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Predation risk of the Critically Endangered Raso lark *Alauda razae* after its translocation to Santa Luzia Island – an artificial bird nest experiment

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RESUMO

A calhandra-do-ilhéu-Raso *Alauda razae* é uma das aves mais raras e ameaçadas do mundo. Esta espécie esteve confinada ao Raso até à translocação em 2018 para a ilha vizinha Santa Luzia. A sobrevivência desta está altamente dependente do tempo de incubação bem-sucedido e de riscos baixos de predação. Neste estudo, primeiramente identificámos potenciais predadores por meio de armadilhas de isco em Santa Luzia. Posteriormente, avaliámos o impacto relativo das espécies de predadores na sobrevivência com ninhos experimentais. O rato-doméstico *Mus musculus* foi capturado em todos os locais em densidade duas vezes superior no sul. As experiências com ninhos artificiais sugeriram um forte impacto predatório sobre os ovos. Identificámos pelo menos dois tipos diferentes de provável predação de ninhos: nocturno (atribuído a ratos), afectando 25–50% dos ovos, e diurno (atribuído provavelmente ao corvo-do-deserto *Corvus ruficollis*), afectando até 100% dos ovos. Actualmente, as taxas de sucesso de nidificação das calhandras do Raso permanecem pouco estudadas, mas é considerado naturalmente muito baixo no Raso, sem mamíferos introduzidos, devido à forte predação pela osga gigante *Tarentola gigas*, ela própria uma espécie ameaçada. A adaptação desta ave a diferentes ecossistemas e à pressão de predação será crucial para a sobrevivência a longo prazo.

Palavras-chave: conservação de ilhas, erradicação, ilhas Desertas, roedores invasores

ABSTRACT

The Raso lark *Alauda razae* is one of the rarest and most threatened birds worldwide. This species was confined to Raso until its translocation in 2018 to the nearby Santa Luzia Island. Its survival is high dependent on successful incubation time and minimal predation risk. In this study, we firstly identified potential predators through bait trapping on Santa Luzia. Secondly, we assessed the relative impact of predator species on experimental nest survival. The house mouse *Mus musculus* was captured at all sites with a density two-fold higher in the southern area. The artificial nest experiments suggested a heavy predatory impact on eggs. We identified at least two different types of likely predation of nests: nocturnal (assigned to mice), affecting 25–50% of eggs, and diurnal (assigned probably to brown-necked raven *Corvus ruficollis*), affecting up to 100% of eggs. Currently, the Raso lark nest success rates remain poorly studied but it is considered to be very naturally low on Raso, which is free of any introduced mammals, owing to heavy predation by the giant gecko *Tarentola gigas*, itself a threatened species. The adaptation of this bird to different ecosystems and predation pressure will be crucial for its long-term survival.

Keywords: Desertas Islands, eradication, invasive rodents, island conservation

INTRODUCTION

Introduced mammals have become widespread on islands with breeding bird colonies, using them as food source (Atkinson 1985, Robertson *et al.* 1998, Stapp 2002, Towns *et al.* 2006). Because of the naivety of many island birds to predation and the consequential lack of behavioural, morphological and other life history anti-predator responses, the impact of introduced mammals has been devastating, often leading to local or even global extinction (Atkinson 2001, Courchamp *et al.* 2003, Towns *et al.* 2006). Birds are particularly sensitive to predators during their reproduction stage, as predators may affect eggs, chicks and adults (Sanders & Maloney 2002). Nest success monitoring can help evaluate these short-term effects (Jones *et al.* 2008). However, this has many limitations, such as the high number of nests to be monitored to obtain accurate results and the possible perturbation during nest checking (Duron *et al.* 2017). Thus, researchers prefer assessing artificial nests instead (Major & Kendal 1996, Latorre *et al.* 2013), with the advantage of

being able to control the influence of many parameters on the predation rate (shell resistance, egg size, colour, location, smell; Stirnemann *et al.* 2015; Duron *et al.* 2017), to test different hypothesis and predator strategies.

In 2003, the Cabo Verde government created the Desertas marine protected area (MPA) that comprises Santa Luzia, Raso (7 km²), Branco (3 km²), and the surrounding sea (594 km²). This internationally recognized MPA holds the entire population of the Critically Endangered Raso lark *Alauda razae* (Fig. 1). In 2018, a translocation project of Raso larks from Raso to Santa Luzia started (Brooke *et al.* 2020). In this work, we studied the predation risk of *A. razae* on Santa Luzia. We aimed to (i) identify potential predators present in this new ecosystem, and assess their impact using artificial nest experiments; (ii) estimate more precisely the presence of introduced rodents, especially *Mus musculus*, on the different translocation sites with bait trapping.



