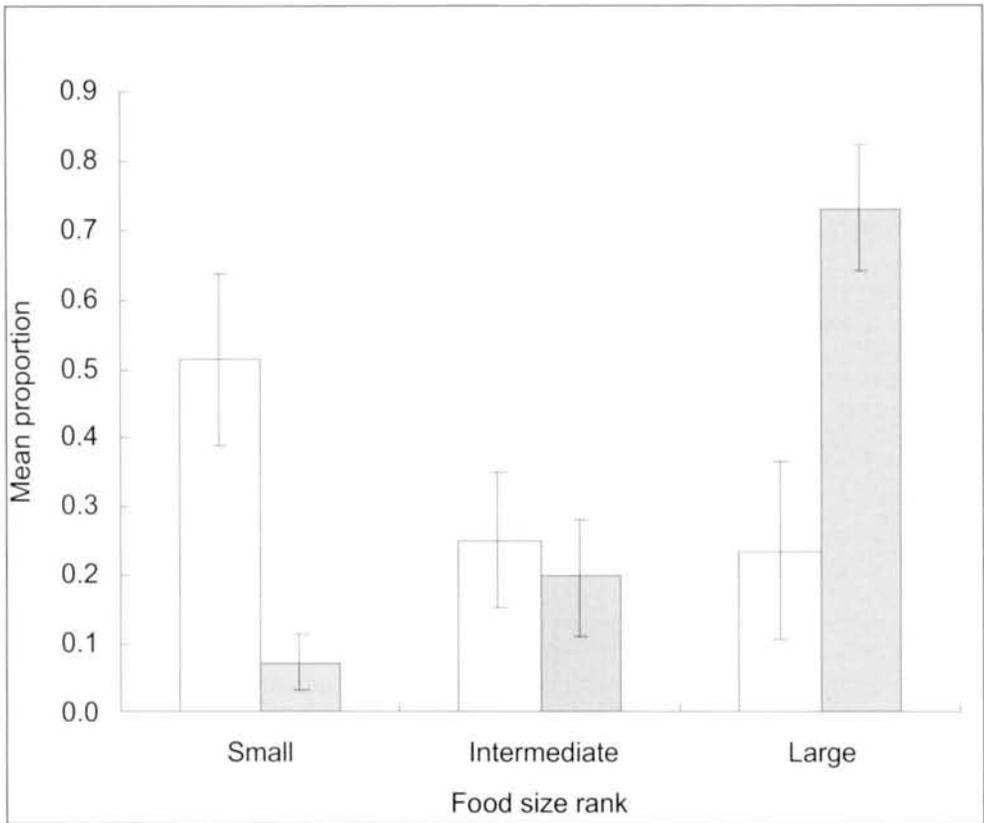


Fig. 2. The mean proportion of food item remains of different sizes in pellets of *B. ibis* (white bars) and *E. garzetta* (grey bars) collected at S'Albufera de Mallorca in May 2005.

Note: Error bars show 95% confidence intervals of the mean values.

Fig. 2. Proporción mitjana de les diferents mides de les restes trobades a les egagròpiles de *B. ibis* (barres blanques) i d'*E. garzetta* (barres grises) col·lectades a S'Albufera de Mallorca el maig de 2005.

Nota: les barres d'error mostrades marquen els intervals de confiança del 95% respecte als valors mitjans.

to assume, from the locality and season, that the majority of samples derived from breeding birds.

As *B. ibis* and *E. garzetta* utilise similar food resources we should expect the presence of each to be mutually detrimental to their success, so that the preferences of each species change (Torok, 1993). In addition, the presence of *B. ibis* has emerged to be negatively associated with the nesting success of *E. garzetta* in other studies (Bennetts *et al.*, 2000; Hilaluddin *et al.*, 2003), where the proposed explanation was the displacement of *E. garzetta* by *B. ibis* from preferred

nest sites.

