

Conserving Chile's most critically endangered bird species: First data on foraging, feeding, and food items of the Másafuera Rayadito (Aves: Furnariidae)

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> Abstract

First data of foraging, feeding, and food items of *Aphrastura masafuerae* from Alejandro Selkirk Island, Chile are presented. Brood-caring Másafuera Rayaditos 1) forage mostly inside dense vegetation below the protective cover, 2) leave the vegetation only for a short duration to fly from the nest site to the foraging destination and to stop on a rock before entering the nest hole to control surroundings, 3) minimize energetic costs by foraging mainly hill-parallel, 4) use a 3–4 ha home range by visiting distance zone in different frequency, 5) transport nestling faeces off the nest hole but do not hide them from predators, and 6) feed their nestlings with arthropod prey, mainly small butterfly larvae, in which there are nice-differentiated from sympatric Másafuera Cinclodes. More detailed studies on the breeding ecology and foraging are needed implement management plans and avoid extinction of this badly known island endemic.

> Kurzfassung

Erste Daten zu Furagieren, Füttern und Nahrungsgrundlagen von *Aphrastura masafuerae* der Insel Alejandro Selkirk (Chile) werden präsentiert. Brutpflegende Másafuera-Schlüpfer 1) furagieren meist unterhalb der dichten und schützenden Vegetationsdecke, 2) verlassen die Vegetation nur kurzzeitig, um vom Nest zum Ort der Nahrungssuche zu fliegen und bevor sie in die Nisthöhle einfliegen um die Umgebung zu kontrollieren, 3) minimieren ihre energetischen Kosten durch meist hang-parallele Nahrungssuche, 4) nutzen ein 3–4 ha großes Revier indem sie die Distanzzonen verschieden häufig frequentieren, 5) transportieren Kotballen ihrer Nestlinge aus der Nisthöhle, aber verstecken sie nicht vor Fressfeinden und 6) füttern ihre Nestlinge mit Arthropoden als Beute, meistens mit kleinen Falterlarven, wodurch sie sich in Bezug auf die Nestlingsnahrung vom sympatrischen Másafuera-Uferwippen anders einnischen. Es werden noch detailliertere Studien zur Nahrungs- und Brutökologie benötigt, um Managementpläne erstellen zu können und das Aussterben dieses wenig bekannten Inselendemiten zu verhindern.

> Key words

Habitat use pattern, nesting ecology, brood care, ovenbirds, island endemics, biodiversity conservation, home range structure, *Aphrastura masafuerae*, *Cinclodes oustaleti baekstroemii*, Alejandro Selkirk, Juan Fernández Islands.

Introduction

The Másafuera Rayadito *Aphrastura masafuerae* (Aves: Furnariidae) is endemic to Isla Alejandro Sel-

kirk, where it is restricted to the high altitudes dominated by fern stands and tree fern forest. *Aphrastura*

masafuerae, described by PHILIPPI & LANDBECK in 1866, presently is Chile's most threatened bird species. It is listed as a "critically endangered species" in the Red List (BIRDLIFE INTERNATIONAL, 2010). Having a total population of only about 140 individuals, it is the most prone to extinction amongst all bird species of Chile (HAHN *et al.*, 2009).

Few field observations of the Másafuera Rayadito have been made since its scientific description. The bird was not seen for fifty years (comp. MILLIE according to JOHNSON & GOODALL, 1967; TORRES & AGUAYO, 1971) and already categorised as probably extinct (VAURIE, 1980), until BOURNE (1983) rediscovered it by seeing four individuals. Then BROOKE (1988) and HAHN (1998) informed of a live population. On February 2nd 1986 BROOKE (1988) saw an adult bird carrying unidentified food, but it disappeared and was not followed. No other information of food sources and feeding behaviour existed.