Fig. 1. The Critically Endangered Raso lark on Santa Luzia (photo by S. Caut).

MATERIAL AND METHODS

The experiments were conducted on Santa Luzia the 12–19 November 2021, at the start of the likely reproduction period for the Raso lark (Donald & Brooke 2006). Santa Luzia is presently uninhabited but holds introduced mammal species (cats, mice, and possibly rats) due to historical (Lopes & Monteiro 2015) anthropogenic activities. The domestic cat had a significant impact on the local fauna until its recent eradication in 2020 (Medina & Nogales 2009, Medina *et al.* 2012, 2021). Early indications are encouraging with the released breeding birds, as their annual survival seems similar to the Raso population (Brooke *et al.* 2020).

We estimated the rodent population size using 20 Sherman traps (34x13x13 cm) baited with peanut butter. Trap stations were set for

one or two consecutive nights every 10 m along two perpendicular line transects (with the first trap in common) in three translocation sites of *A. razzae* (Fig. 2A, B). Traps were opened in the late afternoon and checked and closed each morning. We collected general information for each trap: whether or not it sprung, the presence of bait, and captures of rodents and non-target species. We calculated an index of abundance (IA) taking into account the number of corrected trap-nights (Nelson & Clark 1973). Captured individuals were killed to collect tissue samples and we recorded the sex, sexual maturity and biometric parameters (body length, BL, and weight without viscera, W).

