Threatened avifauna of the Juan Fernández archipelago, Chile: the impact of introduced mammals and conservation priorities

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De las 17 especies de aves nidificantes en el archipiélago de Juan Fernández, ocho son endémicas y ocho están incluidas en el Libro Rojo de Chile, pero la situación es particularmente crítica para *Aphrastura masafuerae* y *Sephanoides fernandensis*. Los mamíferos introducidos tienen un impacto significativo en las aves: ratas, gatos, perros y coatíes representan una amenaza directa para las poblaciones de aves, mientras que los conejos y cabras asilvestrados destruyen el hábitat. Dado que eliminar todos los mamíferos introducidos es difícil, se debería comenzar con las cabras en la Isla Alejandro Selkirk, y conejos en la Isla Robinson Crusoe e Isla Santa Clara. Se deberían eliminar los gatos del asentamiento de San Juan Bautista. En Santa Clara, parecería posible eliminar todos los mamíferos introducidos, lo que incrementaría la posibilidad de que esta isla funcione como un refugio natural para las especies amenazadas.

Background

The geographically isolated Juan Fernández Islands were probably untouched by Man until their discovery by European sailors in 1574. Polynesians did not reach further east than Easter Island and native Americans perhaps not west of the South American continent. Endemism in animal and plant species is remarkably high[24,28]. Five endemic bird species and three endemic subspecies occur on the islands, or approximately 50% of Chile's endemic birds[13,23]. Thus, the islands are of major importance for the country's endemic avifauna, being categorised as an Endemic Bird Area (EBA)[25] and Key Area for threatened Neotropical birds[30].

Goats and pigs were brought to the archipelago by the discoverer Juan Fernández[31]. Goat numbers rapidly increased as they found suitable habitats, a lack of predators and there were no inhabitants to hunt them. High numbers were reported throughout the 17th century on Másatierra (now Isla Robinson Crusoe), until the introduction of dogs, which reduced the population. When Alexander Selkirk—model for Daniel Defoe's Robinson Crusoe—lived on the island (1704–1709) goats were less numerous and difficult to hunt. Other mammals were subsequently introduced; herbivores caused vegetation destruction and alien predators reduced native bird life. *Sephanoides fernandensis leyboldi*, an endemic hummingbird taxon, became extinct in the early 20th century, and other forms have reached critically low population levels[12].

Studies of environmental preference and the influence of introduced mammals on the archipelago have been few[21], but are the basis for successful conservation. The principal aim of this study is to present information concerning the status, distribution and impact of introduced mammals. Their potential impact on the fragile avifauna is also discussed, as are tactics for future conservation management for the benefit of the endemic birds.

Study area

The Juan Fernández archipelago is in the south-east Pacific Ocean, 587–775 km west of Chile at 33°28'–33°47'S 78°47'–80°47'W, and consists of the islands of Isla Robinson Crusoe (formerly Másatierra; 47.11 km^2), Isla Alejandro Selkirk (formerly Másafuera; 44.64 km^2), Isla Santa Clara (2.23 km^2) and several small rocks[8,18]. While Santa Clara reaches only 375 m, Yunque Mountain on Robinson Crusoe is 915 m[24]. The summit of Alejandro Selkirk, Pico del Inocentes, is 1,380 m high (pers. obs. 1995). With the exception of the San Juan Bautista settlement, the Juan Fernández archipelago has been a Chilean National Park since 1935 and gained UNESCO Biosphere Reserve status in 1977. It has been considered among the 11 most seriously threatened protected areas in the world[1]. Detailed descriptions of the archipelago and its habitats are available in Castilla[8], Hahn[12,14], Skottsberg[24] and Stuessy[27].

Methods

Between 1992 and 1995 three visits were made by IH to study the ecology of the Juan Fernández archipelago. All three major islands were visited for a total of 220 days (24 November 1992–2 February 1993, 24 March–13 April 1994 and 19 October 1994–13 February 1995). In general, identifying the birds and mammals was straightforward. Tape-recordings were made using a DAT-Recorder (Sony HD-S100).