Main reasons for the small population seem to be man-made habitat destruction and introduction of alien species. For a broader discussion of reasons for decrease refer to BOURNE *et al.* (1992), CUEVAS & LEERSUM (2001), and HAHN & RÖMER (2002). However, predation by native Másafuera Hawks *Buteo polyosoma exsul* was not seriously considered before our studies (HAHN *et al.*, 2004a, b). Another not investigated and possibly limiting factor may be competition with a second insectivorous ovenbird in the same island, the Masafuera Cinclodes *Cinclodes oustaleti baeckstroemii*.

1) The reproductive period is of high critical importance to a species, in particular for island birds (e.g. MOORS, 1985). As *A. masafuerae* is in danger of extinction, the first purpose of this work is to make ecological information available on home range structure, foraging behaviour and food sources during the breeding season, as these will become important for future conservation activities. Therefore we investigate the orientation and distance of foraging flights from and to the nest by adult rayaditos. We additionally want to analyse the faeces transports away from the nest and their importance in keeping the nest locality secret from hunting hawks.

2) Islands are generally species poor ecosystems. This is especially obvious for the land birds of Alejandro Selkirk. We suggest a similar scarcity in the number of insect (prey) species, and, thus a strong reliance on certain types of prey. In this study we aim to present observations on the feeding behaviour and food items conducted at the only nest sites ever been found of the Masafuera Rayadito. Furthermore, we aim to discuss the potentially important effect of competition risk as a factor limiting its breeding performance by present-

ing comparative data on the food items of *Cinclodes oustaleti baeckstroemii*.

Study area

The study area is Isla Alejandro Selkirk (formerly Másafuera), the westernmost island of the Juan Fernández Archipelago. The island is positioned in the south-east Pacific Ocean (33° 45' south and 80° 45' west of Greenwich) off the coast of Chile. It is 167 km west of Isla Robinson Crusoe, the other major island, and is about 769 km distant from the South American continent. The area of Alejandro Selkirk is about 44.6 km², some 10 km from north to south and six from east to west. Reaching 1320 m at the Pico del Inocentes, it is the highest island of the archipelago. Alejandro Selkirk is part of the Chilean national park „Islas Juan Fernández“ that was founded in 1935. Because of its international value the archipelago was declared an UNESCO Biosphere Reserve in 1977. More detailed geographical descriptions may be taken from CASTILLA (1987), SKOTTSBERG (1956), and STUESSY & ONO (1998).

Field work and data collection

Field work on Juan Fernandez Archipelago was carried out during the breeding seasons of the years 1992/93, 1994/95, 2001/2002, and 2009. However, up to present only four nest sites of this species have ever been found (HAHN *et al.*, 2004a; in press). The data presented here comes from these four monitored nest sites (comp. Hahn *et al.*, 2004a; IN PRESS). Optic identification of birds based on the original species description (PHILIPPI & LANDBECK, 1866), which was supplemented later on (HAHN & RÖMER, 1996). As Másafuera Rayaditos generally rarely leave the dense vegetation, they are difficult to find. Mostly they are only recognised by the slight moving of a fern frond. If seen directly (which is rare at all), they attend to rapidly consume their food, making it difficult to identify the specific items additionally. Thus the first necessity was to detect a home range of a pair. This was possible after learning the vocalisations in the field, especially common call and morning song (comp. HAHN & MATTES, 2000). Then it was necessary to find a nest site where food items could be identified in the bill of adult rayaditos. Finding a nest site and a suitable observation point was still among the most difficult requirements for the planned observations, as the nests are well hidden and the terrain is badly accessible.

