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ON THE ECOLOGY AND CONSERVATION OF THE CRITICALLY ENDANGERED MASAFUERA RAYADITO (*APHRASTURA MASAFUERAE*)

Jorge A. Tomasevic[1,2], Peter J. Hodum[3], & Cristián F. Estades[1]

[1]Lab. Ecología Vida Silvestre, Depto. Manejo Recursos Forestales, Fac. Ciencias Forestales, Universidad de Chile, Casilla 9206, Santiago, Chile. *E-mail*: jatomasevic@yahoo.com

[2]School of Forest Resources, Box 352100, University of Washington, Seattle, WA 98195-2100, USA.

[3]Juan Fernández Islands Conservancy, Oikonos Ecosystem Knowledge, Benicia, CA 94510, USA.

Resumen. – Sobre la ecología y conservación del Rayadito de Masafuera (*Aphrastura masafuerae*), especie en peligro crítico. – El Rayadito de Masafuera (*Aphrastura masafuerae*) es una especie escasamente estudiada actualmente en peligro crítico de extinción, endémica de la Isla Alejandro Selkirk en el Archipiélago Juan Fernández, Chile. La última estimación de su tamaño poblacional fue tan baja como 140 individuos. Entre las posibles causas para esta disminución están la pérdida y degradación de su hábitat y potencialmente la falta de sitios apropiados para nidificar. Realizamos una nueva estimación de su tamaño poblacional usando conteos puntuales e investigamos los patrones de uso de hábitat en la época post-reproductiva de los años 2006 y 2007. Además, establecimos 81 cajas anideras (en tres áreas) para estudiar su ecología reproductiva y para aumentar potenciales sitios de nidificación. Nuestra estimación de densidad promedio para el rayadito fue de 0,54 ± 0,19 ind./ha en el año 2006 (promedio ± EE, aproximadamente 250 individuos en la parte sur de la isla). No pudimos cubrir todos los lugares donde se encuentra la especie, pero extrapolando la estimación conservadora de hábitat potencial de 1000 ha estimamos que la población total es de 500 individuos (148–932, 95% IC). Encontramos una relación positiva significativa entre el número de rayaditos y la cobertura de canelo (*Drymis confertifolia*) (GLM Poisson, P = 0,045), incluso considerando que los canelos cubren aproximadamente el 8% de la superficie de la zona sur de la isla. Un año después del establecimiento, siete de 42 cajas anideras (grupo en la zona sur) mostraron signos de uso por rayaditos: tres nidos completos y cuatro nidos sin completar. Los tres nidos completos tenían una estructura de soporte (1042,99 ± 18,16 cm^3) construida en base a raicillas de caneo y helecho arbóreo (*Dicksonia externa*) y una copa suave (313,68 ± 112,08 cm^3) hecha con plumas de fardela (*Pterodroma externa* and *P. longirostris*). Nuestros resultados muestran un tamaño poblacional similar al encontrado a fines de la década de los 1980, aunque la especie aún enfrenta considerable amenaza. La probabilidad de ocupación de las cajas anideras no estuvo relacionada con el diámetro del árbol o por la altura donde se instaló la caja. Estos resultados sugieren que el canelo y cajas anideras podrían ser usados en un plan de restauración del hábitat para el rayadito.

Abstract. – The Masafuera Rayadito (*Aphrastura masafuerae*) is a little known, critically endangered, endemic bird species of Alexander Selkirk Island, Juan Fernández Archipelago, Chile. The last assessment reported a population as low as 140 individuals. Possible causes for its decline could be habitat loss and degradation, and potentially a lack of nest sites. We conducted a new population assessment using point counts and investigated habitat use patterns during the post-breeding season of 2006 and 2007. We also installed 81 nest boxes (in three areas) to study the species' breeding ecology and to increase potential nest sites. Our estimated mean rayadito abundance for 2006 was 0.54 ± 0.19 ind/ha

