Studies on Neotropical Fauna and Environment

ISSN: 0165-0521 (Print) 1744-5140 (Online) Journal homepage: http://www.tandfonline.com/loi/nnfe20

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To cite this article: Ricardo A. Figueroa, Ema S. Corales & Jaime R. Rau (2018): Prey of the güiña (Leopardus guigna) in an Andean mixed southern beech forest, southern Chile, Studies on Neotropical Fauna and Environment

To link to this article: https://doi.org/10.1080/01650521.2018.1477032

Published online: 04 Jun 2018.

STUDIES ON NEOTROPICAL FAUNA AND ENVIRONMENT
https://doi.org/10.1080/01650521.2018.1477032

Prey of the güiña (*Leopardus guigna*) in an Andean mixed southern beech forest, southern Chile

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ABSTRACT

We quantified the güiña diet (*Leopardus guigna*) by analyzing 39 scats collected during summer–autumn 2001 in an Andean mixed *Nothofagus–Lophozonia* forest, southern Chile. Five small mammal species, three passerine species, lizards of one genus, and insects of two orders were identified in the scats. Small mammals were the most frequently consumed prey (47% of all identified prey individuals) and constituted most of the biomass contributed by all prey (75%). The arboreal/scansorial small mammals *Oligoryzomys longicaudatus, Irenomys tarsalis*, and *Dromiciops gliroides* were the most frequently consumed vertebrate prey (14.4, 11.5 and 11.5% of all identified prey individuals; 22.7, 21.5 and 18.2% of biomass contributed by all prey, respectively). The frequency of each small mammal species in the scats was not reflected in its respective capture-frequency as evaluated by live-trapping. *O. longicaudatus, I. tarsalis*, and *D. gliroides* were 'overconsumed' regarding their capture-frequency. *Akodon longipilis*, the most frequently captured species, was not found in the scats. As a whole, the arboreal/scansorial small mammals were preyed upon by güiñas much more than expected given their capture-frequency. Our results suggest that the güiña is a predator partially specialized for arboreal/scansorial small mammal species, being able to take alternative prey when available.

ARTICLE HISTORY
Received 6 September 2017
Accepted 4 May 2018

KEYWORDS
Arboreal/scansorial small mammals; *Dromiciops gliroides*; *Irenomys tarsalis*; *Oligoryzomys longicaudatus*

RESUMEN

Cuantificamos la dieta de la güiña (*Leopardus guigna*) mediante el análisis de 39 heces colectadas durante el verano y otoño de 2001 en un bosque andino mixto de *Nothofagus-Lophozonia* en el sur de Chile. Cinco especies de micromamíferos, tres especies de aves paserinas, lagartijas de un género e insectos de dos órdenes fueron identificadas en las heces. Los micromamíferos fueron las presas más frecuentemente consumidas (47% de todos los individuos presa identificados) y constituyeron la mayor parte de la biomasa aportada por todas las presas (75%). Los micromamíferos arbóreos/trepadores tales como *Oligoryzomys longicaudatus, Irenomys tarsalis* y *Dromiciops gliroides* fueron las presas vertebradas más frecuentemente consumidas (14,4, 11,5 y 11,5% del total de individuos presa identificados; 22,7, 21,5 y 18,2% de la biomasa aportada por todas las presas, respectivamente). La frecuencia de cada especie de micromamíferos en las heces no se reflejó en su respectiva frecuencia de captura evaluada por trampeo de vivo en el área de estudio. *O. longicaudatus, I. tarsalis* y *D. gliroides* fueron aparentemente 'sobre-consumidos' con relación a su frecuencia de captura. *Akodon longipilis*, la especie más frecuentemente capturada, no fue detectada en las heces. Tomadas como un todo, las presas arborícolas/trepadoras fueron consumidas más de lo esperado con relación a su frecuencia de captura. Nuestros resultados sugieren que la güiña es un depredador parcialmente especializado en la captura de micromamíferos arborícolas/trepadores, siendo capaz de tomar presas alternativas cuando éstas están disponibles.

Introduction

The güiña or kodkod cat (*Leopardus guigna*) is one of most elusive and cryptic wild cat species of the Neotropical region (Nowell & Jackson 1996; Gálvez et al. 2013), and very little is known of its life history and basic ecology (Sanderson et al. 2002). This species is characterized by (i) being endemic to the southern temperate forest ecoregion (30–50°S, 70–75°W), (ii) being forest-dependent (Sanderson et al. 2002; Acosta-Jamett & Simonetti 2004; Zúñiga et al. 2009; Gálvez et al. 2013; Fleschutz et al. 2016), (iii) exhibiting a low abundance (Dunstone et al. 2002; Acosta-Jamett et al. 2003; Sepúlveda-Sánchez & Skewes 2015), (iv) having one of the most restricted geographic distributions among Neotropical wild cats (≈ 340,000 km^2; Cuyckens et al. 2015), and (v) being the smallest feline of South America (mass of adult individuals = 1.3–2.5 kg; Dunstone et al. 2002; Sanderson et al. 2002). In addition, güiñas have suffered a strong population

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Published online 04 Jun 2018

decline, distributional retraction, and reduction of their genetic diversity because the persistent habitat loss and fragmentation (Nowell & Jackson 1996; Acosta-Jamett et al. 2003; Cuyckens et al. 2015; Napolitano et al. 2015a), illegal killing as retaliation for poultry depredation (Silva-Rodríguez et al. 2007; Zorondo-Rodríguez et al. 2014), and road kills (Napolitano et al. 2015b). Infectious diseases transmitted by domestic cats in anthropogenically influenced areas constitute an additional important threat for güiñas (Mora et al. 2015). For these reasons, the güiña is considered one of the most threatened wild cat species in southern South America (Nowell & Jackson 1996), being listed as vulnerable or near threatened (Napolitano et al. 2015b).