In work by Gawlik (2002) it was suggested that prey availability was considered the most likely factor to constrain the growth of populations of wading birds. As such, competition for prey between *B. ibis* and *E. garzetta* may be important, although a previous dietary study by Yen (1991) found no evidence of competition for food between *B. ibis* and *E. garzetta*. It would be interesting to investigate, as a follow up study, whether relative quantities of prey types taken by the birds can be associated with abundance/avail-

lability data (as in Marchetti *et al.*, 1998). If real and pellet determined abundances differ significantly it would imply that selection of prey is not only determined by what is most available, and some preferences and foraging tactics may apply, perhaps in relation to energy maximisation. For instance, in relation to foraging technique, the incidence of crayfish remains in pellets may be affected if, for example, one species imitates snowy egrets *Egretta thula* and selects individuals that have recently moulted their shells (King & LeBlanc, 1995).

B. ibis and *E. garzetta* are similarly sized species, so we might expect them to take similarly sized prey if the relationship between predator size and prey length in herons discussed by Ramo & Busto (1993) holds. Morphology (e.g. bill size) may also be important in determining which prey are preferred (Lombardini *et al.*, 2001). If *B. ibis* and *E. garzetta* take similar sized prey then prey length will not be an important factor in diet segregation between the species. It was also suggested by Ramo & Busto (1993) that the correlation between predator and prey size holds in cases of more extreme differences in predator size rather than over a continuum. As *E. garzetta* and *B. ibis* are similar in size the association with prey size may not apply. In an experimental study by Cézilly *et al.* (1988) *E. garzetta* showed a strong preference for taking larger prey items, which was tested again here. This may be a result of larger items being more profitable for the birds although handling times can alter value so that items of intermediate size are more worthwhile (Roger *et al.*, 2000).

Main findings

The main findings of this comparative dietary study indicate that food type choice is not as important as prey size in segregating resources between cattle and little egrets. This is surprising considering the well-documented preferences that each bird species has: for fish in *E. garzetta* and for insects in *B. ibis*. The food niche overlaps calculated as in Pianka (1973) indicate that *E. garzetta* and *B. ibis* were more similar in the type

of food resources they utilised than in the size of prey items found in their pellets. However, this is not to suggest that preferences for prey type are not important for resource partitioning. *E. garzetta* differed significantly from *B. ibis* in both parameters:- prey size and food type.

The most obvious differences for prey type choice were in the preference displayed for coleoptera by *B. ibis*, a trait not evident in *E. garzetta*, which not unexpectedly showed a marked preference for fish, but also for orthoptera (mainly grasshoppers).

Cézilly *et al.* (1988) demonstrated that *E. garzetta* showed a preference for large food items rather than smaller items (on a scale comparable with this study), in line with predictions made based on energy maximisation theory. The results of this study support the previous findings. *E. garzetta* shows a marked partiality towards larger prey, based on remains found in their pellets. The results do not concur, however, with the study by Hafner *et al.* (1982) where *E. garzetta* took smaller prey than all other birds in the study (which included *B. ibis*). In contrast, *B. ibis* pellets at s'Albufera repeatedly contained remains of more small prey items with larger prey remains being found less frequently.

B. ibis and *E. garzetta* are known to make frequent use of different habitat types in their foraging. With this in mind, it is important to recognise the possibility that the differences in prey type and size choice may be a result of differences in availability of these items in each species' foraging grounds. Indeed, habitat use is another parameter cited as an important contributor to effective resource partitioning between competing species (Rakocinski, 1991; Ramo & Busto, 1993; Schoener, 1974).