(mean ± SE, approximately 250 individuals in the southern area). We could not survey all the areas where the rayadito might be found, but extrapolating to a conservative estimate of potential habitat of 1000 ha we estimate a total population size of 500 individuals (148–932, CI 95%). We found a significant positive relationship between number of rayaditos and canelo (*Drymis confertifolia*) cover (GLM Poisson, $P = 0.045$), with canelo coverage approximately 8% of the southern area. A year after establishment, seven out of 42 boxes (southern group) had been occupied: three complete and four incomplete nests. All three complete nests had a supporting structure (1042.99 ± 18.16 cm^3) of canelo and tree-fern (*Dicksonia externa*) rootlets and a soft cup (313.68 ± 112.08 cm^3) of petrel (*Pterodroma externa* and *P. longirostris*) feathers. Our results showed rayadito population levels similar to what was found in the late 1980s, although the species still faces considerable threats. The probability of box occupation was not affected by tree diameter or box placement height. These results suggest that canelo trees and nest boxes could be used in the restoration of the rayadito habitat. *Accepted 19 October 2010.*

Key words: Masafuera Rayadito, *Aphrastura masafuerae*, Furnariidae, island conservation, Alexander Selkirk Island, Juan Fernández Archipelago, Chile.

INTRODUCTION

The Masafuera Rayadito (*Aphrastura masafuerae*, Furnariidae) is a landbird species endemic to Alejandro Selkirk Island (formerly known as Masafuera I.), Juan Fernández Archipelago, Chile. It inhabits remnants of luma (*Myrceugenia schultzei,* 600–800 m a.s.l.) forests, mixed-forests of canelo (*Drimys confertifolia*) with tree fern (*Dicksonia externa*, 800–1100 m a.s.l.), and highland ferns (*Lophosoria quadripinnata*) between 1100 and 1380 m a.s.l., the summit of the island (Brooke 1988, JAT pers. obs.).

There have been only a handful of reports on this species, with all of them consistently finding very few individuals, reporting the species as rare and possibly confined to the higher parts of the island (Lönnberg 1921, Johnson 1967, Bourne 1983, Brooke 1987, 1988, Hahn & Römer 1996, Hahn *et al.* 2005a). The first attempt to establish the population size for this species was conducted by Brooke (1988) who used fixed-width transects to estimate a mean abundance of 1 ind./2.5 ha, with approximately 330 individuals for the entire island. A more recent estimation by Hahn *et al.* (2006) suggested a significant decrease to about 140 individuals by the early 1990s. This estimate supported the species being uplisted to Critically Endangered by IUCN (Birdlife International 2006).

The breeding ecology of the Masafuera Rayadito (hereafter rayadito) is poorly known. Prior to this study, only four nests had ever been found (Hahn *et al.* 2004). All of them were placed in rock crevices at different heights above the ground and at elevations above 1200 m a.s.l.. Because Hahn *et al.* (2004) were unable to reach the interior of those nests, nest materials, overall shape, and egg characteristics remained undescribed. the authors suggested that the rayadito may breed below 1200 m a.s.l., they did not to find any nests at lower elevations.

The main objective of this study was to provide relevant biological information that can be useful in the design of a conservation plan for the rayadito. To do so, we focused on: 1) conducting a new population assessment, 2) studying some aspects of the species' breeding biology, 3) establishing potential predation pressures upon eggs, and 4) studying post-breeding habitat use.

METHODS

Study area. We conducted the study on the Alexander Selkirk Island, Juan Fernández Archipelago National Park, Chile (33°46'S,