Predators

The archipelago's only autochthonous bird predators are Red-backed (Másafuera) Hawk *Buteo polysoma exsul*, on Alejandro Selkirk, and American (Juan Fernández) Kestrel *Falco sparverius fernandensis* and Short-eared Owl *Asio flammeus suinda* on Robinson Crusoe and Santa Clara. All other breeding birds are their potential prey. Among birds, Másafuera Hawk mainly preys on juvenile or

injured petrels[17]. For example, in January 1993, one was observed with a recently captured and still alive Juan Fernández Petrel *Pterodroma externa* during daylight, when all adult petrels have usually left the island.

In the early 1980s Másafuera Hawks were released on Robinson Crusoe to prey on introduced rabbits. They have failed to significantly reduce rabbit numbers, but Robinson Crusoe's seabird population has been additionally endangered by the introduction. Populations of Kermadec Petrel *Pterodroma neglecta juana* and Másatierra Petrel *Pterodroma defilippiana*, which nest on the ground, are very low[5] (D. Gücking & W. Fiedler pers. comm. 2000). Their breeding sites are poorly protected against hawk attacks compared to burrow-nesting petrels on Alejandro Selkirk. The impact of introduced Másafuera Hawks on endemic landbirds of Robinson Crusoe, such as Juan Fernández Firecrown *Sephanoides fernandensis* and Juan Fernández Tit-tyrant *Anairetes fernandezianus*, cannot be estimated. *Buteo polysoma exsul* does attack small/passerine birds: IH repeatedly observed it hunting Másafuera Rayadito *Aphrastura masafuerae*[15].

Among introduced mammalian predators, those that threaten birds include Norwegian Rat *Rattus norvegicus*, Ship Rat *R. rattus* and House Mouse *Mus musculus*. Despite being largely herbivorous, these rodents are also known to be carnivores, and are known from Robinson Crusoe and Alejandro Selkirk[29,31], but not previously from Santa Clara. However, in April 1994, IH found several damaged eggs of Pink-footed Shearwater *Puffinus creatopus* on Santa Clara, probably eaten by rodents.

Observations indicate a high density of rats on the Juan Fernández archipelago. Inhabitants report that food is difficult to store without rats reaching it during winter (R. Schiller pers. comm. 1995). In January 1995, IH found a dead *Rattus rattus* at 1,100 m near a mixed petrel colony on Alejandro Selkirk and, in 1994, IH repeatedly observed rats on the ground and climbing in bushes on Robinson Crusoe, e.g. in Puerto Ingles, the Anson Valley and at Mirador Selkirk. All bird species are theoretically at risk from rat predation. The situation is especially critical for *Aphrastura masafuerae* and *Sephanoides fernandensis*, as their populations are low[5,9,12], and *Sephanoides* is at particularly high risk at night due to their nocturnal torpor.

In January 1995, IH found a party (two adults and two juveniles) of *Mus musculus* at 1,000 m, the first record of the species from the montane Alejandro Selkirk far from the fishing settlement. Food sources for rodents are numerous, as they are able to take various vegetables, arthropods, dead petrels and petrel eggs.

Feral cats *Felis cattus* were observed on Alejandro Selkirk and Robinson Crusoe, but are apparently absent from Santa Clara. On 10 December 1994, IH observed a cat crossing the Plan del Yunque (south of Villagra, Robinson Crusoe). Feral cats persist on Alejandro Selkirk as well, despite the lack of rabbits. Thirteen petrels taken by cats were found within a mixed petrel colony; nine Stejneger's *Pterodroma longirostris* and four Juan Fernández Petrels. Petrels are probably the most important cat prey, but depart the island in winter. Local people report that cats frequently search shores for carrion at this season. In San Juan Bautista, on Robinson Crusoe, the high numbers of cats are a serious threat to Juan Fernández Firecrown, of which a significant proportion of the population winters there[18]. E. Rojas (pers. comm. 1994) reported that a one cat killed three Juan Fernández Firecrowns within six months. IH and Roy *et al.*[19] have also observed such events. On Robinson Crusoe they have been observed predating Juan Fernández Tit-tyrants[5].