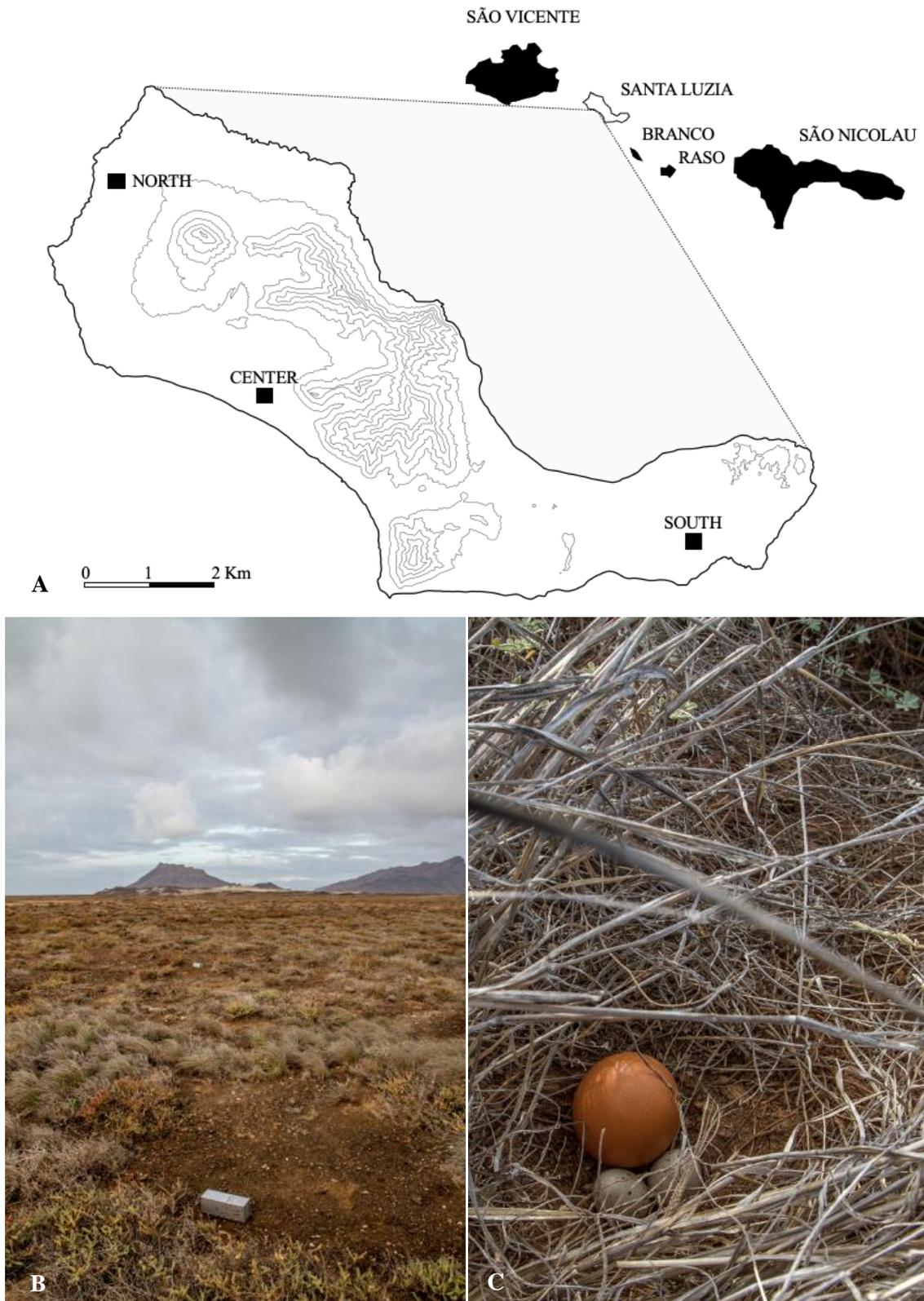


Fig. 2. Study area and study sites (photos by S. Caut). **A)** The geographical position of the Desertas Islands of the Cabo Verde Archipelago (Santa Luzia, Branco and Raso) and the tree selected study sites (mouse trapping and artificial bird-nest predation experiment) in the north, centre and south of the study area, Santa Luzia. **B)** Picture of trapping line in the characteristic ecosystem of Santa Luzia. **C)** Picture of one of artificial bird-nests containing two Raso lark artificial small eggs and one large hen egg.

An artificial bird-nest predation experiment was conducted at the same tree sites (Fig. 2C), located at minimum 4 km apart. Artificial nests with tree eggs were placed on the ground, directly in the vegetation, as natural Raso lark nests. Two different egg sizes were used: large hen eggs (*Gallus gallus*, 55x42 mm) and small weighted plastic eggs (30x20 mm) similar to Raso lark's. Each nest was checked at sunrise and sunset, to distinguish nocturnal from

diurnal predation events. If any egg was pierced, nibbled, or had disappeared, the nest was considered to be depredated (Martin & Joron 2003).

Due to the small sample sizes, rodent capture comparisons between study sites were made using chi-square nonparametric statistics (Siegel & Castellan 1988). We tested differences between sexes and body condition among study sites with factorial ANOVAs (STATISTICA, <https://www.statistica.com/>).

RESULTS

Rodent trapping confirmed only the presence of *Mus musculus* across the island. The mean IA of mice was 50.64% (Fig. 3A). We observed mice abundance twice as high in the south than in the north (χ^2 ; $P < 0.001$). The southern mice had significantly larger BL and heavier W (Fig. 3B) [(F(BL)_{2,36} = 296.00, $P < 0.001$; F(W)_{2,36} = 74.79, $P < 0.001$] independently of the sex [F(BL)_{1,36} = 7.1, $P = 0.484$, F(W)_{1,36} = 0.04, $P = 0.853$]; but in the north and central sites they were identical [P Posthoc (BL) = 0.347, P Posthoc (W) = 0.954]. We observed no lactating/ pregnant

females or males in the reproductive phase.

In our artificial bird nest experiment, we found two different types of predation: diurnal, present in the centre and south of the island with values of 100% of large egg pierced and sometimes moved several meters from the nest – a signature of an avian predator; and nocturnal, corresponding to a movement of small eggs up to 50 cm from the nest in > 25% of nests in the north and centre and up to 60% in the south – a signature of rodents (Fig. 3C).

DISCUSSION

We observed many Raso larks during our stay (morning and evening) at all study sites, some in courtship, confirming the good choice of the areas for both experiments. Fortunately, no rat capture was made during our mission, which seems very surprising given the ability of rats to disperse and adapt to oceanic islands (Courchamp *et al.* 2003, Towns *et al.* 2006). However, we found high densities of mice. A possible explanation for their high densities would be the recent eradication of cats from the island and absence of other rodents. Indeed, we found no evidence of cats, neither in rodent trapping or night transects, just old droppings. In fact, where mice co-occur with

other introduced mammals, their density is suppressed (Courchamp *et al.* 1999). Meso-predator release is an issue which needs consideration as may lead prey endemics to extinction (Courchamp *et al.* 1999, Caut *et al.* 2007, Angel *et al.* 2009). Many studies have shown that cats heavily predate mice on Santa Luzia both in the dry and in the rainy period (Donald *et al.* 2005, Medina *et al.* 2012, 2021). Thus, the removal of cats could lead to an increase in mice numbers. From an ecosystem point of view, all the trophic relationships could be modified directly or indirectly by changes in predation competition (Courchamp & Caut 2006, Caut *et al.* 2007).