Knowing the food habits of animal species is fundamental to disentangle their life histories, better understand food requirements and their role in ecosystems, as well as guide preliminary conservation actions (Litvaitis 2000). Despite increasing interest in understanding the natural history and ecology of the güiña, its diet and prey use require more research. To our knowledge, five studies have directly focused on the güiña's diet (Dunstone et al. 2002; Correa & Roa 2005; Zúñiga et al. 2005; Galuppo 2014; Moreira-Arce et al. 2015) and two others have reported circumstantial observations of prey taken by this small felid (Sanderson et al. 2002; Altamirano et al. 2013). All these studies indicate that güiñas prey upon a wide spectrum of prey including small mammals, lagomorphs, birds, reptiles, and invertebrates. However, the small number of studies along with the very small sample size in some cases (< 25 scats) limit the power of inference on possible patterns of the relative importance of prey species. Here, by analyzing scat samples of güiñas as well as estimated availability of small mammals obtained by live-trapping, we report on (1) prey species consumed by güiñas, (2) relative importance of prey species in the diet, and (3) congruence of capture-frequency of small mammal species and frequency of small mammals consumed in an Andean mixed *Nothofagus–Lophozonia* forest in southern Chile.

Materials and methods

Study area

We studied the güiña's diet in the Malleco National Reserve (MNR hereafter; 16,625 ha; 38°09′S, 71°48′W), Araucanía region, southern Chile. This reserve is located close to the Andean mountain range, thus having a rough topography (800–2000 m in elevation, slopes up to 30°), and it is almost entirely covered by continuous old and second-growth native forest. The most elevated hilltops and slopes are mostly covered by associations of *Lophozonia obliqua, L. alpina* and *Nothofagus dombeyi*, and pure stands of *Araucaria araucana* (52% and 22% of the total area, respectively; CONAF-ONF 1997). The low slopes and valleys are mostly covered by mixed forest composed by *L. obliqua, L. alpina, Laureliopsis philippiana, Weinmannia trichosperma, Eucryphia cordifolia* and *Dasyphyllum diacanthoides* (8% of the total area, CONAF/ONF 1997). Vegetation at the study site is dominated by *N. dombeyi* and *L. philippiana*, and some scattered old *N. alpina*. Tree height and diameter at breast height (dbh) ranged from 20 to 30 m and 20 to 60 cm, respectively. Canopy cover ranged from 50 to 80% and the midstory comprised dense thickets of southern bamboo (*Chusquea* spp.) with saplings of *N. dombeyi, L. philippiana* and some dispersed shrubs (*Fuchsia magellanica, Aristotelia chilensis, Drimys winteri*). The forest floor comprised diverse herbs and abundant fallen old trees (0.5–1.5 m in diameter). Climate is moist-temperate with mean annual rainfall and temperature of 1400 mm and 12°C, respectively (CONAF/ONF 1997).

Diet analysis

The diet of güiñas was determined by analyzing 39 fresh scats collected opportunistically between the austral mid-summer and early autumn 2001 (19–21 February, 15–20 March, and 12–19 April) along footpaths and roads crossing forest stands. Footpaths and roads comprised about 6.5 km in distance and were distributed within an area of about 60 ha. Twenty-one (53.8%) scats were collected from three latrines and the remaining were found scattered on the area. We made sure that scats were from güiñas either by frequent nocturnal sightings (N = 10) of individuals at the sites where samples were found, presence of fresh footprints around individual scats (N = 8) or latrines (N = 3), and by size and form of these scats (N = 39). In our study site, the güiñas' scats tended to be cylindrical, subdivided, and tapered toward extremities, a common feature of wild small cats (Chame 2003; Muñoz-Pedreros 2010). However, the güiña is the only species of small wild cat of the genus *Leopardus* present in the study area, which makes misidentification of scats unlikely. Like Freer (2004), we also observed that scats lacked any twisting at the ends and that they were within a certain size range (length = 10 ± 1.4 mm (N = 5), width = 1.5 ± 0.1 (N = 8)).