Results

As *Másafuera Rayaditos* generally rarely leave the dense vegetation cover, they are seen seldom. Mostly they are recognised by the slight moving of a fern frond or a call only (Fig. 1). Thus, without telemetry it is difficult to study home range structure and home range size. However, during the nestling time the adults regularly leave the vegetation cover (HAHN *et al.*, 2004b) (Figs. 2 & 7). Firstly, to enter the nest hole located in a rock upwards from the basing fern stand. Secondly, after feeding the nestlings and taking off, they fly above the fern cover to their next site of food search. Time is probably scarce because of high food demands for own nutrition and juvenile feedings (ca. 500 per pair and day). However, they fly tight above the ferns (0.5–2 m) and by that quickly reach the point of first food search. This point generally represents the most nest distant one during food search. From the point of landing they move inside the fern stand more or less directly towards the nest site, still searching for food. This behaviour allows studying the structure of the feeding range during the nestling time.

Orientation and distance of foraging flights

In regard to the topographical structure of the steep terrain, all detected home ranges were placed on slopes. 200 flights of adult *Másafuera Rayaditos* leaving the hole of nest site 2 were optically followed, compass point and geomorphologic orientation registered. The home range, surrounding the central nest site, was subdivided into eight compass point classes, each covering an angle of 45°. Three of these compass point classes were facing downhill, three uphill, and two hill-parallel.

137 flights (68.5 %) followed hill-parallel directions (NW, SE), although these directions mathematically took a proportion of 90 degrees (25 %) only. Thus, hill-parallel flights were over 170 % more often than expected by assuming statistically equal distribution. Contrary, flights directed downhill (6.5 %) or uphill (25 %) were underrepresented: although these areas each covered a proportion of 135 degrees or 37.5 % of the studied home range.

An observation series on the flight distance during foraging was aimed to give further information of home range extension and size. The distance of 312 flights off the nest sites 2 and 4 to the destination location was registered. The two observed nest sites (in two different years; Table 2) were located at the same rock, just a few meters apart from each other. Thus, differences of home range size were not caused by

the geomorphology of the surrounding terrain (or factors resulting from it). The first station after flying off the nest site was the basis of starting to forage. Seven distance categories were distinguished (Table 2, col. 1).

Home ranges were foraged up to a maximum of 100 meters by adult rayaditos. However, already flights of more than 75 meters were rare compared to the other categories, especially at nest site 4. The low number of flights off nest site 2 into the 0–10 m zone probably resulted from the nest site's downhill exposition (NE), by which the height above ground was greater than at nest site 4. Except for this, the distance categories of the home ranges 2 and 4 were frequented similarly and generally show the same tendency for both breeding pairs: the area up to 30 meters distance around the nest site was frequented most and the number of flights was decreasing along with larger distances. This pattern becomes even more obvious by calculating flight numbers per surface area. The area per distance category was calculated (Table 2, col. 8), and based on this the probability for a visit in any 100 m category given (Table 2, col. 9). The calculation results show a decrease in successive stages of flight numbers along with larger distance to the nest site.

Faeces transports

Principally the taking away of egg-shells and faeces over considerable distances is done by numerous passerine birds to not been discovered by predators. Hole-breeding birds additionally have to keep the nest cavity clean and accessible. Faeces were already registered in order to transports per time unit (HAHN *et al.*, 2004b). Here spatial observations of faeces transports were done according to distance and drop-down point to obtain the information, if *Másafuera Rayaditos* try to keep their nest site location secret from predators by taking faecal matter far away and/or inside the fern stands. Five distance categories were distinguished at nest site 4, to which the nestling excrements were taken by adult *Másafuera Rayaditos*. Farther than 20 meters away from the nest site faeces transports could not always be followed. If the rayadito kept the faeces in the bill throughout the flight, the distance to its disappearance in the vegetation cover was noted.

The quantitative registrations (Table 3) show that most faeces (n = 16) were already dropped inside the 20 meter radius, close to the nest site. Considering the distances in the Tables 2 and 3, less than 30 % of the faeces were carried more than 20 meters from the nest site, although about 80 % of the flights led further anyway. Most faeces were dropped down during the flight off the nest hole.