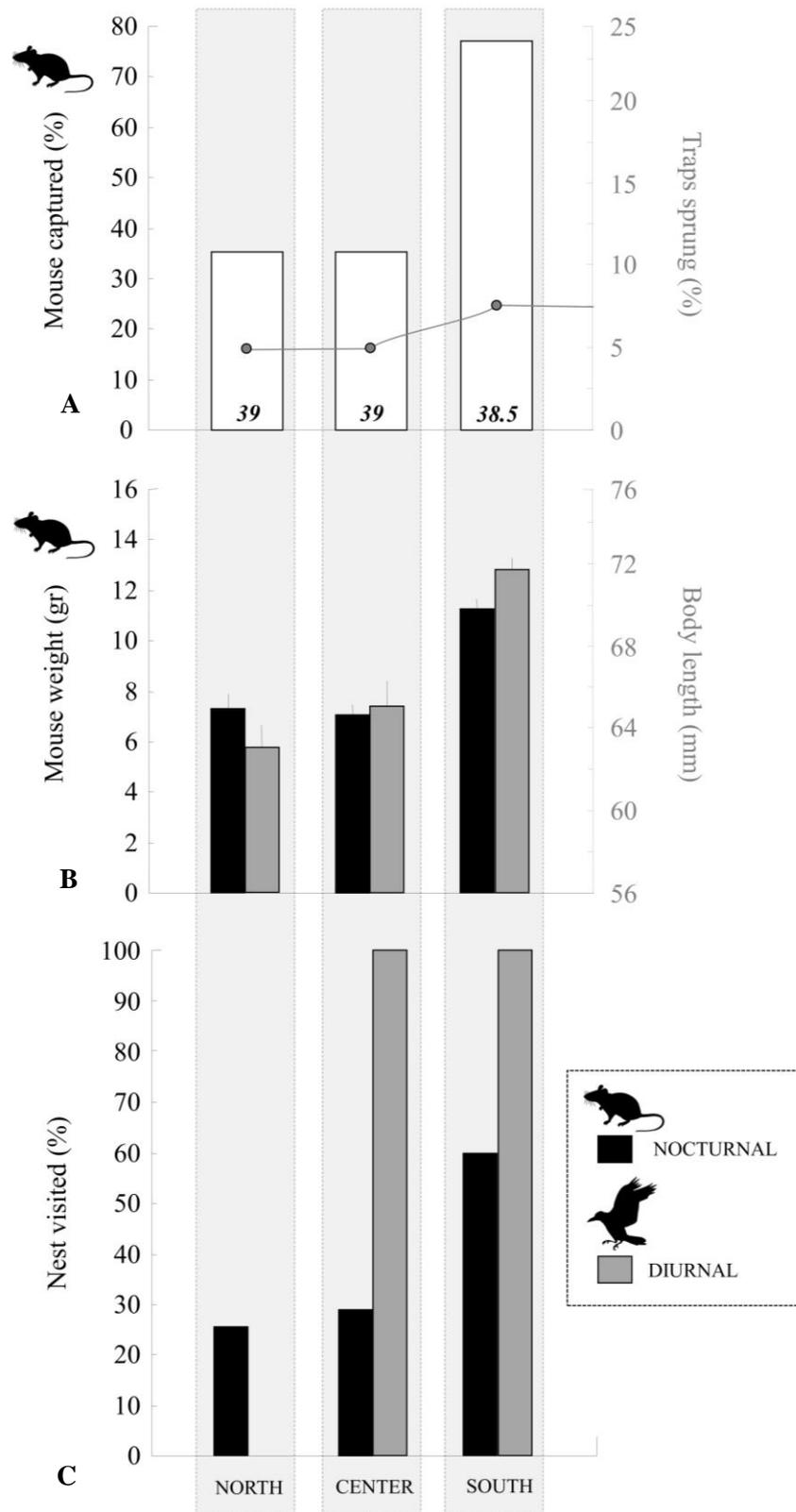


Fig. 3. Results of the bait-trapping and artificial nest predation experiments. **A**) Proportion of mice captures during the study in the three study sites (north, centre and south). Bars represent the percentage of corrected trap-nights containing at least one mouse. The number of corrected trap-nights is marked in italics inside each bar (see text for correction factor). Grey circles represent the percentage of traps that sprung. **B**) Biometrics data (weight in the black bar and body length in the grey bar; mean \pm standard deviation) for the mice captured and dissected in the tree stations ($N_{\text{north}}=14$, $N_{\text{centre}}=14$, $N_{\text{south}}=14$). **C**) Proportion of diurnal and nocturnal nest predation over two nights and one day (north site) and one night and one day (centre and south sites).

Ground nesting birds experience high nest predation, especially those that breed in shrub and grassland habitats (Yanes & Suarez 1995). Despite the absence of terrestrial mammals and the paucity of avian predators, a high proportion (reaching 95%) of *A. razzae* nests fail on Raso, their original ecosystem (Castell 1999, Donald & Brooke 2006). This is especially due to the endemic giant gecko *Tarentola gigas* (Lopes *et al.* 2019). This species is also thought to feed on seabird eggs and chicks (Hazevoet 1995, Pinho *et al.* 2018). Notably, the giant gecko is absent from Santa Luzia and nest survival rates seem similar to the ones on Raso.

Of the potential avian predators on Santa Luzia, only the brown-necked raven *Corvus ruficollis* or neglected kestrel *Falco tinnunculus neglectus* were likely to predate eggs. Both species breed in small numbers (one to three pairs) on Santa Luzia, but are probably well established on the island and are enough to predate 100% of the nests in the centre and south of the island. We observed a group of five individuals of brown-necked raven in the centre and south. They actively searched on the ground in the morning and in the evening in the bushes and were most likely responsible for nest predation. Corvids are well known to be a major predator of nests (Ekanayake *et al.