We quantified the number of individuals preyed upon by güiñas on the basis of those body elements clearly identifiable in the scats. Small mammals were identified and quantified on the basis of skulls or tooth pairs (with each pair representing one prey individual), following keys in Pearson (1995). Because we did not find any remains of bird beaks or feet in the scats, avian prey were identified and quantified only on the basis of feathers. We identified feathers by using two complementary methods: microscopic analysis of feather structures such as nodes and barbules (Reyes 1992; Rau & Martínez 2004), and a comparison of feather coloration patterns with reference collections. When feathers of a particular species appeared in a scat, we deemed it as pertaining to one prey individual. Reptiles were recognized by presence of skulls, mandibles, tails, feet or scales, and insects by head capsules, elytra or feet following keys in Peña (1986). To quantify these types of prey, we reconstitute as many prey individuals as possible by assembling the available body parts within each scat. As with avian prey, when only reptile scales were present in a scat, we deemed it as pertaining to one prey individual. Due to the difficulty identifying reptile prey at the species level in the scats, it is possible that we had subestimated the number of individuals. We identified the prey individuals to the lowest taxonomic level possible. We estimated the biomass contribution of each prey species in the diet by multiplying the number of prey individuals in the scats by the mean body weight of that prey species (Marti 1987). Mean body weights of small mammals and reptiles were based on individuals captured in the same study area, while mean weight of birds and insects were obtained from Egli (1996) and Figueroa et al. (2006), respectively. We assumed that unidentified prey weights were similar to the mean weight of the most closely related identified taxa.

Small mammal trapping

In order to obtain an estimate of prey availability during the time we collected scats, we evaluated the small mammal capture-frequency in the study area by live-trapping using medium sized Sherman traps (24 × 9.4 × 7.5 cm). Thirty-nine lines of 10 or 15 Sherman traps (7–12 m apart) each were set in forest or shrub patches near to footpaths or roads where we collected scats. Live-trapping lines were separated 100 to 300 m. Due to time constraints, each live-trapping line was maintained only for two nights. The rugged terrain prevented us from installing all the live-trapping lines on the same dates; therefore, we first installed a part of the live-trapping lines on one date, and then moved them to the other selected trapping places. Thus, the dates of small-mammal trapping extended 4–6 days beyond the dates of scat collection. In each live-trapping line we installed most traps on ground level and almost one-third of them (5–7 traps) above ground level (1–2 m) in order to increase the probability of capturing arboreal/scansorial small mammals. Total effort was 928 trap-nights (non-functional traps were discounted). All traps were baited with rolled oats. Due to the short trapping duration, captured animals were marked by haircut and individuals of the same species were marked on different parts of their body.

We recognized the number of prey individuals captured in the live-trappings could not truly reflect the prey availability to güiñas, as the prey availability is a combination of the abundance and the vulnerability of a prey species to capture (Gawlik 2002). Thus, we only considered the capture-frequency as a partial indicator of prey availability.

Analysis of prey use

In order to compare prey consumption and prey availability, we correlated the frequency of scats containing individuals of each prey species with the capture-frequency of each species using Spearman´s rank correlation following Jaksic (1979). This statistical procedure, based on the comparison of ranks of the values of each variable, allows us to include a value zero in a pair of data (Fowler et al. 1998). Thus, we included in our analysis one species present in the scats but absent in the traps, and two species present in the traps but absent in the scats. In addition, to detect a potential relationship between use of strata of small mammals (arboreal/scansorial and cursorial/fossorial) and small mammals preyed upon by güiña we compared the frequency distribution of arboreal/scansorial and ground/fossorial species (see Table 1 for a definition of these functional groups) in scats versus field live-trappings using the chi-square test. Because the low frequency of birds in diet and the impossibility of identifying reptiles at the species level, we did not evaluate the use of these prey types by güiñas.

Results

We identified 104 prey individuals in 13 prey categories in the güiña scats. Güiñas consumed both nocturnal and diurnal vertebrate prey, all of them being forest-dwelling species. Small mammals were the most numerous prey in the scats (almost half of prey individuals) and accounted for the highest contribution of biomass (Table 1). Both by number and biomass, birds and reptiles were a minor component of the diet (Table 1). Although insects accounted for almost a third of the prey individuals, their biomass contribution was minute (Table 1). Among small mammals, arboreal/scansorial species accounted for more than a third of the prey individuals and more than half of biomass contributed by all prey

Table 1. Diet of güiñas (*Leopardus guigna*) as determined by analysis of scats (n = 39) collected during summer and autumn 2001 in an Andean mixed *Nothofagus–Lophozonia* forest of the Malleco National Reserve, Araucanía region, southern Chile.

Prey taxa	Body weight (g)	Habits	Habitat	Number of individuals	Frequency (%)	Biomass (%)
Mammals					47.0	80.2
Rodentia						
Abrothrix olivaceus	24	G, N, C	F, PS	6	5.8	8.1
Chelemys macronix	62	F, N	F, PS	2	1.9	7.0
Irenomys tarsalis	32	A, N	F	12	11.5	21.5
Oligoryzomys longicaudatus	27	S, N	F, PS	15	14.4	22.7
Unidentified rodents[a]	34			2	1.9	2.7
Marsupialia						
Dromiciops gliroides[b]	27	A, N	F	12	11.5	18.2
Birds					4.9	9.9
Passeriformes						
Scelorchilus rubecula	60	G, D	F	2	1.9	6.7
Troglodytes aedon	10	A, D	F	1	1.0	0.6
Aphrastura spinicauda	18	A, D	F	1	1.0	1.0
Unidentified birds[a]	29.3			1	1.0	1.6
Reptiles					17.3	8.1
Squamata						
Liolaemus spp.	8			18	17.3	8.1
Insects					30.8	1.8
Coleoptera	1			27	26.0	1.5
Orthoptera	1			5	4.8	0.3
Total of prey individuals					104	
Total biomass[c]						1782.3

[a]Mean body mass of the most closely related identified taxon. [b]According to D'Elia et al. (2016), the specimens inhabiting our study area belong to a distinct species, *Dromiciops bozinovici*. [c]Represents the sum of the biomass contribution of each consumed individual prey item (see text for an explanation on estimation of biomass contribution).

