EDITORIAL

It is with great pleasure that I write this editorial note for no. 15 of AIRO. We were informed that Thompson Scientific accepted our journal to be indexed and abstracted in Biological Abstracts and Biosis Previews. Therefore, those choosing AIRO to publish their work can now reach a worldwide readership. This will confer us more responsibility in pursuing the task of publishing a journal with quality standards.

The volume 15 is dedicated mostly to seabirds. It includes articles from meetings promoted by the Portuguese Society for the Study of Birds on the island of Madeira: a workshop on Manx Shearwater and the First International Congress on Atlantic Birds. We wish this volume to contribute to the knowledge on ecology and conservation of seabirds in Portugal, especially those from the Atlantic archipelagos of Madeira and Azores.

Jaime Albino Ramos
INVASIVE ALIEN SPECIES AS A THREAT TO SEABIRD POPULATIONS: AN ACCOUNT OF HABITAT RESTORATION ON ‘ILHÉU DA PRAIA’ (GRACIOSA, AZORES) SPECIAL PROTECTION AREA

MARIA PITTAS GROZ & J. C. PEREIRA

SUMMARY - This work presents an account of habitat restoration implemented in Ilhéu da Praia Special Protection Area (Graciosa, Azores), focusing on the eradication of introduced species. Intentional introduction of exotic species, especially Tamarisk Tamarix africana, Hottentot Fig Carpobrotus edulis and mammals such as Cats Felis catus, Goats Capra hircus and Rabbits Oryctolagus cuniculus took place several times. The work included an eradication programme for introduced rabbits, control of soil erosion, multiplication and re-introduction of native flora and removal of invasive alien flora. The eradication was conducted using a grain based pellet with 0.02 mg/kg of brodifacoum and monitoring results indicate that rabbits were eradicated from the islet. Results also show a survival rate of 44.4% for Festuca petraea indicating that this should be considered a key-species in the restoration of coastal habitats in the Azores. Surveys of both Common Terns Sterna hirundo and Roseate Terns Sterna dougallii after the restoration work reveal a clear increase in the number of breeding pairs, indicating that the habitat restoration actions have contributed to a significant improvement of breeding conditions.

ESPÉCIES EXÓTICAS INVASORAS COMO AMEAÇA À CONSERVAÇÃO DAS POPULAÇÕES DE AVES MARINHAS: RESTAURO DE HABITAT NATURAIS NA ZONA DE PROTECCÃO ESPECIAL ‘ILHÉU DA PRAIA’ (GRACIOSA, AÇORES). Este trabalho apresenta os resultados de uma experiência de restauro de habitats naturais implementada na Zona de Protecção Especial “Ilhéu da Praia” (Graciosa, Açores), que incidiram sobretudo na erradicação de espécies introduzidas. A introdução intencional de espécies exóticas, nomeadamente a Tamargueira Tamarix africana, o Chorão Carpobrotus edulis e mamíferos, incluindo Gata Felis catus, Cabra Capra hircus e Coelhos Oryctolagus cuniculus ocorreu várias vezes. Procedeu-se a um programa de erradicação para os coelhos introduzidos, controlo da erosão do solo, multiplicação e re-introdução de flora nativa e remoção de flora exótica invasora. A erradicação foi levada a cabo utilizando um isco em grão com 0,02 mg/kg de brodifacoum e os resultados da monitorização indicam que os coelhos foram erradicados do ilhéu. Os resultados revelam também uma taxa de sobrevivência de 44,4% para o Bracel-da-rocha Festuca petraea indicando que esta espécie deve ser considerada uma espécie-chave no restauro de habitats costeiros dos Açores. Censos de Gaivina Sterna hirundo e de Gaivina-rosada Sterna dougallii realizados depois dos trabalhos de restauro evidenciam um claro aumento no número de casais reprodutores, indicando que as acções de restauro contribuíram para uma melhoria significativa do habitat de nidificação.

Nearly 40% of bird species are declining across Europe and many of these widespread declines result from threats to habitats (Tucker & Evans 1997). According to these authors human uses have a negative impact on birds either through direct habitat destruction or through habitat deterioration, changing particular features of the habitat that are essential for individual species. In addition, invasive

1Direcção Regional do Ambiente, Colónia Alemã, 9900-014 Horta, Portugal. e-mail maria.j.pitta@azores.gov.pt
2Silpermar-Aquaculture, Avenida Humberto Delgado, n.º 6A, 2860-021 Alhos Vedros, Portugal
alien species, defined according to the Convention on Biological Diversity, whose introduction and/or spread threaten biological diversity, are now considered the second cause of biodiversity loss at the global level, after direct habitat destruction (Shine et al. 2000).

The breeding seabird assemblage of the Azores comprises five species of Procellariiformes, four Charadriiformes and one Pelecaniform. The regular breeders are: Bulwer’s Petrel Bulweria bulwerii, Cory’s Shearwater Calonectris diomedea, Manx Shearwater Puffinus puffinus, Little Shearwater Puffinus assimilis and Madeiran Storm Petrel Oceanodroma castro, Yellow-legged Gull Larus cachinnans atlantis, Common Tern Sterna hirundo and Roseate Tern Sterna dougallii. There are two occasional breeders, Red-billed Tropicbird Phaethon aethereus and Sooty Tern Sterna fuscata, a possible breeder Fea’s petrel Pterodroma feae and a possible former breeder White-faced Storm petrel Pelagodroma marina (Monteiro et al. 1996a). Nevertheless the chronicles of Gaspar Frutuoso dating from 1561 list ten abundant seabird species distributed through all the islands of the Azores archipelago (Frutuoso 1561 - printed as Frutuoso 1983). According to these historical chronicles the significant decline in the abundance of seabird species in the 16th century is related to predation by introduced Ferrets Mustela furo.

The introduction, accidental or intentional, of invasive alien plants and mammals seems to have caused significant changes in the seabird’s natural habitats and communities of the Azores: (a) The coastline and cliffs of all islands now exhibit different plant communities (Sjögren 1973), partly due to the invasion of densely rooted exotic species resulting in major losses of suitable burrowing ground for seabirds (Monteiro et al. 1996b; own observations). (b) Habitat loss due to overgrazing by introduced herbivores (sheep, goats and rabbits) affects some important seabird colonies in the Azores (e.g. Topo, Cabras and Praia Islets). Rabbits, in particular, have a detrimental effect on burrows of Procellariiformes and promote soil erosion (Monteiro et al. 1996b; own observations).

This work presents an account of habitat restoration, focusing on the eradication of introduced species in order to improve the breeding conditions for seabirds at Ilhéu da Praia, Graciosa Island. The work took place between 1995 and 2002 and included an eradication programme for introduced rabbits and control of soil erosion during the two first years, multiplication and re-introduction of native flora specimens, and removal of invasive flora species in the following years.

**STUDY AREA AND METHODS**

**Study area**

Ilhéu da Praia, a Special Protection Area (SPA) and an Important Bird Area (IBA) by BirdLife International (Heath & Evans 2000) is a small islet with 10.8 ha, 1.5 km distant from the settlement of Praia on Graciosa island (Figure 1). The islet is barren due to an advanced process of coastal erosion, mainly in the east and southeast ends. Natural habitats suffered enormously from human intervention resulting in the dramatic reduction of native species and intentional introduction of exotic species such as Tamarisk Tamarix africana and Hottentot Fig Carpobrotus edulis. The intentional introduction of mammals took place several times including Cats Felis catus, Goats Capra hircus and Rabbits Oryctolagus cuniculus, with a total population estimated in 100-200 individuals. Specimens of the two first species have failed to survive in the islet and there are no recent records of their occurrence. Ilhéu da Praia Special Protection Area is one of the most important breeding sites for seabirds in the Azores archipelago including colonies of Calonectris diomedea, Oceanodroma castro, Puffinus assimilis, Sterna hirundo and Sterna dougallii (Table 1). Although breeding status is still not confirmed Pterodroma feae and Bulweria bulwerii also occur in the islet. Other bird species occur in the islet such as several species of waders (Calidris alba, Arenaria interpres, Limosa limosa and Numenius phaeopus), endemic passerines (Motacilla cinerea patriciae, Turdus merula azorensis and Serinus canaria) and the endemic Azores Buzzard (Buteo buteo rothschildi). Gulls and herons also occur (Ardea cinerea and Larus cachinnans atlantis).

Before human intervention on Praia Islet, the plant communities should have been those that are native of coastal areas. According to Sjögren (1973) the association Festucetum petraeae is characteristic of Azores coastal habitat, occurring mainly in sea cliffs. The characteristic species of this association
is the common endemic *Festuca petraea*, which usually develops costal prairies. Other species are found in this association such as the common *Solidago sempervirens* and *Crithmum maritimum*, the less common *Tolpis suculenta* and even rare endemic plants like *Azorina vidalii* and *Myosotis maritima*. This coastal vegetation is highly influenced by salt water spray and small trees like *Erica azorica* remain as small shrubs marking the transition to macaronesian coastal forests composed by *Myrica faya*, *Picconia azorica* and, as a result of deliberate introduction, the invasive *Pittosporum undulatum*.

Surveys took place made in Graciosa during springtime in 2000 in order to find plant species belonging to the coastal habitat *Festucetum petreae*, which could have occurred in the study area. Rare species like *Myosotis maritima*, *Azorina vidalii* and *Spergularia azorica* were found in Ilhéu de Baixo, an offshore islet close to Ilhéu da Praia, with relative good self sustaining populations, confirmed by the observation of numerous seedlings and young plants. In the main island only one specimen of *Azorina vidalii* was found, near the coast in Carapacho. *Tolpis suculenta* were found in Quitadouro and Baía do Filipe. *Solidago sempervirens*, *Festuca petraea*, *Erica azorica* and *Myrica faya* occurred regularly along the coastline.

**METHODS**

The eradication programme was conducted over the entire islet using a grain based pellet with 0.02 mg/kg of brodifacoum as the active ingredient to eradicate the estimated population of 100-120 Rabbits, between 20 September and 2 October 1997. Two methods were used to cover the islet with poison bait, a standard approach by placing 150-200g of bait on a 20m grid, modified when heavy infestation or activity was detected by using a closer spacing, and broadcasting the bait on cliff faces and other inaccessible areas whenever necessary. Bait was laid over the islet three times (20, 24 and 30 September) using 90kg, 70kg and 30kg, respectively. Preliminary bait stations were set on the 12th of September (Bell et al. 1997).

Monitoring was done during visits to the islet when bait was re-laid for the second and third times. Bait was placed near the location when any sign was found and all key areas were checked. Looking for live rabbits was also carried out at dawn and dusk together with spotlighting at night. Leg hold traps were also used where active rabbit burrows were found.

Control of soil erosion was first accomplished, from 1995 to 1996, by cutting down tree branches...
from the introduced specimens of Tamarisk and laying them into the erosion scars. Following that, in 1997, debris dams were constructed to assist in collecting the soil, mainly in the east and southeast ends of the islet. As a result of this action soil has been retained and vegetation is spreading along the target areas (own observations).

Following the surveys, seeds and plants were collected, depending on the abundance of each species at the sites described in the “Study area” section, and used for ex-situ production. In 2000, a 6m² nursery was installed on arable soil, in the main island in order to germinate and grow plants for later re-introduction in the intervention area. During 2001, one year after small plants from the species described above were planted on the interface between the pasture and the eroded coastal area of islet, plants of Festuca petraea (450 individuals) and plants of Erica azorica (30 individuals) were by far the most abundant species, according to the coastal habitat targeted for restoration (Festucetum petraeae). Survival rate was defined as the number of survived plants/number of plants re-introduced. Colonization rate was defined as the number of seedlings or new plants/number of plants re-introduced.

Specimens of invasive alien species occurring in the intervention area, such as Carpobrotus edulis, were manually and gradually removed. Considering that Tamarisk is non-invasive, individual trees were regularly trimmed but not completely eradicated, in order to prevent soil erosion.

Surveys of the breeding colonies of Roseate Tern and Common Tern are carried out since 1988 all over the Azores archipelago and data gathered on Ilhéu da Praia allowed us to make some considerations on the impact of the present habitat restoration on the islet tern colonies (Meirinho et al. 2003).

RESULTS AND DISCUSSION

Dead rabbits were found in most locations on the islet. As time progressed signs of live rabbits became less obvious and then disappeared. During all the monitoring and spotlighting activities over the last two days and nights, no live rabbits were seen and no fresh rabbit activity was found (Table 1).

Table 1. Maximum population estimates for seabird species breeding in Ilhéu da Praia Special Protection Area compared to the total estimates for the Azores, Portugal and Europe (pairs).

<table>
<thead>
<tr>
<th>Species</th>
<th>Ilhéu da Praia</th>
<th>Azores</th>
<th>% Azores</th>
<th>Portugal</th>
<th>% Portugal</th>
<th>Europe</th>
<th>% Europe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calonectris diomedea borealis</td>
<td>343</td>
<td>173,600-203,900</td>
<td>&lt; 1%</td>
<td>190,250 - 229,150</td>
<td>&lt; 1%</td>
<td>244,060 - 285,160</td>
<td>&lt; 1%</td>
</tr>
<tr>
<td>Puffinus assimilis baroli</td>
<td>50</td>
<td>840 - 1,530</td>
<td>3-6 %</td>
<td>2,640 - 4,030</td>
<td>1-2 %</td>
<td>3,040 - 4,430</td>
<td>1-2 %</td>
</tr>
<tr>
<td>Oceanodroma castro cold season</td>
<td>200</td>
<td>665 – 740</td>
<td>27-30 %</td>
<td>3,050 - 4,550</td>
<td>4-7 %</td>
<td>3,350 - 4,850</td>
<td>4-6 %</td>
</tr>
<tr>
<td>Oceanodroma castro hot season</td>
<td>100</td>
<td>250 - 300</td>
<td>33-40 %</td>
<td>3,050 - 4,550</td>
<td>2-3 %</td>
<td>3,350 - 4,850</td>
<td>2-3 %</td>
</tr>
<tr>
<td>Bulweria bulwerii</td>
<td>20</td>
<td>50 – 70</td>
<td>28-40 %</td>
<td>6,050 – 8,070</td>
<td>&lt; 1%</td>
<td>7,050 – 9,070</td>
<td>&lt; 1%</td>
</tr>
<tr>
<td>Sterna dougallii</td>
<td>136</td>
<td>1,000</td>
<td>14%</td>
<td>1,005 – 1,015</td>
<td>13%</td>
<td>1,600</td>
<td>9%</td>
</tr>
<tr>
<td>Sterna hirundo</td>
<td>951</td>
<td>4,000</td>
<td>24%</td>
<td>-</td>
<td>-</td>
<td>100,000</td>
<td>&lt; 1%</td>
</tr>
</tbody>
</table>

Adapted from Meirinho et al. (2003)
2). Few non-target species were affected. Invertebrates (insects) were seen eating the bait but they were not affected by the poison (own observations). Only two Blackbirds *Turdus merula* were found dead, and no Azores Buzzards were killed by secondary poisoning. All rabbits corpses found were concealed (Bell *et al.* 1997). During visits to the islet in the following years no signs of rabbit activity were observed (own observations), indicating that they were eradicated from the islet.

After re-introduction most plant specimens have endured indicating that some native plant species respond readily to management actions. Data from the number of *Festuca petraea* plants re-introduced (450 plants) and the number of plants that survived (200 plants) indicates a survival rate of 44.4%. Individuals of this species have also started to flourish and to produce seedlings regularly. From the 450 individuals initially planted (2001), there were 973 in the islet in 2004, indicating a colonization rate of 1.16%. Plants of *Erica azorica* showed a lower success: of the 30 individuals planted only 3 survived, indicating a survival rate of 10% for this species. These results show that *Festuca petraea* should be considered as a key-species in the restoration of coastal habitats in the Azores.

There was a clear increase in the number of both Common Terns and Roseate Terns after the restoration work (Figure 2). The survey that refers to 2002 indicates 133 breeding pairs of Roseate Terns and 641 breeding pairs of Common Terns. Unfortunately there is no information regarding other breeding seabird species in Ilhéu da Praia for the period before and after the restoration work. Regardless of the numerous factors that affect the distribution of tern species in the Azores archipelago it seems that the habitat restoration actions contributed to an improvement of the breeding conditions at Ilhéu da Praia for these two species. Past and present information on seabird population status presented in Monteiro *et al.* (1996b) indicate dramatic declines in population levels for most seabird species and regression in their breeding distributions since the 15th century.

Both tern species nest on islets, namely to avoid invasion by mammalian predators, despite the large availability of mainland sites (Ramos 1995), and breeding biotopes may be the limiting factor for the present populations of small Procellariiformes (Ramos *et al.* 1997). The introduction of herbivores, such as rabbits has contributed to high levels of competition for nest cavities, because potential nesting sites are likely to be occupied by rabbits (Tucker & Evans 1997; own observations). High levels of intraspecific and interspecific interference competition may be a result of alteration of breeding habitats in historical times and competition for nesting sites may play an enhanced role in limiting present seabird populations (Monteiro *et al.* 1996b; Ramos *et al.* 1997).

The restoration work at Ilhéu da Praia shows that offshore islets in the Azores represent a strategic opportunity to develop restoration programmes for threatened habitats and species. When compared to areas in the main islands, offshore islets are a cost-effective option in terms of habitat management. Regardless of the success

### Table 2. Results of the rabbit eradication programme: amount of bait used, number of corpses found and number of live rabbit sightings. / Tabela 2. Resultados do programa de erradicação de coelhos: quantidade de isco utilizado, número de indivíduos encontrados mortos e número de observações de indivíduos vivos.

<table>
<thead>
<tr>
<th></th>
<th>12 September</th>
<th>20 September</th>
<th>22-25 September</th>
<th>29-30 September</th>
<th>1-2 October</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bait (kg)</td>
<td>preliminary bait stations</td>
<td>90</td>
<td>70</td>
<td>30</td>
<td>-</td>
</tr>
<tr>
<td>Live rabbit sightings</td>
<td>-</td>
<td>12</td>
<td>2</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Corpses found</td>
<td>-</td>
<td>10</td>
<td>12</td>
<td>57</td>
<td>2</td>
</tr>
</tbody>
</table>

2. M. P. ITTA-GROZ & J.C. PEREIRA

7
of isolated management actions, such as the work reported here, the eradication of invasive alien species should have adequate resources allocated in the scope of a broader action plan (Wittenberg & Cock 2001). A well-designed legal and institutional framework is essential to provide a basis for effective eradication and control measures (Shine et al. 2000).

In conclusion, results from the present work indicate that island habitats respond to management readily (King 1985), as evidenced by the rapid implementation of self-sustaining populations of endemic coastal vegetation in Ilhéu da Praia. Priorities regarding seabird species and habitats conservation in the Azores should aim at alien mammal eradication and habitat restoration actions.

Acknowledgments: we thank the following people and institutions: Junta de Freguesia de São Mateus through the endless help of Luís Vasco Silva, Maria Olívia Silva, José Gregório Sousa, Cecília Melo and Valdemiro Vasconcelos; Câmara Municipal da Graciosa in the person of Luís Manuel Reis for his hospitality providing accommodation at no charge and handling logistical aspects, and warden Luís Aguiar for assisting field work and follow up habitat restoration actions. This work was accomplished under the scope of project LIFE 94/P/A211/P/0134/ACO and project LIFE B-43200/98/509 supported by the European Union LIFE Programme. We would like to thank Jaime Ramos for his helpful suggestions and an anonymous referee for critically reviewing an earlier draft of this paper.

REFERENCES


SUMMARY - Historical data on the Azores breeding Puffinus species is reviewed through the analysis of historical chronicles from the 16th and 17th century. The seabird populations of the Azores suffered dramatic declines following the colonisation of the islands mainly due to habitat destruction, the introduction of predators and direct human exploitation. Inventories of all the seabirds populations became available only recently and the first comprehensive surveys of shearwaters and petrels of the Azores were conducted from 1996 to 1998. The surveys detected 12 new locations of Puffinus puffinus on Flores and Corvo islands, with a total estimated population of 115-235 pairs. A total of 68 new locations of Puffinus assimilis were detected on all islands, except Terceira, with a total estimate of 840-1530 pairs. A revision of the Azores Special Protection Areas Network was proposed on the basis of that information, enlarging the present area by approximately 80%. Management plans for seven Special Protection Areas were produced. The present status of Manx Shearwater Puffinus puffinus and Little Shearwater Puffinus assimilis populations is outlined and conservation-orientated research priorities are discussed.

The Azores archipelago consists of nine volcanic islands and numerous small islets, forming three groups along a tectonic zone running WNW-ESE between 37º and 40ºN latitude, 25º and 32ºW longitude, in the middle of the Atlantic Ocean ca. 1500 km west of mainland Portugal. The islands are the emergent part of underwater volcanoes with very narrow insular platforms that descend rapidly to depths of 2000-3000 m in the channels between islands. Submerged seamounts (banks) are important topographic features and their combined area at 500m depth exceeds 2,160 km² (Tucker & Evans 1997).

Surrounded by the Atlantic Ocean, the Azores have a mild climate: low thermal amplitude, high

María Pitta Groz 1 , L.R. Monteiro 1 , J.C. Pereira 2 , A.G. Silva 3 & J.A. Ramos 4

1 Direção Regional do Ambiente Colónia Alemã 9900-014 Horta, Portugal. e-mail: maria.j.pitta@azores.gov.pt / 2 Silpermar-Aquaculture, Avenida Humberto Delgado nº6A 2860-021 Alhos Vedros, Portugal / 3 Instituto Superior de Psicologia Aplicada, Rua Jardim do Tabaco, 1149-041 Lisboa, Portugal / 4 IMAR, Depto Zoologia, Fac. Ciência e Tecnologia, Universidade de Coimbra, 3004-517 Coimbra, Portugal / 1 tragically killed in a plane accident on the 11th December 1999
precipitation and humidity are properties of this archipelago with a marked oceanic climate (Borges 1990). These warm-water seas are characterised by low relatively stable levels of productivity (Raymont 1980) but that can be substantially elevated locally, due to upwellings at seamounts, island shelfbreaks and thermal fronts.

On land, the natural vegetation of the Azores islands is composed of a fairly large number of endemic plant communities, originated to some extent from the Tertiary Period. These plant communities are susceptible to environmental change and invasion of alien species, in many cases being a consequence of such changes. Plant communities differ in all the islands depending on factors that include altitude, climate, topography, geological differentiation and human influence (Sjogren 1973).

The Azores were uninhabited by humans until 1433 when they were colonised by the Portuguese. The discovery of the Azores islands took place in 1427 in Santa Maria island and proceeded westwards until 1452, with the discovery of Flores and Corvo. Human settlement and land use had different levels of impact in the islands of the archipelago but the intensive use of the coast and its resources has been a common factor affecting seabird colony distribution since then. The introduction, accidental or intentional, of invasive alien plants and mammals together with the intensive exploitation of natural resources as a result of colonisation, caused significant changes in the natural habitats and communities of the Azores archipelago. In this paper historical data of the Azores breeding Procellariiformes is reviewed focusing on the available information of Manx Shearwater *Puffinus puffinus* and Little Shearwater *Puffinus assimilis*. The present status, distribution, conservation and management of these two species are outlined in order to provide a discussion on the conservation-orientated research priorities.

**HISTORICAL REVIEW**

The historical chronicles of Gaspar Frutuoso dating from 1561 list eight Procellariiformes among 10 seabird species distributed through all the islands of the archipelago in abundant colonies. The breeding seabirds of the Azores archipelago currently comprise five species of Procellariiformes that include Bulwers’ Petrel *Bulweria bulwerii*, Cory’s Shearwater *Calonectris diomedea*, Manx Shearwater *Puffinus puffinus*, Little shearwater *Puffinus assimilis* and Madeiran Storm Petrel *Oceanodroma castro* (Monteiro *et al.* 1999). Two other species of Procellariiformes referred as “calcá-mar” and “boeiro” are mentioned by Monteiro *et al.* (1996) as being the possible former breeders White-faced Storm Petrel *Pelagadroma marina* and Fea’s Petrel *Pterodroma feae*, respectively. The species named “Alauda” referred as occurring in Ilhéu de Baixo (Graciosa) and solely used for the production of oil remains unidentified.

According to Warham (1996) seabirds, including petrels, were a mainstay of the economy of some human populations. In the Azores, according to Frutuoso (1561-printed as Frutuoso 1983) two main species were intensively captured, “Pardela” and “Estapagado” considered to be Bulwer’s petrel and Manx shearwater respectively by Monteiro *et al.* (1996). The Procellariiformes were harvested in different periods of the year according to the breeding period of the species and the use of the resources. The adults would be captured for food and cooked fresh or salted like fish for later consumption. There are also references to the use of these birds to feed pigs. The feathers collected were used in beds and covers. The young birds would be captured later in the season for their stomach oil. Ten birds would produce approximately 2 l of oil (Frutuoso 1561-printed as Frutuoso 1983). The Manx Shearwaters were captured from January to April using fire to attract the birds and dogs to capture them. The exportation of “estapagados” from the island of Corvo to Flores and the market price of “1/2 vintém” for 8 to 10 “pardelas” reveals the economic importance of this species at that time (Frutuoso 1561 - printed as Frutuoso 1983). It is clear that enormous amounts of “estapagados” were captured following human colonisation as indicated by the mention of captures of 10,000 individuals per night and the references to people specialised in hunting seabirds (Frutuoso 1561 - printed as Frutuoso 1983).

According to the historical chronicles of Gaspar Frutuoso Manx shearwaters were abundantly
present in São Miguel, Santa Maria, Terceira, Graciosa, São Jorge, Flores and Corvo at the time of colonisation. Later, in the 16th century, a significant decline in the abundance of “estapagados” and “pardelas” is mentioned and related to predation by ferrets *Mustela furo*. In the early days of settlement, there is also indication of conflicts between the use of land for agricultural purposes and the burrowing behaviour of procellariiform species. This conflict must have intensified the exploitation of these bird species as an economic resource, limiting in a dramatic way, until the present days, the distribution of these species in the archipelago.

**STATUS AND DISTRIBUTION**

*Puffinus puffinus*

The Manx shearwater has a large world population (ca. 300,000 pairs) concentrated at a few sites off North-west Europe and it is a SPEC (Category 2) species with a threat status of localised (Tucker & Heath 1994). In the Macaronesian islands the species has small colonies and in recent years there is evidence of falling numbers (Tucker & Heath 1994).

The first comprehensive surveys of small to medium-sized shearwaters and petrels in the Azores archipelago, conducted from 1996 to 1998 detected 68 new locations of *Puffinus assimilis* on all islands, except Terceira (Monteiro *et al.* 1999). Virtually all locations occurred along inaccessible high cliffs and closer inspection was impossible. Most of the cliffs where calls of *P. assimilis* were heard seemed to have layers of soil for cavities, with little cover of Cane grass *Arundo donax*. In several cliffs in Santa Maria and S. Miguel islands it was clear that apparently occupied cliffs had very little *A. donax*, whereas nearby unoccupied cliffs were covered with this exotic plant species. Discrete breeding colonies were delimited according to presence/absence of birds calling associated with physical discontinuities (Monteiro *et al.* 1999). It was possible to confirm breeding on Morro de Castelo Branco (Faial) where an active nest site with a broken egg was found in the 4th May 1998 (Monteiro *et al.* 1999). With the addition of new sites a total population of 840-1530 pairs was estimated (Monteiro *et al.* 1999).

**MAIN THREATS**

According to the historical chronicles (Frutuoso 1561-printed as Frutuoso 1983) past threats include intensive human exploitation and habitat deterioration. Although human exploitation no longer constitutes a threat to these species habitat deterioration is a present threat and encompasses several aspects such as introduced predators, increased native predators, coastal development and vegetation change at nest sites (Tucker & Evans 1997). The introduction of alien mammals from continents, particularly predators, such as cats *Felis catus* and rats *Rattus* sp., has been a major factor contributing to the extinction of bird species in islands (Moors *et al.* 1992). In the Azores the past and present occurrence of predators such as *Mus musculus*, *Rattus rattus*, *Rattus norvegicus*, *Felis catus*, *Mustela nivalis* and *Mustela furo* has had a profound impact in the populations of small Procellariiformes depriving ground nesting birds of using otherwise suitable breeding sites (Tucker & Evans 1997). Colonies are now largely confined to precipitous cliffs and islets and it is likely that birds have either moved to such sites from more accessible areas, or that only those colonies in
inaccessible sites have survived (Monteiro et al. 1999). Therefore breeding biotopes may be the limiting factor for the present populations of Procellariformes (Ramos et al. 1997). Changes in the coastal plant communities mainly due to the invasion of *A. donax* (Sjogren 1973) has resulted in major losses of suitable burrowing ground (Monteiro et al. 1995) and high levels of intraspecific and interspecific interference competition for nest cavities may be a result of alteration of breeding habitat in historical times (Ramos et al. 1997). The reduction in exploitation of Cory’s shearwater by humans may lead to greater pressure for nest cavities but this fact can be mitigated by building artificial nests for small petrels that are impossible to be excavated by Cory’s shearwater (Ramos et al. 1997, Bolton et al. 2004).