* 2015, Madden *et al.* 2015, Duron *et al.* 2017). This species has already been mentioned to have a possible impact on lark's nests on Raso, where they are also in small groups (Castell 1999, Brooke *et al.* 2020). Similarly, neglected kestrel can be a major predator, but more on juveniles and adults than eggs. During the translocation programs, several predation events were observed on adult larks (e.g., kestrels killed at

least six of the 12 birds released on the first two days, even if events were favoured by the presence of the black protruding antennae of *A. razzae* tags, Brooke *et al.* 2020).

The results of nocturnal predation are directly related to our mice trapping capture results. Captures at the north and centre were almost identical, and, in the south, it was twice as high for both IA and nest night predation. Mice are omnivorous and can impact a range of taxa including plants, invertebrates and birds (Jones *et al.* 2008, Angel *et al.* 2009), including in Cabo Verde (Pinho *et al.* 2022). Small eggs represent a potential resource for mice, as their shell strength is weak enough to break. In our study, we used plastic eggs that were much more resistant than real eggs, a reason behind why mice moved them, possibly through an attempt to break them. The use of commercial quail eggs *Coturnix japonica* would be better but they were not available during our experiment. We did not observe any traces of teeth or displacements on the large eggs, probably too heavy and resistant for mice. In a review study about the impacts of mice on flora and fauna on islands, mice predation on seabird eggs and chicks was higher on islands where mice were the only introduced mammal (Angel *et al.* 2009). On islands where mice are one of several introduced mammals, the effects of dominance, competition and predation by larger species may render them less of a threat to native vertebrates (Courchamp *et al.* 2003, Caut *et al.* 2007, Angel *et al.* 2009). Unfortunately, there are no studies on the impact of mice on the biodiversity of Santa Luzia and this is an important point for future research.