Habits: G, ground-dweller (i.e. they spend most of their life at ground level); A, arboreal (i.e. they spend most of their life in trees); F, fossorial (i.e. they are adapted to digging and life underground); S, scansorial (i.e. they have the ability to climb trees); D, diurnal; N, nocturnal; C, crepuscular. Habitat: F, forest; PS, prairie/shrubland. References: (Greer 1965; Mann 1978; Marshall 1978; Kelt 1993; Rau et al. 1995; Rozzi et al. 1995).

taxa (Table 1). At the species level, *Oligoryzomys longicaudatus*, *Irenomys tarsalis* and the marsupial *Dromiciops gliroides* were the most frequent prey in the güiña scats, and jointly constituted almost 60% of the total biomass (Table 1).

In the field, we caught 46 individuals belonging to six species of small mammals. The most frequently captured species were *Abrothrix longipilis* followed by *O. longicaudatus* and *Abrothrix olivaceus* (23, 10 and 6 individuals, respectively). *Irenomys tarsalis, Loxodontomys micropus* and *D. gliroides* were the least captured species (≤ 3 individuals). The frequency of each small mammals species in the scats of güiñas was not reflected in its respective capture-frequency in the field ($r_s = -0.01$, $P > 0.05$, number of pairings = 7; Figure 1). *Irenomys tarsalis, O. longicaudatus* and *D. gliroides* were apparently 'overconsumed' regarding their capture-frequency in the field. *Abrothrix olivaceus* apparently was consumed according its capture-frequency in the field. Interestingly, *A. longipilis*, the most frequently captured species in the field, was not found in the scats. As a whole, the arboreal-scansorial small mammals were preyed upon by güiñas much more than expected given their capture-frequency in the field (Figure 2). Conversely, güiñas preyed upon ground-fossorial small mammals much less than expected (Figure 2). These differences did appear to be statistically significant ($\chi^2 = 20.6$, df = 1, $P < 0.05$).

Discussion

Overall diet

In our study site, güiñas fed primarily on small mammals which accounted for half of the all prey individuals and most of the consumed biomass. Coincidently, all previous studies based on analysis of scats collected during the same seasons indicate that by number small mammals are the primary prey of güiñas (Dunstone et al. 2002; Freer 2004; Correa & Roa 2005; Zúñiga et al. 2005; Galuppo 2014). As in our study, these studies show that by number birds, reptiles or insects constitute secondary prey. A study based on occasional direct observations and prey remains also showed that güiñas prey upon rodents, birds and lizards, but the importance level of prey was not measured (Sanderson et al. 2002). The fact that small mammals accounted for almost 80% of consumed biomass suggest that they are energetically profitable prey for güiñas. In addition, the high consumption of small mammals by güiñas could be explained by both the high protein value of these prey and their relatively high availability in the environment (Bisceglia et al. 2008).

The consumption of both nocturnal and diurnal prey by güiñas is consistent with their circadian activity rhythm. Güiñas tend to be active both during the day and night (Dunstone et al. 2002; Sanderson et al. 2002;

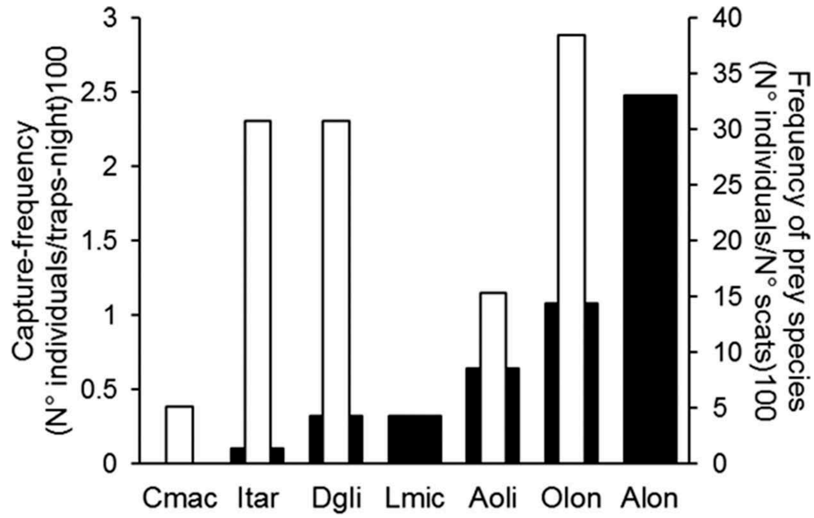

Figure 1. Comparison between the frequency of prey species in the scats (white bars) of güiñas (*Leopardus guigna*) and the prey availability of small mammal species in the field (black bars) as estimated by capture-frequency in live-trapping during summer–autumn 2001 in an Andean mixed *Nothofagus–Lophozonia* forest of southern Chile. Alon = *Abrothrix longipilis*, Aoli = *A. olivaceus*, Cmac = *Chelemys macronix*, Dgli = *Dromiciops gliroides*, Itar = *Irenomys tarsalis*, Lmic = *Loxodontomys micropus*, Olon = *Oligoryzomys longicaudatus.*

