EUROPEAN RABBITS AND PETRELS AS THE STAPLE PREY OF THE SHORT-EARED OWL (*ASIO FLAMMEUS*) IN THE JUAN FERNÁNDEZ ARCHIPELAGO OFF THE COAST OF CHILE

Los conejos europeos y petreles como las presas principales del nuco (*Asio flammeus*) en el archipiélago de Juan Fernández, Chile insular

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Resumen.- El nuco (*Asio flammeus*) es un depredador tope en el ecosistema terrestre del archipiélago de Juan Fernández, pero su dieta es escasamente conocida allí. Durante marzo de 2005 recolectamos 19 regurgitados de nuco en un pastizal de la isla Robinson Crusoe. El análisis de los regurgitados reveló que los nucos depredaron sobre conejos europeos (*Oryctolagus cuniculus*), petreles (*Pterodroma* spp.), lauchas domésticas (*Mus domesticus*) e insectos. Los conejos europeos y petreles constituyeron casi el 60,9% y 20,7% del total de las ocurrencias de presas en los regurgitados, respectivamente. Nuestros hallazgos coincidieron con los de un estudio realizado 14 años antes, lo cual sugiere que los nucos tienen un fuerte vínculo trófico con conejos y petreles. Es posible que el patrón que detectamos haya resultado de una disponibilidad estable de esos taxones presa combinada con una especialización trófica del nuco sobre ellos. Ya que los petreles son numerosos en el archipiélago de Juan Fernández, estos podrían convertirse en un recurso trófico primario de los nucos ante una erradicación completa de los conejos.

INTRODUCTION

Knowing what top predators feed on is essential to understanding how they adapt to and persist in island ecosystems invaded by allochthonous prey species (*e.g*., Polis *et al*. 1997). The Short-eared Owl (*Asio flammeus*) is a top predator widely distributed throughout the world. This species mainly occupies terrains with low vegetation (*e.g*., grassland, tundra, marsh, moorland, and savanna) across large continental regions and on oceanic islands (Holt *et al*. 1999, König & Weick 2008, Wiggins *et al*. 2020). Short-eared Owls prey primarily on small mammals and secondarily on birds and insects (Clark 1975, Holt *et al*. 1999, Wiggins *et al*. 2020). However, the amount in which these owls consume those prey may depend on the local and seasonal prey availability (Clark 1975, Page & Whiteacre 1975, Martínez *et al*. 1998).

In Chile, the Short-eared Owl inhabits a large part of the national territory, including oceanic islands (Araya & Millie 1986, Figueroa *et al*. 2017). As in other regions, in Chile it preys heavily upon small mammals, consuming variable numbers of birds depending on the season (Martínez *et al*. 1998). This diet pattern is even observable in the Juan Fernández Archipelago. Fuentes *et al*. (1993) found that in this archipelago, almost 80% of the prey of the Short-eared Owl were mammals, with the European Rabbit (*Oryctolagus cuniculus*) accounting for 61% of the diet by frequency. Marine birds were the second most consumed prey. Later, Figueroa *et al*. (2017) provided a rough approximation of the prey spectrum of this owl species in that archipelago, including unpublished data.

Here, we provide a further analysis to assess whether there is persistence in the prey composition in

the diet of the Short-eared Owl in the Juan Fernandez Archipelago. If the dietary pattern has remained over time, our results should mirror those previously documented by Fuentes *et al*. (1993).

MATERIALS AND METHODS

Study Area

The Juan Fernández Archipelago is in the Pacific Ocean (33°38'29"S, 78°50'28"W) at almost 590 km off Valparaíso on the coast of Chile. This archipelago is composed of three volcanic islands: Robinson Crusoe (47.11 km^2), Santa Clara (2.23 km^2), and Alejandro Selkirk (44.64 km^2). The climate in these islands is subtropical maritime with high humidity (73-79%). Temperatures and precipitation range from 4.2 to 28.8°C and 24.1 to 180.1 mm, respectively (Dirección Meteorológica de Chile). Rainfall decreases during spring and summer.