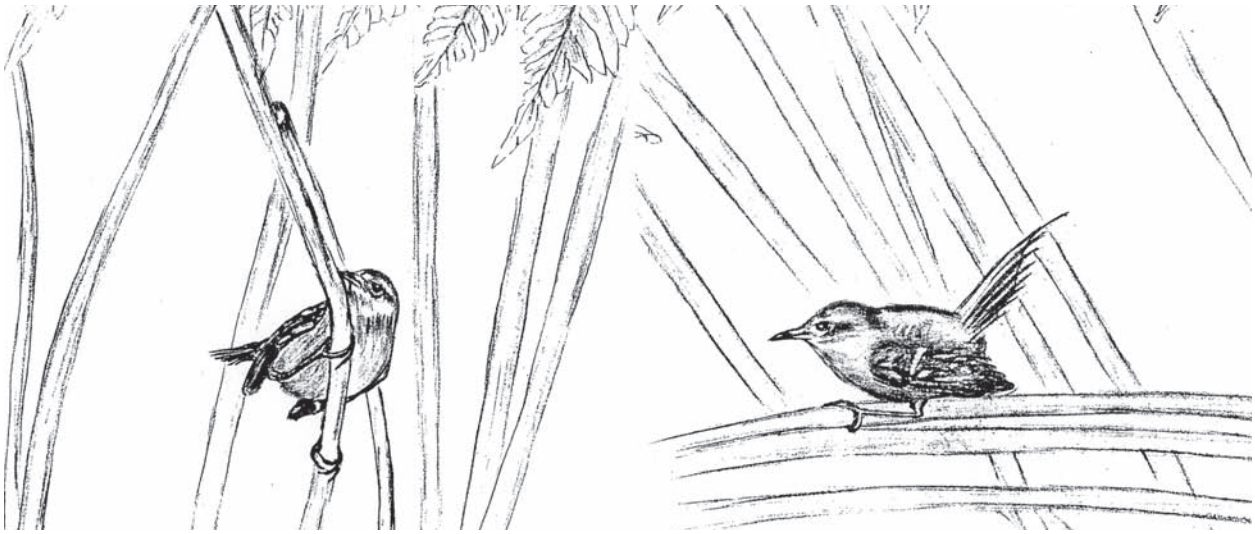


Fig. 1. Adult Másafuera Rayadito *Aphrastura masafuerae* forage in the alpine fern stands of *Lophosoria quadripinnata* for arthropod prey. They forage together in pairs, using vertical as well as horizontal structures, or stay in vocal contact in the shelter of a dense vegetation cover. Drawing by Erika Römer on base of photographs by IH.