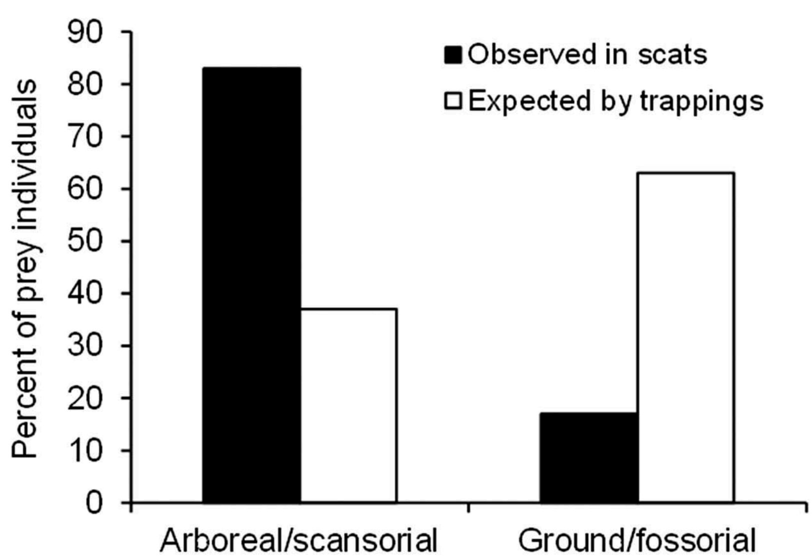

Figure 2. Observed frequency of arboreal/scansorial and ground/fossorial small mammal prey in the güiña (*Leopardus guigna*) scats and the expected frequency of these prey according to live-trapping in the field in an Andean mixed *Nothofagus–Lophozonia* forest of southern Chile.

Delibes-Mateos et al. 2014; Galuppo 2014; Hernández et al. 2015). However, the higher consumption of nocturnal small mammals in our study site was possibly due to the fact that güiñas tend to be more active during night. Studies based on camera traps suggest that güiñas in some localities of southern Chile are mostly active during night, and apparently could synchronize their hunting activity with peak activity of small mammal prey (Delibes-Mateos et al. 2014; Hernández et al. 2015). For example, the marsupial *D. gliroides* exhibit peaks of activity during the 2 hours following midnight until just before dawn (Franco et al. 2011), just when güiñas also tend to be more active (Sanderson et al. 2002; Hernández et al. 2015).

Although güiñas commonly capture birds during the day (Sanderson et al. 2002), it is possible that in our study site they had also taken some bird prey at night. Altamirano et al. (2013) observed güiñas on several occasions attempting to prey upon cavity nesting bird species at night taking advantage of their well-developed tree climbing ability (Sanderson et al.

2002). However, only one attempt was successful, resulting in the capture of a nestling of *Aphrastura spinicauda*, a diurnal prey species also consumed by güiñas in our study site. On the other hand, ground-dwelling forest birds such as *Scelorchilus rubecula*, which are more vulnerable to predation, appear to be a common prey of güiñas (Sanderson et al. 2002; Freer 2004; this study).

Even though lizards were a secondary prey of güiñas in MNR, the frequency of consumption of these prey was unexpectedly high (17% of all identified prey individuals). To our knowledge, the only report of lizard predation is that of Sanderson et al. (2002) who observed an individual carrying one *Liolaemus pictus*. The relatively high consumption of lizards by güiñas in our study site is consistent with the high field availability of these prey during austral summer. We detected at least six species of lizards in MNR (Ricardo Figueroa, pers. obs.) most of which seemed to be abundant in the study area based on observations within the güiñas' hunting areas (e.g. *Liolaemus pictus, L. chiliensis*, and *L. tenuis*). The relative high consumption of lizards together with assumed high abundance of lizards in this study might represent an indication of the ability of güiñas to take advantage of variable prey availability as observed in some species of wild cats (Nowell & Jakson 1996). However, more detailed studies are necessary to test for this presumption.

Like shown in previous studies (Correa & Roa 2005; Zúñiga et al. 2005), güiñas in MNR consumed a considerable amount of insects. Even when felids are reputedly carnivorous, it is known that small wild cats commonly prey upon invertebrates (Nowell & Jackson 1996). Even though this prey type contributes very little to the total of consumed biomass, insects could provide complementary nutrients (e.g. fatty acids, minerals) to the diet of small wild cats (Redford & Dorea 1984; Deblauwe & Janseens 2008). Most of the insect remains we identified in scats belonged to ground beetles, locusts, and crickets. These insect groups were abundant during summer and autumn in our study site and possibly güiñas take them opportunistically.