Feral dogs *Canis lupus* occur on Alejandro Selkirk and Robinson Crusoe, where they are principally restricted to the settlement. In March 1994 IH observed two dogs on Robinson Crusoe obviously searching for rabbits at the Plan del Yunque. Dogs in La Punta belong to inhabitants, but mainly feed independently, e.g. on petrels[3]. On Alejandro Selkirk dogs live around the Las Casas huts. The inhabitants leave this island in winter (May–October), usually with their dogs. But, in the past, dogs were sometimes lost during hunting trips and became wild. Thus, they learned to take petrels, goats or seals.

Coatimundi *Nasua nasua*, introduced onto Robinson Crusoe to reduce rat numbers, was abundant until the 1980s. Today few remain, between Pangal and Puerto Frances. Coati predation on nesting seabirds is probable, as IH found two recently dead Pink-footed Shearwaters, at Centinela, near a coati. When disturbed, it escaped to a *Eucalyptus globulus* tree. Bourne *et al.*[4] and D. Gücking & W. Fiedler (pers. comm. 2000) also presented evidence of coatis and/or cats predating seabirds.

Herbivores

In addition to predators, Man has also introduced herbivores with devastating affects for bird habitats. Since the islands discovery in 1574, the autochthonous vegetation of the archipelago has been modified and/or destroyed by introduced mammals, principally herbivores[14].

Sheep *Ovis ammon* f. *aries* were introduced to all three islands, where they lived in open areas. Their eradication in the 1980s presented a social problem, as inhabitants used their wool, skin, and meat (R. Schiller pers. comm. 1994). As early as 1616, van Schouten reported the presence of cattle on Robinson Crusoe[31]. During the past two decades numbers have been reduced and in 1994 only ten

were present on Alejandro Selkirk and the 150 on Robinson Crusoe were restricted by fences to the island's western part. Nevertheless, soil trampling by cattle still represents a serious problem on western Robinson Crusoe. Horse *Equus przewalskii* f. *caballus*, donkey *Equus africanus* f. *asinus* and their hybrids have been more numerous since the 19th century. Presently, only c.25 live on Robinson Crusoe, where they are kept in gardens.

The most devastating effect on vegetation has been caused by goats, which were introduced by Juan Fernández, subsequently became wild and increased with time, though few data are available. Recently, not more than three were present on Santa Clara and fewer than 100 were estimated on Robinson Crusoe[10]. Since the settlement on Robinson Crusoe was founded in 1850, goats have been significantly reduced by hunting and are now largely restricted to the island's steep south-eastern cliffs. On Alejandro Selkirk c.3000–5000 goats are present (pers. obs. 1995). Local people kill c.300–500 annually in October–April (the island is uninhabited during the rest of the year), but to date the overall goat population does not appear to have been affected by these losses.

With the successful reduction of goats on Robinson Crusoe and Santa Clara, feral rabbits *Oryctolagus cuniculus* currently represent the main cause of vegetation destruction. Though introduced as recently as c.1930, rabbits now occur in high densities on these islands. In 1982, Saiz & Ojeda[21] undertook a census on Robinson Crusoe, which estimated a population of 52,012 rabbits. Our observations (1994) suggest even higher numbers occur on Santa Clara, probably due to the absence of cats, dogs, hawks, and Man. Torres & Aguayo[29] and R. Schiller (pers. comm. 1995) reported that rabbits were also brought to Alejandro Selkirk, but disappeared shortly after arrival, perhaps exterminated by Másafuera Hawks.

Discussion and conclusions

Four of the eight endemic breeding birds of the Juan Fernández archipelago are listed within the Red List of the Terrestrial Vertebrates of Chile (RLC)[11], which has eight categories. Two of the four, Másafuera Rayadito and Juan Fernández Firecrown, are in category two ('in danger'; category one is 'extinct'). Eight of the total of 17 breeding birds in the archipelago are listed in the RLC and 14 of all 56 birds species recorded on the islands are included in the RLC. Thus, 47% of the breeding and 25% of all recorded bird taxa are threatened, partially due to their very limited ranges and consequently small populations. But human impacts, especially through the introduction of alien mammals, have altered the ecosystem and additionally endangered native bird species.