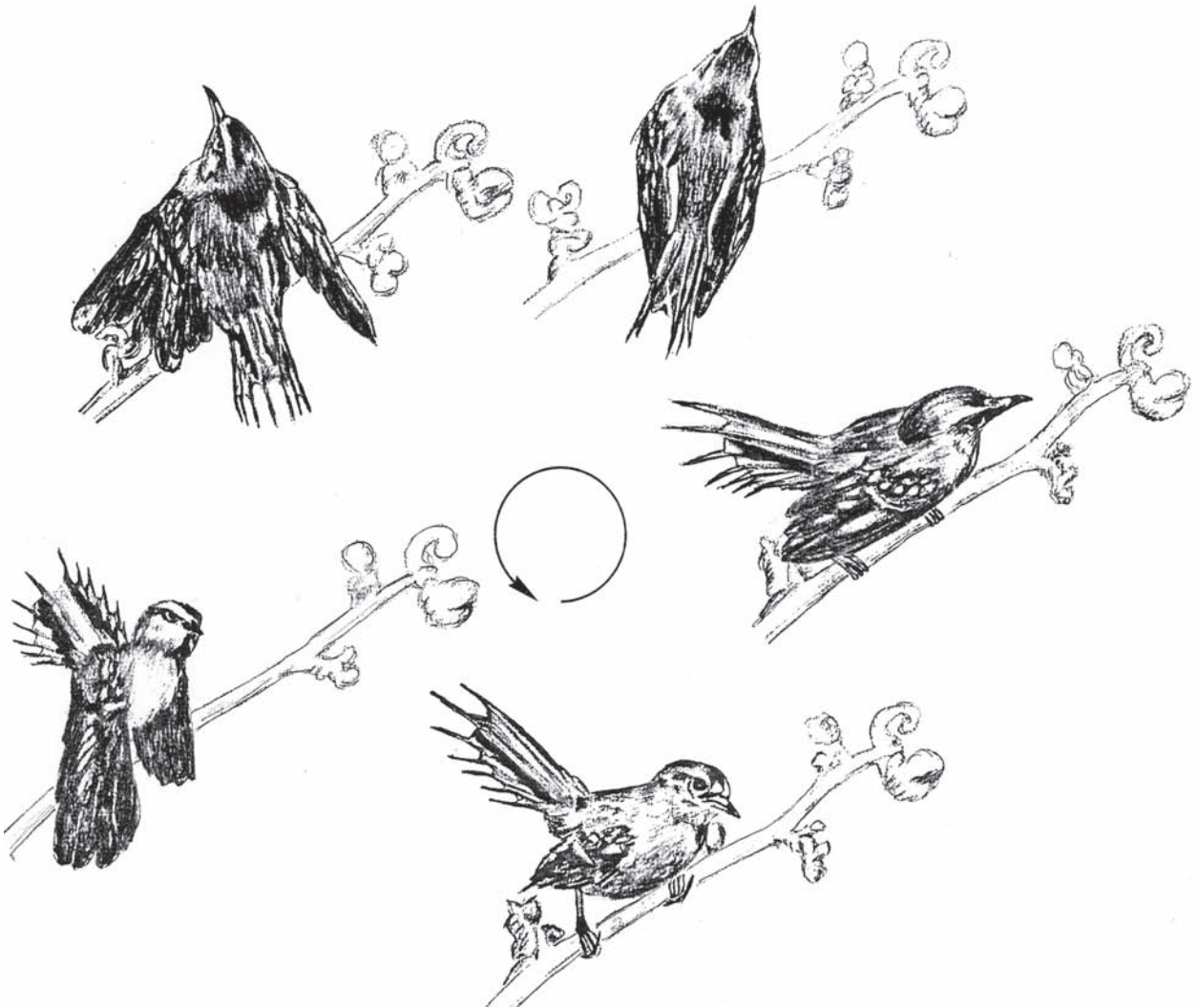


Fig. 2. Másafuera Rayadito *Aphrastura masafuerae* leave the fern stand cover only by exception, for example when disturbed during foraging or in the presence of a potential predator. The illustration shows the wren-like warning behaviour because of a nearby hawk close to the nest site. Drawing by Erika Römer on base of photographs by IH.

Tab. 1. Flight direction and geomorphologic orientation of brood caring *Aphrastura masafuerae* flying off nest hole 2 (January 6th).

geomorphologic orientation	compass point	total (n = 200)	%
downhill	N	6	3
downhill	NE	1	0.5
downhill	E	6	3
uphill	W	18	9
uphill	SW	5	2.5
uphill	S	27	13.5
hill-parallel	NW	67	33.5
hill-parallel	SE	70	35
sum	–	200	100

Tab. 2. Foraging flights of brood caring *Aphrastura masafuerae* and their distance to the nest sites 2 (January 9th) and 4 (January 9th).

distance zone (m)	flights off nest site 2		flights off nest site 4		flights total		area (m ²)	flights per 100 m ² of the distance category
	total	%	total	%	total	%		
0– 10	5	2.5	11	9.8	16	5.1	314	1.62
10– 20	26	13.0	20	17.9	46	14.8	943	1.57
20– 30	44	22.0	19	17.0	63	20.2	1570	1.29
30– 40	31	15.5	14	12.5	45	14.4	2200	0.65
40– 50	25	12.5	25	22.3	50	16.0	2827	0.57
50– 75	51	25.5	21	18.7	72	23.1	9817	0.24
75– 100	18	9.0	2	1.8	20	6.4	13745	0.05
sum	200	100	112	100	312	100	31416	–