CONCLUDING REMARKS

Translocating a portion of a threatened population to a new locality is a common practice for conservation purposes (Fischer & Lindenmayer, 2000, Parker *et al.* 2013) and is the most obvious measure in the case of the

Raso lark. However, effective post-release monitoring of bird translocations is vital for improving overall translocation success (Parker *et al.* 2013). It seems that the presence of avian predators and a new mammalian

predator can have a harmful impact. This artificial experiment is a first step to study the nest success in Santa Luzia. There is still insufficient evidence to state whether the Raso lark will be able to cope with mice predation, as they can partially compensate high nest losses by rapid re-laying (Brooke *et al.* 2020). Further studies on real bird nests may be needed to corroborate this result. A study on two lark species showed they are capable of producing three clutches per season as an adaptation to predation pressure to increase chances of successful fledging (Yañes & Onate 1996). This study showed that nest lost

was not as disastrous as compared to female lost, and mice are not expected to predate on adult females. Thus, the evolution of the mice population after cat eradication and its predation upon Raso larks should be monitored. The same is true for the predation pressure exerted by avian predators, specifically of eggs by crows, and of juveniles and adults by kestrels. In addition, the possibility of standardizing studies on Raso and Santa Luzia could be a major asset for a better understanding of predator-prey relationship and adaptation to their environment.

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REFERENCES

- Angel, A., Wanless, R.M. & Cooper, J. (2009) Review of impacts of the introduced house mouse on islands in the Southern Ocean: are mice equivalent to rats? *Biological Invasions*, 11, 1743–1754.
- Atkinson, I.A.E. (1985) The spread of commensal species of *Rattus* to oceanic islands and their effect on island avifaunas. *Conservation of Island Birds*, 3, 35–81.
- Atkinson, I.A.E. (2001) Introduced mammals and models for restoration. *Biological Conservation*, 99, 81–96.
- Brooke, M., Gregory, L., Geraldès, P., Castello, L., Donald, P.F., Melo, T. & Bores, J. (2020) Lessons and surprises from an inter-island re-introduction of the critically endangered Raso Lark *Alauda razae* of Cape Verde. *PARKS*, 26, 47–58.
- Castell, P. (1999) Notes on the breeding biology of Raso Lark *Alauda razae*. *Bulletin of the African Bird Club*, 6, 103–106.
- Caut, S., Casanovas, J.G., Virgos, E., Lozano, J. & Courchamp, F. (2007) Rats dying for mice: modelling the competitor release effect. *Austral Ecology*, 32, 858–868.
- Courchamp, F. & Caut, S. (2006) Use of biological invasion and their control to study the dynamics of interacting populations. *In: Cadotte, M.W., McMahon, S.M. & Fukami, T. (Eds), Conceptual Ecology and Invasions Biology: reciprocal approaches to nature.* Springer, The Netherlands, pp. 243–269.
- Courchamp, F., Chapuis, J.L. & Pascal, M. (2003) Mammal invaders on islands: impact, control and control impact. *Biological Reviews*, 78, 347–383.
- Courchamp, F., Langlais, M. & Sugihara, G. (1999) Cats protecting birds: Modelling the mesopredator release effect. *Journal of Animal Ecology*, 68, 282–292.
- Donald, P.F. & Brooke, M. (2006) An unlikely survivor: the peculiar natural history of the Raso Lark. *British Birds*, 99, 420–430.
- Donald, P.F., Brooke, M., Bolton, M.R., Taylor, R., Wells, C.E., Marlow, T. & Hille, S.M. (2005) Status of Raso Lark *Alauda razae* in 2003, with further notes on sex ratio, behaviour and conservation. *Bird Conservation International*, 15, 165–172.