Populations of Másafuera Rayadito[6,12] and Juan Fernández Firecrown[4,5,9,18,19,26] are critically low. The latter was common in the 19th century[17]. In 1986 Brooke[6] estimated the population of Másafuera Rayadito to be probably c.500 individuals but, using line transects, IH[12] estimated c.150 adult Másafuera Rayaditos in 1992–93 and 1994–95, suggesting a subsequent decrease. Glade's[11] classification of both species in the RLC is consistent with our investigations. Other endemic landbirds, e.g. Juan Fernández Tit-tyrant, Juan Fernández Kestrel, Grey-flanked (Másafuera) Cinclodes *Cinclodes oustaleti baeckstroemii* and Másafuera Hawk, have very limited ranges and must be considered under threat. The current situations for seabirds on Isla Robinson Crusoe and on

Table 1. Mammals recorded from the Juan Fernández archipelago, Chile.

		Status			Islands			
Scientific name	Common name	effect	feral	dom.	RC	SC	AS	Source
Felis cattus	Feral Cat	P	x	x	x		x	1, 2
Canis lupus f. *familiaris*	Feral Dog	P	x	x	x		x	1, 2
Nasua nasua	Coatimundi	P	x		x			1
Rattus norvegicus	Norwegian Rat	P, H	x		x	?	x	1, 3
Rattus rattus	Ship Rat	P, H	x		x	?	x	1, 2, 3
Mus musculus	House Mouse	H	x		x	?	x	1, 3
Sus scrofa	pig	P, H	†		†			2
Ovis ammon f. *aries*	sheep	H		†	†			2
Bos primigenius f. *taurus*	cattle	H		x	x		x	1, 2
Equus przewalskii f. *caballus*	horse	H		x	x		†	1
Equus africanus f. *asinus*	donkey	H		x	x		†	1
Capra aegagrus f. *hircus*	goat	H	x	x	x	†	x	1, 2
Oryctolagus cuniculus	rabbit	H	x		x	x	†	1
Present mammal species		5 P, 8H	8	6	11	1	7	

Status: P = bird predator, H = habitat destroyer, † = extinct, x = record.
Islands: RC = Isla Robinson Crusoe, SC = Isla Santa Clara, AS = Isla Alejandro Selkirk.
Source: 1 = pers. obs. (1992–1995), 2 = Wester[31], 3 = R. Schiller (pers. comm. 1995).

Isla Alejandro Selkirk are different. In 1995, populations of the two endemic petrels on Alejandro Selkirk were high[5], but numbers of Stejneger's Petrels taken by cats are probably great and little is known concerning reproductive success[5]. In contrast, the four seabird species breeding on Robinson Crusoe and Santa Clara have much lower populations.

Three principal factors are responsible for the small populations of native bird species on Juan Fernández: habitat destruction by introduced herbivores, predation by introduced predators and competition with introduced birds.

Vegetation modification and destruction[22] have mainly been induced by goats, rabbits, sheep and cattle. Direct human influence—such as selective cutting of sandalwood *Santalum fernandezianum* and Chonta Palm *Juania australis*—may also have contributed to these changes. But, such factors have not been as serious as that of the impact of herbivores. Today, feral rabbits on Robinson Crusoe and Santa Clara, and goats on Alejandro Selkirk, are the main factors influencing habitat destruction.

