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# How important are seabirds in the diet of black rats on islands with a superpredator?

Sandra Hervías[a,c,d,*], Filipe R. Ceia[b], Tânia Pipa[d], Manuel Nogales[c], Rocío Ruiz de Ybáñez[a], Jaime A. Ramos[b]

[a] Animal Health Department, Veterinary Faculty, Regional Campus of International Excellence "Campus Mare Nostrum", University of Murcia, 30100 Espinardo, Murcia, Spain
[b] Marine and Environmental Research Center (IMAR/CMA), Department of Life Sciences, University of Coimbra, Apartado 3046, 3001-401 Coimbra, Portugal
[c] Island Ecology and Evolution Research Group (IPNA-CSIC), Astrofísico Francisco Sánchez 3, 38206 La Laguna, Tenerife, Canary Islands, Spain
[d] Portuguese Society for the Study of Birds, Avenida João Crisóstomo, 18-4° Dto, 1000-179 Lisboa, Portugal

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ABSTRACT

This study assessed the impact of introduced black rats (*Rattus rattus*) on Cory's shearwater (*Calonectris diomedea borealis*) in a multi-invaded insular ecosystem where rats are mesopredators. We hypothesized that black rats should have little impact on Cory's shearwaters in the presence of cats as superpredators. Stomach contents and stable isotope analysis (SIA) in tissues of black rats were analyzed to assess the trophic ecology and the importance of Cory's shearwater in their diet. We also studied the isotopic signature in tissues of house mouse (*Mus domesticus*) to confirm previous data showing no predation of this species on Cory's shearwaters. For both rodent species, temporal variation in diet composition in response to the availability of seabird prey was evaluated, and short- and long-term consistency in diet was tested using different tissues from the same individual. For black rats a Bayesian isotope mixing model (SIAR) was applied to determine the relative contribution of each prey to the individual diet. SIA of mouse tissues varied between the Cory's shearwater breeding and non-breeding periods. However, no significant differences were found in diet and SIA for black rats. In contrast, individuals of both species showed a strong consistency in diet which apparently benefited their body condition index. Although black rats supplement their diet with Cory's shearwater eggs and chicks (8.3% in stomach contents and 10.6% in the SIAR model), their current impact on the Cory's shearwater population appears to be small, probably due to several factors including the small size of the rat population and a high level of rat predation by cats.


## 1. Introduction

Despite considerable evidence for a strong negative effect of introduced rodents on island seabirds (Ruffino et al., 2009; Brooke et al., 2010), the assessment of prey selection and impact caused by rodents is often difficult to measure (Major et al., 2006). Understanding the feeding behaviour of rodents and their trophic interactions with other exotic mammals on islands is the first step in the design of conservation plans (Jones et al., 2008).

Among seabirds, procellariiform species are strongly affected by invasive rodent species, e.g., rats, throughout the world (Atkinson, 1985; Jones et al., 2008; Towns et al., 2009). However, the impact of rodents on seabirds can be more complex when they are preyed upon by other introduced vertebrates (Rayner et al., 2007). Research on the effects of multiple invasive mammals on island fauna has increased over the last decade (Cuthbert, 2002; Bonnaud et al., 2010; Hervías et al., 2013a), because several predator species may produce different effects on prey populations from what might be expected for each predator species individually (see Ritchie and Johnson, 2009 for review). For example, cats (*Felis silvestris catus*) and black rats (*Rattus rattus*) are well known as predators of seabirds (Igual et al., 2006; Medina et al., 2011) and coexist in many insular systems (Jeschke and Genovesi, 2008) where cats (superpredators) may moderate the impact of rodents (mesopredators) on seabirds (Rayner et al., 2007; Russell et al., 2009).

Rodents have generalist and opportunistic foraging strategies, modifying their diet in relation to prey availability (Ruffino et al., 2011). This results in strongly fluctuating impacts on alternative resources, as occurs during the breeding period of seabirds

* Corresponding author at: Animal Health Department, Veterinary Faculty, Regional Campus of International Excellence "Campus Mare Nostrum", University of Murcia, 30100 Espinardo, Murcia, Spain. Tel.: +34 868884719; fax: +34 868884147.
*E-mail address:* shparejo@gmail.com (S. Hervías).

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(Atkinson, 1985), when rodents may obtain higher nutritional values from their consumption than from terrestrial prey items (Drever and Harestad, 1998). Previous studies have used stable isotope analyses (SIA) to evaluate the importance of seabirds in the diet of rodents, but mostly in relatively simple ecosystems with rodents as the sole predator of seabirds (Stapp, 2002; Caut et al., 2008; Pisanu et al., 2011).