Coastal developments such as hotels, marinas and other tourist facilities, housing or industrial and agricultural land-claim can threaten seabirds by destruction of nesting sites and has a widespread impact in the Macaronesian archipelagos (Tucker & Evans 1995). Fortunately, oil pollution, to which *Puffinus puffinus* is considered highly vulnerable (Tucker & Evans 1995), is less frequent in the Macaronesian seas.

**CONSERVATION AND MANAGEMENT**

Islands seabird populations are highly vulnerable and predisposed to extinction (Diamond 1985). The first inventory of the Important Bird Areas in Europe listed 7 sites recognising that the populations of seabirds breeding in the Azores were poorly known at the time (Grimmet & Jones 1989). But the first legal action towards the conservation of wild birds was the adoption of the Birds Directive in 1990 in the Autonomous Region of the Azores designating a total of 15 Special Protection Areas. Recent inventories of the Azores breeding seabirds identified important breeding sites and provided population estimates (Monteiro & del Nevo 1992, Monteiro et al. 1996, Monteiro et al.

---

**Table 1.** Records of Manx Shearwater *Puffinus puffinus* in the Azores archipelago. / **Tabela 1.** Registros de Fura-bucho do Atlântico *Puffinus puffinus* no arquipélago dos Açores.

<table>
<thead>
<tr>
<th>Place and date</th>
<th>Occurrence</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flores, May 1865</td>
<td>2 adults taken from holes with eggs in the ovaries*</td>
<td>Godman 1866</td>
</tr>
<tr>
<td>Santa Maria, 1903</td>
<td>specimen record</td>
<td>Coleção do Museu Carlos Machado</td>
</tr>
<tr>
<td>Corvo, 16 June 1929</td>
<td>1 egg in poor condition</td>
<td>Chavigny &amp; Mayaud 1932</td>
</tr>
<tr>
<td>Corvo, July 1931</td>
<td>specimen record</td>
<td>Chavigny &amp; Mayaud 1932</td>
</tr>
<tr>
<td>Flores, April 1962</td>
<td>12 birds of the south coast</td>
<td>Bannerman &amp; Bannerman 1966</td>
</tr>
<tr>
<td>São Miguel, 7 September 1983</td>
<td>1 abandoned egg*</td>
<td>Le Grand 1993</td>
</tr>
<tr>
<td>Flores, June 1994</td>
<td>1 bird calling in Fajã Grande</td>
<td>Monteiro et al. 1999</td>
</tr>
<tr>
<td>Corvo, July 1994</td>
<td>few birds at sea</td>
<td>Monteiro et al. 1999</td>
</tr>
<tr>
<td>Santa Maria, 1994</td>
<td>individual without brood patch</td>
<td>Monteiro et al. 1999</td>
</tr>
<tr>
<td>Santa Maria, 27 March 1998</td>
<td>1 bird caught on the ground of Vila islet without a brood patch</td>
<td>Monteiro et al. 1999</td>
</tr>
<tr>
<td>Santa Maria, 9 August 1998</td>
<td>1 bird caught on the ground of Vila islet</td>
<td>Monteiro et al. 1999</td>
</tr>
<tr>
<td>Santa Maria, 1996-1998</td>
<td>1 bird calling off Vila islet</td>
<td>Monteiro et al. 1999</td>
</tr>
<tr>
<td>Graciosa, 1996-1998</td>
<td>1 bird calling off Praia islet</td>
<td>Monteiro et al. 1999</td>
</tr>
<tr>
<td>Santa Maria, 2000</td>
<td>2 birds on the ground of Vila islet</td>
<td>Pereira pers. com.</td>
</tr>
</tbody>
</table>

---

14

**CONSERVATION OF** *Puffinus* **SPECIES IN THE AZORES**
**Figure 1.** Map of the Azores archipelago showing the actual SPA area (black) and the enlargement area (grey) recently proposed by Monteiro & Groz (1999) plotted against the breeding colonies of *Puffinus puffinus* (black arrows) and the breeding colonies of *Puffinus assimilis* (white arrows) reported by Monteiro, et al. (1999): 1-Ponta do Marco to Pico João de Moura, 2-Pão de Açúcar to Pingas, 3-Ponta do Marco-Coroa do Pico, 4-Pão de Açúcar, 5-Alagoa, 6-Fajã da Gata to Peniche, 7-Ponta da Fajã-Fajã Grande, 8-Ponta dos Ilhéus-Fajã Lopo Vaz, 9-Ponta da Caveira-Ponta Fernão Jorge, 10-Baixa do Moinho-Alagoa, 11-Ilhéu Furado-Cabouco, 12-Morro Castelo Branco, 13-Ribeira Funda, 14-Mistério da Praínha-Baía de Canas, 15-Terra Alta, 16-Foros, 17-Mingato, 18-Ponta Ruiva-Fajã João Dias, 19-Pico do Loiçano, 20-Fajã Santo Cristo, 21-Fajã Cubres-Fajã do Labaçal, 22-Ilhéu de Baixo, 23-Ilhéu da Praia, 24-Ponta da Barca, 25-Ponta da Ferraria-Ponta do Escalvado, 26-Porto Santa Iria, 27-Fajã Araújo-Água Retorta, 28-Ilhéu da Vila, 29-Baía do Raposo-Baía do Salto dos Cães, 30-Ponta do Norte, 31-Pontinha-Ponta do Cedro, 32-Ponta do Castelo-Malbusca.

This work allowed the identification of 15 Important Bird Areas in Europe recently promoted by Birdlife International and made clear that the actual SPA of the region covered only 21% of that area. A revision of the Azores Special Protection Areas Network was proposed on the basis of that information enlarging the present area approximately 80% (22,028 ha that represent 9.4% of the region’s territory, see Figure 1) (Monteiro & Groz 1999). Conservation and management programmes for seabirds are quite recent in the region. Only in 1998, a Governmental Nature Conservation Department was created aiming at the implementation of management plans for protected areas and species. However management actions such as the eradication of introduced mammals from SPAs (Ilhéu de Vila Franca do Campo in São Miguel and Ilhéu da Praia in Graciosa), habitat rehabilitation actions (Ilhéu de Vila Franca do Campo on São Miguel, Ilhéu do Topo on São Jorge and Ilhéu da Praia on Graciosa) the allocation of wardens to more accessible SPAs (Flores, Terceira, Graciosa and Faial), the allocation of interpretation signs to all the region SPAs and the implementation of educational programmes (leaflets, posters, rescue campaigns, radio and TV spots) have been developed since 1995 with funding from the European Union. Management plans for 7 Special Protection Areas in the islands of Santa Maria, Terceira, Faial, São Jorge, Graciosa, Flores and Corvo were produced.

CONSERVATION-ORIENTATED RESEARCH PRIORITIES

The best available knowledge regarding Puffinus puffinus and Puffinus assimilis populations of the Azores has allowed us to determine single management actions and to assist decision making. However conservation-orientated research is still lacking:

- Listening for nocturnal vocalisations has been shown to be the most practical method to determine the distribution and population levels of these populations but further research into vocal activity is needed in order to reduce the bias of the estimates obtained in this way;
- Extensive surveys to identify new breeding sites are necessary along the entire coastline of the archipelago according to the unsurveyed sectors referred by Monteiro et al. (1999);
- Monitoring the breeding sites already identified is vital to follow population levels and determine the conservation status. Studies focusing on the relationships between cliff characteristics and presence of Puffinus species are also needed;
- Estimation of the impact of predators on local populations, especially cats and rats, is fundamental to implement further eradication programmes;
- Comprehensive studies of natural, social and economic factors and human activities regarding each SPA of the region is essential to implement management plans.

REFERENCES


**LOW-TECH AND HIGH-TECH METHODS FOR THE STUDY AND CONSERVATION OF PROCELLARIIFORMES: SOME EXAMPLES FROM A CASE STUDY OF THE MADEIRAN STORM PETREL OCEANODROMA CASTRO IN THE AZORES**

MARK BOLTON

**SUMMARY -** Procellariiform seabirds typically nest on remote offshore islands, often on cliffs that are friable, dangerous and largely inaccessible for scientists. Many species nest below the surface, in rock cavities or burrows dug in the soil, and most are active at the breeding colony only during the hours of darkness. Whilst these features present certain challenges to the biologists who attempt to understand the breeding ecology of these enigmatic birds and who work to further their conservation, some of these same features may be turned to advantage. During the last 15 years there has been increasingly rapid development of equipment and technologies to study the breeding behaviour of the Procellariiformes. This paper reviews the advantages and drawbacks of a number of such techniques, and gives examples from a recent study that has established a population of Madeiran storm petrels Oceanodroma castro breeding in artificial nesting chambers on Praia islet, Graciosa, Azores.

Throughout the Macaronesian islands, populations of most procellariiform species have suffered steep declines in recent history. It is probable that over the course of the last few hundred years, populations of most shearwater and petrel species have been decimated from teeming thousands to a few tens of thousands at best, and in some cases, such as the storm petrels *Hydrobatidae* and *Pterodroma* petrels, only tiny relict populations which number a few hundred, or even just a few tens of individuals now remain, and their future is uncertain. Whilst the precise extent of the decline is unknown, the Madeiran storm petrel was considered extremely abundant on the island of Corvo, Azores in the 17th century, as many thousands were harvested for oil and food (Chagas 1645-50, cited in...
Monteiro et al. 1996). It is probable that before human settlement of the Azores archipelago in the 15th century, all the procellariiform species would have been extremely abundant as the islands would have been without ground predators. In 1996 the population estimate of Madeiran storm petrels for the entire Azores archipelago was given as 200 pairs of hot season birds, breeding on just two small islets, and some 600 pairs of cool season storm petrels, limited to three offshore islets (Monteiro et al. 1996). There are no contemporary breeding records from the island of Corvo.

In some situations it is clear that there is now high competition for suitable nest sites (Ramos et al. 1997), probably as the number of islands which are predator free has reduced and more birds are concentrated into the few remaining islets and stacks which are free of introduced mammals. The smaller species, such as the Madeiran storm petrel, are those likely to be worst affected as they are easily ousted by the larger species, such as Cory’s shearwater, and may be killed in disputes over burrow occupancy (pers. obs.).

The high degree of philopatry and site fidelity of the shearwaters and storm petrels has, over the course of evolutionary time, led to a high degree of speciation, such that populations of similar looking animals, which are geographically close, prove to be taxonomically quite distinct. Such is the case for Pterodroma madeira and Pterodroma feae (Imber 1995), and recent work on the sympatrically breeding hot and cold season populations of Madeiran storm petrels nesting in the Azores also indicates that these two groups, though time-sharing the same nest holes in many cases, are in fact from distinct populations (Monteiro & Furness 1998). Whilst this phenomenon contributes greatly to biodiversity, it presents a challenge for conservation, as such species necessarily have severely restricted breeding distributions, with many occurring on just a small group of islands, or in some cases, on just a single island. Further features of the nesting characteristics of the petrels and shearwaters also present challenges to study:

1. Nesting grounds are generally located on remote islands, which are often difficult to access, and so there may be a tendency to collect data only during periods of relatively good weather which may lead to bias.

2. Nests are frequently located in difficult terrain, on sheer cliff faces, or as in Azores, on cliffs which are very friable;

3. Nests are usually underground, in burrows or in rock crevices or boulder scree.

4. Adults only visit the nesting colony under the cover of darkness as many of the smaller species are very vulnerable to predators when on land.

5. Breeding seasons are very protracted, necessitating long periods of fieldwork to collect data on breeding performance.

6. Many of the smaller species are very intolerant of disturbance at the nest site, and will abandon the breeding attempt if handled during the egg stage.

However, some of these features can be turned to advantage in the development of conservation and monitoring methods. For example the existence of competition for nest sites can be demonstrated and conservation benefit gained, by the provision of artificial nesting chambers, which then also facilitate the collection of data with a minimum of subsequent disturbance. The fact that adults only return to the nest during the hours of darkness means that nests only need to be inspected once each day to obtain complete attendance data. Cavity nesting allows the use of monitoring devices which record the passage of a bird through a tunnel.

This paper examines a variety of high-tech and low-tech methods for the study and conservation of Procellariiformes. Whilst it principally draws on examples from work currently in progress on the conservation of the two populations of Madeiran storm petrels in the Azores, the principles can be applied and extended to other procellariiform species, and adapted to local contexts. It is hoped that this paper will provide a forum for discussion about the wider use of remote monitoring devices in petrel conservation and research.

**STUDY SITES AND METHODS**

This paper outlines some of the techniques that were employed in a research programme investigating the ecology and conservation of Madeiran storm petrels on Praia islet, Graciosa, Azores, Portugal 37°57’N 39°03’W. The islet holds
an estimated 100 pairs of summer breeding and 200 pairs of winter breeding Madeiran storm petrels (Monteiro et al. 1999). The few known natural nest sites have been located in crevices under, or within volcanic rocks, or in burrows dug in the soil.

Use of artificial nest chambers

On Praia islet, nest sites suitable for Madeiran storm petrels were considered to be limiting (Ramos et al. 1997). A number of studies have shown that some storm petrel species will breed in artificial nest chambers (e.g. Allen 1962, Bolton 1996, De Leon & Minguez 2003). In order to increase the availability of potential nest cavities for Madeiran storm petrels, as well as facilitate the use of remote monitoring equipment, 115 nest boxes were installed on Praia islet between February and April 2000. Rather than engineering boxes from PVC, because of the quantities involved and limitations on local workshop facilities, readily available low cost plastic plant containers were used as the basis of the nesting chambers. The containers were 22cm in diameter, and well weathered so had no strong smell, and a 6cm diameter entrance hole was cut 3cm from the top. The containers had a depth of 25 cm to allow for later installation of electronic weighing equipment, once the chambers were occupied. The lower section was filled with coarse gravel for good drainage, then finer substrate, and finally a layer of dried grass, as nesting material. If nesting material is available, both Madeiran and European storm petrels will construct deep nests. A flexible lid was cut from plastic sheeting, which could easily be peeled back for inspection of the nest contents, to mark the adult or to measure the chick. Details of the nest chamber construction have recently been published by Bolton et al. (2004).

In designing and installing the boxes on the Praia islet, a number of features had to be taken into consideration:
1. Easily accessible to storm petrels.
2. Not accessible to shearwaters.
3. Not in areas used by nesting common and roseate terns.
4. Not in dangerous areas for night work.
5. Inconspicuous to visitors to the island.

Two locations were chosen and two methods of installation were used. Firstly, in an area of cliff plateau, where there were a number of natural, low erosion faces, and no breeding shearwaters, holes 25cm diameter and 30cm deep were dug to house the artificial nest chambers. A curved entrance tunnel was dug from the erosion face to the nest chamber entrance. The nest chamber was covered either by a large flat stone slab, or by a round cement slab or with a lid made from a mixture of stones and expanding polyurethane foam. The latter method provided a covering that was an excellent fit to the hole, inconspicuous, light to remove, provided good insulation from the sun, and could be produced in large quantities.

In a second area, also within 20m of the cliff edge at the summit of the islet, a low wall was constructed from local stone slabs, incorporating 50 plastic nest chambers into the structure, with entrance tunnels leading to groups of several chambers. Access to each nest chamber was effected by removing a stone slab placed over the nest and removing the flexible plastic cover.

All artificial nest chambers were installed in advance of the main arrival of storm petrels of the hot season population in May. In order to attract storm petrels to the nest boxes, a series of loud speakers were located among the banks of artificial nests and along the wall. A 12 volt auto-reverse cassette player, activated by a light intensity sensor, and fed by a 12 volt battery, recharged by a solar panel and wind turbine was used to play the song and calls of hot season birds between 21.00hrs and 06.00hrs nightly. The equipment functioned permanently from mid April, until it was deactivated in early July, when further nest occupancy seemed unlikely. We examined the importance of the seasonal timing of the use of storm petrel tape lures to attract nesting petrels by varying the timing onset of the use of tapes for three groups of nests. Petrel song was played almost nightly until 1st July in all cases.

Monitoring techniques

Adult nest attendance was monitored at both natural and artificial nest sites using a variety of techniques:
1. Entry-indicator barriers

Overnight passage of a storm petrel along the nest entrance tunnel is indicated by the displacement of a small sticks or stiff wire placed
across the nest entrance tunnel (Davis 1957). The technique has the advantage of being extremely low-tech, but highly functional. Placing such barriers across the nest entrance simply shows which nests were visited up to the time that they are subsequently inspected. In practice, I found signal-to-noise ratio to be rather poor, with a great deal of false triggering caused by lizards, that also took up residence in the boxes. I found up to twice as many barriers dislodged by late afternoon, compared with the number dislodged at 08.30 hrs. Placing sticks horizontally, rather than vertically helped to reduced such false triggering by lizards, since they could simply pass beneath horizontal barriers, though I also found that on a small number of occasions known passage of adult storm petrel had failed to dislodge the barriers. The autonomy of the system is very limited as it can only indicate a single entry or exit, and the quality of the information obtained is low, as the identity of the individual returning to the nest is obviously not recorded.

1. Visual inspection of nest chambers.
   Each day that researchers were present on the island, all known natural sites and those artificial sites where the entrance barriers indicated that a bird had returned during the night, were inspected visually. The use of indicator barriers therefore obviated the need to open every nest box each day, although once an egg had been laid in a nesting chamber, inspections were carried out each day, as change-overs were not always registered by the entrance barriers.

2. Photographic system.
   Cameras have been deployed for a number of decades for recording nest visits and information on food delivery to the nestlings, and the system described here is not novel. The device employed a swinging “gate” hanging from the ceiling of the entrance tunnel, which, when deflected by the passage of the returning adult, triggered a small “compact” camera that recorded both the identity of the bird, which was individually plumage dyed and/or colour ringed, and the hour and day of the event. Used in this manner, a camera can be considered as a reliable, cost effective, multi-channel stand-alone data logger, the use of which does not require the attachment of devices to the adults. I have found that adult storm petrels can be

### Table 1. Characteristics of remote monitoring systems for Procellariiformes. / *Tabla 1. Características de sistemas de controlo remoto para o estudo de Procellariiformes.*

<table>
<thead>
<tr>
<th>System</th>
<th>Level of information</th>
<th>Autonomy</th>
<th>Cost / nest*</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photographic</td>
<td>Individual identification of each individual</td>
<td>Film camera: 40 events (15-30 days)</td>
<td>from Δ110</td>
<td>Stand alone units</td>
<td>Delay and cost accessing data</td>
</tr>
<tr>
<td>Entrance coils</td>
<td>Distinguishes between males and females</td>
<td>Digital camera: several hundred events</td>
<td>Δ160 (min. 16 nests)</td>
<td>No maintenance costs</td>
<td>Complex; requires networked nests</td>
</tr>
<tr>
<td>PIT tags</td>
<td>Individual identification of large number of individuals</td>
<td>c. 10 days</td>
<td>Δ1000 per nest</td>
<td>Stand alone or networked; many individuals uniquely identifiable</td>
<td>High unit costs</td>
</tr>
<tr>
<td>Nest balances</td>
<td>Mass of nest contents</td>
<td>1 – 10 weeks</td>
<td>Δ400 - Δ1000</td>
<td>Infer data on many parameters; stand alone units; high autonomy.</td>
<td>Individuals not specifically identified</td>
</tr>
</tbody>
</table>

*Values given were applicable in 2000.
easily plumage marked during incubation without removal from the nest, or handling, which reduces disturbance to a minimum. The mass production of compact cameras means that a high degree of technology is available at a very low cost. A bespoke attendance monitoring system may incorporate far less technology, but be much more expensive (see Table 1).

**Autonomy**

For film cameras, the maximum degree of autonomy, which is achieved by entry-only recording is determined by the number of exposures on a roll of film, that is, up to 40 nest visits. Given the periodicity of nest visits of Madeiran storm petrels, this approximates to about 30 days. In practice, I have found that maximum autonomy is well below this, as some entries result in two frames being exposed, and chicks wandering out of the nest results in wasted exposures. In practice, autonomy may be reduced to only 15 days. Future developments in digital camera technology will greatly expand the autonomy of camera-based remote monitoring applications. Although there is a trade-off between image quality and storage capacity, low-cost digital compact cameras have capacity to store up to several hundred images, and this capacity is likely to increase rapidly in coming years.

**Advantages**

Particular advantages of a photography-based remote monitoring system are as follows:

1. Individual identification from plumage marks or colour rings, coupled with precise time and date imprinting.
2. Technically very simple, and only a minimum knowledge of electronics is required to assemble a system and to maintain it operative in the field, such that field repairs may be carried out fairly easily.
3. The monitoring units are stand-alone, that is, they do not need to be linked to a central scanner or logger. This is a considerable advantage in situations where birds are nesting at low densities, and suitable nest sites are widely spaced. If a single unit fails, it does not compromise the success of the entire monitoring programme, and the failed unit can be substituted. Networked systems suffer from the disadvantage that failure of a central unit (scanner, logger, or central power supply) results in failure of the entire system.
4. The system can easily be configured for recording entry-only (which gives greater autonomy) or entry and exit (giving visit duration, and a safeguard against missed arrivals).

**Disadvantages**

The principle drawback of such a system are:

1. The delay before developing films/download digital images in order to access the data
2. The ongoing film purchase and developing costs for film systems
3. The possibility of theft. Islands which are accessible to researchers are often similarly accessible to tourists and other visitors and unwelcome disturbance of equipment may be a serious problem.

3. Magnet-coil system.

Granadeiro *et al.* (1998), based at Glasgow University, have developed a system for monitoring petrel attendance at the nest, which was first trialed on Cory's shearwater in the Selvagens islands, and has now also been successfully used with other procellaniform species in the Falkland Islands (J.P. Granadeiro, pers. com). The system is based on the principle that the passage of a magnet through a coil through which a current is passed, creates a voltage change, the direction of which is dependent on the orientation of the magnet. However, a magnet passed inwards through a coil creates the same signal as a magnet in the reverse orientation passing outwards. So if the male were marked with a magnet in one orientation and a female with a magnet in the opposite orientation, a male entering the nest would generate the same signal as a female departing. To overcome this, two coils are used, and from the order of activation of the coils and the pattern of the voltage change, it is possible to distinguish between the male and the female and between entries and departures. The magnets employed for Madeiran storm petrels weigh just 0.2 g and are cylindrical, measuring 4.2mm in length and 2.8mm in diameter. They are mounted at the base of the central tail feathers using cloth-backed tape, and a preliminary two-month trial on 12
individuals has revealed no problems for the birds, and all magnets have remained attached. The system is powered by a 12 volt 90 Ahr battery pack, which gives a power autonomy of over 2 weeks. The coils are placed at the entrance to either natural nests or boxes, and up to 16 coils are networked to a central scanner, which sequentially monitors the voltage of each coil, and pauses at a particular coil when it registers a voltage deviation from zero. The time taken to complete a circuit of all coils is measured in milliseconds, so there is no danger of missing an arrival at one nest whilst scanning others. If a voltage change is detected at a coil, then the scanner will pause to record the entire voltage change sequence, for up to 20 seconds. There is a possibility that when paused at one nest, events at a second nest may be unrecorded, but logging of the subsequent departure corresponding to the missed arrival should ensure that no visit to the nest goes completely unrecorded. The data are logged to a datapack in a Psion handheld computer, which is a secure storage even in the event of power failure. The data are uploaded into a portable PC at regular intervals. The storage capacity of the datapack is of the order of 2000 events.

**Autonomy**

Given a renewable power backup (solar or wind power), autonomy is theoretically set by the data storage capacity of the datapacks, and for Madeiran storm petrels, should give an autonomy of several weeks.

**Advantages**

The main advantages of the system are:

1. A high level of measurement of the timings and dates of arrivals and departures.
2. Cost-efficient when all channels are used (see Table 1).
3. No ongoing maintenance costs
4. Potentially extremely high autonomy (many weeks), with renewable power backup (solar, wind).
5. Most natural nest sites can easily accept the entrance coil (6cm diameter, 10cm length).

**Disadvantages**

1. Being a networked system, a high density of nests is required.
2. Central failure results in loss of data from all nests.
3. The system distinguishes only between males and females, rather than individual recognition, and therefore relies on the assumption that adults only visit their own nests. This may not be valid.
4. The system is technically complex, so field repairs are difficult.

**4. Pit-tags**

Though not used in the present study, a description of the PIT tag system is included here for discussion. The system is based on technology developed for the individual recognition of laboratory animals. A Passive Integrated Transponder tag is a radio frequency device that transmits a unique signature when interrogated by a detector. The tag itself has no internal battery, hence the term "passive," The detector excites the tag circuitry by radio frequency induction and receives the signature back from the tag. The detector antenna may be contained within a handheld device (in the case of recognition of laboratory animals), or alternatively, situated around a nest or nest entrance to register the presence or entry and exit of adults at the nest. The smallest implantable tag commercially available measures 2.1mm in diameter and 11.4 mm in length and weighs 0.06g. The maximum detection range for this size of tag is 7 to 15 cm.

For monitoring of nest attendance in the field, a PIT tag system offers a good degree of flexibility. Individual antenna readers can be linked to individual data loggers, or networked together in groups of four, depending on nest densities. Power consumption can be as low as 40 mA per antenna, giving an autonomy of around 10 days for four units powered from a 90Ahr battery. Antennae are commercially available at a unit cost of c. €650, and a four-channel datalogger €1600, or one-channel dataloggers for c. €280. PIT tags are c. €3 each.

**Autonomy**

Principally set by the power consumption, which is relatively heavy in comparison to other systems, at around 10 days for a 90 Ahr battery. Actual autonomy could be considerably extended with in-situ solar or wind recharging systems.
Advantages
1. A large number of individuals are uniquely identifiable. However, this is less of a benefit in a nest monitoring situation, where a very small number of individuals are expected to visit a nest.
2. Flexibility of either networked or stand-alone datalogging

Disadvantages
1. High unit costs compared with other systems.
2. Technically complex, so field repairs are difficult.

5. Nest balances

The use of automated electronic balances to record the weight of adults at the nest is a long-established technique (see, for example Monaghan et al. 1989, 1992). Typically, a load cell is incorporated into a nest pan, or a perch placed close to the nest. The nest pan or perch must be designed in such a way that the free movement of the cell cannot become obstructed by debris or faeces. Data may be recorded manually, by an observer in a hide reading the measurement from the balance on which a bird has settled. This may be done visually, or balances may be networked to a central data processor. Alternatively, data may be downloaded to a datalogger at predetermined intervals. In the current study of Madeiran storm petrels, a trial has begun for recording the weight changes of the chick. It is anticipated that the same balances will be used to record mass changes of adults during incubation. The system which has been developed in conjunction with Glasgow University is built around a 200g load cell. The downward force of the applied load is measured as a voltage difference, which is then downloaded to a single-channel datalogger at user-defined intervals. The logger fits in a 35mm film canister, has a capacity for 1,800 readings, and battery life is 2-5 years. The battery autonomy of the load cell is 2-3 weeks. The data are uploaded to a PC, either in the field, or by retrieving the logger, which is connected to the load cell via a jack plug. The production cost of this system was approximately €400 per unit. Commercially produced units may be considerably expensive.

Advantages
1. Weight data can be used to infer a large number of other parameters, such as laying date, egg neglect, hatching success and adult foraging performance.
2. Stand alone units gives great flexibility in deployment
3. High system autonomy, which can be for many weeks, with an appropriate load cell battery.

Disadvantages
1. Possibility of fouling the movement of the nest pan with debris necessitates periodic inspections.

PRELIMINARY RESULTS

Madeiran storm-petrel nest box occupancy: summer 2000

Of 115 nest boxes installed by April 2000, a total of 47 were occupied during daylight on at least one occasion between May and August 2000. A total of 13 eggs were laid in 12 nest boxes: at one box, a second egg was laid after the first had been lost. The level of daytime occupancy was not a use-ful indication of the probability of an egg being laid in a particular box. On two occasions
eggs were laid in boxes that had never been occupied during daylight (both these eggs failed, due to erratic incubation shifts followed by abandonment). There was no difference in the number of days of daytime occupancy prior to laying for nests in which eggs were subsequently laid, and those in which they were not (median + IQR (n) 2.0 days + 9.5 (13) and 2.0+2.8 (24) respectively, Mann-Whitney U=148.0 P=0.81, analysis restricted to boxes occupied on or before the date of the laying of the last egg, on 25th June).

**Timing of tape lure deployment**

At sites where tape lures were first employed in either mid-April (group 1) or mid-May (group 2) the onset of broadcast tape lures was closely followed by daytime nest occupancy and egg laying (Figure 1). The proportion of nest boxes in which eggs were subsequently laid was identical between these two groups (10/90 and 2/18 respectively). However, deployment of petrel song after 16th June did not result in daytime occupancy, or egg laying. All eggs in nest boxes were laid between 24th May and 25th June.

