ACTIVITY PATTERNS OF THE VULNERABLE GUIÑA (*Leopardus guigna*) AND ITS MAIN PREY IN THE VALDIVIAN RAINFOREST OF SOUTHERN CHILE

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ABSTRACT

The guiña (*Leopardus guigna*) is a small felid found primarily in temperate mixed forests of southern Andean and coastal ranges in Chile and Argentina. It is considered a vulnerable species, and is one of the least studied felids in the world. In this study our main aim was to document the relationship between the activity pattern of the guiña and that of its main prey in the Valdivian rainforest (Comau Fjord, southern Chile) using a camera-trap survey. We documented the activity patterns of small mammals and two ground-foraging bird species, as these have been previously cited as the main prey of this felid. Guiñas showed two nocturnal activity peaks, at the beginning and the end of the night, and a weak peak of activity at midday. Small mammals consistently revealed nocturnal activity, whereas both birds were strongly diurnal. Our results revealed a high overlap between the activity patterns of guiñas and small mammals, whereas this was negligible for the bird species. These findings support the idea that small mammals are guiñas' preferred prey in the Valdivian rainforest. Our study contributes to the understanding of the temporal relationships between the guiña and its prey, and may help to design effective management strategies to conserve this vulnerable felid.

Keywords: Activity patterns, Camera-trapping; Chile; Kodkod; *Leopardus guigna*; Predator-prey interactions

INTRODUCTION

Camera-trapping surveys have been recently used to assess the relationship between the activity patterns of predators and their prey in several regions worldwide through robust statistical analyses (e.g. Monterroso et al., 2013). This is especially useful for species that are cryptic, rare, and live in remotes areas (Linkie and Ridout, 2011; Foster et al., 2013). One such species is the guiña, kodkod, or Chilean cat (*Leopardus guigna*), the smallest of the neotropical wild cats (1.2-2.2 kg; Nowell and Jackson, 1996). This is a buffy to brownish felid heavily patterned with small black spots on the back and flanks, although dark individuals are also common (Redford and Eisenberg, 1992; Freer, 2004). As in other felids, the spot pattern of the guiña can vary between individuals (Freer, 2004). The guiña is found primarily in central and southern Chile and adjoining areas of Argentina (Redford and Eisenberg, 1992; Quintana et al., 2000). The species is strongly associated with the moist temperate mixed forests of southern Andean and coastal ranges (Acosta and Simonneti, 2004; Gálvez et al., 2013). The guiña is categorized as Vulnerable by the International Union of Conservation Nature, with a decreasing population trend, mainly as a consequence of habitat loss and human persecution, because it occasionally predates on poultry (Silva-Rodríguez et al., 2007; Acosta and Lucherini, 2008). The guiña is one of the least studied felids in the world. As a consequence, very little is known about its natural history, particularly about guiña-prey interactions. The few studies have suggested that small mammals form the major part of the guiña's diet (58-72% of prey remains; Freer, 2004; Correa and Roa, 2005; Zuñiga et al., 2005), of which rodents and a Microbiotherid marsupial *Dromiciops gliroides* predominate (Freer, 2004). The guiña also frequently takes

avian prey (16-20% of prey remains; Freer, 2004; Zuñiga et al., 2005), mostly insectivorous birds that predominantly forage on the ground (Sanderson et al., 2002).

In this study, we aimed to document the relation between the activity pattern of the guiña and that of its main prey. To achieve this goal, we surveyed the activity of guiñas, small mammals, and birds in the Valdivian rainforest of southern Chile using camera-trapping.

MATERIAL AND METHODS

Study area

Field work was carried out in the Huinay Biological Reserve in the Los Lagos Region of southern Chile, 42°22´ S, 72°24´ W (Figure 1). The reserve lies in a representative area of the continental fjords of the northern end of Chilean Patagonia. The climate is temperate and humid, with an annual average temperature of 10.5ºC and average annual rainfall greater than 6000 mm (Huinay Scientific Research Foundation; <www.fundacionhuinay.cl>). The landscape is dominated by the Valdivian temperate rainforest, characterized by evergreen trees like ulmo (*Eucryphia cordifolia*) and tineo (*Weinmannia trichosperma*), deciduous *Nothofagus* sp. trees, and conifers, including the alerce (*Fitzroya cupressoides*) in higher elevations (Di Castri and Hajek, 1976). A dense understory of bamboo (*Chusquea quila*) and several species of ferns (e.g. *Lophosoria quadripinnata* and *Blechnum chilense*) is common. This area is within the distribution range of several mammalian terrestrial carnivores, including *Leopardus guigna*, *Lycalopex griseus*, *Galictis cuja* and *Puma concolor* (Iriarte, 2008).