- Duron, Q., Bourguet, E., De Meringo, H., Million, A. & Vidal, E. (2017) Invasive rats strengthen predation pressure on bird eggs in a South Pacific island rainforest. *Current Zoology*, 63, 583–590.
- Ekanayake, K.B., Whisson, D.A., Tan, L.X.L. & Weston, M.A. (2015) Intense predation of non-colonial, ground-nesting bird eggs by corvid and mammalian predators. *Wildlife Research*, 42, 518–528.
- Fischer, J. & Lindenmayer, D.B. (2000) An assessment of the published results of animal relocations. *Biological Conservation*, 96, 1–11.
- Hazevoet, C.J. (1995) *The birds of the Cape Verde Islands*. British Ornithologists' Union, Tring, UK, 192 pp.
- Jones, H.P., Tershy, B.R., Zavaleta, E.S., Croll, D.A., Keitt, B.S., Finkelstein, M.E. & Howald, G.R. (2008) Severity of the effects of invasive rats on seabirds: a global review. *Conservation Biology*, 22, 16–26.
- Latorre, L., Larrinaga, A.R. & Santamaria, L. (2013) Rats and seabirds: effects of egg size on predation risk and the potential of conditioned taste aversion as a mitigation method. *PLoS ONE*, 8, e76138.
- Lopes, R., Pinho, C.J., Santos, B., Seguro, M., Mata, V.A., Egeater, B. & Vasconcelos, R. (2019) Intricate trophic links between threatened vertebrates confined to a small island in the Atlantic Ocean. *Ecology and Evolution*, 9, 4994–5002.
- Lopes, E. & Monteiro, R. (2015) Espécies introduzidas e medidas de conservação/ Introduced species and conservation measures. In: Vasconcelos, R., Freitas, R. & Hazevoet, C.J. (Eds), *Cabo Verde – História Natural das ilhas Desertas/ The Natural History of the Desertas Islands – Santa Luzia, Branco e Raso*. Sociedade Caboverdiana de Zoologia, Portugal, pp. 276–307.
- Madden, C.F., Arroyo, B. & Amar, A. (2015) A review of the impacts of corvids on bird productivity and abundance. *Ibis*, 157, 1–16.
- Major, R.E. & Kendal, C.E. (1996) The contribution of artificial nest experiments to understanding avian reproductive success: a review of methods and conclusions. *Ibis*, 138, 298–307.
- Martin, J.L. & Joron, M. (2003) Nest predation in forest birds: Influence of predator type and predator's habitat quality. *Oikos*, 102, 641–653.
- Medina, F.M., Melo, T., Oliveira, P., Nogales, M. & Geraldes, P. (2021) Trophic ecology of an introduced top predator (*Felis catus*) on a small African oceanic islet (Santa Luzia, Cabo Verde Islands). *African Journal of Ecology*, 59, 88–98.
- Medina, F.M., Oliveira, P., Geraldes, P., Melo, J. & Barros, N. (2012) Diet of feral cats *Felis catus* L., 1758 on Santa Luzia, Cape Verde Islands. *Zoologia Caboverdiana*, 3 (2), 67–73.
- Medina, F.M. & Nogales, M. (2009) A review on the impacts of feral cats (*Felis silvestris catus*) in the Canary Islands: implications for the conservation of its endangered fauna. *Biodiversity and Conservation*, 18, 829–846.
- Nelson, L.J. & Clark, F.W. (1973) Correction for sprung traps in catch/effort calculation of trapping results. *Journal of Mammals*, 54, 295–298.
- Parker, K.A., Ewen, J.G., Seddon, P.J. & Armstrong, D.P. (2013) Post-release monitoring of bird translocations: why is it important and how do we do it? *Notornis*, 60, 85–92.
- Pinho, C.J., Santos, B., Mata, V.A., Seguro, M., Romeiras, M.M., Lopes, R.J. & Vasconcelos, R. (2018) What is the giant wall gecko having for dinner? Conservation genetics for guiding reserve management in Cabo Verde. *Genes*, 9, 599.
- Pinho, C.J., Lopes, E.P., Paupério, J., Gome, I., Romeiras, M.M. & Vasconcelos, R. (2022) Trust your guts? The effect of gut section on diet composition and impact of *Mus musculus* on islands using metabarcoding. *Ecology and Evolution*, 12, e8638.
- Robertson, A., Jarvis, A.M., Brown, C.J. & Simmons, R.E. (1998) Avian diversity and endemism in Namibia: patterns from the southern African bird atlas project. *Biodiversity and Conservation*, 7, 495–511.
- Sanders, M.D. & Maloney, R.F. (2002) Causes of mortality at nests of ground-nesting birds in the Upper Waitaki Basin, South Island, New Zealand: a 5-year video study. *Biological Conservation*, 106, 225–236.
- Siegel, S. & Castellan, N.J.Jr. (1988) *Non parametric statistics for the behavioural sciences*. MacGraw Hill Inc, New York, USA, 399.
- Stapp, P. (2002) Stable isotopes reveal evidence of predation by ship rats on seabirds on the Shiant Islands, Scotland. *Journal of Applied Ecology*, 39, 831–840.

- Stirnemann, R.L., Potter, M.A., Butler, D. & Minot, E.O. (2015) Compounding effects of habitat fragmentation and predation on bird nests. *Austral Ecology*, 40, 974–981.
- Towns, D.R., Atkinson, I.A.E. & Daugherty, C.H. (2006) Have the harmful effects of introduced rats on islands been exaggerated? *Biological Invasions*, 8, 863–891.
- Yanes, M. & Suarez, F. (1995) Nest predation patterns in ground-nesting passerines on the Iberian Peninsula. *Ecography*, 18, 423–428.

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