The Juan Fernández Archipelago supports a unique biota with high endemism of terrestrial plants and animals resulting from its long-term biogeographical isolation (Schlatter 1987, Stuessy *et al*. 1991, Hahn *et al*. 2006). Because of its ecological uniqueness, the archipelago is in the National System of State Protected Areas (SNASPE) and is part of the World Network of Biosphere Reserves (Campos *et al*. 2009). In addition, Birdlife International declared the archipelago as an Endemic Bird Area (Stattersfield *et al*. 1998). Despite this, the native biota has suffered successively the predatory impact of several species of invasive allochthonous animals brought by settlers to the archipelago. These species include goats (*Capra hircus*), coatis (*Nassua nassua*), rats (*Rattus* spp.), mice (*Mus domesticus*), domestic cats (*Felis catus*), and European rabbits (Hahn *et al*. 2006, Campos *et al*. 2009).

Methods

In December 2005, we collected 19 pellets of Short-eared Owls within grassland patches between Puerto Francés and Rebaje de la Piña on Robinson Crusoe Island. We were sure the pellets were from Short-eared Owls because we found them scattered on the ground where we observed these owls hunting and perching. In addition, pellet shape, size, and texture matched those previously described for the species (see Holt *et al*. 1987).

We dissected pellets using the dry method as in Holt *et al*. (1987). Before analyzing pellets, these remained at the laboratory's room temperature until they were sufficiently dry to remove the anatomical pieces more cleanly. We identified mammalian prey by skull, mandibles, teeth, and hair features. Avian prey were identifiable only by feathers. In this case, we used two complementary methods: microscopic analysis of feather structures (Reyes 1992, Rau & Martínez 2004), and a comparison of feather coloration and shape patterns with reference collections. Insect prey were recognizable by elytra, head capsules, or feet.

Because all pellets with avian prey contained only feathers, we could not be sure if they belonged to only one or more individuals. Therefore, we quantified the importance of prey by tallying the frequency of their occurrence in pellets as follows: number of occurrences of each prey taxon divided by the total number of occurrences of all prey taxa, expressed as a percentage. Although Fuentes *et al*. (1993) did not clearly explain how they quantified prey importance, we assumed they used the same method.

RESULTS

The Short-eared Owl pellets collected contained remains from house mice, rabbits, petrels, and bettles. Mammalian prey accounted for almost 70% of the prey occurrences in the pellets, with European rabbits being the most frequent prey (Table 1). Petrels (*Pterodroma* spp.), the only avian prey taxon in the pellets, were secondary in occurrence (Table 1). House mice and beetles occurred in a low frequency (< 10%).

DISCUSSION

Our analysis revealed that Short-eared Owls in the Juan Fernández Archipelago feed primarily on European rabbits and secondarily on petrels. The incidence level of these prey was similar to that reported by Fuentes *et al*. (1993). However, we found two extra prey taxa: house mice and beetles. In terms of prey classes consumed, the diet in the Juan Fernandez Archipelago is similar to those in continental areas of southern South America (Rau *et al*. 1992, Martínez *et al*. 1998, Cirignoli *et al*. 2001, Baladrón *et al*. 2014, Torres *et al*. 2014). Our analysis also confirmed the Short-eared Owl in Chile is a predator specialized on vertebrates, birds and mammals being the basis of its diet ((Figueroa *et al*. 2017, Cadena-Ortíz *et al*. 2019).

Although there are similarities between the diets from the archipelago and continental Chile, there is also an evident difference. In the archipelago, native rodents are absent, and Short-eared Owls have become dependent on the introduced European rabbit. Even though allochthonous rodents (*Mus*, *Rattus*) are also present in the archipelago, the owls consume them in low or nil proportions (Fuentes *et al*. 1993, this study). A higher abundance and biomass possibly make European rabbits a more profitable prey for Short-eared Owls. Conversely, up to date, there is no evidence that these owls consume lagomorphs in continental Chile (Rau *et al*. 1992, Martínez *et al*. 1998, Escobar *et al*. 2005), even though the European rabbit and European hare (*Lepus europaeus*) are abundant. Perhaps because native rodents are relatively more abundant in

Table 1. Diet of Short-eared Owl (*Asio flammeus*) determined by analysis of pellets collected in the Juan Fernández Archipelago off the coast of Chile. Collection dates: this study, in March 2005, Fuentes *et al.* (1993), from November 1988 to April 1991. FO (frequency of occurrence) = number of occurrences of each prey taxon divided by the total number of occurrences of all prey taxa, expressed as a percentage.