Tab. 3. Faeces transports of brood caring *Aphrastura masafuerae* at nest site 4 (January 9th).

distance (m)	total	%
0– 5	2	9
5– 10	4	18
10– 15	8	37
15– 20	2	9
> 20	6	27
sum	22	100

Feeding behaviour and food items

Only at one of the four known nest sites of the Másafuera Rayaditos *Aphrastura masafuerae* (comp. HAHN *et al.*, 2004a), a suitable and closely observation point was present. At nest site 4 prey items of the two adults were identified in the bill, before they entered the nest hole for feeding the nestlings. It was qualitatively distinguished in prey types per feeding event. Mostly only one type of prey was carried during one feeding event. However, sometimes two prey types were brought at once.

Five different types of prey were recorded (Table 4). Only arthropods were observed as food for nestlings, no vegetable one. More than two thirds of all recorded feedings contained butterfly larvae. Catching larvae from the fern fronds with an insect net showed that all “small, green” specimens belonged to one single species (Fig. 3). The small whitish silver moth is very likely to be the imago of this larva, and to belong to the same species. Thus, about three quarters of the prey seems to come from only one species. The remaining quarter consisted of spiders (Fig. 4). Pill bugs and big brown lepidopteron larvae were fed by exception only, and were never present in samples of insect nets. As the small green lepidopteron larva was the most important food source, its numbers and aggregation with other prey items per feeding event were registered.

About half of the feeding events contained two small green lepidopteron larvae alone (Table 5). Másafuera Rayaditos are also able to carry three of these larvae or one larva together with a different arthropod prey. The proportion of feeding events of one single larva is relatively high (over one third). Thus, this was obviously not caused by their transport ability, as clearly shown by the other feeding events and the small size of larvae (comp. Fig. 3). More probable is the low density of suitable arthropod prey throughout



Fig. 3. Brood-caring Mésafuera Rayadito *Aphrastura masafuerae* carries two small green lepidopteron larvae to the nest hole for feeding the nestlings.

Fig. 4. Brood-caring Mésafuera Rayadito *Aphrastura masafuerae* carries a spider to the nest hole for feeding the nestlings. It landed just left of the nest entrance, controlling the surroundings before entering.

Fig. 5. Small entry to the nest hole of the first nest site discovered for the Mésafuera Rayadito *Aphrastura masafuerae*. The entrance is just brought enough to allow the birds to enter, representing a firm natural protection from any larger predators.

Fig. 6. A Mésafuera Hawk *Buteo polyosoma exsul* has discovered the nest hole, sitting right in front of it, later trying to snap with its talons inside. An adult Mésafuera Rayadito *Aphrastura masafuerae* is warning just two meters apart on a projecting rock. The hawk attack remained unsuccessful, as the nest entrance was small and the nest itself too deep. Photos: I. Hahn.

the home range. Adults were foraging in an area of up to 100 meters distance from the nest, feeding nestlings every ca. 3 ½ minutes on average (HAHN *et al.*, 2004b). Although rayaditos are highly active (VAURIE (1980) describes them as “restless birds”), the vari-

ability and density of their prey seems small. Thus, it is probable that Mésafuera Rayaditos depend on one specific prey species, which is small and often found single.



Fig. 7. Foraging adult Másafuera Rayadito *Aphrastura masafuerae* stops shortly on top of a fern frond to search for arthropod prey items between the small leaves of a *Lophosoria quadripinnata*.