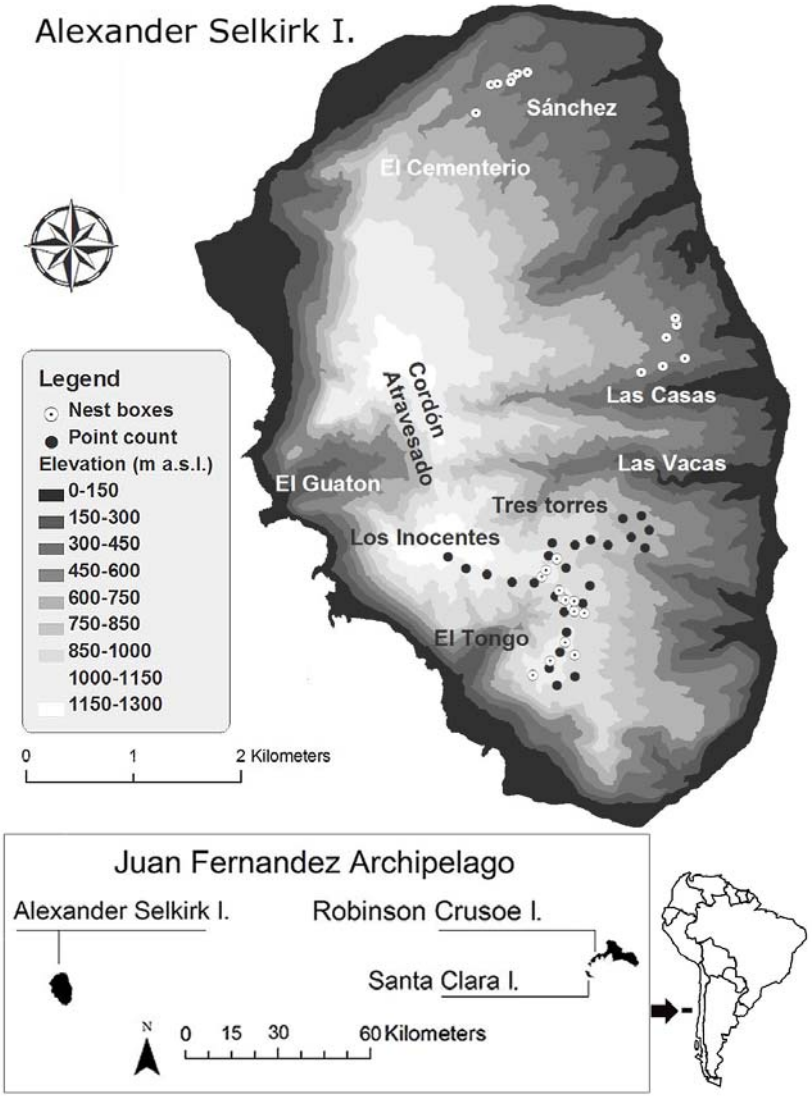

FIG. 1. Study area: Juan Fernández Archipelago National Park, Chile. Black circles indicate plots where we conducted both point counts and vegetation assessments (radius of the plots in the figure does not show the actual radius of sampling plots). White circles with black dot in the center indicate locations of nest box groups (see Methods).

80°47'W, Fig. 1) during the Austral summers of 2006 and 2007. This island has suffered from severe human-induced degradation pressure during the last two centuries. The main factors affecting the native vegetation on the island have been the introduction of goats (*Capra hircus*) for meat production and the destruction of native woodlands, mainly by wildfires.

We centered most of our work on the southern part of the island, where we had previously observed rayaditos and where park

rangers had suggested were the highest concentrations of rayaditos (we explored other areas of the island as well). We established 25 sampling plots (Fig. 1), all of which were separated by at least 200 m. We selected representative conditions of terrain, vegetation cover, and elevation. We conducted both a density estimation and vegetation assessment on these plots during the 2006 field season. During both field seasons, we covered as much surface of the island as the rugged terrain and logistical constraints permitted.

Field seasons. We conducted our field work from 1 February to 13 April 2006 and from 23 January to 6 March 2007.

Population assessment. To assess the rayadito's abundance, we conducted fixed-radius point counts (Bibby *et al.* 1992). We preferred these counts to variable-radius point counts because the dense vegetation cover and the low abundance of the species made it impractical to fit a detectability curve. We conducted all point-counts during non-rainy days. We estimated the SE of the mean abundance using the jackknife estimator (Zahl 1977).

We chose a maximum observation radius of 30 m that was practical for both dense forest and open areas. We conducted two-observer point counts that consisted of two simultaneous 5-min counts with two independent observers separated by 80 m. Five minutes after we completed the first two counts, we conducted another pair of counts following the protocol used by Estades & Temple (1999). We averaged these four counts as one observation for that sample point.

We conducted a first series of 50 point counts (25 plots x 2 simultaneous point counts) during February 2006 and a second series of 40 point counts (20 x 2) during March 2006. Due to bad weather conditions (14 out of 17 days of rain), we were unable to conduct point counts during the 2007 season.

Habitat use. We assessed rayadito habitat use at both coarse and fine scales. The coarse-scale approach consisted of visually estimating the vegetation cover divided into three categories (trees, ferns, or prairies) in each 80-m-radius plot. We used each vegetation type as an independent variable to explain the number of rayaditos found on each sampling plot using GLM, assuming a Poisson-distribution error structure (Kutner *et al.* 2004). We conducted these analyses in R v.2.8.1 for Windows (Ross & Gentleman 1996).