Field sampling

Field sampling was based on camera-trapping of both guiñas and their main prey and was carried out in early spring 2013 (September-October). We set 18 camera traps in an area of approximately 2000 ha in a nonuniformly layout due to field conditions (i.e. very steep slopes, dense vegetation, snow, etc.), and the scarcity of footpaths within the study area. The average distance between neighboring cameras was ~600 m. We used 3 camera-trap models: (HCO ScoutGuard Model: SG550V, n= 13; Ltl Acorn Model: Ltl-5210, n= 3; Wildview Model X8IR, n= 2). We mounted camera-traps on trees approximately 0.5–1.0 m off the ground along pathways or trails. We used a mixture of canned sardines and vegetable oil as attractant to increase the animals' curiosity (Freer, 2004), and thus detection probability. Each camera trap was maintained in the field at the same site for a minimum of 31 days (32.7±1.5 days per camera) and we inspected them at least once to replace the battery or card and to add more attractant. We considered consecutive images of the same species taken by the same camera within 30 min to be detections of the same animal, unless they were clearly individually distinguishable (Kelly and Holub, 2008; Davis et al., 2011; Monterroso et al., 2013). In principle, different guiñas could be distinguished because they present frequently different fur patterns (see above). However, during our study when the same camera took several images within 30 minutes (n=6), similar fur patterns between images indicated that these corresponded to the same individual. Images separated by a longer interval were considered to be independent detections, although they could be of the same individual (Kelly and Holub, 2008; Davis et al., 2011; Monterroso et al., 2013).

Prey species

To compare the activity patterns of the guiña and its prey species, we selected the most common prey, small mammals and ground-foraging birds (Freer, 2004; Correa and Roa, 2005; Zuñiga et al., 2005). Our study area is within the distribution area of at least 12 native and 3 invasive small mammal species (Iriarte, 2008). Among them, *Abrothrix longipilis* (30-50 g), *Abrothrix olivaceus* (24-42 g), *Irenomys tarsalis* (30-60 g), and *Oligoryzomys longicaudatus* (22-35 g) seem to be common (R. Fitzek personal communication). Because it is difficult to accurately identify small-mammal species from pictures taken by camera traps, we pooled all the independent detections of these species into a category of 'small mammals'. In addition, we selected two bird species, the chucao tapaculos (*Scelorchilus rubecula*; average weight 38 g; Correa and Figueroa, 2001; hereafter chucao) and the black-throated huet-huet (*Pteroptochos tarnii*; average weight 154 g; Correa and Figueroa, 2001; hereafter huet-huet). These may constitute an important food source for the guiña, not only because they are terrestrial (Correa et al., 1990; Amico et al., 2008), but also because they are abundant in Chilean rainforests (Jiménez, 2000), and particularly in the study area (J. Martínez-Padilla personal communication).

Statistical analysis

We classified the activity of the guiña and its prey into three periods (Monterroso et al., 2013): twilight (defined as the period from one hour before to one hour after both sunrise and sunset), day, or night (Lucherini et al., 2009). The probability density function of activity pattern was estimated nonparametrically using kernel density (Ridout and Linkie, 2009). Following the estimation of the distribution function, we performed pairwise comparisons of activity patterns between guiña

144 and prey species by estimating the coefficient of overlap Δ_1. This has been
145 suggested by Ridout and Linkie (2009) and Linkie and Ridout (2011) for small
146 sample sizes, i.e., <50 detections. The coefficient of overlap ranged from 0 (no
147 overlap) to 1 (complete overlap). The precision of this estimator was obtained
148 through confidence intervals, as percentile intervals from 500 bootstrap samples
149 (Linkie and Ridout, 2011).

150 All statistical analyses were performed using R software 2.13.0 (R Development
151 Core Team, 2011), using an adaptation of the scripts developed by Linkie and
152 Ridout (2011) available at <www.kent.ac.uk/ims/personal/msr/overlap.html>.

153 **RESULTS**

154 A total of 590 trap-days were conducted during the study. We obtained 209
155 independent detections, 21 of which were guiñas, 98 small mammals, 76
156 chucaos, and 14 huet-huets. Other wild mammals, such as *Galictis cuja* and *Pudu*
157 *puda*, and birds, such as *Caracara plancus, Phrygilus patagonicus*, and *Turdus*
158 *falcklandii magellanicus*, were also detected sporadically (<6 independent
159 detections in all cases).