Fig. 8. Másafuera Cinclodes *Cinclodes oustaleti baekstroemii* mostly hunt on flying insects. They are acrobatic and fast flyers, and do not depend on the shelter of a vegetation cover to escape hawks. Mostly frequenting open and rocky habitats, they are rarely seen on ferns like here.

Fig. 9. Másafuera Cinclodes *Cinclodes oustaleti baekstroemii* also nest in natural hole of rock walls. As their nest entrances are wider than those of Másafuera Rayaditos, the nest itself is located even deeper inside the rock for inhibit hawk predation.

Fig. 10. A Másafuera Cinclodes *Cinclodes oustaleti baekstroemii* carries several small whitish-silvery lepidopteron imagines inside the nest hole for feeding the nestlings near the top of Los Innocents Mountain. Photos: I. Hahn.

Discussion

The results of this study indicate that *Aphrastura masafuerae* is principally insectivorous. The Thorn-tailed

Rayadito *Aphrastura spinicauda*, closely related and widely distributed on the mainland, is also known to mainly feed on small arthropods (VUILLEUMIER, 1967; JOHNSON & GOODALL, 1967; own observations IH & PV 1993–2009). However, single observations re-

Tab. 4. Prey item types identified in the bill of adults before entering the nest: *Aphrastura masafuerae* (nest site 4; January 9th) and *Cinclodes oustaleti baeckstroemii* (nest site 6; January 25th). Prey types were counted per nestling feeding event (qualitative), not the number of individual items of prey (quantitative).

types of prey	<i>Aphrastura masafuerae</i>		<i>Cinclodes o. baeckstroemii</i>	
	total	%	total	%
pill bug (Isopoda spec.)	1	1	0	0
spider (Araneida spec.)	21	24	1	4
lepidopteron larvae (big, brown)	1	1	0	0
lepidopteron larvae (small, green)	58	68	6	24
lepidopteron imago (whitish silver)	5	6	18	72
sum	86	100	25	100

Tab. 5. Prey items per nestling feeding event in the bill of adults identified before entering the nests: *Aphrastura masafuerae* (nest hole 4 in HAHN *et al.*, 2004a; January 9th) and *Cinclodes oustaleti baeckstroemii* (nest site 4 in HAHN *et al.*, 2005; January 25th).

prey items per feeding event	<i>Aphrastura masafuerae</i>		<i>Cinclodes o. baeckstroemii</i>	
	total	%	total	%
one lepidopteron larva (small, green)	12	36	0	0
two lepidopteron larvae (small, green)	15	46	0	0
three lepidopteron larvae (small, green)	1	3	0	0
one lepidopteron larva plus different arthropod prey (unspecified)	5	15	0	0
ca. 2–3 lepidopteron imagines plus larva	0	0	2	11
ca. 2–4 lepidopteron imagines	0	0	3	16
ca. 5–6 lepidopteron imagines	0	0	5	28
ca. 7–8 lepidopteron imagines	0	0	3	16
ca. 10 lepidopteron imagines	0	0	5	28
sum	33	100	18	100

vealed that *A. spinicauda* was pecking ripe berries from *Berberis*, *Ribes* (HUMPHREY *et al.*, 1970), and *Gunnera* (R. SCHLATTER pers. comm.). Two *Gunnera* species occur as well on Alejandro Selkirk, but *A. masafuerae* yet has not been observed feeding on these. According to their reduced nutrition value these berries may not be used for raising nestlings. At present, resulting from the lack of more detailed data, we are not able to present a more reliable inter-specific comparison of feeding and food items of these (only) two *Aphrastura* species.