Use of small mammal prey

We recognize that low sample size impedes any strong inferences on small mammal prey use by güiñas based on the live-trapping, since it is likely that low capture probabilities led to a very inaccurate estimate of small mammal availability in this study. For example, we could have subestimated the frequency of arboreal small mammals in the field due to the fact that the position of traps on tree branches or trunks did not necessarily coincide with the routes of animals. Further, the lower number of traps placed above ground level possibly led to a lower capture probability of arboreal species compared to ground-dwelling ones. Finally, live traps of any kind are inefficient in capturing all species present in a particular area (Rau et al. 1995; Freer 2004; Fontúrbel & Jiménez 2009). For these reasons our trapping method might not truly reflect the real availability of arboreal species, and any inferences based on our estimate should be taken cautiously.

Considering the drawbacks mentioned above, our analysis suggests that güiñas predated more upon arboreal/scansorial species, particularly upon *I. tarsalis* and *D. gliroides*, in relation to their capture-frequency in the field as estimated by live-trapping. Similarly, Moreira-Arce et al. (2015) found that these two species accounted for almost 50% of all small mammal prey individuals consumed by güiñas in remnants of coastal native forest of southern Chile, and frequency of consumption of these species was higher than expected based on field abundance. It is important to mention that, differently to our study, Moreira-Arce et al. (2015) estimated the abundance of small mammal prey (minimum number of individual known alive) in forest stands by installing 20 grids (6×6 traps each) for five nights (trapping effort = 3600 trap-nights), combining Tomahawk-like and Sherman traps with the half traps consistently placed on and above ground level (2 m height). Despite strong differences in the spatial configuration of live-trapping and sampling effort, it is striking that both the study of Moreira-Arce et al. (2015) and ours came to very similar results regarding the prey use by güiñas. However, this coincidence must be carefully considered because both studies were based on sample sizes not satisfactorily large (<40 scats), which could lead to biased estimates about the consumption level of small mammal prey. Even so, the absence in the scats of the most frequently captured terrestrial small mammal species in our study site, *A. longipilis*, strengthens the assumption that güiñas prefer arboreal/scansorial small mammals.

Additionally, the high representation of the arboreal/scansorial small mammal prey in the güiña diet could result from the exploitation of forest stands richer in this prey type. Previous studies indicate that when güiñas are active they tend to concentrate in old and second-growth forest remnants with a high vertical cover (Dunstone et al. 2002; Sanderson et al. 2002; Acosta-Jamett & Simonetti 2004). These are habitat characteristics that favor the presence of *I. tarsalis* and *D. gliroides* which are strongly associated with forest stands with old trees providing cavities, closed canopy, fallen old trees and dense southern bamboo thickets (Mann 1958; Greer 1965; Marshall 1978; Kelt 1993; Fontúrbel et al. 2010; Formoso & Sánchez 2014). Similarly, the scansorial *O. longicaudatus* is a habitat-generalist but may concentrate in forest stands with dense southern bamboo carpets (Murúa & González 1986).

Like Moreira-Arce et al. (2015), our results suggest that in continuous mature native forest the güiña is a predator partially specialized in arboreal/scansorial small mammal species. Interestingly, other authors found that in Patagonian rainforests, commercial pine plantations, and fragmented forests where arboreal prey appear to be scarcer, the most abundant terrestrial rodent species became an important alternative prey to güiñas (Dunstone et al. 2002; Freer 2004; Galuppo 2014; Moreira-Arce et al. 2015). This implies that this wildcat species could adapt to changes in the locally available prey spectrums influenced by distribution range of prey species or changes in habitat conditions (e.g. vertical cover loss). More studies are necessary to confirm if observed patterns in the güiñas' diet in continuous old and second-growth forests of southern Chile persist on a wider spatial range.

Acknowledgments

We thank Marcelo Saavedra for his valuable support Assistance by Alejandro Corales with rodent trappings and scat collection is deeply appreciated. We also appreciate the constructive comments from two anonymous peer reviewers and from Dr. Thomas Puettker.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This study was partially financed by the Chilean Forest Service (CONAF) and National Forest Office of France (ONF) through the Malleco-Tolhuaca project "Supporting the Conservation and Sustainable Management of the Chilean Native Forest".

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References

Acosta-Jamett G, Simonetti JA. 2004. Habitat use by *Oncifelis guigna* and *Pseudalopex culpaeus* in a fragmented forest landscape in central Chile. Biodivers Conserv. 13(6):1135–1151.

Acosta-Jamett G, Simonetti JA, Bustamante RO, Dunstone N. 2003. Metapopulation approach to assess survival of *Oncifelis guigna* in fragmented forests of central Chile: a theoretical model. Mastozool Neotrop. 10(2):217–229.

Altamirano TA, Hernández F, de la Maza M, Bonacic C. 2013. Güiña (*Leopardus guigna*) preys on cavity-nesting nestlings. Rev Chil Hist Nat. 86(4):501–504.

Bisceglia SBC, Pereira JA, Teta P, Quintana RD. 2008. Food habits of Geoffroy's cat (*Leopardus geoffroyi*) in the central Monte desert of Argentina. J Arid Environ. 72(6):1120–1126.