	This study	Fuentes *et al.* (1993)	Overall
Prey taxa	FO% (N)	FO% (N)	FO% (N)
Mammals			
House Mouse (*Mus domesticus*)	8.7 (2)	0.0	3.9 (2)
European Rabbit (*Oryctolagus cuniculus*)	60.9 (14)[a]	60.7 (17)	60.8 (31)
Unidentified mammals	0.0	21.4 (6)	11.8 (6)
Birds			
Petrels (*Pterodroma* spp.)	21.7 (5)	17.9 (5)	19.6 (10)
Insects			
Beetles (Scarabaeidae)	8.7 (2)	0.0	3.9 (2)
Total occurrences	23	28	51
Total pellets	19	20	39

[a]All mandibles and molars retrieved were from juvenile individuals.

the continental areas (Martínez *et al*. 1998, Cirignoli *et al*. 2001, Torres *et al*. 2014), Short-eared Owls may not be as trophically dependent on lagomorphs, as on the island.

Both the study by Fuentes *et al*. (1993) and ours show that the occurrence of avian prey in the Short-eared Owl diet in the Juan Fernández Archipelago is about 20%. This proportion is higher than in the diet of continental conspecifics. A seasonal study based on large numbers of pellets revealed that the numerical proportion of birds in the Short-eared Owl's diet ranged from 2% to 12% throughout the year (Martínez *et al*. 1998). Other more time-limited studies or studies based on small samples also showed a low proportion, or even absence, of birds in the diet of Short-eared Owls (Rau *et al*. 1992, Cirignoli *et al*. 2001, Baladrón *et al*. 2014, Torres *et al*. 2014, Formoso & Esmoris 2023).

The high similarity between our results and those of Fuentes *et al*. (1992) suggests that dietary patterns of the Short-eared Owls in the Juan Fernandez archipelago have remained constant over time. This could result from a stable availability of European rabbits and petrels combined with a local specialization of the Short-eared Owl on both prey taxa. The importance of rabbits as a primary prey of Short-eared Owls in the archipelago is consistent with the hypothesis that introduced medium-sized prey (*e.g*., lagomorphs) can substantially modify the original structure of local food webs (Barbar *et al*. 2016). Before humans introduced rabbits and rodents to the Juan Fernández Archipelago, Short-eared Owls may have been trophically dependent on colonial marine birds, particularly petrels. If rabbits were eliminated from the archipelago, perhaps then Short-eared Owls would return to prey heavily on that avian prey, reestablishing an ancestral predator-prey relationship. Alternatively, they could increase predation on introduced mice and rats.

Fuentes *et al*. (1992) raised the possibility that rabbit eradication from the island could lead to a paradoxical situation. They argued that as the petrels already suffered attacks from introduced predators (coatis, cats), higher predation by Short-eared Owls could further reduce the petrel population. In turn, the owls could suffer a population decline as one of their staple prey becomes scarcer. Similarly, Barbar *et al*. (2016) warned that when lagomorphs become a staple prey for native predators, the extirpation of the former could have disastrous consequences in local food webs. Notwithstanding, after the eradication of rabbits from Santa Clara Island and Robinson Crusoe Island (Camus *et al*. 2008), there is no evidence of a substantial decrease in the local petrel populations (Carboneras *et al*. 2020, Medrano *et al*. 2023). Indeed, the Juan Fernández Petrel (*Pterodroma externa*) population reaches almost 3 million individuals (Carboneras *et al*. 2020). In addition, the Short-eared Owl population appears to be naturally small in the archipelago. Hahn *et al*. (2006) estimated only < 50 individuals spread across Robinson Crusoe Island and Santa Clara Island. Therefore, petrels could still be an abundant food resource to sustain the Short-eared Owl population in the Juan Fernández Archipelago.

Even though our evidence came from a small sample, it has allowed us to hypothesize the eventual ecological changes discussed above. In this regard, we propose that the success of current rabbit and rat eradication programs in Robinson Crusoe Island should gauge the effect

on the diet of native top predators. That would also help to understand how broad is the "marine-food flank" of the Short-eared Owl in the Juan Fernández Archipelago.

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