In addition, we recorded a suite of fine-scale habitat features at all sites where we found rayaditos. In these opportunistic observations, we recorded the number of individuals, their main behavior (foraging, calling, defense, or flight), maximum fern height, total fern cover, total canelo cover, and maximum tree height in a 10 m radius circular plot. Fern and canelo cover were recorded at different height levels, therefore they may not add to 100%. We also recorded the geographical coordinates (using GPS) and distance to the nearest creek whenever possible.

Nest-box experiment. The Thorn-tailed Rayadito (*Aphrastura spinicauda*) is the mainland sister species of the Masafuera Rayadito. It also inhabits forests and nests on cavities on trees created by natural wood decay or by woodpeckers (Johnson 1967, Vaurie 1980). Even though it is one of the most abundant birds in Chilean mainland forests (Estades & Temple 1999, Tomasevic 2002, Cornelius 2006), there is evidence that its population size may be limited by the availability of nesting sites in second-growth and fragmented forests (Cornelius 2006, Tomasevic & Estades 2006, Cornelius *et al.* 2008). For that reason, we decided to try using nest-boxes for the Masafuera Rayadito, particularly considering that natural

tree cavities on the island may be very scarce because of the small average diameter of trees remaining on most of the island (Tomasevic, pers. observ.). Our objective was not to test the nest-site limitation hypothesis *per se* (Newton 1994) but to increase the availability of potential nesting sites, considering the critically low population level of the rayadito (Hahn & Römer 1996).

We installed 81 nest boxes in 27 groups of three (in order to increase the probability of occupation per group) during the 2006 field season. We set them only in native trees, either luma or canelo (depending on the dominant forest type), from 1.5 up to 5 m (2.65 ± 0.15 m, mean ± SE) above the ground. The entrance of the boxes was oriented randomly (Rayleigh test, n = 42, r = 0.20, $P = 0.19$; Zar 1999). We focused most of our effort on the southern part of the island where we found most of the rayaditos but also provided boxes in areas where rayaditos were very scarce (center group) or absent (northern group, Fig. 1). We installed 14 nest-box groups in canelo remnants of the southern part of the island (n = 42 boxes), with sites ranging from 993–1103 m a.s.l. (1039 ± 27.88 m). We also installed six groups in the central part of the island (mainly in the Las Casas creek where we detected just one rayadito) at elevations ranging from 415–552 m a.s.l. (497 ± 47.32 m), and seven groups on the northern part of the island ranging from 381–582 m a.s.l. (457 ± 74.05 m). Both the central and northern groups were installed on luma remnants that differed from the southern groups by vegetation characteristics (composition and structure) and moisture conditions (JAT pers. observ.). We decided to install nest boxes in these northern and central groups, even though there were no rayaditos present in that elevational range (we observed some rayaditos along the creeks of the northern section above 600 m a.s.l.), to offer an opportunity for the species to settle in currently unoccupied areas.

Predation experiment. To determine potential predators of rayadito eggs, we conducted an experiment with clay eggs. We used the egg dimensions of the Thorn-tailed Rayadito based on our experience with that species in south-central Chile (Tomasevic & Estades 2006). We built 80 clay eggs that we distributed in two paired situations: 1) nest in nest-box vs. nest on the ground of the same tree, and 2) nest on tree trunk vs. nest on tree fern. In all situations, we simulated nests using tree-fern leaves. To avoid olfactory attraction, we wore latex gloves when we made the artificial eggs and set up the nests. We set this experiment in a two-day period and checked the fate of the nests after seven nights of exposure.

RESULTS

Habitat description and use patterns. The sampling plots were located from 680–1350 m. a.s.l. and were dominated by fern cover (78.6 ± 4.96%), followed by prairies (12.9 ± 3.55%), and finally by canelo trees (8.6 ± 3.43%). Canelos are only present from 850–1150 m a.s.l. on the southern part of the island, whereas ferns can be found from 650–1380 m a.s.l. throughout much of the island.

Table 1 shows the mean attributes of the vegetation around the sites where we made opportunistic observations of rayaditos. Most of them were located close to creeks, where canelo trees are found more often (Table 1).