**Figure 1.** Cumulative percent occupancy of Madeiran storm petrel nest boxes in relation to the timing of the onset of a local tape lure. / **Figura 1.** Percentagem cumulativa de ocupação de caixas ninho por Roquinho em relação ao início de utilização de gravações.

**Table 2.** Breeding performance of Madeiran storm petrels nesting in natural sites and nest boxes, Praia islet, Graciosa, Azores, 2000. / **Tabela 2.** Sucesso reprodutor de Roquino em ninhos naturais e artificiais no ilhéu da Praia, Graciosa, Açores, 2000.

<table>
<thead>
<tr>
<th>Percentage egg neglect (median + IQR (n))</th>
<th>Natural sites</th>
<th>Nest boxes</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.23% + 23.76% (8)</td>
<td>2.78% + 10.00% (7)</td>
<td>MWU=16.0 P=0.16</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hatching success (n)</th>
<th>Natural sites</th>
<th>Nest boxes</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>46% (13)*</td>
<td>46% (13)</td>
<td>Fisher’s Exact Test P=1.000</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fledging success (n)</th>
<th>Natural sites</th>
<th>Nest boxes</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>33.3% (15)</td>
<td>100% (5)</td>
<td>Fisher’s Exact Test P=0.033</td>
<td></td>
</tr>
</tbody>
</table>

*Maximum estimate: nine nests not followed from the start of incubation
Breeding performance

Although pairs of Madeiran storm petrels breeding in nests for the first time were probably inexperienced breeders, I found no differences in the incidence of temporary egg neglect or hatching success compared with birds breeding in natural sites, which were likely to be more experienced birds (Table 2). The proportion of hatched young that were successfully reared to fledging was higher for birds nesting in boxes than for birds breeding in natural cavities.

DISCUSSION

Provision of nest boxes for storm petrels has resulted in moderate occupancy rates, even in the first year following installation. Such boxes greatly facilitate the collection of data on breeding performance by visual inspections, and reduce the level of nest disturbance to a minimum. In addition the use of nest boxes permits the installation of a variety of remote monitoring equipment that might otherwise be problematical or impossible to install.

In situations where populations of Procellariiformes are believed to be limited by the availability of suitable nest sites, for example where the availability of breeding habitat has been reduced by increased inter-specific competition for nest sites, the provision of nest boxes can greatly increase the number of individuals attempting to breed and/or breeding successfully. If well designed and adequately sited, nest boxes should provide a very suitable micro-environment for incubation and chick growth, and the breeding success of birds should be at least as high as that of experienced birds nesting in natural sites. Losses due to disturbance by larger bodied Procellariiformes sharing the same breeding grounds, and losses due to egg damage on a hard nest floor substrate are expected to be reduced in nest box situations, but small sample sizes currently prevent the testing of this hypothesis.

Acknowledgements: this research was funded by the Portuguese Fundação de Ciência e Tecnologia (PRAXIS/C/BLA/13194/98) and was carried out from the University of Azores, Department of Oceanography and Fisheries.

Logistic support was provided by the Câmara Municipal da Santa Cruz and the Junta da Freguesia de São Mateus (Praia), and the Jardim Botânico de Fáial provided the material for manufacturing the nest boxes. I’m grateful to Renata Medeiros, Ana Mendes and Becky Hothersall for assistance in the field, and Jane and Jack for their understanding at my frequent absences from home. I thank Sr. Mário Melo for his services as a ferryman, transporting materials and personnel to the island.

This paper is dedicated to the memory of Dr Luis Monteiro, who was tragically killed in a plane crash in the Azores in December 1999. Luis had planned and obtained the funding for this research, and it is entirely due to his efforts that conservation and research of seabirds in the Azores has advanced so rapidly in the last decade.

REFERENCES


CENSUSSING MANX SHEARWATERS

PUFFINUS PUFFINUS

C.M. Perrins

SUMMARY - Most procellariiform birds nest in burrows or in rock screes on offshore islands and are only active at the colonies at night; accordingly, they are notoriously difficult to census. This paper concentrates on methods for estimating the population size and trends in numbers of Manx Shearwater Puffinus puffinus, using the birds’ responses to tape-recordings of their calls. Problems with the technique are discussed.

Most seabirds are colonial. Hence the biologist is commonly confronted with a large, dense mass of birds which are difficult to count. Further, since most species take several years to reach maturity and the immatures spend part or much of the breeding season visiting the colony, it is even more difficult to determine the number of breeding pairs which are present. Censussing most procellariiforms, apart from the albatrosses Diomedeidae, is particularly difficult because most shearwaters and petrels are only active at the colonies at night. Since they walk poorly and are slow to take-off from the land, they are very vulnerable to predation when visiting the nesting colony. Also, and again presumably because of their vulnerability on land, most species breed on off-shore islands where they nest in burrows or rock screes, so as to be out of sight during the day. In confirmation of their vulnerability, they have frequently been exterminated by the introduction of predators onto island breeding sites. Diurnal visitors, to even large colonies, may see not a single bird and hence, not surprisingly, these species have proved difficult to count and the size of most colonies is poorly known. Yet a number of these species are considered to be declining and perhaps threatened and so there is a special need to be able to monitor the size of their populations.

In this paper I review the main census methods which have been used to estimate the numbers of Manx Shearwaters and then consider a technique for measuring population change. These methods should be applicable to many species.

ESTIMATING POPULATION SIZE

A number of methods have been proposed from estimating the size of shearwater and petrel populations. The most obvious ones involve counting the numbers of occupied burrows and extrapolating from the area of the colony (Walsh et al. 1995, Wormell 1976). These methods have their uses and can be quickly carried out, but they also have many limitations (Walsh et al. 1995). Amongst these are that it is often difficult to ascertain which burrows are and are not in use (Smart 1986), and this is even more difficult where other species of birds such as Puffins, Fratercula arctica are present.

On many islands, many of the burrows may be excavated by and inhabited by rabbits *Oryctolagus cuniculus*. It is also even more difficult to use this technique for measuring population trends. While not discounting its use in a number of situations, the method is not discussed further in this paper.

Two other methods have been used for censusing Manx Shearwaters. The first involves mark-recapture techniques and was first used on Skokholm in the mid 1960s (Harris 1966, Perrins 1968). In Perrins’ study, a sample of young shearwaters was obtained prior to fledging by taking them from their burrows, ringing them and returning them to their burrows. Later, when the young were fledging (at night), teams of people went out ringing the fledglings and the total number of young was estimated using standard mark-recapture techniques (Southwood 2000). In Harris’ study, large numbers of fledglings were ringed at night and the island was searched in the daylight for predated fledglings and the ringed/un-ringed ratio in the corpses used to calculate the number of fledglings, again using mark-recapture. The two studies yielded remarkably similar results.

Both these studies required a considerable team to be present on the island during the fledging period (and at least one person prior to the fledging period in the case of Perrins’ study). Both also involved teams of people working at night, sometimes near to the cliff edge. In addition to the logistic difficulties of this technique, the estimate obtained was that of the number of fledglings in that particular year. Without prior knowledge of the nesting success and without knowing how variable this might be between years, it is difficult to relate such estimates to the number of breeding pairs. So, for true comparisons, the breeding success would have to be determined for each year in which an estimate of the numbers of fledglings was made.

The second method used for estimating the numbers was developed from play-back work carried out on Skokholm by Brooke (1978) and it this technique that this paper examines in detail. James & Robertson (1985) working on Skomer, used Brooke’s study to estimate the number of pairs in burrows (see also Walsh et al. 1995). This method was used in 1998 to estimate the numbers of breeding pairs of Manx Shearwaters on Skomer, Skokholm and Middleholm (Table 1) and is described in detail in Smith et al. (2001). The method relies on the fact that, if a tape-recording of a male shearwater call is played down a sample of burrows during the incubation period, most incubating males, but no incubating females, respond to that call. Hence if one can establish, for a given number of breeding pairs, the number of males that respond to the tape, one can estimate the number of pairs breeding in the burrows by using the formula:

\[
\text{Total occupied} = \text{No. burrows} \times \left( \frac{\text{No. responding}}{\text{No. burrows}} \right) \times \left( \frac{1}{\text{No. sampled}} \right)
\]

In order to calculate this estimate, the following three parameters are necessary:

1) **The number of burrows**

An attempt was made to count all the burrows on the islands. The islands were divided into squares of one hectare which were further

<table>
<thead>
<tr>
<th>Island</th>
<th>No. burrows</th>
<th>No. sampled</th>
<th>% sampled</th>
<th>No. responses</th>
<th>Estimated number of pairs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skomer</td>
<td>149,507</td>
<td>11,320</td>
<td>7.6</td>
<td>3,298</td>
<td>101,794</td>
</tr>
<tr>
<td>Skokholm</td>
<td>84,322</td>
<td>5,427</td>
<td>6.4</td>
<td>1,274</td>
<td>46,184</td>
</tr>
<tr>
<td>Middleholm</td>
<td>3,269</td>
<td>291</td>
<td>8.9</td>
<td>111</td>
<td>2,990</td>
</tr>
<tr>
<td>TOTAL</td>
<td>237,098</td>
<td>17,007</td>
<td>7.2</td>
<td>4,683</td>
<td>150,968</td>
</tr>
</tbody>
</table>
might have responded to the tapes, though, as they had no sexed birds, they could not be sure. The sex of the females of the pairs in the study burrows was determined by cloacal examination just after laying and the sex of the bird present in the burrow was established on each of the 13 visits. In this study, no females responded to the tape.

In all, 7 eggs (14%) were lost in the 49 study burrows, by the time of the last inspection (16 June). This measurement makes the assumption that egg loss in the study burrows was typical of the population and not a result of observer disturbance. We think that this is probably acceptable since 10/71 eggs (14%) were lost in an intensively studied plot where the birds were disturbed less frequently, but over a series of years had become more accustomed to disturbance by the observers. Further, all seven losses appeared to be associated with some other problem, such as burrow collapse and predation, which was not associated with our visits.

Another error that could arise would be if non-breeders occupied burrows and responded to the tapes. We do not know how often this happens. Amongst the 49 study burrows there were seven burrows which were not laid in and so were not included in the measure of response rates. However, on the 13 visits to these, we obtained three responses from birds which were, presumably, non-breeders. On the same visits we obtained 273 responses from breeders; on this basis non-breeders contribute only some 1% of the responses. There may be more non-breeders in the burrows during the night; if so, day-time surveys should reduce the effect of this problem on any census.

3) Play-back responses
The method for this part of the census follows that recommended by Walsh et al (1995) with some minor amendments. We attempted to sample at least 5% of the burrows in each square or part square. In practice, the 5% target was comfortably exceeded in most squares. To ensure that burrows were selected as randomly as possible, a cane was thrown into an area that was fairly typical of the square (in terms of burrow density) and all burrows within a circle around the marker were sampled. Circles of 8.0, 5.6 or 1.0 m radius (200, 100 or 3.1m²) were drawn around the cane. Since the aim

### Table 2. Response rate (male Manx Shearwaters responding per burrow). 49 burrows were tested on each occasion. 1/Response rate = 2.325. / Tabela 2. Taxa de resposta às gravações (respostas de machos de Fura-bucho do Atlântico /buraco). Em cada mês foram testadas gravações em 49 buracos.

<table>
<thead>
<tr>
<th></th>
<th>May</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean no. males responding</td>
<td>21.1</td>
<td>21.4</td>
</tr>
<tr>
<td>Response rate (%/b)</td>
<td>0.430</td>
<td>0.436</td>
</tr>
</tbody>
</table>
was to sample at least 5% of the burrows in each square, successive circles were sampled until the necessary number was reached. It was found useful to have a range of circle sizes; the observer usually started with a large one, but could sample a smaller circle after this if the 5% target was not achieved. This saved time, by not requiring the observer to complete another large circle.

A tape of a male Manx Shearwater call was played in the mouth of a sample of burrows. The tape was played at what sounded to us to be a natural volume on a small tape-recorder inserted into the burrow entrance for a maximum of 15 seconds (i.e. about 4-5 call ‘cycles’). Whether or not there was a response was recorded; in a few cases more than one male in the same burrow system responded and this had to be allowed for. Play-back was carried out during the day for safety and for


<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>51</td>
<td>12</td>
<td>70</td>
<td>15</td>
<td>87</td>
<td>17</td>
</tr>
<tr>
<td>B</td>
<td>75</td>
<td>19</td>
<td>102</td>
<td>35</td>
<td>193</td>
<td>18</td>
</tr>
<tr>
<td>C</td>
<td>299</td>
<td>56</td>
<td>255</td>
<td>45</td>
<td>259</td>
<td>27</td>
</tr>
<tr>
<td>D</td>
<td>200</td>
<td>81</td>
<td>235</td>
<td>65</td>
<td>296</td>
<td>61</td>
</tr>
<tr>
<td>E</td>
<td>63</td>
<td>17</td>
<td>65</td>
<td>14</td>
<td>66</td>
<td>17</td>
</tr>
<tr>
<td>F</td>
<td>14</td>
<td>3</td>
<td>17</td>
<td>3</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>G</td>
<td>11</td>
<td>2</td>
<td>16</td>
<td>6</td>
<td>15</td>
<td>4</td>
</tr>
<tr>
<td>H</td>
<td>98</td>
<td>23</td>
<td>97</td>
<td>17</td>
<td>120</td>
<td>10</td>
</tr>
<tr>
<td>I</td>
<td>271</td>
<td>72</td>
<td>293</td>
<td>88</td>
<td>199</td>
<td>74</td>
</tr>
<tr>
<td>J</td>
<td>339</td>
<td>77</td>
<td>311</td>
<td>75</td>
<td>455</td>
<td>107</td>
</tr>
<tr>
<td>L</td>
<td>473</td>
<td>147</td>
<td>506</td>
<td>132</td>
<td>596</td>
<td>186</td>
</tr>
<tr>
<td>M</td>
<td>234</td>
<td>85</td>
<td>231</td>
<td>80</td>
<td>240</td>
<td>67</td>
</tr>
<tr>
<td>N</td>
<td>207</td>
<td>51</td>
<td>249</td>
<td>67</td>
<td>261</td>
<td>39</td>
</tr>
<tr>
<td>O</td>
<td>93</td>
<td>27</td>
<td>99</td>
<td>29</td>
<td>140</td>
<td>38</td>
</tr>
<tr>
<td>P</td>
<td>151</td>
<td>30</td>
<td>205</td>
<td>60</td>
<td>234</td>
<td>57</td>
</tr>
<tr>
<td>Q</td>
<td>84</td>
<td>34</td>
<td>82</td>
<td>26</td>
<td>77</td>
<td>17</td>
</tr>
<tr>
<td>R</td>
<td>190</td>
<td>48</td>
<td>235</td>
<td>44</td>
<td>329</td>
<td>65</td>
</tr>
<tr>
<td>S</td>
<td>97</td>
<td>37</td>
<td>187</td>
<td>67</td>
<td>127</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>2950</td>
<td>821</td>
<td>3255</td>
<td>868</td>
<td>3706</td>
<td>851</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>82</td>
<td>133</td>
<td>13</td>
</tr>
<tr>
<td>C</td>
<td>171</td>
<td>201</td>
<td>40</td>
</tr>
<tr>
<td>D</td>
<td>105</td>
<td>120</td>
<td>14</td>
</tr>
<tr>
<td>E</td>
<td>141</td>
<td>203</td>
<td>35</td>
</tr>
<tr>
<td>F</td>
<td>30</td>
<td>43</td>
<td>6</td>
</tr>
<tr>
<td>H</td>
<td>58</td>
<td>96</td>
<td>26</td>
</tr>
<tr>
<td>I</td>
<td>438</td>
<td>583</td>
<td>93</td>
</tr>
<tr>
<td>J</td>
<td>172</td>
<td>232</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>1197</td>
<td>1611</td>
<td>259</td>
</tr>
</tbody>
</table>
practical reasons. As mentioned above, it is also possible that by working during the day one avoids complication arising from responses from most non-breeding, immature birds that temporarily occupy burrows at night.

The play-backs (=samples) were carried out from 31st May to 14th June on all three islands. The census was timed to be after almost all pairs would have laid, but before any would have hatched and to coincide with the studies of the response rate in the burrows (see above). The earliest eggs are laid in about mid-April and no eggs were laid in the study burrows after 17th May and no chicks had hatched by 14th June. Brooke (1990) found that most (c.95%) shearwater eggs on Skokholm hatched between 16 June-15 July.

The technique has a number of potential errors which are discussed in Smith et al. (2001). Two however, deserve mention here. First, the response rate requires a considerable amount of work and it was not practicable to measure response rates across the whole of the study area, though arguably it would be valuable to have more than one set of study burrows in order to check for any variation in response rate. Previous workers (James & Robertson 1985, Smart 1986) have used a correction factor of 1.98 whereas we used 2.325 on the basis of our actual observations of a small study plot at the time. Our figure gives a higher population estimate (by some 15%). The 1.98 is derived from work by Brooke (1978a,b) who found that at any time some 55% of the incubating birds were males and that about 8% of the males did not respond to playback. Hence in 100 occupied burrows one would expect 50.6 responses. In our study we obtained an average of 43% responses and only in three of the 13 tests did the response rate exceed 50% (51.0, 53.1 and 53.1%). However, both Harris (1966) and Brooke (1978b) found that males took a greater share of the incubation period.

Second, the formula contains the number of burrows. This was necessary because only a proportion (not less than 5%) of the burrows could be sampled in the time available. However, suitable burrows are not easy to define because most of them are started by rabbits Oryctolagus cuniculus and they vary greatly in length, some being too short to be suitable as nesting burrows for shearwaters (Brooke 1990). There was some concern that different counters might differ in their criteria for accepting a hole in the ground as a potentially useable site for nesting. In many circumstances this may not matter very much. Consider a patch of ground with many holes of various lengths and a population of x pairs of birds. If one observer comes along and counts 1000 burrows and a second comes along and counts 2000 burrows, this will not
result in different estimates of shearwater numbers. This is because the second observer will record only half as many responses per burrow as the first observer. The crucial point is that the characterisation of a useable burrow must not change between counting the burrows and measuring the response rates. Between-observer variation in the characterisation of burrows does not affect the estimates, provided that the characterisation remains the same between counting the burrows and playing the tape-recording.

**MEASURING POPULATION CHANGE**

Counting seabirds is usually undertaken in order to obtain information on their numbers and most counts are aimed at obtaining an estimate of the total number of breeding pairs. Such counts require a complete coverage; in large colonies this is usually both difficult and time-consuming. The census of shearwater numbers on Skokholm and Skomer took some 1000 hours to of work, rather more than half in the winter, a time when it would not always be easy to be resident on offshore islands. Hence, for both financial and logistic reasons such a survey could not be undertaken frequently.

However, in many cases, especially if a complete census has been made, it may be sufficient to monitor small, but (hopefully) representative, sub-sections of the colony in order to see whether the population is stable, increasing or decreasing. In an attempt to do this we set up some trial plots in which we are currently attempting to census the birds on an annual basis using play-back.

The plots are circles of 17.84m radius ($=1000m^2$) and the tape recording was played at all burrows in the circle. To date, three censuses have been made on 18 plots on Skomer (1998, 1999 and 2000) and two on eight plots on Skokholm (1999, 2000). On Skomer the three censuses were carried out by different groups while on Skokholm about half the 2000 counts were carried out by people who did the 1999 counts. The results are shown in Table 3. In all four possible correlations (Skomer 1998-1999, 1999-2000, 1998-2000 and Skokholm 1999-2000 the number of birds responding the plots were highly significantly correlated (Figure 1) with $R^2$ values falling between 80.8 and 87.1. The plotted data show a tendency for there to be proportionately larger between-year differences in the plots with smaller numbers of responses, but this is not very strong.

The burrow counts vary much more than the number of responses (Table 4): on Skomer the burrow counts increased by 10% from 1998 to 1999 and by 14% between 1999 and 2000 whereas the number of responses increased by 5.7% between 1998 and 1999 and decreased by 1.9% between 1999 and 2000. On Skokholm the burrow count increased by 35% between 1999 and 2000 while the response count decreased by 15%.

It must be stressed that we do not know whether there were any real changes in either the number of suitable burrows or the number of nesting shearwaters. However, it seems that there is little point in counting burrows in such a study. The variation in

---

**Table 4.** The total numbers of burrows and responses by Manx Shearwater on Skokholm and Skomer Islands 1998-2000 and the percentage differences between years. / **Tabela 4.** Número total de buracos e de respostas a gravações por Furabucho do Atlântico nas ilhas de Skomer e Skokholm em 1998-2000, e a percentagem de diferenças entre anos.

<table>
<thead>
<tr>
<th></th>
<th>Burrows</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skomer</td>
<td>No.</td>
<td>% diff</td>
</tr>
<tr>
<td></td>
<td>2950</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skokholm</td>
<td>No.</td>
<td>% diff</td>
</tr>
<tr>
<td></td>
<td>1197</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>34</td>
<td></td>
</tr>
</tbody>
</table>

---

CENSUSING MANX SHEARWATERS
their numbers is great and since the prime aim of this census is long-term monitoring of the shearwater population, the recording of the numbers of responding shearwaters in a number of fixed plots spread across the island should be sufficient in itself. Provided that every possible burrow is sampled, the number of burrows does not matter.

There is also no need to know the response rate. The response rate is important for the estimate of total numbers (see above). However, it is not necessary for the measurement of population change; here effectively we are counting the number of incubating males and there is no reason why this should not give as good an indication of population change as a count of all incubating birds. There is one caveat to this. In most species shortly after the female has laid the egg, she goes away to sea to replenish her reserves leaving the male to take the first incubation stint. In a small number of species e.g. the Short-tailed Shearwater *Puffinus tenuirostris* the egg-laying period is remarkably synchronised (Serventy 1963) and in some other species fairly restricted (Warham 1990). In the period immediately after egg-laying one might expect the burrows to contain a sex ratio which was very strongly skewed in favour of males. As the incubation period progresses, the varying lengths of the off-duty stints of the two members of the pairs leads to a more equal sex ratio. Hence it might be better to delay a play-back study until later in the incubation period when there was a greater likelihood that the sex ratio would be nearer parity. Nevertheless, in the Manx Shearwater, with quite a large spread of laying, there was no evidence for any change in the sex ratio between the 7th of May and the 16th of June (Smith *et al.* 2001). However, Harris (1966) found that males had longer incubation stints than females in the first half of the incubation period which is in line with Brooke’s finding that 55% of the incubating birds were males.

**CONCLUSIONS**

These preliminary results suggest that this technique can be used to monitor changes in the populations. It is easily, safely and speedily carried out and can be undertaken by quite inexperienced teams. The unambiguous, permanent, marking of the centre of the circles is essential; the mark should be tall enough to stand out from the vegetation. Apart from marking these on a map, each site should be photographed, from the same, or at least a known, geographical direction in such a way as to show the centre marked clearly.

The use of responses to tape-recordings of the males’ calls is a good way of locating nesting Manx Shearwaters. The use of a male call is preferable to that of a female since only males respond to males calls (females may respond to the calls of their mates, but not apparently to other males’ calls, Brooke 1990), so that if the response rate can be established, realistic correction factors can be employed to obtain estimates of numbers. The technique is clearly easier to use than most other methods for estimating populations and may also be used over difficult terrain. It can also be used for establishing population size and for obtaining sub-samples to watch for population changes.

The technique is probably also applicable to a wide range of procellariiformes since many species have sex-specific calls and respond well to play-back (see examples listed in Warham 1996). The extent to which the techniques outlined here can be used to determine population size of change in these species needs to be investigated.

**REFERENCES**


MANX SHEARWATER CONSERVATION AND PROPOSED RAT ERADICATION PROJECT ON THE HEBRIDEAN ISLANDS OF CANNA & SANDAY, WEST SCOTLAND

ABBIE PATTERTON

SUMMARY- From the data collected on seabird numbers over the past 30 years on the islands of Canna and Sanday (west coast of Scotland), a steep decline in numbers of certain seabird species, including Manx Shearwater Puffinus puffinus, was noted in 1998. This decline was attributed to predation by Brown Rats Rattus norvegicus. This paper presents the details of the project for rat eradication established in these islands.

The islands of Canna and Sanday lie off the west-coast of Scotland within the Inner Hebrides archipelago. The islands are closely situated and connected by a pedestrian footbridge. Both islands are served by commercial ferry from the fishing town of Mallaig on the mainland. The islands are in the ownership of The National Trust for Scotland and, at present, there are only fourteen human inhabitants. The main occupation on the island is mainly arable and sheep farming and tourism.

Over the past thirty years, the Joint Nature Conservation Council (JNCC) has been collecting breeding data on seabirds through the, “Seabird Monitoring Programme, Canna Studies”. The Highland Ringing Group has been instrumental in the collection of these data. The Highland Ringing Group has also been collecting data on a variety of seabird species looking at mainly, population numbers, breeding success, biometric data and collection of food samples. There is also a ringing programme to establish dispersal patterns, mortality, age return to islands and age at first breeding.

From the detailed data collected, it was noted in 1998 that there was a steep decline in numbers of certain seabird species. Burrow nesting birds such as Manx Shearwater Puffinus puffinus, showed a very dramatic decline of 89% (1998) in two decades. Taking into account all factors such as habitat, predators, food availability, none was found to be contributory to these declines except the predator issue. There had been for some time circumstantial evidence that Brown Rats Rattus norvegicus, were instrumental in the decline and thus inhibiting the recruitment of certain species.

The National Trust for Scotland investigated the possibility of setting up a rat control measure that would assist the shearwaters to fledge their young. The issue of feral cats was also looked at as a possibility of causing mortality to adult birds arriving in the colony at night and a trapping scheme.

The National Trust for Scotland, Lochvoil House, Dunuaran Road, Oban, Argyll PA34 4NE, Scotland. e-mail: apatterson@nts.org.uk
was also set up and run by the National Trust for Scotland to coincide with the rat control measure. Other species of seabirds were also in decline and it was thought that rats were also the major cause of this decline. An island-wide investigation into a rat eradication project with follow-up control and management programme has now been implemented (1998), and research is currently being carried out to establish what impact this management programme might have on non-target species. This paper presents the details of the project for rat eradication established in the islands of Canna and Sanday.

**DATA ON SEABIRD SPECIES**

In order to assess the impact of predators, baseline data on breeding success of seabirds must be gathered. Several species have shown either a decrease in numbers or a shift from prime habitat. The Fulmar *Fulmarus glacialis*, has shown signs of fluctuating numbers over the past twenty-five years (1973-1998). From the beginning of the study in 1973 the population was around 420 apparently occupied sites (AOS) and in 1998 the (AOS) was 471. There was a decrease in 1981, to under 400 and in 1990 to 410, and a rise in 1997 to 435. The peaks in AOS were in 1977 ; 680, 1980 ; 685, 1988 ; 590, 1992 ; 680, and in 1995 ; 650.

In Scotland the recently re-introduced White-tailed Eagle *Haliaeetus albicilla* was reported to have colonised the island of Canna around 1981. This large raptor is known to feed regularly on Fulmars and this may account for part of the decline in 1981. Approximately 50% of food remains found at White-tailed Eagle nest sites were Fulmar, with the remaining 50% being rabbit (pers.obs.) However, this predation does not affect the whole of the island's population of scattered Fulmar sites, since White-tailed Eagles only hunt within certain areas. Outwith these areas the Fulmars remain untouched while breeding. Fulmars within these, “non predated” areas however do show signs of pressure from ground predators. Many suitable sites are often unused or abandoned and although undisturbed, only inaccessible sites are occupied for breeding.

It also has to be taken into account that previous counting difficulties may have an effect on the overall numbers since several counts were made from the sea, also there are numbers of non-breeders occupying sites in mid summer. The productivity at two monitored sites in particular, where rat signs are evident, has shown that in 1997, out of 16 Fulmar eggs laid only 4 chicks fledged. And in 1998 out of twelve eggs laid only 1 chick fledged. This trend is also reflected within the Shag *Phalacrocorax carbo* colony where there has been a high rate of total nest failure and a move from nesting in boulder sites to more open cliff sites. (Data from R. Swann).

**MANX SHEARWATER CONSERVATION**

The Manx Shearwater colony on Canna was first counted in 1973. From a defined study area with selected burrows being monitored for occupancy, estimates could be made of the island's population which, in 1974, was between 1000-1500 pairs. In May 2000 a check was made using tape-recorded calls at 400 burrows within the study area. The call back result was zero (R. Swann, pers.com.). It is difficult to put a time on when the rats were first introduced to the island but it is estimated to be within the past 100 years. There is a regular ferry service and many fishing boats tie up at the pier on the island at night. Some food for the animals – sheep and cattle - on the island will also have been transported from the mainland to the islands. It would be quite easy for rats to arrive from that source and quickly multiply. There are no rat control measures at present in operation and these transport events still take place to this day.