Crayfish

It was interesting to note that the birds did not differ significantly in their use of the invasive crayfish species *P. clarkii*. In previous dietary studies it has been found that *B. ibis* is unlikely to take crayfish (Correia, 2001) whereas *E. garzetta* more opportunistically exploits the

introduced resource. In this study crayfish remains appeared infrequently and in small amounts in the pellets analysed. Crayfish remains were found in a greater proportion of *E. garzetta* pellets than *B. ibis* pellets but the difference between the species was not significant. The confirmation that *B. ibis* was feeding on *P. clarkii* in s'Albufera was unexpected, considering previous studies and the species' general preference for foraging on dry land. However, the species is well known for its association with large grazing animals and at s'Albufera, cattle, buffalos and horses habitually enter the wetland to graze. They are frequently accompanied by *B. ibis* so s'Albufera birds may come into contact more readily with crayfish than was the case in the study by Correia (2001), and opportunistically take them. Alternatively, as it was the nesting season when the pellets were collected the incidence of crayfish in the food of both species may be linked with the benefits the food type would give in egg production (Correia, 2001). It would be interesting to know if frequency of feeding on *P. clarkii* in s'Albufera changes between seasons as the nutritional demands of the birds alter. For this a more long-term study would be necessary.

Mammal hair

The incidence of mammal hair in the pellets of both species was not included in the results of this study as a separate food type as no bones or other evidence of ingestion of small mammals were found. However, the discovery of mouse (*Mus musculus*) hair was of great interest and warrants discussion here. As the hair appeared in a large proportion of pellets, and in significant quantity in each, it is highly improbable that ingestion was accidental. We speculate that the hair may have been consumed as roughage to aid in the formation of pellets. It appears highly unlikely that the birds had consumed the entire animal as no mammal bones were found in the remains. Ingestion of owl pellets by the egrets also seems unlikely for the same reason.

Digestion imbalance

Discrepancies are likely to occur between the findings of a dietary study by pellet analysis and one by direct observation of captive birds or indeed by analysis of stomach contents (Casaux, 2003; Casaux *et al.*, 1997). Pellets do not allow exact determination of diet due to inconsistencies in the number of meals each pellet represents, differences in digestion rates of different food types and varying times between ingestion and regurgitation (and therefore digestion time) with differing distance from foraging grounds. This study did not apply correction factors to the quantities and quality of the remains of each food type found. It may be that some food types are digested entirely (i.e. soft bodied organisms) so that the weighting of the contribution of hard-bodied organisms in the diet is overestimated. This incongruity could occur both between and within food types, e.g. crayfish remains may be less detectable from younger individuals, as their bodies are not fully hardened. The size of crayfish would also be expected to change over time (seasonally) as each generation matures (Correia, 2001).

A bias towards larger food items is expected as they are more likely to be incompletely digested and also are more easily detected visually, the method by which quantities in each pellets were estimated in this study.

Conclusions and recommendations

Inconsistencies are expected in both parameters by which resource partitioning was investigated in this study. To correct these potential errors further work is recommended in order to develop reliable correction factors by comparison of findings with feeding trials using captive birds. As the presence of other species is known to change the feeding preferences of birds (Torok, 1993) it would be interesting to see whether strategies change if a competitor is artificially removed.

The birds are likely to use habitats more often that better guarantee their foraging success

(Lombardini et al., 2001). Energy intake rates in habitat types can inform conservation to protect the habitats most important for bird species (Wong et al., 2000). Further work should investigate the link between habitat type and food type availabilities (Marchetti et al., 1998) as well as look at temporal changes in diet. This will inform the continued conservation of habitats within and beyond the borders of s'Albufera that are most important in bird species protection, as recommended by Kazantzidis and Gouter (1996).

It will be difficult to sort out the confounding factors that surround prey choice such as differences in colour, shape, nutritional value, activity, size, taste, handling time, etc. Therefore it would be a gross oversimplification to continue to view resource partitioning by only the limited parameters of size and type (Torok, 1993). If energetics and optimal foraging theory are to become the basis for investigation (as in Cézilly et al., 1988) it cannot be assumed that all prey types are of equal value to the predator or that there will be a clear-cut positive relationship between prey size and profitability. However, it is still of value to be aware that the two species studied here are separated even at this rudimentary level of distinction. It is in their separation that their coexistence is enabled, despite competition. Diversity in habit and preference between species is the very mechanism by which diversity overall can persist.

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