Chame M. 2003. Terrestrial mammal feces: a morphometric summary and description. Mem Inst Oswaldo Cruz. 98 (1):71–94.

CONAF/ONF. 1997. Primer plan de ordenación Reserva Forestal Malleco. Temuco (Chile): Corporación Nacional Forestal IX Región y Office National des Forets, Francia.

Correa P, Roa A. 2005. Relaciones tróficas entre *Oncifelis guigna, Lycalopex culpaeus, Lycalopex griseus* y *Tyto alba* en un ambiente fragmentado de la zona central de Chile. Mastozool Neotrop. 12(1):57–60.

Cuyckens GAE, Morales MM, Tognelli MF. 2015. Assessing the distribution of a vulnerable felid species: threats from human land use and climate change to the kodkod *Leopardus guigna*. Oryx. 49(4):611–618.

D'Elia G, Hurtado N, D'Anatro A. 2016. Alpha taxonomy of *Dromiciops* (Microbioteriidae) with the description of 2 new species of monito del monte. J Mamm. 97(4):1136–1152.

Deblauwe I, Janseens GPJ. 2008. New insights in insect prey choice by chimpanzees and gorillas in Southeast Cameroon: the role of nutritional value. Am J Phys Anthropol. 135(1):42–55.

Delibes-Mateos M, Díaz-Ruiz F, Caro J, Ferreras P. 2014. Activity patterns of the vulnerable guiña (*Leopardus guigna*) and its main prey in the Valdivian rainforest of southern Chile. Mamm Biol. 79(6):393–397.

Dunstone N, Freer R, Acosta-Jamett G, Durbin L, Wyllie I, Mazzolli M, Scott D. 2002. Uso del habitat, actividad y dieta de la güiña (*Oncifelis guigna*) en el Parque Nacional Laguna San Rafael, XI Región, Chile. Bol Mus Nac Hist Nat. (Chile). 51:147–158.

Egli G. 1996. Biomorfología de algunas aves de Chile Central. Bol Chil Ornitol. 3(1):2–9.

Figueroa RA, Corales ES, Martínez DR, Figueroa R, González-Acuña D. 2006. Diet of the Rufous-legged Owl (*Strix rufipes*, Strigiformes) in an Andean *Nothofagus-Araucaria* forest, southern Chile. Stud Neotrop Fauna Environ. 41(3):179–182.

Fleschutz MM, Gálvez N, Pe'er G, Davies ZG, Henle K, Schüttler E. 2016. Response of a small felid of conservation concern to habitat fragmentation. Biodivers Conserv. 25 (8):1447–1463.

Fontúrbel FE, Jiménez JE. 2009. Underestimation of abundances of the Monito del Monte (*Dromiciops gliroides*) due to a sampling artifact. J Mamm. 90(6):1357–1362.

Fontúrbel FE, Silva-Rodríguez EA, Cárdenas NH, Jiménez JE. 2010. Spatial ecology of monito del monte (*Dromiciops *gliroides*) in a fragmented landscape of southern Chile. Mamm Biol. 5(1):1–9.

Formoso AE, Sánchez JP. 2014. First description of the breeding nest of *Irenomys tarsalis*, a sigmodontine rodent endemic to southern Andean forests. Rev Mex Biodiv. 85 (3):987–989.

Fowler J, Cohen L, Jarvis P. 1998. Practical statistics for field biology. Hoboken (NJ): John Wiley & Sons.

Franco M, Quijano A, Soto-Gamboa M. 2011. Communal nesting, activity patterns, and population characteristics in the near threatened monito del monte, *Dromiciops gliroides*. J Mamm. 92(5):994–1004.

Freer R. 2004. The spatial ecology of the güiña (*Oncifelis guigna*) in southern Chile [PhD Thesis]. Durham (UK). University of Durham.

Galuppo SE. 2014. Diet and activity patterns of *Leopardus guigna* in relation to prey availability in forest fragments of the Chilean temperate rainforest [Master Thesis]. Saint Paul (MN): University of Minnesota.

Gálvez N, Hernández F, Laker J, Gilabert H, Petitpas R, Bonacic C, Gimona A, Hester A, Macdonald D. 2013. Forest cover outside protected areas plays an important role in the conservation of the vulnerable guiña *Leopardus guigna*. Oryx. 47(2):251–258.

Gawlik DE. 2002. The effects of prey availability on the numerical response of wading birds. Ecol Monogr. 72(3):329–346.

Greer JK. 1965. Mammals of Malleco Province, Chile. Publ Mus Michigan State Univ. Biol Ser. 3:49–152.

Hernández F, Gálvez N, Gimona A, Laker J, Bonacic C. 2015. Activity patterns by two colour morphs of the vulnerable guiña, *Leopardus guigna* (Molina 1782), in temperate forests of southern Chile. Gayana Zool. 79(1):102–105.

Jaksic FM. 1979. Técnicas estadísticas simples para evaluar selectividad dietaria en Strigiformes. Medio Ambiente. 4 (1):114–118.

Kelt DA. 1993. *Irenomys tarsalis*. Mamm Species. 447:1–3.

Litvaitis JA. 2000. Investigating food habits of terrestrial vertebrates. In: Boitani L, Fuller TK, editors. Research techniques in animal ecology: controversies and consequences. Methods and Cases in Conservation Science. NY: Columbia University Press. p. 165–190.