Superpredators can influence mesopredator behaviour by killing them or instilling fear, which limits their distribution and abundance (Ritchie and Johnson, 2009; Russell et al., 2011). In the present study, we therefore took into account the possible influence of cats on the feeding behaviour of the rats. Our goal was to evaluate the impact of black rats as mesopredators of Cory's shearwaters (*Calonectris diomedea borealis*) in a multi-invaded insular ecosystem where cats play the role of top predators. Moreover, we assessed the isotopic signature in tissues of house mouse (*Mus domesticus*) to confirm previous data showing no predation of this species on Cory's shearwaters using infrared-triggered camera traps (Trophy Cam 8MP; Bushnell, Overland Park, KS, USA) (Hervías et al., 2013a). The diet of black rats and the isotopic signature of black rat and house mouse tissues were studied over a whole year to identify differences between seabird breeding and non-breeding periods. Rat stomach contents were analyzed and simultaneously SIA (representing digested food) was performed for multiple tissues with different turnover rates to measure changes in diet and consistency (diet overlap) within and among individuals (Araújo et al., 2007). Although rats and cats can compete partially for seabirds, the latter are more effective seabird predators (Moors and Atkinson, 1984). Consequently, black rats were expected to have less impact on Cory's shearwaters. If individuals of the two rodent species do not shift their diet in relation to the availability of Cory's shearwater, resulting in the exploration of different resources which could be consistent over time, there may be advantages for more consistent individuals, such as better body condition (Votier et al., 2010; Ceia et al., 2012). We hypothesized that individuals more consistent in their diet should have better body condition than those exploring less consistent food resources over time. Specifically, we asked whether (i) diet and isotopic signature of rodents change between the breeding and non-breeding periods of Cory's shearwater, (ii) individual dietary differences are consistent within short- and long-term periods, and (iii) consistency in diet benefits body condition.

## 2. Materials and methods

### 2.1. Study site

The study site was *Pão de Açúcar* (39°40′36″ N, 31°06′ 57″ W) on Corvo (Azores, North Atlantic Ocean), above 100 m elevation and at 500 m distance from the only human settlement. Corvo is a small oceanic island (17 $km^2$; 0–718 m a.s.l.), mostly covered by pastures and surrounded by steep cliffs (>200 m in height). No native mammals are present but there are three introduced mammalian species: house mice, black rats and cats. Only the two latter are known to prey upon Cory's shearwaters (Hervías et al., 2013a). In 2011, cat density estimated in the study area was 0.734 (0.581–0.927) individuals/ha (Oppel et al., 2012).

The estimated population of Cory's shearwater in the Azores is 188,000 pairs (65–70% of the European population; BirdLife International, 2004). Specifically, Corvo has the highest density of Cory's shearwater in the archipelago (Furness et al., 2000) and provides a nesting habitat for a total of six seabird species (Groz et al., 2005). Cory's shearwaters arrive in March, egg laying typically occurs in late May, hatching in late July, and juveniles leave the burrows in late October/beginning of November (Granadeiro, 1991; Ramos et al., 2003). Seabirds are not available to rodents from November to May at the study site.

### 2.2. Capture and biometrics of rodents

Trapping was carried out every month from March 2011 to February 2012. Each month, 15 folding traps (XLF15, 10 cm × 10 cm × 38 cm; H.B. Sherman Traps Inc., Tallahassee, FL, USA) baited with peanut butter were placed around Cory's shearwater nests. They were activated every night until at least three individuals of each rodent species were captured. To prevent capturing individuals with empty stomachs, traps were only opened 4 h after sunset. The rodents caught were euthanised by ether asphyxiation in situ, blood samples were collected from the jugular vein and kept on ice until centrifugation. Individuals were identified as black rat or house mouse and classified according to sex (by examination of external genitalia). We measured (in mm) body, tail, foot and ear length. Rodents were weighed (in g) using a spring balance (100 g for house mouse and 600 g for black rat; Pesola AG, Baar, Switzerland).

Samples of muscle and hair were collected from both species, and the stomach of each rat was removed. We could not use stomach contents of the house mice because they were found either empty or with food too highly fragmented (e.g., Osinski et al., 2002). The stomach content of the black rats was analyzed in the laboratory using a magnifying glass. Tissues were stored at −20 °C (muscle) or in a dry place (hair) for later SIA. The blood samples were separated into plasma and red blood cells (RBC) using a centrifuge (15 min at 3000 rpm), stored frozen, and later freeze-dried and homogenized prior to SIA.

### 2.3. Rat stomach analysis

Stomach contents of black rats were separated into different components (animal or plant matter) and when possible, individual prey items were identified to species level. Birds and mammals were identified using reference material from our own collection (bones, feathers and hair) and for invertebrates we followed the criteria of Vieira et al. (2003). Dietary information was presented as a percentage of occurrence, defined as the proportion of stomachs with a particular food item, following Daniel (1973).

### 2.4. Stable isotope analysis

Stable isotope values were determined for rat and mouse tissues (plasma, RBC, muscle and hair), and for the prey identified in the rat stomach analysis. Feathers from killed Cory's shearwater chicks were collected at the nests. Herbivorous plants and ferns were collected and dried, and the most common terrestrial invertebrates found in stomachs (Isopoda, Diplopoda and Hymenoptera) were stored in 80% ethanol.

Prior to SIA, plasma, RBC and muscle samples were freeze-dried and ground to a fine powder. Lipids were extracted from plasma and muscle using successive rinses with 2:1 chloroform: methanol solution (Cherel et al., 2005). Hair and feathers were cleaned of surface contaminants using the same solution, air-dried and then cut into very small pieces. Plant and invertebrate samples were ground to a fine powder.

Stable isotope ratios of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) were determined via a Finnigan ConFlo II interface to a Thermo Delta V mass spectrometer coupled to a Flash EA1112 Series elemental analyser (Thermo Scientific Inc., Waltham, MA, USA). Approximately 0.3 mg of each sample was combusted in a tin cup for the simultaneous determination of $\delta^{13}C$ and $\delta^{15}N$. Results are presented in the usual δ notation based on the Pee Dee Belemnite (PDB) for carbon and atmospheric $N^2$ (AIR) for nitrogen, and