Introduced predators such as rats, cats and dogs endanger all bird species found in the archipelago. Among landbirds, rat predation is probably critical for Másafuera Rayaditos and Juan Fernández Firecrowns. The latter is immobile at night due to torpor and cannot escape predators[7]. Indeed, rats can develop specific foraging strategies and were observed on the ground as well as climbing bushes. Many insular bird populations have suffered 'ecological catastrophes' following the arrival of rats. For example, on Lord Howe Island five endemic forest species were eliminated by rats within only a few years[2]. The extinction of the endemic Másafuera Firecrown on Alejandro Selkirk is probably related to the introduction of rats and cats[7]. Following its extinction there was reduced pollination among hummingbird-adapted plants. Green-backed Firecrown *Sephanoides sephaniodes* reached Alejandro Selkirk around 1981[3,4], but became extinct in c.1995 (pers. obs. 1992–1995, Roy *et al.*[20]). On Robinson Crusoe, it occurs in high numbers and competes with Juan Fernández Firecrown for food (pers. obs. 1994)[4,9,18–20,26].

Since the late 1970s conservation, including the reduction of alien mammalian introductions, has been co-ordinated by the Chilean Corporación Nacional Forestal (CONAF). Feral dogs, sheep and pigs have been eradicated, and goat numbers reduced. Bourne *et al.*[4], Hahn[12], and Roy *et al.*[20] all presented detailed suggestions concerning future conservation action. The primary aim must be the removal of all introduced animals, especially goats, rabbits, rats and cats. Priority should be placed on the eradication of goats on Alejandro Selkirk, rabbits on Robinson Crusoe and Santa Clara, and cats in the settlement of San Juan Bautista. Due to its small size and more accessible terrain, it may be possible to swiftly eradicate introductions from Santa Clara, which could then become a natural refuge for at least the seabirds.

The prevention of fresh alien arrivals is of critical importance for future conservation, while the archipelago's endangered taxa also require further ecological research, including continuous monitoring of populations and their reproductive success. Much vital data for many bird species is unavailable. The Másafuera Rayadito (on Alejandro Selkirk) and the Juan Fernández Firecrown (on Robinson Crusoe), which are both highly endangered and aesthetically attractive, could function as flagship species. The Juan Fernández archipelago should be treated and managed as one of the world's most spectacular, but also most endangered biosphere reserves. International funds should be used to finance surveys, conservation action and especially eradication programmes.

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Figure 1. Male Juan Fernández Firecrown *Sephanoides fernandensis* resting, following nectar-feeding on an allochthonous shrub, in the settlement on Isla Robinson Crusoe (Ingo Hahn)

Figure 2. Female Juan Fernández Firecrown *Sephanoides fernandensis* feeding on an allochthonous thistle *Cirsium* sp. in Valle Puerto Ingles (Ingo Hahn)

Figure 3. Juan Fernández Tit-Tyrant *Anaeretes fernandezianus* exclusively occurs in forests of Isla Robinson Crusoe, where it forages for various arthropods (Ingo Hahn)

Figure 4. Red-backed (Másafuera) Hawk *Buteo polysoma exsul* is the only native bird predator on Isla Alejandro Selkirk (Ingo Hahn)

Figure 5. Grey-flanked (Másafuera) Cinclodes *Cinclodes oustaleti baeckstroemii* is endemic to Isla Alejandro Selkirk; habitats along washes are preferred (Ingo Hahn)

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Figure 6. Adult Juan Fernández Petrels *Pterodroma externa* leave Isla Alejandro Selkirk prior to daylight; only injured birds remain, like this one with a broken wing (Ingo Hahn)

Figure 7. Feeding area of Red-backed (Másafuera) Hawk *Buteo polysoma exsul* showing prey items: *Pterodroma longirostris*, *P. externa* and introduced Ship Rats *Rattus rattus* (Ingo Hahn)

Figure 8. Vegetation destruction and erosion caused by introduced goats on Isla Alejandro Selkirk; the autochthonous fern stands of the alpine region are part of the limited breeding habitat of the highly endangered Masafuera Rayadito *Aphrastura masafuerae* (Ingo Hahn)

Figure 9. At some high-altitude sites on Isla Alejandro Selkirk the vegetation is still intact; below 400 m (see background) the habitat is principally grassland, which is the preferred grazing area for introduced goats (Ingo Hahn)

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