It is estimated that the decline in Manx Shearwater began perhaps in the eighties but was very apparent in the nineties. The National Trust for Scotland was alerted to this dramatic decline early in 1998 and immediately set out to implement a control programme to try and halt the decline. Funding was obtained from Scottish Natural Heritage who financed the setting up of the control programme within the Manx Shearwater colony. Wooden boxes were made to a specification that allows rats entry to the bait - first generation rodenticide warfarin poison. The poison was placed inside the box and contained within a “manger” to stop spillage appearing outside the box where other
wildlife, or grazing stock, would have access to the poison. In total, thirteen rat bait-boxes were put in place within the Manx Shearwater colony in time for the 1998 season.

The Manx Shearwater colony was situated on grassy talus slopes between 20 to 60 meters above sea level. In some places the slopes run steeply up from a vehicle track to terminate at the foot of a vertical basalt rock face. In other areas the talus slopes run from the track to the top of the cliffs. The soil depth on the talus slopes is substantial in places and the soil is not hard packed and thus easy to burrow into. Rabbit *Oryctolagus cuniculus*, are very abundant and are regarded as a pest on the island. They inhabit the shearwater slopes and sometimes create soil erosion. Though the rabbits are a problem on these slopes they are not the reason for the complete failure of Manx Shearwaters at this site.

Due to the proximity of the shore below the shearwater colony, rats scavenge a living over the winter months on food washed up on the beach. Dead birds and seals and other organic waste material often comes ashore on tidal currents. When the birds arrive back on the island to breed in April, rats find them an alternative food supply when winter storms die out and debris on the tideline is much reduced. This feeding trend over the years has prevented the shearwater from producing young to fledging and has resulted in a sharp decline in the colony.

Recently all the historically known shearwater sites have been checked for presence or absence. There were several birds calling at some of these locations at night but breeding remains to be proved. The terrain is very difficult, as the talus slopes are very steep and situated halfway up high cliffs (100 meters), requiring climbing expertise. Some areas have been checked in June 2000 but another check must be made in late August and in early September when chicks, if any, should be exercising their wings at night prior to fledging. Burrows can be checked for presence of young using droppings and downy feathers at the entrance as indicators.

Monitoring some of the seabird colonies, which are vulnerable to rats, began in 1999 and will continue. If rats are eliminated in future then productivity will show a demonstrable increase.

**RAT ERADICATION PROJECT**

To tackle rat eradication on a large inhabited island requires much forward planning and the peculiarities of the island’s fauna taken into account. On setting up protocols several questions arise and must be addressed.

The main question on these islands was; What effect would warfarin pose on raptors if they, for example, ingest high numbers of rabbits that have died as a result poisoning? Canna has a good population of raptors, some of which are very rare in the UK and are all legally protected.

Other questions needing answers include;

1. Will secondary poisoning result from raptors ingesting “contaminated” rabbit?
2. Killing large amounts of rabbits with warfarin may deplete a food source that is important for the raptor’s survival.
3. Will warfarin affect small birds eating the poisoned grain?
4. What effects will warfarin have on other incidental species, such as small mammals?

The answer to the first question was not too difficult. Warfarin breaks down fairly rapidly after ingestion and acts slowly on mammals such that virtually all die underground and away from predators. Looking at birds that would eat rats and small mammals that have themselves ingested quantities of warfarin, Barn Owl *Tyto alba* and Tawny Owl *Strix aluco* are two species associated with farmland where over a fairly long period of time, have killed and eaten rats and small mammals in large numbers. Within farmland plagued with rats and small mammals, farm managers use strong doses of warfarin and in most cases this has not had any effect on these species. Both species have been intensely studied over a long period of time, and there are no records of warfarin causing death through secondary poisoning from warfarin. (pers. obs).

The second question has not been addressed any detail at this point in time, but on other islands where rats have been eliminated, rabbits have remained and have subsequently recovered their numbers. It may be possible to phase the poisoning so that rabbits can recover in some areas before the
next area is targeted. This should maintain rabbit numbers for raptors. However this will also mean a food source for rats remains present. If necessary rabbits could be re-introduced shortly after poisoning is completed.

Question three does not present too much of a problem if the targeting methods are specific. By placing warfarin in controlled circumstances the poison can only be taken by the target species. Placing warfarin well into rabbit burrows or within rock crevices, or in control boxes where small birds cannot gain access avoids uptake by non-target species. It has also been noticed on other islands that birds do not succumb readily to warfarin – a bait specifically developed for mammals. Mammal blood is fundamentally different from bird blood and this anti-coagulant does not appear to have any effect on any bird species eating it (B Zonfrillo, pers. com.). This leads on to the fourth question, i.e. what will be the affects on small mammals where there is no way of excluding them from access to the poison? While checking rat bait boxes within the Manx Shearwater colony, Wood Mouse *Apodemus sylvaticus*, the only indigenous mouse, was found to be affected by warfarin (pers. obs.).

**SMALL MAMMAL SURVEY 1999**

To address the last point a survey of small mammals was instigated in 1999 and methods of addressing the problem are still in the process of active consideration. Some mice may have to be transported during rat eradication and later re-introduced or perhaps trapped alive and held in prepared areas where they cannot escape until released. While mice will take the poison, shrews, that are insectivores, will not and are therefore safe.

Results from the preliminary survey on Sanday were inconclusive and a further more exhaustive survey has now been completed. Analyses of results are in preparation.

A low density of small mammals on Sanday could be the result of rats predating them. Monitoring after rat eradication should show the answer to this question.

**MONITORING/FIXED POINT PHOTOGRAPHY**

The aim of this monitoring is to establish productivity within certain seabird colonies on the island of Sanday that are vulnerable to rat predation. Two Herring Gull *Larus argentatus* colonies were selected and counting began in 1999. Fixed point photography on ledges that should contain Fulmars began in 1999. Rats have access to these ledges and Fulmar can been seen in the area but do not nest. On an adjacent ledge where rats do not have access, there are several nesting Fulmars, which are also part of the fix point photography monitoring.

Monitoring will continue on the island of Sanday each season after the rats are eradicated. We hope to see productivity rise in the gull colonies and the spread of Fulmars along ledges.

**RAT MONITORING**

This stage will be to plot where the rats are during the winter period (2000-2001). An experienced fieldworker will be employed to carry out this work that is not without hazard. It is hoped that rat distribution can be plotted to assist the targeting of warfarin when the eventual eradication project finally gets under way. The distribution maps will also be used to monitor the effects of the project once rats are eliminated.

A control plan has to be formulated so that once the islands population of rats are cleared, it must be ensured that the islands thereafter remain rat free. At present a variety of boats visit the small harbour in Canna, in particular fishing boats, which arrive at night, still in the process of clearing up their last catch. There are no rat-guards or poison on these vessels or any other vessel that ties up at the pier. It is customary for fishing vessels to clean up after the catch is stored away by housing any fish parts from the deck, but there are always scraps to attract rats. Rats trapped on board can be transported to other areas and because of this, and measures have to be put in place that will prevent rats returning to Canna from other areas on board fishing boats.

Apart for the ferry that serves the islands, all other boats such as yachts do not normally tie up at the pier but anchor in the bay and people come
ashore via small crafts. The problem we face here is that the yacht people are looking for a place to get rid of their rubbish and look for rubbish bins on these islands. The Trust provides a rat-proof bin for this purpose but, on occasions there can be anything from 10 to 40 yachts in the bay and the rubbish bins do not cope with this demand. People then illegally revert to dumping overboard and rats then have access to this rubbish washed up.

Food for stock is occasionally brought to the island and this could prove to be difficult to control any rats contained within the food. Cattle are fed using a feeding ring along the shore edge in winter. These areas attract rats to feed and measures will have to also here be implemented.

The local human inhabitants are rat conscious and have rat-proof bins and much of the rubbish is burned. They also place warfarin around their houses to keep rat numbers down. Organic waste material is kept separate and fed to the free-range chickens. This will attract rats, in particular over the winter period and the Trust will examine closely how we can prevent this. Scraps of meat leftovers are fed to the dogs.

CONCLUSION

There is compelling evidence to show that rats are a problem with burrowing, ground and cliff nesting birds on the islands described. Without the detailed data collected by the Highland Ringing Group, we would not have had reference information. Though it is the Manx Shearwater that has highlighted the problem in recent times, with the rapid decline in the nineties and their sad disappearance from the study site in 2000, several other bird species have also been affected. It may be that the Manx Shearwater have simply moved back to using their historic sites, and hopefully work being carried out at this time may reveal that this is the case. If so, then the Trust can implement a control programme to help sustain the breeding populations to secure future recruitment.

It is not just Manx Shearwater that are suffering from the rat predation. As mentioned, several other species show signs of this pressure and it is because of widespread predation, that a total rat eradication from these islands is necessary. The work will involve individuals, professional groups, Trust staff, and most important, the local inhabitants of the islands. Without their co-operation, in particular with the control programme following the eradication programme, we will all be wasting our time. Rats must be prevented from re-invading the islands once they have been totally eradicated.

The problems faced with using a first generation rodenticide such as warfarin have to be clearly understood. Though warfarin is widely accepted because of its low toxicity by comparison to the harmful nature of secondary rodenticides, it is still important to look at the effects it can have on other none targeted species, such as small mammals. It is clear from evidence that Wood Mouse is effected by warfarin. Biometrics taken this year from Wood Mouse on Canna has clearly shown that they are markedly bigger than mainland Wood Mouse. Further details of island wood mice are being investigated at present. However, though it is doubtful that a sub-species of Wood Mouse restricted to only the island of Canna is present, the use of poisons will have to ensure that this population survives by one method or another.

Monitoring the gull colony and Fulmar ledges will continue as a control on how effective the eradication programme has been when completed on Sanday. The eggs and young of these two species are vulnerable to rats since they nest on the shore and accessible cliff ledges. Similar monitoring will be required on Canna and data currently collected by the Highland Ringing Group, will be of great use to monitor species productivity after the rat eradication is complete.

Once rats have been cleared from the islands then monitoring must continue to see if any further rats are found. The Trust must also look at the problems with fishing boats tying up at the pier at night and prevent rats from re-invading the islands by that method. The human inhabitants are rat conscious around their houses but must ensure safe ways of feeding chickens without also attracting rats. Feeding farm animals in winter also cannot be stopped and some measure of control will also be required.

Acknowledgements: The information gained for this account would not have been possible without the input and help from a variety of professional individuals and Canna island residents.
Special thanks go to Bernie Zonfrillo for all his continuing support despite my awkward insistence on several issues. Also thanks to Bob Swann for his information on all monitoring, past and present, on Canna. Organisations such as Scottish Natural Heritage have been very supportive in both financial terms and always ready to offer advice or part with information. A special thanks also has to go to The Nation Trust for Scotland who have allowed me time to pursue the rat issue as this is not within my work remit.

REFERENCES


Large numbers of staging Balearic Shearwaters *Puffinus mauretanicus* along the Lisbon coast, Portugal, during the post-breeding period, June 2004

Martin Poot

ABSTRACT — Relatively large numbers of Balearic Shearwaters were present along the Lisbon coast between Guincho and Cascais in June 2004, suggesting that this area was used as a major staging area during the post-breeding period. A minimum of 1,294, 953, and 1,177 Balearic Shearwaters were observed respectively on 2, 3 and 4 of June 2004, meaning that approximately 14% of the total population of this rare and globally threatened seabird was using this area. The majority of Balearic Shearwaters were rafting (on average 60%), but active foraging flocks were also present (the largest with 700 birds, together with 540 Gannets *Morus bassanus*, and some other species). The largest proportion of rafting Balearic Shearwaters was found south of Cascais (the largest flock with 900 birds), probably because the west-east oriented coast provides shelter from the prevailing north-western wind. The observations were compared with information from the early nineties, when the species was more numerous, and with recent information on the occurrence of the species along the Portuguese coast.

Números elevados de Fura-bucho *Puffinus mauretanicus* ao longo da costa de Lisboa durante o período pós-nupcial, Junho de 2004. Em Junho de 2004 foi observado um número relativamente elevado de Fura-buchos ao longo da costa de Lisboa, entre o Guincho e Cascais, indicando que esta zona é uma das principais áreas de alimentação desta espécie no período pós-nupcial. Nos dias 2, 3 e 4 de Junho foram observados respectivamente um mínimo de 1294, 953, e 1177 Fura-buchos, ou seja, aproximadamente 14% da população desta ave marinha rara e globalmente ameaçada. Embora a maioria dos indivíduos se encontrasse a descansar em grupo (em média 60%), foram também detectadas bandos de Fura-buchos em alimentação (o maior bando com cerca de 700 indivíduos, juntamente com 540 Alcatrazes *Morus bassanus* e com outras espécies). A maior proporção de Fura-buchos a descansar e o maior bando de aves (900 indivíduos) foi detectado a sul de Cascais, provavelmente porque a orientação Este-Oeste desta costa confere proteção contra os ventos dominantes de nordeste. As observações foram comparadas com dados do início dos anos noventa, numa altura em que esta espécie era mais abundante, e com dados recentes sobre a ocorrência desta espécie ao longo da costa portuguesa.

The Balearic Shearwater *Puffinus mauretanicus* is a rare and globally threatened seabird (BirdLife International 2002). Its breeding distribution is confined to the Balearic Islands, in the western Mediterranean. In the late nineties its total population has been estimated at 17,000-20,000 birds (Mayol & Aguilar 1998, Merne & Yésou 1997), with a breeding population of 3,000-5,000 pairs (Mayol-Serra et al. 2000). However, recent estimates are lower, with a total maximum of 9,200 birds (BirdLife International 2004) and 1,750-2,125 breeding pairs (SEO/BirdLife 2001). Recent demographic studies show an alarming decreasing trend, which could drive the Balearic Shearwater to extinction in an estimated 40 years (Oro et al. 2004). This has led biologists to catalogue the species as critically

——

1Dolomieten 8, 3524 VG, Utrecht, The Netherlands. E-mail: mjmpoot@hetnet.nl
endangered (Arcos & Oro 2004). Adult survival (78%) is unusually low for a Procellariform and seems to be the main cause of the current decrease, suggesting mortality factors other than natural ones alone outside the breeding season (Oro et al. 2004).

Balearic Shearwaters migrate after the breeding period via the Strait of Gibraltar into the Atlantic, leaving the Mediterranean from May. Largest numbers congregate off western France in June-October, and move back again to the Mediterranean in September-November (Mayol-Serra et al. 2000). Some of the birds migrate as far north as the Irish, North and even Baltic Sea; others are recorded as far south in waters off West Africa (Snow & Perrins 1998). A fraction of the populations remains in the Mediterranean around Balearics and off south-east Spain all year (Arcos & Oro 2004). The species feeds on small shoaling fish and squid, taken mainly by pursuit-plunging, pursuit-diving, and surface-seizing (Snow & Perrins 1998), but also feeds substantially on fishery discards (Arcos & Oro 2002).

To reach the staging areas in the Gulf of Biscay, large numbers pass by along the Portuguese Atlantic coast every year. Besides many observations of flying Balearic Shearwaters from different coastal sites, in the early nineties it was also found that the Portuguese coast in general and the Lisbon coast specifically is important for staging Balearic Shearwaters (Paterson 1997). In recent years for Portugal only data of ‘passing’ birds have been published (SPEA 2000, Ruiz & Martí 2004). Nowadays, with a declining population, up-to-date information about its ecology and distribution during the whole annual cycle is important for conservation strategies (BirdLife International 2002). As a contribution towards an update of information on the occurrence of Balearic Shearwaters along the Portuguese coast, herewith observations in June 2004 along the Lisbon coast between Guincho and Cascais are presented, indicating that the area was used as major staging area during the post-breeding period.

**METHODS**

Observations were made of Balearic Shearwaters present along the Lisbon coast, central Portugal (Figure 1) on 2, 3 and 4 June 2004 (time of observations respectively 7:15-10:26h, 6:30-10:10h and 15:35-17:00h; wind direction and force in Beaufort scale (bf) respectively NW 3-4 bf, WNW 2-3 bf and W 1-2 bf). The same stretch of coast between Guincho and Cascais was again visited on three days at the end of August/beginning of September 2004 (27 and 30 August and 2 September 2004; time of observations respectively 17:45-18:15h, wind direction and force respectively SW 5-6 bf, WNW 4-5 bf and E 0-1 bf). Observations made from several vantage points between Guincho and Cascais served to approximate a near total coverage of 12 km of coastline. From every point the sea was scanned systematically, first with a 10x binoculars and then with a 20x telescope (specifically for rafting flocks). In this way most of the coastal zone up to approximately 3-4km from the shore was covered. Double counts were avoided by covering the stretch of coast in a relatively short time during every visit, taking into account the coverage from the different vantage points and the behaviour of the birds (flight direction). The categories of foraging behaviour used are cf. Ashmole (1971). A general distinction was made between rafting and search flight/foraging.

**RESULTS**

**Numbers and flock sizes**

On 2, 3 and 4 June 2004 respectively 1,294, 953, and 1,177 Balearic Shearwaters were counted along the coast between Guincho and Cascais. On 3 June the same stretch of coast was visited twice, early in the morning from 6.30-9.00h and later in the morning from 9.20-10.10h. Later in the morning the number of birds was almost halved (from 953 to 404 birds) and the proportion of rafting birds was 20% lower than early in the morning.

Although most sightings of Balearic Shearwaters corresponded to single individuals (Figure 2), 98% of the foraging birds appeared in flocks of 2 birds or more. The distribution of the number of birds divided over the different flock size classes was different for rafting and foraging/actively searching birds. The smaller flocks (1-25 individuals) consisted largely of active birds whereas the larger flocks (>25 birds) consisted mainly of rafting birds.
Figure 1 Study sites and places mentioned in the text (A-C) and the relative number of Balearic Shearwaters on 2, 3, 4 June 2004 (C), along the Lisbon coast from Guincho to Cascais. In the pie diagram the proportion of birds rafting and birds in search flight/foraging are presented. / Figura 1. Área de estudo e locais mencionados no texto (A-C) e o número de Fura-buecos nos dias 2, 3 e 4 de Junho de 2004 (C), ao longo da costa de Lisboa entre o Gincho e Cascais. O diagrama apresenta a proporção de aves a descansar em grupo, e em busca de alimento/em alimentação.
Rafting concentrations

Most Balearic Shearwaters observed in June 2004 along the Lisbon coast were rafting (on average 60%, range 40-80%). The largest flock consisted of 900 birds near Cascais on 4 June 2004. The shape of the flock was a line and positioned parallel to the coast on a clear foam line in the water (with a W wind, parallel to the coast). Combining all observations in June 2004, largest numbers and largest proportion of rafting birds were found at the south side of the Lisbon coast, south of Cascais (Figure 1).

30 August 2004 yielded a comparable distribution pattern as found in June 2004, but the total number present was much lower, with a maximum of 126 Balearic Shearwaters rafting along the same part of coast south of Cascais (14.50h). At 17.20h the birds had disappeared at this spot and about 20 birds were observed foraging far out at sea. Three days earlier, on 27 August 2004 around 18.00h, only 2 Balearic Shearwaters were seen in search flight here. At that time a strong SW wind was blowing and the high waves made the area probably unfavourable for rafting. On the calm morning of 2 September 2004 no rafting birds were present in the same area. Observed birds were foraging far at sea.

Flying and foraging birds

All observed flying birds along the Lisbon coast consisted of flocks of birds in search flight, indicated by fine reactions towards the water surface, changing directions and/or turning around, regularly followed by synchronised pursuit plunge dives of several birds from the same flock (behaviours cf. Mayol-Serra et al. 2000). No directed flight movements were observed which could be interpreted as migration.

On 2 June 2004 an exceptionally large flock of maximum 700 Balearic Shearwater was foraging between Cabo Raso and Guincho for at least an hour, together with 540 Gannets Morus bassanus, and maximum 18 Cory’s Shearwaters Calonectris diomedea sp., 60 Sandwich Terns Sterna sandvicensis and tens of

---

**Figure 2** Percentage of flocks (A) and total number of individuals (B) in relation to five flock size classes of Balearic Shearwaters based on observations on 2, 3, 4 June 2004 along the Lisbon coast.

// Figura 2. Percentagem de bandos (A) e do número total de indivíduos (B) por várias classes de tamanho de bandos de Fura-bucho nos dias 2, 3 e 4 de Junho de 2004 na costa de Lisboa.
Yellow-legged Gulls Larus michahellis. The Gannets were successful as tens of individuals emerged after diving with long, thin fishes sticking out of the bill (the same as or a little larger than bill size). Although Balearic Shearwaters were also shallow plunge diving here, they were never seen with captive prey.

Observations of birds following or responding to fishing vessels were not made, whereas Yellow-legged Gulls were seen doing so while Balearics Shearwaters were present. Also Balearic Shearwaters were not seen associated with dolphins, while Cory’s Shearwaters and Gannets on several instances actively reacted or followed Common Dolphin Delphinus delphis pods, apparently profiting from food becoming available because of the activity of dolphins cf. Clua & Grosvalet (2001) and Camphuysen et al. (1995). Rafting Balearic Shearwaters near Cascais were observed responding to the foraging movements of Yellow-legged Gulls, profiting from surfacing small fishes, probably caused by attacks of predatory fish from below.

DISCUSSION

Staging in June during the post-breeding period

Balearic Shearwaters are described to occur along the Lisbon coast from May to September, but without any indications that the Lisbon coast is a particular important area for the species during the post-breeding period (Paterson 1997). In the early nineties, the highest numbers along the Lisbon coast were reported in September (with a maximum of 5,000 birds), with an ultimate observation of 11,000 flying south in two hours time on 29 September 1990 (Paterson 1997), the period when the birds return from the Gulf of Biscay (Mayol-Serra et al. 2000). A similar pattern was found along the coast of Galicia with birds present from June-September, with the peak in September, based a long data-series of rafting concentrations for the period 1976-2000 (Mouriño et al. 2003).

Despite the small number of days, the observations presented here clearly indicate that a relatively large number of Balearic Shearwaters staged at least for a couple of days along the Lisbon coast in June 2004. The breeding season of the Balearic Shearwater stretches from February until the end of June, with the last young fledging around July (Snow & Perrins 1998). Therefore the observations fit well in the pattern of birds moving after the breeding season to the Gulf of Biscay (Mayol-Serra et al. 2000). However, more observations are needed to conclude on the status of the birds (breeders and/or non-breeders) and what they are doing here in this time of year (stopping-over and/or moulting).

The question has to be raised whether during the post-breeding period the Lisbon coast so far might have been overlooked as an important staging area. A less intense observation effort from Cabo Raso during the period of May/June, during a relatively intense study of flying birds over sea during two seasons (1999/2000 and 2000/2001) with an intended schedule of counts every two weeks (Ruiz & Martí 2004), might be an indication for this. Furthermore, the flight movements recorded from this famous ‘sea watching point’ (Moore et al. 1997) have been presented as either ‘in the direction of the Balearics or to the Gulf of Biscay’ cf. Ruiz & Martí (2004). Actually, based on the observations presented here it should be taken into account that at least a substantial part of these observations might apply to local foraging birds in active search flights (with e.g. 32% flying ‘north’ in August-October 1999, SPEA 2000).

The current importance of the Portuguese coast for staging

Besides along the Lisbon coast, recently relatively large numbers of Balearic Shearwaters have been reported to stage between Figueira da Foz and Aveiro, but this was in mid August- end of September 2002 (with a maximum of 1,258 birds, found along two ship based-transects parallel along the coast) (Petronilho et al. 2004). The number of over 1,200 birds staging at any moment along two coastal strips (Lisbon coast and Figueira da Foz-Aveiro) means for both areas that approximately 14% of the total population was present (based on the estimated maximum total of 9,200 birds (BirdLife International 2004)). Taking into account observations of considerable numbers in other periods of the year along the two coastal areas (Poot 2003, J. Petronilho pers. com.), the current importance of the Portuguese coast seems evident. Furthermore, in the early nineties the whole coast from Porto to Sines was described as holding numbers of importance in the period May-
September, with e.g. near Porto up to 900 birds in July (Paterson 1997). Also the flight movements of birds near Sagres need to be re-evaluated (Tomé 2001, Walker 1994, 1997, 1998 & 1999), as recent observations in September 2004 indicated that also part of the birds here apply to local foraging birds (R. Tomé, pers. com.).

In contrast to the early nineties, in recent years no observations have been reported of several thousands of Balearic Shearwaters along the Lisbon coast (maximum 1,591 birds flying on 23 September 2000 (Ruiz & Martí 2004)). Also the observations of the largest flocks along the Galician coast date back to the early nineties (Mouriño et al. 2003). In recent years also remarkable lower numbers are reported from the Gulf of Biscay (Yésou 2003), where in the 1980s regularly 8,000-10,000 birds gathered (Mayol-Serra et al. 2000). Large changes in fishery effort and methods have taken place in and outside Portuguese waters, (Cooper et al. 2003) and shifts in spawning patterns of Sardines have been observed in Portuguese waters (Borges et al. 1997, Stratoudakis et al. 2003). However, it is unknown whether these changes have affected distribution and occurrence (and ultimately survival cf. Oro et al. 2004) of Balearic Shearwaters in the Atlantic. Therefore, with a decreasing population, it seems likely that in the last decade also the occurrence of Balearic Shearwaters along the Portuguese coast has changed.

Favourable conditions and foraging ecology along the Lisbon coast

In general, the Portuguese coast is considered to be a very important spawning area for different species of fish, with Sardine Sardina pilchardus as the most abundant species, both interesting as prey for seabirds and humans (Hortense Afonso & do Carmo-Lopes 1994, Gomes et al. 2001). The Lisbon coast, as part of the continental shelf, can be characterised as relatively shallow (up to ca. 200m deep, with close to the coast depths of 20m and less). There is a relatively high productivity resulting from upwelling caused by the Eastern Boundary Currents (Borges et al. 1997), mostly occurring during the summer months, applying to the observation period described here. Furthermore, the abundance of sediments and nutrients carried by the prevailing long shore current from the river Tagus possibly generates particularly favourable conditions for shearwaters to stage along the Lisbon coast.

Mainly shallow pursuit plunge diving was observed with birds swimming under water for only short periods, indicating that prey was caught close to the water surface, possibly shoaling fish like sardines Clupeidae or sandeels Ammoditidae, like along the Galacian coast (Mouriño et al. 2003). Pursuit diving with long periods under water as is described for the breeding period (Aguilar et al. 2003, Arcos et al. 2000, Benvenuti & Dall’Antonia 2004), was not observed. In the large foraging flock observed on 2 June 2004 no Balearic Shearwaters were seen with fish in their bills as was observed in Gannets. It is therefore assumed that the Balearic Shearwaters swallowed the prey under water cf. Rebassa et al. (1998).

Since observations were made from the shore, Balearic Shearwaters might well feed on discards from trawlers further out, as has been observed along the Galician coast (Valeiras 2003) and in Spanish Mediterranean waters during the breeding season (Arcos & Oro 2002). However, Balearic Shearwaters along the Portuguese coast might have a strong coastal distribution since between Figueira da Foz and Aveiro more than 90% of the birds were observed along the transect 1 km from the coast (Petronilho et al. 2004).

Observations of rafting birds

On 4 June 2004 the rafting flock of birds were floating in a line. It seems plausible that the shape of the flock was the result of a passive process by the current. With prevailing winds in Portugal from the NW, the Cascais coast might often give shelter at the south side for rafting Balearic Shearwaters and might explain the distribution of rafting birds along the Cascais coast during the observation period (Figure 1).

Not only does the behaviour of flying birds (search flight vs. migration) warrant further attention, additional observations of rafting concentrations are also welcome as good indicators that the birds really stage in the area. Since Balearic Shearwaters do not seem to feed at night (Arcos & Oro 2002), counts of rafting birds in the evening around sunset might be the best way to estimate the total numbers present in an area cf. the
methodology used in the Gulf of Biscay (Yé sou 2003). Searches for rafting birds should be carried out with a telescope from good vantage points at evenings with weak winds in order to be able to spot the birds (Yé sou 2003). In particular coasts and capes with shelter at the down wind side are suggested as good places to check for rafting Balearic Shearwaters.

Acknowledgements: Many thanks to João Petronilho, Helder Costa, and Ricardo Tomé for additional information on Balearic Shearwaters along respectively the Figueira da Foz-Aveiro, Lisbon and Sagres coast. Special thanks to Yorgos Stratoudakis and Pep Arcos who kindly provided references and information about respectively fish and abiotic conditions in the Portuguese coastal waters and Spanish literature on Balearic Shearwaters, and to Luisa Mendes, John van Dort and Bernard Roelen for inspiration and help with the English and Portuguese language. João Petronilho, António Luís and Pep Arcos commented on an earlier version of the manuscript. Peter van Horssen kindly helped to construct the map. An anonymous referee gave valuable suggestions to improve the paper. Last but not least, special thanks to Gastão Mendes for lending many times a precious car.

REFERENCES


Fish associated with floating drifting objects as a feeding resource for Balearic Shearwaters Puffinus mauretanicus during the breeding season. Ornis Fennica 77: 177-182.