Based on the point-count data, we found a significant positive relationship between the number of rayaditos and the mean cover of canelo trees (GLM Poisson, $P = 0.045$). We found no significant relationship when relating the number of rayaditos to fern cover (GLM Poisson, $P = 0.252$), prairie cover (GLM Poisson, $P = 0.518$), or elevation

TABLE 1. Mean (SE) habitat features of locations of opportunistic observations of Masafuera Rayadito occurred. Number of rayadito individuals (N), fern height (H_{fern}), fern cover (Fern), canelo cover (Canelo), maximum canelo height (H_{canelo}), and distance to nearest creek (D_{creek}) are shown for 2006, 2007, and both field seasons combined.

Season	N	H_{fern} (m)	Fern (%)	Canelo (%)	H_{canelo} (m)	D_{creek} (m)
2006 (n = 15)	1.6 (0.21)	1.8 (0.19)	84.6 (5.94)	24.3 (8.45)	2.4 (0.59)	42.0 (14.45)
2007 (n = 8)	2.0 (0.50)	2.0 (0.26)	50.0 (12.11)	41.4 (18.53)	3.0 (1.10)	38.0 (13.46)
Both (n = 23)	1.7 (0.22)	1.9 (0.15)	74.3 (6.46)	30.0 (8.28)	2.6 (0.52)	40.4 (10.34)

(GLM Poisson, $P = 0.538$) within the potential habitat range.

During 2006, 2007, and an extra visit by PJH in 2009 (PJH pers. observ.), we confirmed the presence of rayaditos in most of the range described by Brooke (1987, 1988). The only area we were unable to survey was the El Guatón drainage (Fig. 1), same as Brooke (1988).

Local abundance and total population size. The rayadito was the most abundant landbird species in the study area. Our mean estimated density for 2006 was 0.54 ± 0.19 ind./ha., which when extrapolated to approximately 460 ha in the southern part of the island gives an estimated population of about 250 individuals in this area; there is 95% confidence that the abundance of rayaditos in the southern part of the island falls between 68 and 429 individuals. Unfortunately, we were unable to conduct point-counts in all potential habitat types, but considering a conservative estimate of 900–1000 ha of total habitat area for the species the total population size of the species might rise to approximately 500 individuals (148–932, 95% CI).

Behavioral observations. Rayaditos were active throughout the entire day in both years, even in adverse weather conditions (cold, rainy or strong winds). Most of our observations were of single individuals (9/15 in 2006, 4/8 in 2007). However, we also found family groups with up to 5 individuals both in 2006 and 2007. We were able to distinguish adults from juveniles due to different plumages (adults showed more worn and duller plumage than juveniles) and behaviors (adults feeding juveniles).

The proportion of behaviors exhibited by individuals varied across years (foraging: 48% in 2006, 20% in 2007; defending territories: 19% in 2006, 40% in 2007; flying: 19% in 2006, 40% in 2007).

Nest-box experiment. During the 2007 season, we checked the use of the nest-boxes. Although it was clear that most breeding activity took place before our field season, we found evidence of use by rayaditos in 7/42 boxes in the southern part of the island. We are confident that this nesting activity was not due to Grey-flanked Cinclodes (*Cinclodes oustaleti baeckstroemii*) because of their larger body size (probably too large to fit through the box entrance) and preferred nesting habitat (they are known to breed in rock crevices on creeks (Hahn *et al.* 2005b) rather than in forests where we installed the nest-boxes). We found no evidence of rayadito nest-box use either in central or northern boxes (n = 39).

Three of the seven used boxes contained complete nests. All three complete nests were constructed using canelo and tree-fern rootlets (2–3 mm diameter) to create a supporting structure (1042.99 ± 18.16 cm^3). Inside this structure there was a cup (diameter: 7.67 ± 0.92 cm, depth: 6.27 ± 0.78 cm, volume: 313.68 ± 112.08 cm^3) constructed of petrel

(*Pterodroma externa* and *P. longirostris*) feathers. In one nest we found a single white, elliptical, unhatched egg, which measured 21.3 x 16.0 mm. The size of this egg was larger than the eggs of the Thorn-tailed Rayadito (18.3 x 14.4 mm, Johnson 1967). This is consistent with the larger size of the Masafuera Rayadito (wing length: 64.8 ± 2.81 mm, bill: 15.3 ± 0.59 mm, n = 5; Johnson 1967, Hahn *et al.* 2004) compared to the Thorn-tailed Rayadito on mainland Chile at similar latitude (35ºS, wing length: 59.1 ± 0.74 mm, bill: 8.1 ± 0.19 mm, n = 42; Estades *et al.* unpubl. data). Because these nests were clearly abandoned long before we checked them, it was not possible to find other evidence of nesting activity (such as fecal sacs).