Our findings on distribution of food sources, vegetation structure (HAHN *et al.*, 2010), and geomorphologic features of the nest surrounding terrain did not give evidence for an unequal usage of the home range by Másafuera Rayaditos: the terrain structure and the vegetation cover were highly homogeneous. More likely the influence of energetic factors is reasonable for such a behaviour (comp. Table 1). This would also explain the fact that flights downhill were nearly four times less numerous than flights uphill: after flights directed downhill the search for food and the transport

had to be done uphill, the most energy consuming way. Prey items are limited in number per area and may be found scattered in the dense vegetation, but not or only exceptionally clustered. Thus, it is of principal advantage for Másafuera Rayaditos to more or less regularly visit different areas around the nest site. However, energy and time costs significantly increase with growing distances from the nest site (comp. Table 2), which might be critical during the nestling time. Adults have to balance between their own energy uptake and expenditures rates on the one hand, and the energetic investment into the needs of the brood on the other, combined with the necessity to control the nest site to shelter their nestlings. The staggered home range usage may represent an optimised economical strategy to invest energy and making sure that breeding efforts turn out to be successful.

Predation on rayaditos by native Másafuera Hawks *Buteo polyosoma exsul* during the breeding season was shown to be a serious threat in previous studies (HAHN *et al.*, 2004a, b). However, Másafuera Rayaditos do not take faeces far away for hiding their nest site, on

average not even to the point of first food search. Most faeces were even dropped down during the flight off the nest hole. Then they were clearly visible on top of the fern fronds, whitely reflecting. These faeces must have been visible for M \acute{a} safuera Hawks, too. Probably the locations of nest sites were all known to resident hawks, especially facing the high number of feeding visits per day and the open homogenous habitat. However, it seems that not the knowledge of the locations is the critical point but the narrowness of the nest entrance and the deepness of the nest itself (comp. Figs. 5 & 6).

M \acute{a} safuera Rayaditos obviously prefer comparatively stationary food items like *lepidopteron* larvae (about two thirds of observed prey items; comp. Tables 4 & 5). They have been observed carrying relatively small insects or their larvae to the nest. These findings may either be an artificial effect of the circumstance that the nestlings during our observations were still young, or of a simultaneous seasonal reproduction of the *lepidopteron* species on the island. The latter might explain the high amount of identical prey items as well as the comparably homogenous size of the larvae carried to the nest. Adult birds should optimise their feeding strategies concerning two major aspects: they firstly should forage as many biomass as fast as possible and secondly be able to calculate the optimal size of each portion to guarantee fastest growing of their offspring possible under the given circumstances. This is generally the case in situations in which the availability of sources is foreseeable depending from stable climate conditions. This should be the case here, as the climate on the Juan Fernandez Islands is fairly constant, and follows a regular seasonality.

Compared to the M \acute{a} safuera Cinclodes, the difference in the food sources is striking. At present we do not have enough data for a significant test of our hypotheses (see also HAHN *et al.*, 2005), but we may be allowed to speculate, that two different reasons may be responsible for this effect (see Figs. 8-10). On the one hand the nestlings of the observed cinclodes may have already been older compared to that of the rayaditos. We know from many bird species, that adults feed mostly soft small larvae to young hatchlings. With growing offspring the hardness of food items also rises in most of these species and parents switch to feed more imagines of certain insect species during late nestling days. On the other hand the different choice of food may be the evolutionary result of inter-specific competition between the two endemic species (comp. also BLONDEL *et al.*, 1999; BLONDEL, 2000). If this would be the case, the food ecology of these two island bird species would be a perfect example of nice building capacities of inter-specific competition preventing competitive interaction of both species in the most sensitive phase of their lifecycle, during reproduction.

Finally, we conclude that more detailed studies on the breeding ecology and foraging of both co-existing ovenbirds on Alejandro Selkirk are required for setting up appropriate management plans and protection activities (including general evolutionary comparisons like in REMSEN, 2003; FJELDSÅ *et al.*, 2005). The M \acute{a} safuera Rayaditos seem to have developed suitable adaptations for protecting their broods against M \acute{a} safuera Hawks, but nothing is known about the interactions with introduced mammals like rats and cats. Maybe such investigations are the key for understanding the critical factors to save Chile's most fragile bird, and lead to successful species conservation.

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