**Which future for Bulwer’s Petrel in the Azores?**

**Joll Bried** and **Karen Bourgeois**

**SUMMARY** - The Bulwer's Petrel is a small procellariiform that breeds in tropical and subtropical islands of the Atlantic and Pacific oceans. The Azores constitutes the northernmost distribution area for the species in the Atlantic. The Bulwer's Petrel used to be an abundant species in the archipelago but turned to be dramatically scarce after the colonization by the Portuguese from the 15th century onwards, due to the introduction of mammals. Currently it occurs in three islets and the total population is less than 70 breeding pairs. Monitoring this species is therefore necessary in order to assess its population dynamics and to study the interspecific competition for nesting places. We present the preliminary results of the monitoring programme for Bulwer's Petrel in the Ilhéu da Vila (Santa Maria) that was started in 2002. Most of the Azorean population breeds in this islet and the number of birds did not increase since the last census made between 1996 and 1999; it may have even been decreasing. A major factor affecting the population dynamics is the competition for nesting places with Cory's Shearwater Calonectris diomedea, which can kill Bulwer’s Petrels while taking its nests. We recommend some conservation measures in order to reduce the competition between both species.

Procellariiformes are long-lived seabirds that breed on oceanic islands and lack adaptations to cope successfully with introduced mammalian predators (Lack 1968). Burrowing Procellariiformes are especially vulnerable to predation and competition for burrows because of their strong fidelity to breeding colonies and their low fecundity (one egg only, without replacement), because they can temporarily desert their egg during incubation, and also because chicks are left alone in the

---

1Departamento de Oceanografia e Pescas, Centro do IMAR da Universidade dos Açores, 9901-862 Horta, Açores, Portugal, e-mail: bried@notes.horta.uac.pt / 2Université d’Aix-Marseille 3, Equipe "Ecologie du Paysage et Biologie de la Conservation", IMEP-CNRS UMR 6116, Institut Méditerranéen d’Ecologie et de Paléoécologie, Bâtiment Villemin, Domaine du Petit Arbois, Avenue Philibert, BP 80 CEREGE, 13545 Aix en Provence Cedex 04, France, e-mail: karen.bourgeois@univ.u-3mrs.fr
burrows with only a few days old (Warham 1990, Bried & Jouventin 2002). The sensitivity of the adults generally increases as species’ body size decreases (e.g., Moors & Atkinson 1984, Atkinson 1985). Because adult survival rate is the parameter with the greatest influence on population dynamics of long-lived species (Weimerskirch et al. 1987, Cuthbert et al. 2001), a slight increase in adult mortality will have much more dramatic consequences for petrel demographic trends than a steeper decrease in reproductive performance.

After the introduction of alien mammals in the Azores archipelago (subtropical northern Atlantic) by the Portuguese during the 15th century, the smallest procellariiform species became extirpated from the main islands and most of them are now restricted to a few islets and remote coastal strips (Monteiro et al. 1996a). Because petrels attend their colonies for long periods (Warham 1990) and suitable nesting sites are currently in low supply in the Azores, the level of inter-specific competition for nest sites has increased. This resulted in a large percentage of nest sites being shared among species, which negatively affects the breeding success of some of these species (Monteiro et al. 1996a, Ramos et al. 1997).

Bulwer’s Petrel Bulweria bulwerii is a small (98 g, Monteiro et al. 1996b) procellariiform which breeds on some tropical and subtropical islands in the Atlantic and Pacific oceans (del Hoyo et al. 1992). Although the world population is not considered threatened according to the IUCN Red List criteria (BirdLife International 2004a), Bulwer’s Petrel is regarded as a “Species of Conservation Concern” (Category 3) with the status of “Rare” in Europe, where total breeding numbers are less than 10000 pairs (BirdLife International 2004b). The Azores is the northernmost limit of the species’ range in the Atlantic, with 50 to 70 breeding pairs restricted to three islets (Monteiro et al. 1996a, 1999). At the time of the Azores colonisation by humans this species was much more abundant in the archipelago (probably several thousands of pairs despite the lack of accurate estimates, Frutuoso 1561), and, in the early 1990s, it was considered more abundant than it actually is (500 to 1000 pairs, Tucker & Heath 1994).

Vila, an islet off Santa Maria island, with 0.08 km$^2$ is mammal free and the last stronghold for Bulwer’s Petrel in the Azores (has more than 80% of the population from the archipelago, Monteiro et al. 1999). On Vila, Bulwer’s Petrel is victim of strong competition for nest-sites with other petrels, especially with the larger (840 g, Monteiro et al. 1996a) Cory’s Shearwaters Calonectris diomedea (Ramos et al. 1997), which may kill them (Ramos et al. 1997, J.C. Pereira unpubl. data). Therefore, it is desirable (1) to evaluate the effects of this interspecific competition on this relict population of Bulwer’s Petrels, and (2) to monitor its abundance and breeding success. In addition, conservation measures for Bulwer’s Petrels should be taken as soon as possible.

In this paper, we present the preliminary results of our monitoring of the Bulwer’s Petrel population from Vila islet and propose some conservation measures.

**METHODS**

Fieldwork was carried out on Vila islet (36º55’N, 25º10’W). Since 2002, we have monitored annually the Bulwer’s Petrel and Cory’s Shearwater populations on Vila. Field sessions were conducted in late June-early July (that is, ca three weeks after laying for the Bulwer’s Petrel and four weeks for Cory’s Shearwater), and between 10 and 15 August (two weeks after chicks of both species hatched; see Monteiro et al. 1996b). During incubation, we determined the number of breeding pairs of each species, counting all nests containing an incubating adult or an unattended egg that were accessible, and then, we extrapolated to the areas that were not exhaustively prospected, as did Monteiro et al. (1996a, 1999 and unpubl. data). On the top of the islet, there is a grassy plateau where habitat conditions are not suitable for Bulwer’s Petrels, but where Cory’s Shearwaters have dug burrows, most of them being too deep. Therefore, we counted Cory’s Shearwater breeding pairs on the plateau as exhaustively prospected, as did Monteiro et al. (1996a, 1999 and unpubl. data). On the top of the islet, there is a grassy plateau where habitat conditions are not suitable for Bulwer’s Petrels, but where Cory’s Shearwaters have dug burrows, most of them being too deep. Therefore, we counted Cory’s Shearwater breeding pairs on the plateau as exhaustively prospected, as did Monteiro et al. (1996a, 1999 and unpubl. data). On the top of the islet, there is a grassy plateau where habitat conditions are not suitable for Bulwer’s Petrels, but where Cory’s Shearwaters have dug burrows, most of them being too deep. Therefore, we counted Cory’s Shearwater breeding pairs on the plateau as exhaustively prospected, as did Monteiro et al. (1996a, 1999 and unpubl. data). On the top of the islet, there is a grassy plateau where habitat conditions are not suitable for Bulwer’s Petrels, but where Cory’s Shearwaters have dug burrows, most of them being too deep. Therefore, we counted Cory’s Shearwater breeding pairs on the plateau as exhaustively prospected, as did Monteiro et al. (1996a, 1999 and unpubl. data).
Because there are no terrestrial predators on Vila, and because the state of many Bulwer’s Petrel eggs that were found unattended suggested that they had been abandoned for a long period, we are confident that the probability of missing a breeding failure occurring during the first three weeks of incubation (= missing a breeding attempt) was very low. Bulwer’s Petrel chicks were ringed during the August field session. Breeding success was assessed in August. However, since Bulwer’s Petrel chicks in the Azores fledge from late September onwards (Monteiro et al. 1996b), this parameter may be slightly overestimated.

We checked whether the competition with Cory’s Shearwaters had a negative effect on nest and mate fidelity, as well as on breeding success of Bulwer’s Petrel. To determine year-to-year site and mate fidelity we ringed (or identified if they were already ringed) all the adults that were found. In addition, nests were given an individual code number and mapped; those that were occupied or contained an unattended egg were visited at five-day intervals to allow the identification of both mates as often as possible.

RESULTS

Breeding numbers of Bulwer’s Petrels and Cory’s Shearwaters on Vila islet

We found 18 breeding pairs of Bulwer’s Petrels in 2002, 35 (or 36 since we did not manage to see the content of one nest, even though we managed to ring the adults) in 2003 and 40 (or 42 for the same reason as in 2003) in 2004. Applying the same calculation method as Monteiro et al. (1996a, 1999 and unpubl. data) to our direct counts, we estimated the size of the breeding population of Bulwer’s Petrels at 31 pairs in 2002, 40 to 42 pairs in 2003, and 45 to 48 pairs in 2004 (due to time/meteorological constraints, a small area that was accessible was not prospected in 2002). For Cory’s Shearwaters, we counted, respectively, 383, 292 and 315 breeding pairs, without the plateau area. Since we found 27 breeding pairs in the plateau in 2003, the total number of breeding pairs found this year was 319, and our estimates for 2002 and 2004 were 418 and 344, respectively.

Breeding success of Bulwer’s Petrels

Breeding success, defined as the number of chicks ringed per number of eggs laid, was 38.9% in 2002 (n=18 eggs), 37.1% in 2003 (n=35 eggs) and 37.5% in 2004 (n=40 eggs).

Direct effects of competition

Several adult and/or subadult individuals were found dead at the entrance of burrows that were occupied or excavated by Cory’s Shearwaters or by conspecifics (Table 1). Since 2002, at least 10 nests known to have been occupied by Bulwer’s Petrel have been found occupied by Cory’s Shearwaters, two Bulwer’s Petrel laid in nests that are not classically used by the species (they were semi-open nests; in both cases, the egg was abandoned during incubation), and a Bulwer’s Petrel egg was found on the open ground.

Does competition affect site and mate fidelity?

Between 2002 and 2004, overall nest fidelity rate was 90.0% (n=60 individuals x year) and the divorce rate was 4.8% (n=21 pairs x year).

DISCUSSION

Our three-year monitoring shows that the breeding numbers of Bulwer’s Petrels on Vila islet have not increased since the study of Monteiro et al. (1999), who estimated the size of the breeding population at 50 pairs. The breeding population of Cory’s Shearwaters has remained stable since the census of Ramos et al. (1997), who estimated it at ca 350 pairs. Our discoveries of Bulwer’s Petrel corpses near burrows occupied or excavated by
Cory's Shearwaters also confirm the observations of these authors and suggest that the mortality resulting from interspecific competition with Cory's Shearwaters on Vila islet may be no more sustainable for Bulwer's Petrel. Because Bulwer's Petrel show high year-to-year fidelity to their burrows and to their mates, as in many other petrel species (Bried & Jouventin 2002), the presence of Cory's Shearwaters seems to have little effect (if any) on site and mate fidelity of the Bulwer's Petrels from Vila.

Another factor that might affect the size of the breeding population of Bulwer's Petrel (and also that of Cory's Shearwater) on Vila is nest site availability (Ramos et al. 1997). Our discoveries of Bulwer's Petrel corpses near burrows occupied by conspecifics, that of an egg on the open ground, and the occurrence of breeding attempts in very open nest-sites suggest that this species may experience a shortage of suitable nest sites on Vila, in line with the conclusions of Ramos et al. (1997). Although such breeding attempts may have been performed by young, inexperienced females (see e.g., Brooke 1990, Ramos et al. 1997), the occupancy of active nests of small petrel species by some individual Bulwer's Petrels on this islet (Ramos et al. 1997, this study) supports the “nest shortage” hypothesis. Under these conditions, Bulwer's Petrels might face also strong intra-specific competition for nest-sites.

Because colony attendance may vary from year to year, depending on food availability at sea (Weimerskirch 2002, see also Dunlop et al. 2002), it was necessary to conduct our study on several years. In addition, conducting a longer-term monitoring (including mark-recapture of breeders in their burrows) of the population of Bulwer's Petrels from Vila islet is desirable in order to obtain reliable estimates of reproductive parameters such as breeding success, and to model the population dynamics. The latter point is the most important in terms of conservation of the Azorean population since there is no evidence of breeding by Bulwer's Petrel at the two other islets where it occurs (Praia and Baixo islets, 350 km NW of Vila, Monteiro et al. 1999; J. Bried, M.C. Magalhães, M. Laranjo & A. Meirinho, unpubl. data). The low breeding success (ca only 50% of that on the Desertas islands, the nearest breeding locality to the Azores, situated ca 900 km south-east of Santa Maria; Nunes 2000) and our current estimates of population size suggest that immigration may occur. The recapture on the Desertas islands of an individual that was found prospecting on Vila supports the hypothesis of an exchange of individuals between the Azores and other localities. Genetic analyses should help to determine whether or not the population from Vila has experienced a bottleneck during the last centuries and/or if it represents a sink.

The installation of artificial nests that are impossible to excavate by Cory's Shearwaters remains a conservation priority for Bulwer's Petrel. Installing artificial nests for the small petrel species on Vila islet had already been proposed by Ramos et al. (1997). This measure has already proven its efficacy for the Madeiran Storm Petrels Oceanodroma castro from another islet of the Azores (Bolton et al. 2004). Obviously, human disturbance at these nests should be minimized in order to enhance the site fidelity of the birds (see Bried & Jouventin 1999).

Prior to this, however, and to maximise the efficiency of the artificial nests, it should be determined which types of Bulwer's Petrel burrows are the most likely to be taken over by Cory's Shearwaters, and which areas of Vila islet are the most suitable for Bulwer's Petrels. We are currently implementing such a study.

**Acknowledgements:** this work was funded by the Life Programmes “Conservação das Comunidades e HABs de Aves Marinhas dos Açores” and “Gestão Integrada das Zonas Costeiras e Marinhas nos Açores” (Contracts B4-3200/95-351 and B4-3200/98-509, respectively), and by the OGAMP Programme (Ordenamento e Gestão das Areas Marinhas Protegidas, Interreg IIIIB-MAC/4.2/A2), both coordinated by R.S. Santos. It was also part of JB’s post-doctoral contract at the Instituto do Mar (IMAR/FCT-PDOC-001/2001-BirdEco and FCT grant SFRH/BPD/20291/2004). KB was supported by IMEP-CNRS. We thank the Direcção Regional do Ambiente from the Azores for allowing us to work on Vila islet, M.C. Magalhães and V.C. Neves for field assistance, J.M. Soares and the Clube Naval from Santa Maria for transportation to Vila, and an anonymous referee for his comments.
REFERENCES


SOCIAL COMPOSITION, MASS REGULATION AND SITE-FIDELITY OF MIGRANT ROBINS ERITHACUS RUBECULA WINTERING IN A MARGINAL HABITAT

PAULO CATRY

ABSTRACT - Studying wintering migrants in ecologically marginal habitats can reveal interesting patterns, leading to new information concerning their social organisation and individual wintering strategies. I studied Robins (Erithacus rubecula) in a site ("Lezíria") in Southern Portugal where they can find relatively little cover and no fruit-food resources that are known to be important for this species during winter. Comparisons with more typical habitats revealed that Robins wintering in the marginal site are mostly juvenile. Biometrics and molecular evidence suggest that the sex-ratio of the wintering population in this site is relatively female-biased. Robins at the marginal site had small fat reserves and low muscle scores compared to other habitats. Fat reserves increased from autumn to winter. Such results are discussed in the context of strategic mass regulation, in relation to food predictability and predation risk. Robins wintering in the "Lezíria" were territorial, and few floaters, if any, were present at the study site. Out of 23 colour-ringed individuals, 4 (17%) came back in a winter subsequent to initial marking.

Organização social, condição corporal e filopatia de Pisco-de-peito-ruivo Erithacus rubecula invernantes num habitat marginal. O estudo de aves migradoras em habitats marginais durante o Inverno pode contribuir para revelar aspectos interessantes sobre a organização social e as estratégias individuais de invernada encontradas nessas espécies. Estudaram-se Piscos-de-peito-ruivo (Erithacus rubecula) invernantes num habitat marginal ("Lezíria") onde a vegetação proporciona pouco abrigo e não se encontra nenhum alimento sob a forma de frutos ou bagas. Os Piscos-de-peito-ruivo invernantes neste habitat são, por comparação com outras áreas, predominantemente juvenis. Estudos de biometria e de determinação do sexo por análise genética sugerem também que o sex-ratio desta população é fortemente desequilibrado a favor das fêmeas. Os Piscos-de-peito-ruivo invernantes no habitat marginal tinham poucas reservas de gordura e tinham "índices musculares" baixos, sendo por isso mais leves. As reservas de gordura aumentaram do Outono para o Inverno. Estes padrões são discutidos no contexto das teorias de regulação das reservas corporais em relação com a previsibilidade do acesso ao alimento e com o risco de predação. Os Piscos-de-peito-ruivo invernantes na "Lezíria" revelaram um comportamento predominantemente territorial. De 23 indivíduos marcados com anilhas coloridas, houve 4 (17%) que voltaram aos mesmos territórios num Inverno posterior ao da sua marcação.

Studies of bird population structure and behaviour often focus on favoured habitats, where birds can be found in large numbers and are more easily caught and observed. However, studies in marginal habitats can help to unravel interesting patterns and processes related to population regulation, as well as alternative behavioural strategies for reproduction and survival (e.g. Newton 1998).

Robins Erithacus rubecula wintering in Iberia typically display a skulking behaviour that makes it particularly difficult to study their spatial behaviour without using capture and recapture methods with

1Unidade de Investigação em Eco-Etologia, Instituto Superior de Psicologia Aplicada, Rua Jardim do Tabaco 44, 1149-041 Lisboa, Portugal. e-mail: paulo.catry@netc.pt
mist-nets or other traps (but see Cuadrado 1995, 1997). Most studies of Robins wintering in Iberia have focused on woodlands and shrublands that provide plenty of cover and food for this Palearctic migrant (e.g. Cuadrado 1992, 1995,1997, Herrera 1977, 1998, Tellería et al. 2001, Catry et al. 1999, 2004a). Cover (mostly provided by shrubs), on one hand, and berries and acorns, on the other, are seen as important resources for wintering Robins (Herrera 1977, 1998, Cuadrado 1995, Johnstone 1998). Here, I present observations on a sample of Robins wintering in a site with relatively little shrub cover and completely devoid of fruit or berry-producing plants that Robins might eat. This site is interesting not only because of the marginal ecological conditions, but also because Robins are relatively easy to observe and colour-ringed birds could be readily checked by observation alone.

METHODS

The main study site is located in the alluvial plains (“Lezíria”) of the Tagus (Tejo) Estuary Nature Reserve, in a place called Trinta e Oito Moios (Ponta da Erva). The study area consists of a line of low tamarisks Tamarix sp. that grows along a dyke separating open pastures from salt-marshes, reedbeds and the river. This linear study area measures approximately 3.5km. Robins wintering in this area use the tamarisk line and the dyke, only rarely venturing into the pastures or the salt-marsh vegetation. During winter, tamarisks loose their foliage, meaning that they provide less cover than during other seasons. Robins are present in this area from October to March (occasionally also in September and in April).

Robins were captured and observed in four consecutive winters, from 1998-99 to 2001-2002. All birds caught (using mist-nets or spring-nets baited with mealworms) were aged, measured (wing-chord), weighed and ringed with individual combinations of colour rings. The amount of subcutaneous fat reserves was assessed by visual inspection using a 6-point scale. Pectoral muscles were scored on a 3-point scale with reference to the prominence of the sternal keel and muscle shape, following Gosler (1991).

In the first two winters, the study site was visited every two weeks, and an effort was made to find colour-ringed Robins on each occasion. Observations were mapped on a detailed chart of the area. In the last two winters, colour-ringed Robins were searched for during January only.

To compare the age structure, size and body reserves of Robins from this site with other more typical wintering habitats, we used samples of birds caught in varied locations in southern Portugal, in areas where Robins are absent during the breeding season (in just one of six areas, there were a few Robins nesting, but they represented only about 1% of the wintering population). Robins were sampled in two main habitat types: (1) woodland mostly composed of sessile oak habitats of Quercus suber or Q. ilex, also called “montados”, where shrubs and fruit producing plants were abundant; (2) Mediterranean shrubland growing on limestone, with very dense shrub and very abundant berry producing plants (see Catry et al. 1999, 2004a for more details).

RESULTS

Social structure

I caught 45 individual Robins in the main study site (“Lezíria”) over 4 winters. Trapping was not systematic, although in early years an effort was made to catch all individuals wintering in the study site. A few individuals were caught during autumn, and never seen again. Of 41 birds that could be aged, 90.2% were juveniles. This contrasts with 58.7% juveniles (out of 305 Robins) in other habitats (Yates-corrected \( \chi^2 = 14.0, P<0.001 \)). Samples from other habitats were pooled, as I knew that there were no differences in age structure between them (Catry et al. 1999, 2004a). It could be argued that, because trapping effort was directed towards unringed birds in the main study area, after the first year there were no more adult birds to be caught (because new recruits were always juvenile).

A more conservative comparison is provided by a sample where surviving robins (identified by colour-rings) in the main study area are always assumed to be recaptured, and contribute to the estimate of the proportion of adults in each year they are present in the area. Taking such site-faithful birds into account, the proportion of juveniles drops to 80.4% (N=46), which is still highly significantly different from the proportion found in other habitats (Yates-corrected \( \chi^2 = 7.1, P=0.008 \)).

Five of the Robins caught in the “Lezíria” study area were sexed by molecular techniques (see Catry
et al. 2004a for details on methods), and all proved to be female. The sample size is too small to allow a meaningful comparison with the sex-ratios in other habitats.

Biometrics and body reserves
There were highly significant differences in Robin biometrics between habitats (Table 1). In particular, Robins wintering in the “Lezíria” were much lighter than Robins found elsewhere. Such difference is maintained when we take into account differences in size (wing-length) between habitats by means of an ANCOVA (habitat effect: $F_{2,357}=37.2$, $P<0.001$). Differences in size between habitats (Table 1) are also maintained when we control for age (two-way ANOVA with age and habitat as fixed factors; habitat effect: $F_{2,340}=24.3$, $P<0.001$), meaning that they are not explained by differences in age structure. There were large differences in fat-reserves between “Lezíria” and other habitats, but differences in muscle-scores were only apparent when comparing “Lezíria” to woodland (Table 1).

There were no differences in the mean trapping date (days from October 1) between habitats ($F_{2,363}=1.1$, $P=0.33$), and therefore differences in fat and muscle scores are probably unrelated to this potential confounding factor.

Robins wintering in the “Lezíria” had lower fat reserves in autumn (October-November: mean fat-score 0.72±0.75, N=18) than in winter (December-February: 1.27±0.75, N=24). The difference between the medians is significant (Mann-Whitney U=132, $P=0.02$). There was no similar seasonal difference in muscle scores (results not shown).

Spatial behaviour and site-fidelity
Colour-ringed Robins that were seen on more than one occasion always remained within the same sector of the study area (home-ranges varying between ca 40 m and 400 m). Home-ranges of neighbours showed little overlap. Aggressive contests (calling and posturing) were observed in border areas. When an individual disappeared, its neighbours often expanded their home-ranges. These observations clearly suggest that Robins were territorial in my study area. However, song was almost never heard, which contrasts with what I found in other habitats (unpubl. data).

Of 23 Robins colour-ringed and present in December and/or January of the first 3 winters of the study, 4 (17%) were seen in at least one subsequent year (one of these was seen in two subsequent years). The resighting probability of marked Robins was very high; just by walking along

| Table 1. Comparisons of biometrics of Robins caught in different habitats in Southern Portugal in Autumn/Winter. Means are presented with standard deviations. Superscripts a, b and c indicate results of Post-Hoc Tukey tests. Means with different superscript letters are significantly different. Post-Hoc tests were not carried out for non-parametric (Kruskal-Wallis) comparisons of fat and muscle scores. |
| --- | --- | --- | --- |
| **Habitat** | **Wing (mm)** | **Body mass (g)** | **Fat score** | **Muscle score** |
| **Woodland** | 73.7 ± 2.0$^a$ | 17.8 ± 1.3$^a$ | 1.6 ± 0.9 | 2.75 ± 0.43 |
| | n=146 | n=143 | n=144 | n=144 |
| **Shrubland** | 72.3 ± 1.7$^b$ | 17.2 ± 1.6$^a$ | 1.7 ± 0.8 | 2.30 ± 0.51 |
| | n=176 | n=174 | n=176 | n=176 |
| **“Lezíria”** | 72.8 ± 1.8$^b$ | 15.5 ± 1.2$^b$ | 1.1 ± 0.8 | 2.18 ± 0.45 |
| | n=44 | n=44 | n=44 | n=44 |
| **Comparison** | $F_{2,363}=23.1$ | $F_{2,360}=40.7$ | K.-W. H = 20 | K.-W. H = 73 |
| | P<0.001 | P<0.001 | P<0.001 | P<0.001 |
any bird’s territory, I usually saw the occupant in approximately 50% of the occasions. As such, and because birds were searched for on several occasions, I find it unlikely that other between-year site-faithful birds would have gone unnoticed. However, I cannot exclude the possibility that some birds would have come back to the study area, but died before they could be recorded, given that checks in the last two winters were only made in January.

DISCUSSION

Social segregation of age and sex classes

The social segregation of age or sex classes in winter is an interesting phenomena, with possible implications for individual fitness and population dynamics (e.g. Rodenhouse et al. 1997, Catry et al. 2005). Here, I show that, in a habitat predicted to be of low quality for wintering Robins (see Introduction), the wintering population is mostly composed by juvenile individuals. Age segregation of Robins wintering in the Iberian Peninsula has been demonstrated before (Figuerola et al. 2001, Tellería et al. 2001, Catry et al. 2004a). My results confirm not only that habitat distribution differs between age-classes, but also strongly suggests, as did previous studies (references above), that juveniles are associated with lower-quality sites.

The small body size (short wing-length, even after controlling for age-structure) of Robins wintering in the “Lezíria” site further suggests that the wintering population is largely dominated by females, and more so than in woodland habitats (see Catry et al. 2004a for detailed data on biometrics). The fact that all five birds sexed by molecular techniques were female further supports this view. Previous studies have confirmed that Robins wintering in Southern Portugal are mostly female, and also that there is a degree of sexual segregation by habitat within this region (Catry et al. 2004a). All this evidence put together suggests, but does not prove, that young and female Robins are more frequent in low quality habitats, which might be linked to the despotic exclusion by territorial dominant individuals (a higher proportion of which would be adult and male) from the best areas.

The regulation of body reserves

Robins wintering in the “Lezíria” site had a comparatively low body mass. Light weights were mostly explained by very low fat reserves in comparison to other habitats (Table 1). One possible explanation is that, due to the scarcity of food resources, individuals had few body reserves. However, this does not fit well with the observation that fat reserves increased from autumn to winter, despite an almost certain reduction in the availability of invertebrate food during the colder season. Increases in fat reserves from autumn to winter (or with decreasing temperatures) have been previously described for Robins wintering in the Mediterranean region (Pilastro et al. 1995, Herrera 1998, own unpubl. data) suggesting that such changes reflect a pattern of strategic mass regulation, rather than a simple direct response of body reserves to food availability (Pilastro et al. 1995).

Strategic mass regulation and predation-risk theories predict that winter fat reserves should vary inversely with food availability and predictability, because fat is an insurance against the sudden deterioration of environmental conditions and reduced access to food (e.g. Cuthill & Houston 1997). Bearing this in mind, we would predict that, in sites with acorn and berries (generally a stable and abundant source of food) Robins should carry lower reserves when compared to places without these foods. However, the pattern I describe is exactly the opposite to this prediction. I hypothesise this to be linked to the fact that predation-risk differs markedly between the “Lezíria” and other habitats. Accumulating and carrying large fat reserves increases the risk of predation for small birds (e.g. Witter & Cuthill 1993), and birds under strong predation pressure are predicted to stay leaner (Lima 1986). In the “Lezíria”, avian predators of birds (such as small raptors) were abundant, and cover for Robins was scarce. By contrast, my other study sites had few bird-eating avian predators (In particular, Sparrowhawks Accipiter nisus were generally absent) and had plenty of thick cover provided by trees and dense shrubs. It appears that these differences in predation pressure might override any differences in food availability and predictability in the strategic regulation of fat reserves. Only more work will permit the confirmation or rejection of this hypothesis.
Besides fat, muscle scores were also low in “Lezíria”, although not much different from levels measured on birds wintering in shrubland. This might reflect a genuine shortage of food resources, in comparison to what was found in woodland, as muscle scores are thought to reflect long-term access to good quality diet instead of short-term strategic body mass regulation (Gosler 1991, 1996).

Territoriality and site fidelity in a marginal habitat

Although both male and female Robins have the ability to defend individual territories in winter (Schwabl 1992, Cuadrado 1995, 1997), many birds are also known to behave as floaters during the non-breeding season (Cuadrado 1997). In the “Lezíria” study site, resident Robins were mostly, if not all, territorial. It is difficult to see how any floaters could have survived in this site, as the entire available habitat seemed to be defended by territorial birds, and there was little cover where a floater could hide from territory owners.