The probability of nest-box occupation was not affected by tree DBH (Logistic regression, $P = 0.61$) or box height (Logistic regression, $P = 0.09$).

Predation experiment. After seven nights, 13/20 eggs in tree trunks, 16/20 eggs on tree ferns, 18/20 on nest boxes, and 9/20 eggs on the ground remained in the nests. We found the greatest losses in nests on the ground, where 11/20 eggs disappeared. We found the lowest rate of egg loss in nest boxes (2/20 eggs). We found two eggs with numerous bite marks of non-native rodents: one in a canelo tree (c. 1.8 m above the ground) and one in a tree-fern (c. 0.5 m above the ground). The egg depredated in the canelo tree trunk showed one marking by *Mus musculus*, and 12 markings by *Rattus* sp.; the egg predated on tree ferns showed no marks by *M. musculus*, but 22 markings by *Rattus* sp. We identified the markings by measuring teeth of rodents collected at the fishermen's settlement on the island.

DISCUSSION

Our results are similar to those obtained by Brooke (1987, 1988). In fact, we confirmed the presence of the species in all of the same areas that Brooke reported, except for those that we were unable to visit. His density estimate (0.4 ind./ha) is slightly lower than ours (0.5 ind./ha), but this difference is not statistically significant as this estimate is contained within our 95% confidence interval. Brooke (1988) estimated the population size at 330 individuals, whereas our estimate is slightly larger, but the extrapolation of our results to the entire island should be made with caution. Both estimates are greater than those presented by Hahn *et al.* (2006) for the 1990s. Unfortunately, we are unable to establish the nature of this difference. In any case, it is clear that the population size of the rayadito is too low to ensure its long-term persistence.

Although we did not assess habitat selection directly (e.g., by comparing used vs random points, Manly *et al.* 2002), the GLM analysis suggests that rayaditos might be selecting for higher canelo cover. Also, when comparing mean canelo cover between the plots where we conducted the point counts (random points, c. 8%) with the locations where we opportunistically found rayaditos (used points, c. 24%), there is a noticeable difference pointing to the same pattern. However, because we assessed vegetation at a smaller scale (10 m) around opportunistic observations points we did not conduct a formal assessment of the latter difference.

The significant positive relationship of the abundance of the species with canelo forest suggests that this species may be more reliant on forests than was previously thought (Johnson 1967). In fact, Brooke (1988) also reported the presence of the rayadito in forests. Moreover, our finding of family groups and the use of nest-boxes below 1200 m a.s.l. suggests that the rayaditos may be breeding in canelo forests, and that their density could be limited by the availability of nesting sites. Restoration action should be focused on ensuring the establishment of canelo seedlings and to

increase the area covered by canelo trees in historically occupied habitat.

The most remarkable findings of the 2007 season were the nests and the egg of the rayadito. Although these data represent nests found in nest boxes, there was neither any previous information on the interior characteristics of the rayadito nests nor on the kind of materials used for their construction; this is also the first egg ever described. This finding excited the local community on both islands of the archipelago, increasing their involvement with the project. We donated the egg to the National Museum of Natural History in Santiago, Chile in September 2007.

Although we have no conclusive evidence about the predators on the rayadito, our results point to the exotic rodents that infest the island. Among the nest locations we tested, ground nests showed the highest loss rate. This could be an effect of petrel activity (when returning to their nests in burrows; JAT pers. observ.) combined with potential predation, but we were unable to distinguish between the two factors. There is evidence that these exotic rodents are also depredating eggs and chicks of the two endemic petrels (*P. externa* and *P. longirostris*, PJH unpubl. data). Although we were unable to assess predation pressure by feral cats (*Felis silvestris catus*), they presumably opportunistically prey on rayaditos, with ground nesting pairs particularly vulnerable. Eradication of these introduced mammals should be the highest priority conservation action on Alexander Selkirk Island as it is critical to ensure the persistence of multiple endemic species and subspecies, including rayaditos and petrels.

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