Mann GF. 1958. Monito del monte *Dromiciops australis* Philippi. Invest Zool Chilenas. 2:159–166.

Mann GF. 1978. Los pequeños mamíferos de Chile. Gayana Zool. 40:1–342.

Marshall LG. 1978. *Dromiciops australis*. Mamm Species. 99:1–5.

Marti C. 1987. Raptor food habits studies. In: Pendleton BA, Millsap BA, Cline KW, Bird DM, editors. Raptor management techniques manual. Washington (DC): National Wildlife Federation. (Science and technology series; 10). p. 67–79.

Mora M, Napolitano C, Ortega R, Poulin E, Pizarro-Lucero J. 2015. Feline Immunodeficiency Virus and Feline Leukemia Virus infection in free-ranging guignas (*Leopardus guigna*) and sympatric domestic cats in human perturbed landscapes on Chiloé Island, Chile. J Wildl Dis. 51(1):199–208.

Moreira-Arce D, Vergara PM, Boutin S, Simonetti JA, Briceño C, Acosta-Jamett G. 2015. Native forest replacement by exotic plantations triggers changes in prey selection of mesocarnivores. Biol Conserv. 192:258–267.

Muñoz-Pedreros A. 2010. Huellas y signos de mamíferos de Chile. Valdivia: CEA Ediciones.

Murúa RE, González LA. 1986. Regulation of numbers in two Neotropical rodent species in southern Chile. Rev Chil Hist Nat. 59(2):193–200.

Napolitano C, Díaz D, Sanderson J, Johnson WE, Ritland K, Ritland CE, Poulin E. 2015a. Reduced genetic diversity and increased dispersal in guigna (*Leopardus guigna*) in Chilean fragmented landscapes. J Hered. 106(1):522–536.

Napolitano C, Gálvez N, Bennett M, Acosta-Jamett G, Sanderson J. 2015b. *Leopardus guigna*. The IUCN Red List of Threatened Species 2015, e.T15311A50657245. doi:10.2305/IUCN.UK.2015-2.RLTS.T15311A50657245.en.

Nowell K, Jackson P. 1996. Wild cats. Status survey and conservation action plan. Switzerland: IUCN/SSC Cat Specialist Group, Gland.

Pearson O. 1995. Annotated keys for identifying small mammals living in or near Nahuel Huapi National Park, southern Argentina. Mastozool Neotrop. 2 (2):99–148.

Peña L. 1986. Introducción a los insectos de Chile. 4th ed. Santiago: Editorial Universitaria.

Rau JR, Martínez DR, Low JR, Tillería MS. 1995. Depredación por zorros chillas (*Pseudalopex griseus*) sobre micromamíferos cursoriales, escansoriales y arborícolas en un área silvestre protegida de Chile. Rev Chil Hist Nat. 68(3):333–340.

Rau JR, Martínez DR. 2004. Identificación de los órdenes de aves chilenas a través de la microestructura de sus plumas. In: Muñoz-Pedreros J, Rau JR, Yáñez J, editors. Aves rapaces de Chile. Valdivia: CEA Ediciones. p. 229–234.

Redford RH, Dorea JG. 1984. The nutritional values of invertebrates with emphasis on ants and termites as food for mammals. J Zool. 203(3):385–395.

Reyes S. 1992. Clave para la identificación de los órdenes de aves chilenas: microestructura de los nodos de las bárbulas [thesis]. Universidad de Los Lagos, Osorno.

Rozzi R, Martínez D, Willson MF, Sabag C. 1995. Avifauna de los bosques templados de Sudamérica. In: Armesto JJ, Villagrán C, Kalin Arroyo MP, editors. Ecología de los bosques nativos de Chile. Santiago: Editorial Universitaria.

Sanderson J, Sunquist ME, Iriarte JA. 2002. Natural history and landscape-use of guignas (*Oncifelis guigna*) on Isla Grande de Chiloé, Chile. J Mamm. 83(2):608–613.

Sepúlveda-Sánchez F, Skewes O. 2015. Mesomamíferos en la Reserva Nacional Nonguén: antecedentes de una reserva reciente y cercana a una gran ciudad, Concepción, Chile. Biodiversidata. 3:45–50.

Silva-Rodríguez EA, Ortega-Solís GR, Jiménez JE. 2007. Human attitudes toward wild felids in a human-dominated landscape of southern Chile. Cat News. 46:19–21.

Zorondo-Rodríguez F, Reyes-García V, Simonetti JA. 2014. Conservation of biodiversity in private lands: are Chilean landowners willing to keep threatened species in their lands? Rev Chil Hist Nat. 87(1):4. http://www.revchilhistnat.com/content/87/1/4

Zúñiga A, Muñoz-Pedreros A, Fierro A. 2009. Uso de habitat de cuatro carnívoros terrestres en el sur de Chile. Gayana. 73(2):200–210.

Zúñiga A, Quintana V, Fierro A. 2005. Relaciones tróficas entre depredadores en un ambiente fragmentado del sur de Chile. Gestión Ambiental (Chile). 11(1):31–42.