Between-winter site fidelity has been demonstrated in many passerine birds (e.g. Holmes & Sherry 1992). However, comparisons between studies are difficult because of varying methodologies and the fact that virtually no studies calculate recapture/resighting probabilities, even when they are clearly below the maximum value of 100% (Catry et al. 2003). Robins in the “Lezíria” study-area were readily found when searched for, and therefore we can be confident that recapture probabilities were close to 100%. Recurrence rates were much lower than reported by other studies using territorial and colour-ringed migrant passerines (Price 1981, Kelsey 1989, Holmes & Sherry 1992), but much higher than other studies of Robins relying on recaptures with mist-nets (Cuadrado 1992, Herrera 1998). These observations are suggestive, but only with more detailed studies of fidelity in other habitats, taking into account recapture probabilities when calculating recurrence rates (Catry et al. 2003, 2004b), it will be possible to fully interpret the results of the present study.

Acknowledgements: Ana Campos, Teresa Catry, Inês Catry and particularly Miguel Lecoq provided invaluable support during fieldwork. An anonymous referee provided useful comments on an earlier draft. This study was financed by Fundação para a Ciência e Tecnologia (FCT-Portugal) as part of the Programa Plurianual (UI&D 331/94) and a by research grants Praxis XXI BPD/16304/98 and BPD/11631/02.

REFERENCES


FACTORES QUE INFLUENCIAM O SUCESSO REPRODUTOR DO FRANCELHO *Falco naumanni* EM PORTUGAL

ANA CORDEIRO¹, ALDINA FRANCO² & JORGE PALMEIRIM²

RESUMO - O Francelho *Falco naumanni* é uma espécie globalmente ameaçada que sofreu um rápido declínio populacional nos últimos 50 anos. No sentido de compreender quais os factores limitantes do sucesso reprodutor da população portuguesa, foram comparados os parâmetros reprodutores de 18 colónias, correspondentes a 70% da população nacional, durante a época de nidificação de 2001. Detectaram-se diferenças significativas entre as datas de início da postura, que foram atribuídas ao facto de algumas colónias serem maioritariamente constituídas por casais subadultos, e diferenças altamente significativas na dimensão da postura, produtividade e sucesso reprodutor, devido provavelmente a diferentes disponibilidades alimentares. Para uma das colónias, os parâmetros reprodutores foram comparados com os obtidos no ano anterior, e as diferenças observadas foram atribuídas a diferentes condições meteorológicas e niveis de predação. Para as restantes colónias, o insucesso reprodutor em 2001 foi atribuído maioritariamente a ovos e crias desaparecidos por causas não apuradas, embora pontualmente a predação tenha sido o factor mais importante. Não foram detectadas correlações significativas entre o tamanho das posturas e a data de postura dos ovos. No entanto, observou-se uma tendência de diminuição do número de crias voadoras à medida que a época reprodutora avançava. Essa tendência só foi significativa para as colónias onde a disponibilidade alimentar poderia ter sido reduzida.

FACTORS INFLUENCING THE BREEDING SUCCESS OF THE LESSER KESTREL *Falco naumanni* IN PORTUGAL. The Lesser Kestrel *Falco naumanni* is a globally threatened species in Europe due to a strong decline in its population size over the last 50 years. In 2001, 18 Lesser Kestrel colonies were studied in Portugal, in order to evaluate the limiting factors for the breeding success of this species. The results of all colonies were compared and significant differences were detected for laying date (which may be related to a higher number of sub-adult males in some colonies), clutch size, productivity and breeding success (probably related with differences in food availability among colonies). Breeding parameters in 2001 were compared with those obtained in the previous year for one colony. The observed differences were attributed to different weather conditions and predation levels. For the other colonies, failures in 2001 were mainly attributed to egg or chick disappearance by unknown causes, although, in some cases, predation was the most important factor. There were no significant correlations between clutch size and laying date. However, later clutches tended to result in fewer fledglings, although this trend was only significant for the colonies where the food availability may have been a limiting factor.

De um ponto de vista evolutivo, a medida mais importante do sucesso reprodutor de um indivíduo é o número de descendentes que sobrevive para contribuir para a geração seguinte de reprodutores (Village 1990, Newton 1979). Isto vai depender de quantas vezes o indivíduo se reproduz, de quantos juvenis são criados em cada época reprodutora e que proporção desses juvenis sobrevive para se reproduzir (Village 1990, Clutton-Brock 1988).

Parâmetros reprodutores tais como o tamanho da postura são influenciados por factores intrínsecos, como a idade da fêmea, e por factores

¹Est. do Mineiro, 16, A-dos-Bispos, 2600 Vila Franca de Xira; e-mail: anap.cordeiro@sapo.pt / ²Departamento de Biologia Animal da Faculdade de Ciências da Universidade de Lisboa, Edifício C2, Campo Grande, 1700 Lisboa
extrínsecos como a disponibilidade de alimento, o clima (que pode afectar a procura ou mesmo a abundância do alimento), o habitat e a densidade populacional (Klomp 1970). Muitas vezes a reduzida disponibilidade de alimento é o factor responsável pelo abandono das posturas ou por um menor número de crias emancipadas (Wiehn & Korpimaki 1997, Village 1990).

Nas aves em geral, e nas aves de rapina em particular, os individuos que se reproduzem mais cedo têm uma maior probabilidade de sucesso do que os que se reproduzem no final da época reprodutora, o que parece estar relacionado com uma diminuição da probabilidade de sobrevivência das crias até à época de reprodução seguinte (Daan 1982 in Bijlsma et al. 1988). As aves mais velhas, com mais experiência, têm geralmente mais sucesso que as aves mais jovens, o que também está relacionado com a data de postura dos ovos, mais tardia nas aves que se reproduzem pela primeira vez (Village 1990, Catry 2000). Desta forma, a qual-gare do dos progenitores é um dos principais factores a afectar o sucesso reprodutor (Lack 1968 in Bijlamsa et al. 1988, Korpimaki & Wiehn 1998). A predação pode ser outra causa para o insucesso reprodutor, ao ser responsável pela perda de posturas e mortalidade de juvenis, e a perseguição humana, dependendo das espécies e das regiões, pode constituir a principal causa do insucesso (Newton 1979, Rocha 1995).

O Francelho ou Peneireiro-das-torres (Falco naumanni) é um pequeno falcão migrador, com distribuição estival no sul euroasiático (Cramp & Simmons 1980). É uma espécie principalmente colonial que nidifica quase exclusivamente em cavidades de edifícios, em áreas de uso agrícola extensivo (González & Merino 1990). Efectua posturas de 3 a 5 ovos (Cramp & Simmons 1980). Actualmente encontra-se entre as espécies de aves mais ameaçadas de Portugal (SNPRCN 1990). No Baixo Alentejo encontra-se a maior parte da população portuguesa distribuída por três colónias principais. Existem ainda várias colónias de dimensão reduzida e casais que nidificam isoladamente (Rocha et al. 2002). Com este estudo pretendeu-se (1) comparar os vários parâmetros reprodutores em várias colónias portuguesas, de forma a averiguar que factores poderão causar diferenças de sucesso reprodutor; e (2) avaliar a inter-relação entre os parâmetros estudados.

M TODOS

Área de Estudo

Neste trabalho estudaram-se colónias e casais isolados de Francelho em dezoito montes alentejanos, os quais correspondem a cerca de 70% da população nacional. Neste trabalho os montes com apenas um casal são designados por colónias. As colónias estudadas localizam-se nos concelhos de Évora, Aljustrel, Ourique e Castro Verde. Um dos casais nidificou nas casas em ruína anexas a uma capela. Uma das colónias situa-se numa estação de caminho de ferro abandonada, enquanto que outra começou a ser habitada por um pastor e respectiva família (com várias crianças) a meio da época reprodutora. As restantes colónias localizam-se em montes alentejanos abandonados ou utilizados para guardar gado, fardos de palha ou alfaias agrícolas, estando uma delas (Colónia 1) incluída numa reserva biológica para a conservação de aves estepárias.

Recolha e análise de dados

Em cada colónia, a localização dos ninhos foi determinada através da observação dos casais a uma distância de cerca de 100m recorrendo a binóculos e telescópio, exceptuando-se os casos em que essa localização era previamente conhecida. Foram efectuadas visitas regulares ao longo da época de reprodução de 2001 em que se registou o número de ovos, crias ou indícios de predação. Em alguns casos, o número de visitas foi condicionado pelo mau estado dos caminhos que só permitiu a circulação quando a época de reprodução já estava avançada. Noutros casos este condicionamento deveu-se à difícil acessibilidade dos ninhos. Em média efectuaram-se 7 visitas por ninho.

Os parâmetros utilizados foram definidos com base em outros estudos realizados com esta espécie (Bijlsma et al. 1988, Donázar et al. 1993, Catry 2000) e nas observações efectuadas neste trabalho: a data de início de postura foi estimada considerando o tempo médio de incubação de 28 dias e o intervalo médio entre a postura de dois ovos de 48 horas (Cramp & Simmons 1980). Este parâmetro é apresentado como o número de dias após o dia 1 de Janeiro. Para calcular o número médio de ovos por postura não se utilizaram posturas de reposição. Definiu-se taxa de eclosão como a proporção de ovos por casal que originaram crias. A taxa de sobrevivência foi definida como o número de crias voadoras por casal com êxito (que produziram pelo menos uma cria voadora). Crias com mais de vinte dias de permanência no ninho foram consideradas voadoras, porque a mortalidade nesta fase baixa consideravelmente (Rocha 1995) e as crias encontradas mortas nas visitas às colónias depois desta fase foram descontadas a este valor. A produtividade refere-se ao número de crias voadoras por casal com indícios de reprodução e o sucesso reprodutor à percentagem de ovos que originaram crias voadoras.

As diferenças nos parâmetros reprodutores entre cada uma das duas maiores colónias estudadas (colónias 1 e 2) e o conjunto das colónias de menor dimensão foram testadas recorrendo ao teste de Kruskal-Wallis (Zar 1999). Com base em cartas de capacidade de uso do solo na escala de 1:50.000, caracterizou-se uma área com dois quilómetros de raio em redor de cada colónia, de forma a incluir as áreas de máxima actividade dos indivíduos (Catry 2000). Consoante o resultado, dividiram-se as colónias em dois grupos, colónias de solo de melhor qualidade para a agricultura e colónias de solo de menor qualidade. Os vários parâmetros reprodutores foram comparados entre estes dois grupos utilizando o teste U de Mann-Whitney (Zar 1999). Para tentar identificar diferenças dos parâmetros reprodutores em anos sucessivos, os parâmetros reprodutores obtidos em 2001 para a colónia 1 foram comparados com os valores médios obtidos por Catry para a mesma colónia no ano anterior (Catry 2000).

Quanto aos dados referentes ao insucesso reprodutor, os ovos que permaneceram no ninho sem ecodir durante grande parte da época reprodutora, juntamente com os ovos de posturas abandonadas foram considerados inviáveis. Nos casos em que se registaram indícios de remoção de ovos por outras espécies, estes foram considerados ovos removidos. Para a mortalidade das crias agruparam-se as crias desaparecidas com as crias mortas. As crias predadas foram consideradas separadamente das crias encontradas mortas. Sempre que não se conseguiu determinar se ocorreu desaparecimento de ovos ou mortalidade das crias, o insucesso reprodutor foi designado por ovos ou crias desaparecidos.

A relação entre os parâmetros reprodutores foi testada a partir de correlações simples, utilizando o coeficiente de correlação de Spearman (Zar 1999) para cada um dos três grupos considerados: as duas colónias maiores (colónias 1 e 2) e o conjunto das colónias pequenas.

Todas as análises foram realizadas recorrendo ao software SPSS for Windows (v. 9.0.1, Inc. 1999).

RESULTADOS

Fenologia e parâmetros da reprodução

Na Tabela 1 estão referidas as colónias estudadas com indicação do número total de casais em cada uma delas. De realçar que a maior colónia do país teve 71 casais, mais quatro que no ano anterior (Catry 2000). Apresentam-se também os valores médios dos parâmetros reprodutores nas dezoito colónias, sempre que o seu cálculo foi possível. A chegada das primeiras aves ocorreu no final de Janeiro, no entanto o primeiro casal a iniciar
a postura fê-lo no dia 10 de Abril (no dia 100 do ano), na colónia 2. O casal mais tardio iniciou a postura no dia 22 de Maio (dia 142) na colónia 1. Embora as colónias de menor dimensão formasem um grupo muito heterogéneo, com uma variância bastante elevada, optou-se por analisá-las

**Tabela 1.** Número estimado de casais e valores dos parâmetros reprodutores (média ± erro padrão) em cada uma das colónias estudadas e para a população portuguesa (estimativa da população segundo Rocha et al. 2002). Dimensão da amostra (número de casais) entre parêntesis. É indicado também o grupo de capacidade de uso do solo atribuído a cada colónia (1 – solo de maior qualidade para a agricultura; 2 – solo de menor qualidade para a agricultura).

<table>
<thead>
<tr>
<th>Colónia</th>
<th>N.º casais</th>
<th>Cap. Uso do solo (n.º dias após 1 de Janeiro)</th>
<th>N.º ovos por casal</th>
<th>Taxa de eclosão (proporção de ovos eclodidos)</th>
<th>Produtividade (n.º crias voad. por casal com indicios de reprodução)</th>
<th>Taxa de sobrevivência (n.º crias voad. por casal com êxito)</th>
<th>Sucesso reprodutor (% ovos que originaram crias voad.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>71</td>
<td>114,7 ± 1,5 (36)</td>
<td>4,1 ± 0,1 (62)</td>
<td>0,8 ± 0,1 (29)</td>
<td>2,2 ± 0,2 (43)</td>
<td>2,8 ± 0,2 (33)</td>
<td>52,6 ± 5,6</td>
</tr>
<tr>
<td>2</td>
<td>44</td>
<td>110,4 ± 1,4 (20)</td>
<td>4,6 ± 0,1 (43)</td>
<td>0,8 ± 0,1 (27)</td>
<td>3,4 ± 0,2 (37)</td>
<td>3,4 ± 0,2 (37)</td>
<td>73,0 ± 3,9</td>
</tr>
<tr>
<td>3</td>
<td>13</td>
<td>112,3 ± 2,6 (3)</td>
<td>4,0 ± 0,0 (2)</td>
<td>1</td>
<td>1,0 ± 1,0 (3)</td>
<td>3</td>
<td>0,0 ± 0,0</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>117</td>
<td>4,0 ± 0,4 (10)</td>
<td>0,5 ± 0,2 (6)</td>
<td>0,4 ± 0,3 (9)</td>
<td>2,0 ± 1,0 (29)</td>
<td>14,8 ± 11,3</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
<td>120,3 ± 7,7 (3)</td>
<td>4,8 ± 0,2 (5)</td>
<td>0,6 ± 0,1 (3)</td>
<td>2,7 ± 0,7 (3)</td>
<td>2,7 ± 0,7 (3)</td>
<td>56,7 ± 12,0</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>110,0 ± 2,7 (3)</td>
<td>4,6 ± 0,3 (3)</td>
<td>0,7 ± 0,1 (3)</td>
<td>4,0 ± 0,0 (2)</td>
<td>4,0 ± 0,0 (2)</td>
<td>60,0 ± 30,6</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>116,0 ± 4,0 (2)</td>
<td>5,0 ± 0,0 (2)</td>
<td>0,5 ± 0,5 (3)</td>
<td>2,7 ± 0,6 (3)</td>
<td>2,7 ± 0,6 (3)</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>6</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>9</td>
<td>5</td>
<td>124,0 ± 0,0 (2)</td>
<td>3,5 ± 0,5 (4)</td>
<td>-</td>
<td>2</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>10</td>
<td>4</td>
<td>116,0 ± 8,0 (2)</td>
<td>4,3 ± 0,3 (3)</td>
<td>0,5 ± 0,5 (2)</td>
<td>2,0 ± 1,2 (3)</td>
<td>3,0 ± 1,0 (2)</td>
<td>46,7 ± 29,1</td>
</tr>
<tr>
<td>11</td>
<td>3</td>
<td>116,5 ± 2,5 (2)</td>
<td>4,0 ± 0,0 (2)</td>
<td>1,0 ± 0,0 (2)</td>
<td>5,0 ± 0,0 (2)</td>
<td>5,0 ± 0,0 (2)</td>
<td>100,0 ± 0,0</td>
</tr>
<tr>
<td>12</td>
<td>2</td>
<td>121,5 ± 0,5 (2)</td>
<td>4,0 ± 0,0 (2)</td>
<td>1,0 ± 0,0 (2)</td>
<td>4,0 ± 0,0 (2)</td>
<td>4,0 ± 0,0 (2)</td>
<td>100,0 ± 0,0</td>
</tr>
<tr>
<td>13</td>
<td>1</td>
<td>131</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>14</td>
<td>1</td>
<td>140</td>
<td>4</td>
<td>0,3</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>1</td>
<td>-</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td>16</td>
<td>1</td>
<td>140</td>
<td>4</td>
<td>0,3</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>17</td>
<td>1</td>
<td>-</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>18</td>
<td>1</td>
<td>116</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td><strong>População portuguesa</strong></td>
<td><strong>270</strong></td>
<td><strong>114,4 ± 1,0 (79)</strong></td>
<td><strong>4,3 ± 0,1 (142)</strong></td>
<td><strong>0,7 ± 0,0 (78)</strong></td>
<td><strong>2,5 ± 0,2 (115)</strong></td>
<td><strong>3,2 ± 0,1 (92)</strong></td>
<td><strong>55,8 ± 3,6 (103)</strong></td>
</tr>
</tbody>
</table>
em conjunto, para comparar as colónias de pequena dimensão com as colónias maiores. Os resultados desta análise deram diferenças significativas para a data de início da postura ($H^2 = 7.9; P < 0.05$), e diferenças altamente significativas para a dimensão da postura, para a produtividade e para o sucesso reprodutor ($H^2 = 10.6; H^2 = 15.9$ e $H^2 = 11.4$ respectivamente, sendo $P < 0.01$).

A capacidade de uso do solo para a agricultura em redor de cada uma das colónias originou a divisão destas em dois grupos: grupo 1 – solos com melhor qualidade para a agricultura; grupo 2 – solos com menor qualidade (Tabela 1). Não houve diferenças significativas a um nível de significância de 0.05. No entanto, verificou-se uma tendência para a taxa de sobrevivência ser maior nas colónias em solo de melhor qualidade ($U = 11.0; P = 0.08$).

Para a colónia 1 compararam-se os parâmetros reprodutores com os valores médios obtidos por Catry no ano 2000. No ano 2001 as posturas foram de maior dimensão e efectuadas mais cedo. As taxas de eclosão e de sobrevivência foram mais elevadas, mas no entanto a produtividade e o sucesso reprodutor foram inferiores (Tabela 2).

### Causas do insucesso reprodutor

As causas do insucesso reprodutor (Figura 1) foram atribuídas maioritariamente a crias ou ovos

<table>
<thead>
<tr>
<th>Início postura (n.º de dias após 1 de Janeiro)</th>
<th>N.º ovos por casal</th>
<th>Taxa de eclosão (proporção de ovos eclodidos)</th>
<th>Produtividade (n.º de crias voad. por casal com indícios de reprodução)</th>
<th>Taxa de sobrevivência (n.º de crias voad. por casal com êxito)</th>
<th>Sucesso reprodutor (% de ovos que originaram crias voad.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000 (dados de Catry, 2000)</td>
<td>Média</td>
<td>134</td>
<td>3,67</td>
<td>0,69</td>
<td>2,3</td>
</tr>
<tr>
<td></td>
<td>Erro padrão</td>
<td>1</td>
<td>0,13</td>
<td>0,04</td>
<td>0,15</td>
</tr>
<tr>
<td></td>
<td>$n$</td>
<td>54</td>
<td>48</td>
<td>63</td>
<td>67</td>
</tr>
<tr>
<td>2001 (presente trabalho)</td>
<td>Média</td>
<td>114,7</td>
<td>4,11</td>
<td>0,78</td>
<td>2,16</td>
</tr>
<tr>
<td></td>
<td>Erro padrão</td>
<td>1,49</td>
<td>0,12</td>
<td>0,05</td>
<td>0,23</td>
</tr>
<tr>
<td></td>
<td>$n$</td>
<td>36</td>
<td>62</td>
<td>29</td>
<td>43</td>
</tr>
</tbody>
</table>

**Figura 1.** Importância relativa das causas do insucesso reprodutor nas colónias 1, 2 e nas colónias de menor dimensão.

**/ Figure 1.** Relative importance of the causes of breeding failure in colonies 1, 2 and smaller colonies group.
desaparecidos. A inviabilidade dos ovos foi a segunda maior causa de insucesso na colónia 2 e nas colónias de menor dimensão. Na colónia 1 registou-se maior mortalidade das crias, quer por predação principalmente por um gato doméstico (cerca de 6%), quer por outras causas (18%). Numa das colónias de menor dimensão encontraram-se vestígios de ovos que tinham sido removidos por um casal de Rolieiros (Coracias garrulus) para depositarem os seus ovos nesse ninho (cerca de 5%).

**Correlação entre os parâmetros reprodutores**

Pela análise das Tabelas 3, 4 e 5, verifica-se que em todas as colónias estudadas houve uma correlação positiva significativa ($P<0,05$) entre a taxa de eclosão, a produtividade, a taxa de sobrevivência e o sucesso reprodutor. A data de postura dos ovos apresentou uma correlação negativa significativa com a produtividade e com o sucesso reprodutor na colónia 1 (nos dois casos $P<0,05$), e com a produtividade e taxa de sobrevivência nas colónias de menor dimensão ($P<0,01$). A dimensão da postura esteve correlacionada positivamente com a produtividade e com a taxa de sobrevivência na colónia 2, com a produtividade na colónia 1 e com a taxa de sobrevivência nas colónias de menor dimensão ($P<0,05$). As restantes comparações entre os parâmetros não mostraram qualquer correlação significativa.

**DISCUSSÃO**

**Fenologia e parâmetros da reprodução**


As diferenças encontradas na colónia 1 entre o ano 2000 e o ano 2001, nomeadamente um atraso no início das posturas e posturas de menor dimensão em 2000, estarão relacionadas com diferenças nas condições meteorológicas. No ano 2000, a elevada pluviosidade registada nos meses de Março e Abril contribuiu para a reduzida disponibilidade alimentar neste período e para a diminuição da eficácia de caça pelos progenitores, dificultando e atrasando a obtenção da condição corporal necessária à produção de ovos (Catry 2000). No ano 2001, depois de um Inverno muito chuvoso, seguiu-se uma Primavera mais seca, em que os dias de precipitação eram intercalados por períodos sem chuva. A influência da pluviosidade na data de início de postura (e consequentemente na dimensão da postura devido à tendência dos casais que se reproduzem mais cedo efectuarem posturas maiores (Aparicio 1994, Korpimaki & Wiehn 1998)) foi também referida por Newton (1979) e por Ferrero et al. (2001). No ano 2001 ocorreu uma elevada predação nesta colónia nos ninhos debaixo de telha que são de mais fácil acesso do que os ninhos em cavidades nas paredes, e na fase em que as crias começavam a voar, principalmente por um gato doméstico. Este facto fez diminuir a produtividade e o sucesso reprodutor, mas não a taxa de sobrevivência que não considera as perdas de postura/ninhada completas que ocorrem quando há predação no ninho.

Nas colónias de menor dimensão, as datas de início de postura foram significativamente mais tardias, o que se pode dever ao facto de várias destas colónias terem sido maioritariamente constituídas por casais com machos subadultos, que iniciam a reprodução mais tarde porque chegam posteriormente das áreas de invernada (Village 1990, Catry 2000). As colónias maiores (colónia 2, por exemplo) são ocupadas no início da época de reprodução por casais adultos, e as cavidades que ficam disponíveis para casais mais tardios (como os constituídos por casais subadultos) são alvo de competição intensa, o que leva a que estes casais procurem colónias próximas (que são mais pequenas). No entanto, há casos (colónia 11, por exemplo) em que machos adultos optam por colónias mais pequenas, o que se pode dever a já terem experiência no local. A experiência em determinado local é apontada como o principal factor que determina a não dispersão de indivíduos adultos nesta espécie (Serrano et al. 2001). A opção por colónias pequenas é uma aposta numa situação
### Tabela 3. Correlação entre os parâmetros reprodutores na colónia 1 utilizando o coeficiente de correlação de Spearman (rs), em que n representa o número de casais considerados para análise. / Table 3. Correlations between breeding parameters in colony 1, using the Spearman Rank Coefficient (rs – coefficient of the test; n – number of pairs considered for analysis).

<table>
<thead>
<tr>
<th></th>
<th>N.º de ovos por casal</th>
<th>Taxa de eclosão (proporção de ovos eclodidos)</th>
<th>Produtividade (n.º de crias voad. por casal com indícios de reprodução)</th>
<th>Taxa de sobrevivência (n.º de crias voad. com êxito)</th>
<th>Sucesso reprodutor (% de ovos que originaram crias voad.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Início da postura</td>
<td>rs: -0,316</td>
<td>-0,265</td>
<td>-0,479</td>
<td>-0,307</td>
<td>-0,431</td>
</tr>
<tr>
<td></td>
<td>p: 0,064</td>
<td>0,258</td>
<td>0,021</td>
<td>0,188</td>
<td>0,040</td>
</tr>
<tr>
<td></td>
<td>n: 35</td>
<td>20</td>
<td>23</td>
<td>20</td>
<td>23</td>
</tr>
<tr>
<td>N.º de ovos por casal</td>
<td>rs: 0,105</td>
<td>0,328</td>
<td>0,147</td>
<td>0,074</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p: 0,588</td>
<td>0,041</td>
<td>0,423</td>
<td>0,656</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n: 29</td>
<td>39</td>
<td>32</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>Taxa de eclosão</td>
<td>rs: 0,502</td>
<td>0,546</td>
<td>0,576</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>p: 0,010</td>
<td>0,007</td>
<td>0,003</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>n: 25</td>
<td>23</td>
<td>24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Produtividade</td>
<td>rs: 1,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>p: 0,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>n: 33</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taxa de sobrevivência</td>
<td>rs: 0,917</td>
<td></td>
<td></td>
<td></td>
<td>0,917</td>
</tr>
<tr>
<td></td>
<td>p: 0,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>n: 31</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Tabela 4. Correlação entre os parâmetros reprodutores na colónia 2 utilizando o coeficiente de correlação de Spearman (rs), em que n representa o número de casais considerados para análise. / Table 4. Correlations between breeding parameters in colony 2, using the Spearman Rank Coefficient (rs – coefficient of the test; n – number of pairs considered for analysis).

<table>
<thead>
<tr>
<th></th>
<th>N.º de ovos por casal</th>
<th>Taxa de eclosão (proporção de ovos eclodidos)</th>
<th>Produtividade (n.º de crias voad. por casal com indícios de reprodução)</th>
<th>Taxa de sobrevivência (n.º de crias voad. com êxito)</th>
<th>Sucesso reprodutor (% de ovos que originaram crias voad.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Início da postura</td>
<td>rs: -0,203</td>
<td>0,200</td>
<td>0,056</td>
<td>0,056</td>
<td>0,111</td>
</tr>
<tr>
<td></td>
<td>p: 0,405</td>
<td>0,427</td>
<td>0,815</td>
<td>0,815</td>
<td>0,650</td>
</tr>
<tr>
<td></td>
<td>n: 19</td>
<td>18</td>
<td>20</td>
<td>20</td>
<td>19</td>
</tr>
<tr>
<td>N.º de ovos por casal</td>
<td>rs: 0,140</td>
<td>0,367</td>
<td>0,367</td>
<td>0,168</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p: 0,488</td>
<td>0,030</td>
<td>0,030</td>
<td>0,336</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n: 27</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Taxa de eclosão</td>
<td>rs: 0,919</td>
<td></td>
<td></td>
<td>0,919</td>
<td>0,959</td>
</tr>
<tr>
<td></td>
<td>p: 0,000</td>
<td></td>
<td></td>
<td>0,000</td>
<td>0,000</td>
</tr>
<tr>
<td></td>
<td>n: 26</td>
<td></td>
<td></td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>Produtividade</td>
<td>rs: 1,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>p: 0,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>n: 37</td>
<td></td>
<td></td>
<td></td>
<td>35</td>
</tr>
<tr>
<td>Taxa de sobrevivência</td>
<td>rs: 0,970</td>
<td></td>
<td></td>
<td></td>
<td>0,970</td>
</tr>
<tr>
<td></td>
<td>p: 0,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>n: 35</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
desconhecida. No entanto, dispersar e nidificar numa colónia desconhecida parece ser a opção escolhida pelos casais que não encontram locais de nidificação nas colónias de origem.

A opção pela dispersão pode ter consequências positivas se não existir predação, se o alimento for abundante e se não sofrerem competição por locais de nidificação ou cleptoparasitismo (Negro et al. 1992), ou negativas se os indivíduos não usufruírem dos benefícios da reprodução colonial: sinais de alarme e/ou ataque conjunto a potenciais predadores, ou efeito de diluição (Ricklefs 1996, Goodenough et al. 1993).

A dimensão das posturas, a produtividade e o sucesso reprodutor mostraram diferenças altamente significativas entre os três grupos considerados, o que se deveu à colónia 2, que apresentou valores mais elevados para estes parâmetros. Isto pode ser explicado por uma maior abundância de presas na área e/ou a uma maior qualidade dos progenitores em termos de prestação de cuidados parentais. De realçar que dois casais com machos subadultos que criaram nesta colónia também obtiveram uma boa produtividade, o que leva a pensar que a experiência dos indivíduos não é o factor determinante neste caso, mas sim a qualidade do habitat (as diferenças de plumagem entre fêmeas subadultas e fêmeas com mais de dois anos não são observáveis; Cramp & Simmons 1980, Mullarney et al. 1999, Bijlsma et al. 1988), por isso a distinção só é possível no caso de estarem anilhadas; um destes machos estava acasalado com uma fêmea também subadulta anilhada).

Tentou-se testar a influência da qualidade do habitat caracterizando a área em redor de cada colónia quanto à capacidade de uso do solo para a agricultura: melhores solos produziam uma maior biomassa vegetal com uma consequente maior abundância e disponibilidade de presas. Esta maior disponibilidade de presas em algumas colónias foi verificada no decorrer do trabalho de campo através de observações de entregas de presas em 9 das colónias estudadas (Cordeiro 2001). No entanto, não houve diferenças
significativas para nenhum dos parâmetros reprodutores. A taxa de sobrevivência teve diferenças quase significativas, o que é facilmente compreendido ao facto deste parâmetro não considerar perdas totais de posturas ou ninhadas, que podem ser devidas a predação e que fazem baixar os outros parâmetros mascarando o efeito da disponibilidade de alimento.

**Causas do insucesso reprodutor**

Uma das causas de insucesso reprodutor mais documentadas em aves de rapina tem sido o uso de pesticidas, com a sua repercussão negativa na estrutura da casca dos ovos e na eclosão (Newton 1979, Bijlsma *et al.* 1988). No entanto, os valores registados de ovos inviáveis são semelhantes aos obtidos por Negro *et al.* (1993) em que se considerou que os níveis detectados de metais pesados e pesticidas organoclorados em ovos de Francelho não seriam detrimen
tais para a reprodução da população estudada.

A principal causa do insucesso reprodutor foi o desaparecimento de ovos ou crias, que pode ser atribuído à predação ou à quebra da casca do ovo durante a incubação e posterior remoção, ou ingestão pelo progenitor (Newton 1979). A colónia 4, que registou um baixo sucesso reprodutor, alberga também Gralhas-de-nuca-cinzenta (*Corvus monedula*) que competem com o Francelho por locais de nidificação e por alimento (podendo cleptoparasitar os Francelhos) e predam ovos (Rocha 1996, Bijlsma *et al.* 1988). É provável que o elevado desaparecimento de ovos nesta colónia se deva a este último factor, mas não foram encon-trados vestígios dessa predação. Na colónia 3, os factores responsáveis pelo insucesso reprodutor poderão ser atribuídos à predação de ovos ou crias por ratazanas (em certas zonas do telhado foram encontrados excrementos), por Cobra-rateira (*Malpolon monspessulanus*), que foi observada sobre o telhado, e por gatos domésticos. No entanto, grande parte do insucesso reprodutor nesta colónia foi atribuído à categoria de ovos ou crias desaparecidos por não terem sido encontrados vestígios de predação. Tal como foi referido, a colónia 12 começou a ser habitada por um pastor e respectiva família durante o período de incubação. Um dos ninhos poderá ter sido abandonado por estar muito exposto a perturbação humana ou os ovos podem ter sido destruídos.

A mortalidade das crias por falta de alimento é referida por vários autores como sendo uma das principais causas do insucesso reprodutor (Donázar *et al.* 1993, Bustamante & Negro 1994). No entanto, não foi possível verificar se foi esta a principal causa da mortalidade, que foi mais elevada na colónia 1. Algumas crias desapareceram dos ninhos, podendo ter sido predadas, ter adocado ou morrido de fome, sendo posteriormente removidas do ninho pelos progenitores.

**Correlação entre os parâmetros reprodutores**

Tal como seria de esperar, os progenitores com um maior número de crias celodidas, conseguiram ter um maior número de crias voadoras, o que se reflecte na produtividade, na taxa de sobrevivência e no sucesso reprodutor.

O declínio sazonal no número de juvenis que atingem a idade de emancipação é conhecido em muitas espécies de aves (Dijkstra *et al.* 1982, Village 1990), e poderá estar relacionado com a qualidade dos progenitores na prestação de cuidados parentais (Lack 1968 in Bijlsma *et al.* 1988, Korpimaki & Wiehn 1998). Nesta espécie, os indivíduos subadultos, sem experiência como progenitores, iniciam a sua reprodução mais tarde (Negro 1991). Nos locais onde o alimento é mais abundante, como parece ser o caso da zona envolvente da colónia 2, mesmo os progenitores subadultos teriam um sucesso reprodutor elevado (obs. pess.), enquanto que nos outros locais (colónia 1 e algumas das colónias de menor dimensão) os casais menos experientes teriam dificuldades em responder ao aumento das necessidades alimentares das suas crias, conduzindo a um menor sucesso reprodutor que os casais que iniciaram a sua reprodução mais cedo.

Ao contrário do descrito por vários autores (Aparicio 1994, Rocha 1995, Catry 2000), não se verificou uma diminuição significativa do tamanho das posturas ao longo da época de reprodução (embora essa diminuição tenha existido e seja quase significativa na colónia 1), o que também poderá estar relacionado com a quantidade de alimento disponível, num ano com boas condições meteorológicas.
Agradecimentos: os autores gostariam de agradecer à Liga para a Protecção da Natureza o apoio logístico concedido para a realização deste trabalho e aos revisores que contribuíram com os seus comentários para o melhorar o manuscrito original.

BIBLIOGRAFIA


Irby, H.L. 1875. The Ornithology of the Straits of Gibraltar, London.


ABSTRACT - The Great Bustard Otis tarda is one of the most threatened steppe birds in Europe. In Portugal, little information is available about the post-breeding habitats used by Great Bustards. In this study post-breeding habitats were investigated during summer and autumn of 2001 in three cultivated areas of Alentejo with different levels of agriculture intensification. Summer and autumn results indicated that cereal stubbles were the most used habitat, although the results were statistically significant only for summer. In addition, analyses showed that other land uses were avoided or poorly used by the species, with exception of chickpea stubble Cicer arietinum that was also selected by the Great Bustards during summer, despite its scarce availability. Areas closer to human related structures, such as roads and inhabited houses, were significantly avoided during autumn but not during summer, suggesting that the potential impacts of these structures in the behaviour of individuals can be less important when food availability is low. This study suggest that the maintenance of extensively cultivated areas is the main conservation measure for post-breeding habitats of Great Bustard. Plantation of chickpea may also be important, although additional research on this subject is needed.

The Great Bustard Otis tarda is a protected and threatened species, listed as Vulnerable (SPEC 1) according to BirdLife International (Goriup 1994) and Endangered in the Portuguese Red Data Book (SNPRCN 1990). In the last decades, both size and range of distribution of populations all over Europe declined strongly, as a result of habitat loss, agriculture intensification and other human related factors (Goriup 1994, Lane et al. 2001). About 50 % of the total world population is concentrated in the Iberian Peninsula (Goriup 1994). The Portuguese population is resident (although showing dispersive movements during the gregarious period), and estimated at about 1400 individuals (Alonso et al. 2003), with main areas of occurrence in the region of Alentejo (Rufino 1989). During the breeding
season males concentrate in displaying areas (leks), with females visiting these areas for copulation. In the post-breeding period the species is gregarious, with flocks of adult males or females with males aged less than two years (mixed flocks are uncommon), concentrating in open and flat cultivated areas (Lane et al. 2001).

Despite being intensively studied in other European countries (e.g. Spain), little information is available on the habitats of occurrence in Portugal during the post-breeding season (but see Moreira et al. 2004). In the present work, post-breeding habitats of Great Bustard in Portugal were investigated, in particular in summer and autumn. Both human related and environmental/land use factors were analysed, with particular attention given to land use preferences and human structures (e.g. roads, houses, villages) potentially impacting in the species. Finally, some considerations about management and conservation of this species and related habitats are discussed.

METHODS

Study Area

The study was conducted in three sub-areas of Alentejo Region: Campo Maior, Cuba and Castro Verde (Figure 1). The climate of the three regions is Mesomediterranean (Rivas-Martinez 1981), with mean annual temperatures ranging from 15 to 17.5ºC and annual precipitation about 500-600 mm (SNIG 2004).

The sub-area of Campo Maior is an open cultivated area of about 3,303 ha, located at Alto Alentejo, and included in the Special Protection Area of Campo Maior. This area is delimited on the west by large olive tree plantations and characterised by intensive agriculture. The irrigated crops occupy seasonally more than 50% of the area (summer), and the main cultivars are corn, sunflower, beetroot, alfalfa, flax and olive groves, alternating with extensive areas of cereal (although some of them being regularly irrigated). The areas of fallow are scarce.

The sub-areas of Cuba and Castro Verde are located in Baixo Alentejo. The first area is an open semi-extensive area of 2,522ha, dominated by extensive cultivation of cereal, sunflower and fallows with and without grazing. Irrigated crops are less abundant and limited to cultivation of corn, melon and partially sunflower. The sub-area of Castro Verde (3,089ha) is included in the Special Protection Area of Castro Verde and is characterised by a typical extensive agriculture with traditional rotation of crops. The crops of cereal alternate with extensive fallows ranging until 5 years.

During autumn, some of the referred irrigated summer crops like sunflower, melon, beetroot and partially corn, are already harvested and transformed into stubbles. Sheep’s grazing is mainly extensive. Cattle’s grazing, although less common, is locally/seasonally intensive, especially during summer in the sub-area of Campo Maior.

Sampling

Sampling effort was divided in two seasons: summer and autumn. Each sub-area was sampled once at each season. Summer sampling took place between 15 July and 15 September 2001, whereas autumn sampling was carried out between 15 October and 20 December 2001. The three sub-areas were sampled on foot in the first 3 1/2 hours after sunrise, along 37 zigzag strip-transects with variable length, separated by 500 meters (strip band - 500m, Bibby et al. 1992).

Each Great Bustard location was registered on military maps (1:25,000) and a posteriori integrated in a Geographical Information System (GIS). In order to evaluate differences between availability and use by Great Bustards, 80 random points were defined per season, distanced at least 500 meters and stratified in proportion of total surface of each sub-area in order to minimize effects of spatial autocorrelation (Osborne et al. 2001).

The information sampled at each random/Great Bustard point enabled the definition of 22 variables in summer and 21 in autumn (7 land use related variables in summer and 6 in autumn; and 15 variables extracted from GIS layers). Land uses for summer were ploughed land, cereal stubble, corn, sunflower, fallow and permanent crops (olive groves, vineyards and orchards). Autumn land uses were ploughed land, cereal stubble, fallow, cereal and permanent crops. Land uses with less than 5% of occupation were grouped in the variable Other Land Uses (e.g. flax, melon, beetroot, tomato, chickpea stubble, burned land
Figure 1. Location and percentage of occupancy of each land use in the study sub-areas during the summer and autumn of 2001. / Figura 1. Localização e percentagem de ocupação dos diferentes usos do solo de cada uma das três sub-áreas de estudo durante o Verão e Outono de 2001.
and alfalfa in summer; and corn, flax, burned land and beetroot, sunflower, corn, tomato and melon stubbles in autumn). The proportion of different land uses, soil type and track/water lines density was assessed using a 100m buffer around each sampling point. Five soil types were considered, from type A (best quality soil) to type E (lowest quality soil).

**Statistical Analysis**

In order to quantify with best accuracy the importance of each variable for Great Bustard both non-parametric univariate statistics and multivariate statistics were used. Univariate statistics were based on Mann-Whitney U tests (Sokal & Rohlf 1995), comparing the values for each variable at random locations and at Great Bustard locations. The multivariate approach consisted in the development of a logistic regression model for Great Bustard selected habitats. Only the variables with univariate logistic regression p-values less than 0.25 were considered for the multivariate analysis (Palma et al. 1999, Hosmer & Lemeshow 2001). Forward Stepwise Logistic Regression was applied to select the variables that best described Great Bustard's areas of occurrence. The significance of each variable was assessed using the Likelihood Ratio test. In order to minimise the effects of collinearity between the independent variables, only variables presenting correlation values smaller than 0.7 were entered in the analyses (Luck 2002).

Recent works (Manel et al. 2001, Osborne et al. 2001) have called attention to the effects of prevalence (i.e. ratio of random points and Great Bustard points) when evaluating the performance of the presence-absence model by means of prediction success tables. Considering this potential problem, and in order to obtain a more reliable estimation of the goodness-of-fit of the model selected, both prediction success for a cut-point of 0.5 and Area Under Curve (AUC) measures from Receiver Operating Characteristic (ROC) plots (Fielding & Bell 1997, Cumming 2000, Pearce & Ferrier 2000) are presented. The AUC statistic and the classification accuracy were validated using jackknife analysis (Bautista et al. 1999, Manel et al. 2001).

All GIS related procedures were conducted using ArcView 3.2. The statistical analyses were performed using statistical software SPSS 10.0.

**RESULTS**

**Summer**

A total of 22 observations of Great Bustard (102 individuals) were recorded in the summer period, 13 in Castro Verde, 5 in Cuba and 4 in Campo Maior. Both isolated individuals and flocks were sighted, with flocks ranging up to 8 individuals (mean number ± standard deviation of individuals per observation=3.59±0.48).

Birds were observed mainly in cereal stubble (50% of the observations), but also in chickpea stubble (23%), fallow (14%), ploughed land (5%), sunflower (5%) and at the border of a small lake (5% observation). Mann-Whitney U tests (Table 1) showed that Great Bustards selected areas of cereal stubble during this season, avoiding the proximity of rivers. These results are similar to those obtained by the logistic regression analysis. The logistic model obtained was highly significant ($\chi^2=19.70$, $P<0.001$), leading to the selection of three variables: Cereal Stubble, the most important variable to the final model (Table 2), Distance to Nearest River and Other Land Uses. According to the logistic regression model the land uses Cereal Stubble and Other Land Uses were preferentially selected by the species whereas proximity of rivers was avoided.

The ROC plots indicate an AUC of 0.80, a very significant result ($P<0.001$). At the same time, this model classified correctly 82.4% of the sampling points. The jacknifed AUC was 0.74, whereas the jacknified classification accuracy indicated 77% of total points classified correctly. These parameters suggest, according to literature on this subject (Manel et al. 2001; Hosmer & Lemeshow 2001) and regarding the scarce data, a reasonable robustness for this model.

**Autumn**

The number of Great Bustard observations was close to those observed during summer, with birds occurring both in flocks and isolated. A total of 26 observations (279 individuals) were registered, 14 in Castro Verde, 9 in Campo Maior and 3 in Cuba. Flock size was now considerable larger than flock size in the summer, reaching 66 birds (mean ± standard deviation number of individuals per observation=10.73±13.86).
As in summer, birds were sighted mainly in cereal stubble (38% of the observations), however, the remaining observations were more or less evenly distributed among the other land uses considered, with 27% in cereal, 19% in ploughed land, 12% in fallow and 4% in permanent crops (vineyards). Despite the large number of observations in cereal stubble, and contrasting with summer, this land use was not significantly selected by the species. Mann-Whitney U tests indicated three important variables in the autumn’s distribution of Great Bustard: Distance to Nearest Road, Distance to Nearest Inhabited House and Other Land Uses (Table 3). According to these results, Great Bustards avoid areas in the neighbourhood of roads and inhabited houses, and areas designated as Other Land Uses.

Table 1. Results of Mann-Whitney U tests for the summer data (significant variables are shown in bold characters). / Tabela 1. Resultados dos testes de Mann-Whitney U para os dados de Verão (as variáveis estatisticamente significativas são apresentadas a negrito).
The logistic regression analysis model was significant ($\chi^2=22.94$, $P<0.001$) with four variables: Altitude, Distance to Nearest Road, Distance to Nearest Inhabited House and Other habitats. ROC plots showed an AUC of 0.83 ($P<0.001$), which indicates a more robust model than that in summer. Classification accuracy of the model indicates that 79% of the sampling points were classified correctly. The jacknifed AUC was 0.78, whereas the jacknifed classification accuracy showed an overall classification of 78%.

**DISCUSSION**

Our results are comparable with those obtained in previous studies of this species. According to Lane et al. (2001) in north-west Spain mean flock size during September 1997 and September 1998, was 3.7 and 5.1 individuals/observation respectively, against 3.59 individuals in this study, during summer. Mean flock size registered in autumn (10.73 individuals/observation) was also similar to those obtained by the same authors during December 1997 and December 1998, respectively 11.0 and 15.9 individuals/observation.

Cereal stubble was in both seasons the main habitat of occurrence, although only significantly selected for summer. These results are consistent with those reported by Lane et al. (2001) and Moreira et al. (2004), but slightly different from those presented by Martínez (1991), who showed that cereal stubbles were used by birds less than expected, selecting alfalfa crops, a scarce habitat in the study area. Ploughed lands, although cited by these authors as an avoided land use, were in this study used in the proportion of their availability. Sunflower, despite poorly used during sampling hours, is probably more used during the hottest hours of the day, providing shade to the individuals (pers. obs.).

When regarding the response of the species to the variable Other Land Uses there were opposite results for summer and autumn. This can be explained by the inclusion of chickpea stubbles (*Cicer arietinum*) during summer (chickpea stubbles were absent during the autumn sampling). This land use, despite occurring in less than 2% of the study area, held about 23% of the species observations, which should be associated with the availability of food in this habitat, especially seeds that remained after harvesting and residual cover of green plant material (about 1-2%). This suggestion is supported by the results of Lane et al. (1999), which indicated both green plant material as the main source of food and the highest proportion of seeds in faecal analysis during summer. The use of Leguminosae species as food resources has already been suggested by Rocha et al. (1996) for the same area of Castro Verde. Considerations about this subject were also made by Moreira et al. (2004), although, the scarcity of these habitats in his study limited the discussion on their importance for the species. Future studies should take into account and evaluate the importance of chickpea as a food supply, and its potential role on the management of areas of occurrence of Great Bustard during the post-breeding season (presently two research projects involving the plantation of Leguminosae for agricultural steppe birds are in progress in Portugal, one at Castro Verde and other at the SPA of Moura-Mourão-Barrancos, also in the Alentejo region).

Roads and inhabited houses seem to play an important role in the autumn distribution of Great Bustards but not during summer. This fact is probably a result of a lesser availability of food during summer (Lane et al. 1999), forcing flocks to occupy more disturbed and less favourable areas. Likewise, higher altitudes were preferred during autumn but not during summer. This is also probably related with the food constraints discussed previously. However, this preference for higher altitudes should reflect a preference for

---

**Table 2.** Summary results of logistic regression analysis for the summer data (Great Bustard points=26; Random points=80). / **Tabela 2.** Resultados resumidos da análise de regressão logística para os dados de Verão (pontos Abelarda=26; pontos Acautórios=80).

<table>
<thead>
<tr>
<th>Variable / Variável</th>
<th>B</th>
<th>S.E.</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other land uses / Outros usos do solo</td>
<td>1.97</td>
<td>0.84</td>
<td>0.019</td>
</tr>
<tr>
<td>Cereal stubble / Restolho de cereal</td>
<td>1.98</td>
<td>0.68</td>
<td>0.002</td>
</tr>
<tr>
<td>Distance to nearest river / Distância ao rio mais próximo</td>
<td>1.84</td>
<td>0.85</td>
<td>0.009</td>
</tr>
<tr>
<td>Constant / Constante</td>
<td>-7.54</td>
<td>2.47</td>
<td>0.002</td>
</tr>
</tbody>
</table>
Table 1. Results of Mann-Whitney U tests for the autumn data (significant variables are shown in bold characters). / Tabela 1. Resultados dos testes de Mann-Whitney U para os dados de Outono (as variáveis estatisticamente significativas são apresentadas a negrito).

| Variable / Variável                                      | | z | | Mean rank / Rank médio | P = |
|--------------------------------------------------------|---|---|--------------------------|------|
|                                                      | Random / Abetarda (n=80) | Great Bustard / Abetarda (n=22) |
| Altitude / Altitude                                    | 1.58 | 50.82 | 61.75 | 0.115 |
| Cereal stubble / Restolho de cereal                    | 1.39 | 51.65 | 59.19 | 0.166 |
| Corn / Milho                                          | 1.52 | 51.31 | 60.25 | 0.130 |
| **Distance to nearest inhabited house /**              | 2.39 | **49.42** | **66.04** | **0.017** |
| **Distância à casa habitada mais próxima**            | | | | |
| Distance to nearest river / Distância ao rio mais     | 1.25 | 51.38 | 60.04 | 0.212 |
| próximo                                               | | | | |
| **Distance to nearest road / Distância à estrada mais**| 3.00 | **48.40** | **69.19** | **0.003** |
| próximo                                                | | | | |
| Distance to nearest track / Distância ao caminho       | 0.40 | 52.81 | 55.62 | 0.686 |
| mais próximo                                           | | | | |
| Distance to nearest village / Distância à povoação     | 0.54 | 54.28 | 51.12 | 0.592 |
| mais próxima                                           | | | | |
| Distance to nearest water line / Distância à linha de  | 1.62 | 50.75 | 61.96 | 0.106 |
| água mais próxima                                      | | | | |
| Fallow / Pousio                                       | 0.58 | 54.35 | 50.88 | 0.564 |
| **Other land uses / Outros usos do solo**             | 2.35 | **56.53** | **44.19** | **0.019** |
| Permanent crops / Cultivos permanentes                 | 0.30 | 53.76 | 52.71 | 0.767 |
| Ploughed land / Lavrados                               | 0.29 | 53.91 | 52.23 | 0.772 |
| Slope / Declive                                        | 0.12 | 53.30 | 54.12 | 0.906 |
| Soil a / Solo a                                        | 0.75 | 54.40 | 50.73 | 0.455 |
| Soil b / Solo b                                        | 0.14 | 53.70 | 52.88 | 0.889 |
| Soil c / Solo c                                        | 1.27 | 55.13 | 48.50 | 0.205 |
| Soil d / Solo d                                        | 1.22 | 51.71 | 59.00 | 0.222 |
| Soil e / Solo e                                        | 0.14 | 53.61 | 53.15 | 0.891 |
| Track density / Densidade de caminhos                 | 0.06 | 53.59 | 53.23 | 0.950 |
| Water line density / Densidade de linhas de água       | 1.04 | 55.17 | 48.37 | 0.297 |

Hilltops and not a preference for a particular range of altitude, because altitude in the sampled areas ranged only from 140 to 240 meters. The selection of hilltops can be interpreted, in the same way as with other species (namely the Little Bustard, Silva et al. 2004) as an anti-predation behaviour, were hilltops are used to increase capability to detect potential predators.

This study suggest that the maintenance of extensively cultivated areas, respecting the traditional pattern of culture rotation, is the main measure for conservation of post-breeding habitats of Great Bustard. Therefore, particular attention must be given to the expansion of irrigated areas at Campo Maior, where over the summer about 50% of the area is cultivated. During autumn, the percentage of irrigated crops in Campo Maior is considerably lower than over the summer (about 20%), a fact that can explain the greater number of observations. The agricultural intensification can also became in a near future, a serious problem in the sub-area of Cuba, as a result of the inclusion of...
this region in a vast irrigated perimeter. According to Mira et al. (1994), during the summer-autumn period the negative consequences for Great Bustard can arise from direct loss of habitat and perturbation of resting and feeding areas but also from the contamination with pesticides.

Acknowledgements: I would like to thank Dr. Renato Coelho and Dr. Francisco Moreira for their helpful critical reviews of previous drafts.

REFERENCES


The Osprey *Pandion haliaetus* has a patchy distribution in the Western Palearctic. Many local populations, especially in the Mediterranean and Macaronesian regions, have decreased dramatically to or very close to extinction during the last decades due to human persecution, habitat destruction and tourism development (Schmidt 1998). Current breeding populations of Osprey in the Macaronesian islands are located only in the Cape Verde (Palma *et al.* 2004) and Canary Islands. In the latter case, the Osprey breeds in Lanzarote, Tenerife, La Gomera and El Hierro, and in the islets of Montaña Clara and Alegranza (Martín & Lorenzo 2001). Single individuals or pairs can be observed in the rest of the archipelago (Martín & Lorenzo 2001). Recent population estimates in the Canarian Archipelago vary between 15 and 20 pairs (Triay *et al.* 2004). Because of its low numbers and limited distribution range in Spain (Balearic, Chafarinas and Canary Islands), the species has been catalogued as Critically Endangered (Triay & Siverio 2003).

**Summary** - Breeding population size and some reproductive aspects of Osprey *Pandion haliaetus* in La Gomera and El Hierro (Canary Islands) were studied during the 2003 and 2004 breeding seasons. All active nests were situated in the southern coasts of both islands. A total of five territorial pairs were detected in La Gomera and one in El Hierro, nesting three in La Gomera and one in El Hierro. These islands contain about 30% of the entire Canarian Osprey population and 16-17% of the Spanish population. Laying dates, estimated in ten day periods, were 21-31 March (*n=3*) and 1-10 May (*n=2*). Mean productivity (0.86) was lower than that estimated by some authors for stable populations. Human activities such as recreational sailing, trekking or camping near the nests could limit the establishment of new pairs and cause low productivity.

Estatuto populacional, reprodução e conservação da Águia-pesqueira *Pandion haliaetus* nas ilhas de La Gomera e El Hierro, Canárias (2003-2004). Estimou-se a população reprodutora e estudaram-se alguns parâmetros reprodutores da Águia-pesqueira *Pandion haliaetus* nas ilhas de La Gomera e El Hierro (arquipélago das Canárias) em 2003 e 2004. Todos os ninhos activos na parte sul de cada uma das ilhas foram observados. Detectaram-se cinco casais com comportamento territorial em La Gomera e um casal em El Hierro, ilhas onde se encontraram três e um ninho, respectivamente. A Águia-pesqueira nestas duas ilhas representa cerca de 30% da população total do arquipélago das Canárias e 16-17% do número de efeitos em Espanha. As postura, avaliadas em períodos de 10 dias, ocorreram entre 21-31 de Março (*n=3*) e 1-10 Maio (*n=2*). A productividade (0,86 crias/casal onde ocorreu postura) foi mais baixa do que os valores apresentados por alguns autores para populações estáveis. As actividades humanas tais como rela de recreio, caminhadas ou campismo em áreas junto aos ninhos poderão limitar o estabelecimento de novos casais e diminuir a produtividade.
Overall, very little information has been published on the biology of Osprey in the Canaries (cf. Martín & Lorenzo 2001). Up to now, studies conducted at La Gomera and El Hierro involved only extensive censuses, that were also carried out in the whole Canarian Archipelago (Díaz et al. 1986, Hernández et al. 1987, Delgado et al. 1988, González et al. 1992). According to these censuses, the species maintained three breeding pairs in both islands during the period 1983-1991. Recently, Martín & Lorenzo (2001) estimated five pairs in each island. Little information is available on its breeding biology; available data refers mainly to isolated observations of non-fledged chicks in their nests.

In the present paper, we present new information on breeding numbers and reproduction (especially productivity) of Osprey in La Gomera and El Hierro. Threats that could affect the population status and breeding success are assessed.

STUDY AREA AND METHODS

The Canary Islands are a volcanic archipelago that is located 100 km off the north-west African coast (27°37’-29°25’N and 13°20’-18°19’W) and is comprised of seven major islands and several small islets and rocks. The islands of La Gomera and El Hierro are situated in the south-west of the Canarian Archipelago (Figure 1), and are the smallest (370 and 269 km², respectively). Their coastlines are predominantly rocky with boulder shore, and cliffs up to 300 m high. Sea conditions are usually good throughout the year in the sheltered coast sectors, mainly with southern or western orientations. Human settlements are scattered along the coast, and a total of five major ports are present in these islands. Around 33% and 58% of the territory of La Gomera and El Hierro, respectively, are protected by Canarian laws and the south-west marine sector of El Hierro (Mar de Las Calmas) has been declared a marine reserve by the Canarian government.

Osprey populations in La Gomera and El Hierro were studied during the breeding seasons of 2003 and 2004 by three to four researchers. In the first year, one visit was made to each island (during the fledging period); La Gomera was surveyed at the end of June (4 days) and El Hierro at the beginning of the same month (4 days). During 2004, several visits (during the mating, incubation and fledging periods) were made to both islands from February to August (23 and 17 days to La Gomera and El Hierro, respectively).

In both islands and years, all known territories and recognizable nests (Delgado et al. 1988, González et al. 1992, Martín & Lorenzo 2001) were inspected and the remaining potential nesting areas were searched carefully for new pairs. Coastal transects by boat and observation from vantage points were carried out, using binoculars and

![Figure 1. Map of the Canary Islands and the position (in black) of La Gomera and El Hierro.](image-url)
telescopes. To avoid disturbance, all observations were made more than 150 meters away from nests.

Each nest was categorized according to Van Daele & Van Daele (1982): active (defended by adults and containing eggs), occupied (defended but no egg laying) or inactive (no adults in the surrounding and no new nesting material). The egg laying dates (estimated in ten day periods) in successful pairs were obtained from the chick estimated ages, using 38 days as incubation period (Triay 1995) and 53-54 days as nestling period (Stotts & Henny 1975, Bustamante 1995). Furthermore, the number of fledged young per active pair (with clutch), breeding success (percentage of pairs with young) and fledging rate (number of fledged young per successful pair) were calculated (Thibault et al. 2001, Triay 1995).

RESULTS AND DISCUSSION

Nests
A total of ten nests, at different stages of preservation, were located on sea cliffs around La Gomera, one in the north coast and the rest in the south. Occupied (n=1) and active (n=4) nests were concentrated in 7.64 km (lineal distance) of the south coast. Mean distance between nests of both categories was 1,910 m (range 1,100-3,080 m). In El Hierro, we located seven nests on coastal cliffs (two of them were very deteriorated, consisting only of some branches). None of them presented signs of occupation during 2003, while in the following year one was active in the southern sector.

In 1991, González et al. (1992) counted eight nest structures in La Gomera (three on the north coast and five on the south) and four in El Hierro. Presumably some nests went unnoticed by these authors and also by us, due to their bad state of conservation; however, it is possible that two nests were built on each island during the period 1992-2002. In Tenerife, only one new nest has been build during the last fifteen years and the nests/pair ratio was 2.2 in 2003 (Siverio 2003).

Although a similar degree of human activity seems to occur on both the north and south coasts of La Gomera, breeding pairs occupied preferentially the southern coast, where sea conditions are usually good during all seasons, and foraging activities are more successful (Grubbs 1977). In fact, the three active nests detected in La Gomera in 1991 were also located in this coastal sector (González et al. 1992).

Population status
As shown in Table 1, notable differences in number of breeding pairs exist between the two island. Two new pairs were counted in La Gomera, while in El Hierro, two pairs apparently disappeared since previous censuses, which mentioned three pairs in 1983, 1984, 1987 and 1991 in both islands (see González et al. 1992). However, our data agrees with estimates made by Martín & Lorenzo (2001) in the case of La Gomera but not in El Hierro (4-5 pairs according to these authors). The current breeding individuals of La Gomera and El Hierro represents 30% and 16-17% of the entire Canarian and Spanish populations, respectively (Triay et al. 2004).

Due to the philopatric behaviour of the species (Poole 1989a, Thibault et al. 2001), it is supposed that the fledging rate of previous years (M. Siverio pers. obs.) has contributed to stability and increase in breeding numbers at La Gomera. It is known that distance between hatching and breeding sites of the majority of individuals (mainly males) of some migratory populations is lower than 50 km (Poole 1989a). The same behaviour has been observed in the resident osprey population in Corsica (West Mediterranean), where median distance between natal and breeding sites of both sexes is around 15 km (Thibault et al. 2001). Distances between La Gomera and Tenerife (around 29 km), and between La Gomera and El Hierro (61 km), could influence the
interbreeding rates of Ospreys between those islands, the rate being higher within closer islands. A similar situation was suggested by Ferreira et al. (1999) for the Cape Verde Archipelago, where the southern and peripheral Sotavento (leeward) group of islands (more dispersed) show a decrease in breeding numbers, which may depend on immigration from the Barlavento (windward) clustered group, with stable or locally increasing numbers.

Reproduction
During the two years a total of seven active pairs were counted, six in La Gomera (three per year) and one in El Hierro. Laying dates of successful pairs (n=5) were: three during 21-31 March and two during 1-10 May. Mean productivity (young fledged/laying pair) and mean fledging rate (fledged young.isSuccessful pair) for each year and island are presented in Table 1. In La Gomera average productivity and fledging rate in both years were 0.83 and 1.25 (n=4), respectively; values of these parameters for the two islands were 0.86 and 1.20 (n=5), respectively.

Table 1. Number of territorial pairs, active pairs (with clutch) and some breeding parameters of Osprey (Pandion haliaetus) in La Gomera and El Hierro (Canary Islands) during 2003-2004. / Tabela 1. Número de casais de Águia-pesqueira (Pandion haliaetus) com comportamento territorial e com ninho, e parâmetros reprodutores destes casais em La Gomera e el Hierro, ilhas Canárias em 2003-2004.

<table>
<thead>
<tr>
<th></th>
<th>La Gomera</th>
<th></th>
<th>El Hierro</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Territorial pairs</td>
<td>4</td>
<td>5</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Active pairs</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Fledged young</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Mean productivity</td>
<td>1</td>
<td>0.66</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Breeding success</td>
<td>50</td>
<td>40</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Fledging rate</td>
<td>1.5</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Previously, laying dates in the Canary Islands were registered in the first fortnight of April (González et al. 1992, Siverio & Siverio 1997, Siverio 2003). Therefore, laying dates in this archipelago range from the first fortnight of February to the first fortnight of May. Overall, pairs in their first or second year of reproduction lay later (Triay 1995, Siverio 2003), but it is impossible to know if this is the case at La Gomera and El Hierro, because birds were not individually marked (Bretagnolle et al. 1994).

Mean productivity at La Gomera (0.83) was very low when compared to other nearby sedentary populations: 1.32 in Tenerife (Siverio 2003), 1.30 in Minorca, West Mediterranean (Triay 2002) or 1.43 in Corsica, West Mediterranean (Thibault & Bretagnolle 2001). Some studies (based on mortality and production) carried out in the United States suggest that the mean productivity needed to maintain a stable population must be 0.8 (Poole 1989b) or between 0.95 and 1.30 (Henny & Wight 1969) fledged young per active pair.

In our study area, low productivity coupled with a probable high adult mortality rate will surely influence population stability. However, depending on the immigration rate from other islands (with stable productivity), this situation might improve. However, in Tenerife (the nearest island to La Gomera), high productivity (>1.5) during recent years has decreased to 0.5 in 2003 (Siverio 2003). In Minorca, decreasing productivity is correlated with a reduction in the number of pairs (Triay 2002, Triay et al. 2004). It is probable that productivity in La Gomera during recent years has been higher than that observed in the present study. For example, if we consider that all young observed by González et al. (1992) in this island had fledged, mean productivity would have been 2.0 (active pairs, n=3).

Threats and conservation
Conservation problems in the islands studied seem to be related with different human activities. In La Gomera, camping and recreational sailing probably caused the loss of one breeding pair in 1999 (M. Siverio pers. obs.). Habitat (nesting cliff tops) modification or destruction could seriously affect the population. In fact, in La Gomera, one pair abandoned its eyrie while an airport was being
constructed during the 1990s. When it was finished, one pair occupied the area again but recent tourist development in its proximities caused the disappearance of the birds. Other activities potentially negative for Ospreys detected in the eyries’ surroundings are sport fishing and wildlife photography. In the vicinity of two nests in El Hierro, one of them occupied at least until 2000 (de la Puente et al. 2003) and the other until 2002 (F. Siverio & P. Felipe pers. comm.), sightseeing tracks were obvious.

Studies carried out in other populations in the United States (Ames & Mersereau 1964, Swenson 1979, Van Dale & Van Dale 1982, Levenson & Koplin 1984), Europe (Odsjö & Sondell 2001, Thibault et al. 2001) and even Tenerife (Triay et al. 2004) have demonstrated that these activities are important negative factors for the breeding success of Ospreys. It has been speculated that repeated human presence during the incubation or the early chick rearing periods keep birds off their nests. Such presence is related to low egg hatchability, due to the overheating of eggs and subsequent embryonic death, or low nestling survival (Swenson 1979, Van Dale & Van Dale 1982, Levenson & Koplin 1984). Furthermore, in these situations potential predation of eggs and chicks by the Yellow-legged Gull _Larus cachinnans_ (common breeder in the studied area) may occur.

Action is needed to reduce the negative impact of the aforementioned activities. Firstly, an annual monitoring plan of the breeding population and the identification of particular threats to each eyrie is very important to take precise conservation measures. During the breeding season, nest and perch surroundings must be restricted to sailing and anchoring. Approximately 150 m are recommended by Rodgers & Schwikert (2002) as the minimum buffer-zone to prevent Osprey flushing caused by vessels and personal watercraft in the foraging and feeding areas of the west coast of Florida. Although no precise studies have been made of the Canaries, we tentatively propose a buffer-zone of more than 200 m for breeding territories and nests. Furthermore, activities such as camping, abseiling or trekking in the proximities of nests must be prohibited, because it has caused the loss of active nests and the low productivity in eyries less than one km apart (Swenson 1979). Finally, information on natal philopatry and mortality, based on a ringing program of young birds would be very useful for Osprey conservation in the Canary Islands.

**Acknowledgements:** Some visits to La Gomera and El Hierro were supported by the SEO/BirdLife and ICIAC, S.L. We are in dept to Francisco M. González and David Acuña for the loan of their boats, which allowed us to conduct the coastal transects of La Gomera and El Hierro, respectively. Special thanks also to Felipe Siverio, Airam Rodríguez and Alejandro Padrón (and his family) for their help during part of the fieldwork. In La Gomera, Juana María Darias (Cabildo Insular de La Gomera) facilitated our visits to this island and, Juan González and Longino Lima (Vicarconsejería de Pesca del Gobierno de Canarias) help us very much during sea prospectons in 2003 in El Hierro. The location map was produced by Jesús Alonso and valuable comments and corrections on the earlier draft of this manuscript were given by Felipe Siverio, Rubén Barone and two anonymous referees.

**REFERENCES**


In Spain, Bluethroats, *Luscinia svecica*, maintain an isolated glacial relict population with two breeding main areas: the Galician-Cantabrian mountains and the mountains of the Central System (Gómez-Manzaneque 2003), which are separated from one another by approximately 250km. Within each area, the populations are fragmented as a result of the unequal distribution of the habitat preferred by the species for breeding, which consists of dense thickets of *Cytisus* spp. (Peris 1982, Domínguez & Fernández-Cordeiro 1991). At the centre of the Iberian Peninsula, the main breeding populations are found in the Sierra de Guadarrama (Gómez-Manzaneque 1989), Sierra de Gredos (Sánchez 1989), and Sierra de Béjar (Peris 1984), with sporadic episodes of breeding also observed in the Portuguese Serra da Estrela (Peris 1981, Jansen 1994).

To date, Spanish Bluethroats have been included within the subspecies *L.s. cyanecula* (Tellería et al. 1999), although Mayaud (1958) recommended that *L.s. azuricollis* should be considered a valid subspecies for Spanish Bluethroats, based on plumage characteristics (absence of a white spot on the throat).

The biometry of the birds breeding in the northeast of the Cantabrian mountains has been analysed by García et al. (2000). Regarding the Central System, data have been published concerning eight birds captured in the Sierra de Gredos and conserved as skins at the British Museum of Natural History (Cramp 1988). Information on live birds is not available.

Here we report the first field data on the biometry of Bluethroats from the centre of the Iberian Peninsula, as a contribution to clarify its sub-specific status, determinate possible differences between sex/age classes and compare with other populations from Iberia and Europe.

Between May and July 2003 and 2004, 67 breeding Bluethroats (56 males, 11 females) were captured using iron traps and vocal lures. The captures were made in localities belonging to the Spanish Central mountains: the Sierra de Béjar (40°21’N 5°41’W, province of Salamanca) and the Sierra de Piedrahita (40°25’N 5°17’W, province of Avila) at altitudes between 1750-1950m a.s.l. Both areas have a dense cover of thickets (*Cytisus oromediterraneus*), reaching heights of 50-100 cm, within patches of pasture, with *Agrostis* and *Nardus* as predominant genera.

For each specimen, the following measurements were taken, after Svensson (1992): 1) Wing-length (maximum chord), third primary-length, tail-length and total body-length (from the tip of the bill to the end of the tail), all with a ruler with a precision of 0.5mm; 2) bill-length to the feathers and tarsus-length, with a 0.1mm precision callipers. The males were divided by age according to the criteria of Svensson (1992) and Jenni & Winkler (1994) into first-year birds (age 5, Euring code) or adults (age 6).

The data was checked for normality and homogeneity of variances. A t-test was used to check for possible differences between sexes.
Differences in wing-length and tarsus-length between the populations studied and those from the north of the Peninsula, taken from García et al. (2000), were assessed also with t-tests. In order to assess the effect of age and presence/absence of a white spot in body measurements (using length of wing, tail, bill, tarsus and total body as response variables), a General Lineal Model (GLM) was carried out. All the biometric values are presented as means ± SD.

In the study area, the males were significantly greater than the females in length of wing, third primary, tail, total body and tarsus, but not in bill-length (Table 1). Only 26 (46.4%) of the total captured males (56) had a white spot on the throat. Its measurements are presented in Table 2. The GLM indicated only a significant effect of age on body measurements (white-spot: Wilks $\lambda=0.84$, $P=0.25$, age: Wilks $\lambda=0.56$, $P=0.001$, interaction term: Wilks $\lambda=0.95$, $P=0.83$). Wing-length ($F_{1,41}=11.3$, $P=0.002$) and tail-length ($F_{1,41}=27.48$, $P=0.000$) were significantly different between first-year birds and adults. When comparing male Bluethroats between northern Spain (García et al. 2000) and central Spain (own data), no significant differences were observed in wing-length or in tarsus-length (Table 3). Neither were significant differences observed in wing-length between first-year males ($t=0.728$, $P>0.05$, power=0.110), nor between adult males ($t=2.006$, $P>0.05$, power=0.492) of each population. The same occurred for tarsus-length ($t=0.284$ and $t=0.626$, both $P>0.05$, power=0.059 and 0.075 for first-year and adult males, respectively).

When comparing the values obtained in the present study with those reported for male Bluethroats from Holland, the wing-length was similar, but tarsus-length and tail-length were greater in the Spanish birds (Table 3).

As is the case of many passerine species, male Bluethroats from the Central System in Spain are larger than females, although the overlap of certain measurements was high. Adult males were larger than juvenile males in the length of the wing, third primary, total body and tail, but not in the length of tarsus and bill. Male birds with or without a white spot on the throat, were similar in biometric measurements, both for first-year individuals and adult males.

According to this data, breeding populations of Bluethroats are biometrically similar within the Iberian Peninsula, despite the different plumage patterns (presence or absence of a white spot). The greater wing-length measured on skinned specimens from the Sierra de Gredos (Cramp 1988) should be interpreted with caution, since normally skins shrink and the data were not subjected to correction factors. These aspects should be taken in post-mortem measurements (Peris 1994).

Mayaud (1958) considered the validity of *azuricollis* as a different subspecies for Iberian birds based only on the absence of white spot on the throat, although only 53.6% of the hereby studied males complian with the pattern. In a polytypic

<table>
<thead>
<tr>
<th>Variable</th>
<th>Male</th>
<th>Female</th>
<th>Test</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wing-length</td>
<td>75.6 ± 1.8</td>
<td>71.1 ± 2.3</td>
<td>$t=7.2$</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(72.0-79.5; 56)</td>
<td>(67.5-75.0; 11)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Third primary-length</td>
<td>58.5 ± 1.5</td>
<td>55.5 ± 1.8</td>
<td>$t=6.0$</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(55.0-62.5; 56)</td>
<td>(53.0-58.0; 11)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tail-length</td>
<td>57.8 ± 2.0</td>
<td>55.1 ± 2.2</td>
<td>$t=4.0$</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(53.5-61.0; 55)</td>
<td>(53.0-58.5; 11)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total body-length</td>
<td>147.8 ± 5.2</td>
<td>140.2 ± 6.4</td>
<td>$t=4.1$</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(139.0-160.0; 47)</td>
<td>(134.5-152.0; 10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bill-length</td>
<td>12.6 ± 0.6</td>
<td>12.4 ± 0.5</td>
<td>$t=1.0$</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td>(11.05-13.61; 55)</td>
<td>(11.50-13.07; 11)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tarsus-length</td>
<td>27.0 ± 0.8</td>
<td>26.4 ± 0.5</td>
<td>$t=2.7$</td>
<td>0.010</td>
</tr>
<tr>
<td></td>
<td>(22.51-29.10; 56)</td>
<td>(25.27-26.90; 11)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
species such as *L. svecica*, the subspecific taxonomy and body measurements do not always agree. In fact, our biometric data do not support such distinction, but they do not rule out either; for instance Iberian populations are biometrically similar to those of central Europe (Netherlands-Germany) only in one measurement.

Zink *et al.* (2003) did not find a correspondence between mtDNA differentiation and subspecies, although they did find some geographic differentiation between northern and southern European populations. Nevertheless, Zink *et al.* (2003) only analysed one specimen of Iberian Bluethroat (from the Sierra de Guadarrama, also in

---

**Table 2.** Means (± SD) of biometric variables taken in male Bluethroats from Central Spain, according to age (first-year, adult). In brackets: range of values and sample size. / **Tabela 2.** Médias (± desvio padrão) de variáveis biométricas de Picos-de peito-azul machos com um ano e adultos, capturados no centro de Espanha. Entre parêntesis indica-se a amplitude dos dados e o tamanho da amostra.

<table>
<thead>
<tr>
<th></th>
<th>Without white spot</th>
<th>With white spot</th>
<th>All males</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First-year</td>
<td>Adult</td>
<td>First-year</td>
</tr>
<tr>
<td>Wing-length</td>
<td>75.3 ± 1.7 (72.5-78.5; 15)</td>
<td>77.0 ± 1.6 (74.0-79.5; 15)</td>
<td>74.5 ± 1.4 (72.0-77.5; 19)</td>
</tr>
<tr>
<td>3rd primary-length</td>
<td>57.9 ± 1.3 (55.0-59.5; 15)</td>
<td>59.9 ± 1.3 (57.5-62.5; 15)</td>
<td>57.7 ± 1.0 (56.0-59.0; 19)</td>
</tr>
<tr>
<td>Tail-length</td>
<td>56.6 ± 1.7 (53.5-59.5; 15)</td>
<td>59.7 ± 0.9 (58.0-61.0; 14)</td>
<td>56.8 ± 1.9 (53.5-60.0; 19)</td>
</tr>
<tr>
<td>T.body-length</td>
<td>147.9 ± 5.4 (141.0-157.0; 13)</td>
<td>150.4 ± 5.0 (142.0-160.0; 10)</td>
<td>146.5± 4.8 (139.0-155.0; 17)</td>
</tr>
<tr>
<td>Bill-length</td>
<td>12.4 ± 0.6 (11.45-13.52; 15)</td>
<td>12.4 ± 0.7 (11.05-13.43; 15)</td>
<td>12.7± 0.5 (11.90-13.37; 19)</td>
</tr>
<tr>
<td>Tarsus-length</td>
<td>27.1 ± 0.7 (25.51-28.00; 15)</td>
<td>26.9 ± 0.8 (25.55-28.32; 15)</td>
<td>27.0 ± 0.7 (25.76-29.00; 19)</td>
</tr>
</tbody>
</table>

---

**Table 3.** Comparison of wing-length, tarsus-length and tail-length (Mean ± SD) of male Bluethroats from several breeding areas. Comparisons made with t-tests from cited references and own data. In brackets, sample size. Values in mm. P = probability. / **Tabela 3.** Comparação do comprimento da asa, tarso e cauda (média ± desvio padrão) de machos de Pisco-de-peito-azul entre várias áreas de nidificação. As comparações foram efectuadas com teste t a partir das referências citadas e deste estudo. Entre parêntesis indica-se o tamanho da amostra. Os valores são em mm. P = Probabilidade.

<table>
<thead>
<tr>
<th>Country</th>
<th>Wing-length</th>
<th>Tarsus-length</th>
<th>Tail-length</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Netherlands</td>
<td>75.4 ± 1.4 (17)</td>
<td>26.6 ± 0.9 (49)</td>
<td>54.0 ± 1.8 (15)</td>
<td>Cramp (1988)</td>
</tr>
<tr>
<td></td>
<td>t=0.41; P=0.680</td>
<td>t=-2.56; P=0.012</td>
<td>t=6.57; P=0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Power=0.069</td>
<td>Power=0.718</td>
<td>Power=1.000</td>
<td></td>
</tr>
<tr>
<td>Northern Spain (Cantabrian Mountains)</td>
<td>75.2 ± 1.6 (81)</td>
<td>27.0 ± 0.8 (81)</td>
<td>54.0 ± 1.8 (15)</td>
<td>García <em>et al.</em> (2000)</td>
</tr>
<tr>
<td></td>
<td>t=-1.36; P=0.177</td>
<td>t=-0.15; P=0.885</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Power=0.268</td>
<td>Power=0.052</td>
<td>Power=0.52</td>
<td></td>
</tr>
<tr>
<td>Central Spain (Gredos Mountains)</td>
<td>78.4 ± 1.9 (8)</td>
<td>27.3 ± 0.7 (8)</td>
<td>57.76 ± 2.01 (56)</td>
<td>Cramp (1988)</td>
</tr>
<tr>
<td></td>
<td>t=-4.03; P=0.001</td>
<td>t=-0.96; P=0.341</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Power=0.977</td>
<td>Power=0.154</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central Spain (Béjar Mountains)</td>
<td>75.60 ± 1.83 (56)</td>
<td>27.02 ± 0.78 (56)</td>
<td>57.76 ± 2.01 (56)</td>
<td>This study</td>
</tr>
</tbody>
</table>

the Central mountains). Central European birds - classified as *L.s. cyanecula* (Cramp 1988), and whose individuals pass the winter in the south and southwest of the Iberian Peninsula (Hernández et al. 2003), might contact with Iberian birds at their wintering grounds. However, there is no information on the wintering areas of Iberian birds. Therefore, and according to the data available, the validity of the subspecies *azuricollis* remains unclear.

**Acknowledgements:** To the “Memoria D. Manuel Solórzano Barruso” Foundation for contributing financial help to one of the co-authors. (S.J. Peris). Field work complies with the current Spanish laws on ringing. Ms. was improved by comments of J.M. Neto and an anonymous reviewer.

**RESUMO**

Apresentam-se as biometrias de Pisco-de peito-azul *Luscinia svecica* a nidificar no centro de Espanha (67 indivíduos: 56 machos e 11 fêmeas). Os machos apresentaram o comprimento da asa, da terceira primária, da cauda, do tarso e do corpo significativamente superiores aos das fêmeas. Apenas o comprimento do bico não diferiu significativamente entre sexos. Os machos de um ano apresentaram comprimentos de asa e de corpo significativamente inferiores aos dos adultos, mas não diferiram no comprimento do tarso e do corpo. Não se encontraram diferenças significativas no comprimento da asa e do tarso entre os machos de áreas montanhosas do Centro e do Norte de Espanha. Os dados não permitem uma distinção subspecífica de grupos de Pisco-de-peito azul que nidificam na Península Ibérica.

**REFERENCES**


ERRATA

Por lapso o último volume do AIRO foi publicado com algumas incorrecções nos artigos que se seguem, corrigindo-se desta forma a figura e a tabela que se encontravam erradas. Pelo facto pedimos desculpa aos autores e aos leitores. / In the last volume of AIRO the following articles had errors in a figure and in a table, which are corrected below. For this fact we apologise to the authors and our readers.


Registros de nidificação de Alfaia *Recurvirostra avosetta* em Portugal (revisão bibliográfica). / *Table 1. Avocet (Recurvirostra avosetta) breeding records in Portugal (literature).*

<table>
<thead>
<tr>
<th>Local</th>
<th>Ano</th>
<th>Habitat</th>
<th>N...casais</th>
<th>Fonte</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mira</td>
<td>1920-1930</td>
<td>dunas</td>
<td>?</td>
<td>Coverley (sem data)</td>
</tr>
<tr>
<td>Lagoas de Mira</td>
<td>1920-1930</td>
<td>dunas</td>
<td>?</td>
<td>Tait (1924)</td>
</tr>
<tr>
<td>Castro Marim</td>
<td>1920-1930</td>
<td>salinas</td>
<td>?</td>
<td>Coverley (sem data)</td>
</tr>
<tr>
<td>Castro Marim</td>
<td>1979</td>
<td>salinas</td>
<td>15</td>
<td>Rufino et al. (1980)</td>
</tr>
<tr>
<td>Castro Marim</td>
<td>1980</td>
<td>salinas</td>
<td>50</td>
<td>P. Monteiro &amp; A. Severo (com.pess.)</td>
</tr>
<tr>
<td>Castro Marim</td>
<td>1991</td>
<td>salinas</td>
<td>136</td>
<td>P. Monteiro &amp; A. Severo (com.pess.)</td>
</tr>
<tr>
<td>Castro Marim</td>
<td>1992</td>
<td>salinas</td>
<td>61</td>
<td>P. Monteiro &amp; A. Severo (com.pess.)</td>
</tr>
<tr>
<td>Castro Marim</td>
<td>1993</td>
<td>salinas</td>
<td>30</td>
<td>P. Monteiro &amp; A. Severo (com.pess.)</td>
</tr>
<tr>
<td>Castro Marim</td>
<td>1994</td>
<td>salinas</td>
<td>63</td>
<td>P. Monteiro &amp; A. Severo (com.pess.)</td>
</tr>
<tr>
<td>Castro Marim</td>
<td>2001</td>
<td>salinas</td>
<td>121-198</td>
<td>Catry (2001)</td>
</tr>
<tr>
<td>Santa Luzia</td>
<td>1979</td>
<td>salinas</td>
<td>30-40</td>
<td>Rufino et al. (1980)</td>
</tr>
<tr>
<td>Vale caranguejo</td>
<td>1980</td>
<td>salinas</td>
<td>5-10</td>
<td>Rufino et al. (1980)</td>
</tr>
<tr>
<td>Vale caranguejo</td>
<td>2002</td>
<td>salinas</td>
<td>161-176</td>
<td>Este estudo</td>
</tr>
<tr>
<td>Arraial Ferreira Neto</td>
<td>2002</td>
<td>salinas</td>
<td>20-28</td>
<td>Este estudo</td>
</tr>
<tr>
<td>Quatro Águas</td>
<td>2002</td>
<td>salinas</td>
<td>15-18</td>
<td>Este estudo</td>
</tr>
<tr>
<td>Fuzeta</td>
<td>2002</td>
<td>salinas</td>
<td>17</td>
<td>Este estudo</td>
</tr>
<tr>
<td>Fuzeta</td>
<td>2000</td>
<td>salinas</td>
<td>5</td>
<td>Este estudo</td>
</tr>
<tr>
<td>Estuário do Sado</td>
<td>1993</td>
<td>salinas</td>
<td>1</td>
<td>Luís Costa (com.pess.)</td>
</tr>
<tr>
<td>Estuário do Tejo</td>
<td>1993</td>
<td>salinas</td>
<td>1-2</td>
<td>Leitão et al. (1998)</td>
</tr>
<tr>
<td>Estuário do Tejo</td>
<td>1996</td>
<td>salinas</td>
<td>1-2</td>
<td>Leitão et al. (1998)</td>
</tr>
<tr>
<td>Estuário do Tejo</td>
<td>1998</td>
<td>salinas</td>
<td>1</td>
<td>L.Gordinho (com.pess.)</td>
</tr>
<tr>
<td>Estuário do Tejo</td>
<td>2000</td>
<td>salinas</td>
<td>2</td>
<td>Este estudo</td>
</tr>
<tr>
<td>Estuário do Tejo</td>
<td>2001</td>
<td>salinas</td>
<td>2</td>
<td>Este estudo</td>
</tr>
<tr>
<td>Estuário do Arade</td>
<td>1991</td>
<td>sapal</td>
<td>?</td>
<td>G. Vowles</td>
</tr>
<tr>
<td>Estuário do Arade</td>
<td>1998</td>
<td>sapal</td>
<td>?</td>
<td>N. Fonseca (com.pess.)</td>
</tr>
<tr>
<td>Maromba</td>
<td>1991</td>
<td>sapal</td>
<td>?</td>
<td>G. Vowles</td>
</tr>
<tr>
<td>ETAR</td>
<td>1998</td>
<td>sapal</td>
<td>?</td>
<td>N. Fonseca (com.pess.)</td>
</tr>
<tr>
<td>Faro</td>
<td>2002</td>
<td>salinas</td>
<td>?</td>
<td>M. Mendes &amp; J. Ministro (com.pess.)</td>
</tr>
<tr>
<td>Faro</td>
<td>2003</td>
<td>salinas</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Albufeira</td>
<td>2003</td>
<td>lagoa costeira</td>
<td>3</td>
<td>J.Ministro (com.pess.)</td>
</tr>
<tr>
<td>Albufeira</td>
<td>2003</td>
<td>lagoa costeira</td>
<td>5</td>
<td>Este estudo</td>
</tr>
</tbody>
</table>