160 Guiña were detected most often during the night (62%) and activity was low
161 during the diurnal and twilight periods (Figure 2). Activity density functions
162 revealed two nocturnal activity peaks, at the beginning and the end of the night,
163 respectively, in addition to a weak peak of activity at midday (Figure 3).

164 Small mammals consistently showed nocturnal activity (80% detections; Figure
165 2); daytime detections were rare and mostly (~70%) involved invasive rats
166 (*Rattus* sp.). Activity density functions showed a unimodal pattern, with a
167 maximum peak before midnight, and decreasing activity afterwards (Figure 3).

Both chucao and huet-huet were strongly diurnal (96 and 93% diurnal detections, respectively; Figure 2), and showed a bimodal pattern of activity, with two major activity peaks after sunrise and before sunset (Figure 3).

The activity pattern of the guiña corresponded closely with that of small mammals (Figure 3). In contrast, we observed a low overlap between the activity pattern of the guiña and that of its avian prey (Figure 3).

DISCUSSION

Our results revealed that, in our study area, guiñas were predominantly nocturnal, with the highest activity occurring after sunset and before sunrise, although they were somewhat active around midday. This activity pattern is very similar to that found by Hernández (2010) through a camera-trap survey in continuous native forests in the Araucanía district (see also Altamirano et al., 2013), and also closely resembles that described by Sanderson et al. (2002) through radio-tracking 7 individuals on Isla Grande de Chiloé. However, guiñas displayed more arrhythmic activity patterns in fragmented forests in the Araucanía (Hernández, 2010), and in two areas of north Patagonian rainforest (Dunstone et al., 2002; Freer, 2004).

We detected a weak peak of guiña activity at midday, which has also been reported in previous studies (e.g. Sanderson et al., 2002). This cannot be explained by the activity patterns of the main prey (see below). In Chilean rainforests, small mammal species reach their minimum annual population density in spring (Muñoz-Pedreros, 1992; Freer, 2004), when our work was performed, and therefore guiñas might be tracking secondary diurnal prey to compensate for a possible reduction in small mammal abundance. However,

Dunstone et al. (2002) observed that the guiña was active during the day in summer, when small mammals are at their highest annual numbers (Muñoz-Pedreros, 1992; Freer, 2004). This suggests that guiñas might increase their activity during the warmest part of the day in the cold and wet Chilean rainforests to minimize thermoregulatory costs. This was reported for the Geoffroy's cat (*Leopardus geoffroyi*) in Torres del Paine National Park in the extreme south of mainland Chile, where individuals became less nocturnal in the colder winter months (Johnson and Franklin, 1991).

The small mammals present in our study area were mostly nocturnal. Only a few records of small mammals were collected during daytime, and nearly all of them were rats, which can be active at different periods of the day (Taylor, 1978; Lode, 1995). Our findings agree with previous studies that indicate that the majority of small mammal species of the Patagonian rainforests are predominantly nocturnal and/or crepuscular (Murúa et al., 1978; Feito and Ortega, 1981; Iriarte et al., 1989). On the other hand, the chucao and huet-huet were mostly diurnal, but decreased their activity during midday. A similar activity pattern was observed for the chucao in the Chiloé Archipelago (Rozzi et al., 1996). These strong bimodal patterns of the chucao and huet-huet activity might suggest a strategy of antipredator behavior (Lima and Bednekoff, 1999), as the birds decreased their activity when the guiña increased its activity, and therefore predation risk was higher.

Although we did not perform a specific survey of small mammal abundance, the high number of pictures obtained through camera-trapping suggests that they may be abundant in the study area. This suggests that they are the main prey of the guiña in the study area. Indeed, most guiña scats collected there contained

small mammals (Delibes-Mateos et al., unpublished results), as in other areas (Freer, 2004; Correa and Roa, 2005; Zuñiga et al., 2005). Our results revealed a high consistency in the overlap between activity patterns of guiñas and small mammals, and a negligible overlap with that of less frequently consumed prey species, such as chucao and huet-huet. In other words, based on activity patterns, the guiña should prefer small mammals over ground-foraging birds. In fact, although birds are usually the second main prey of this felid, their importance in the guiñas's diet is always much lower than that of small mammals (Freer, 2004; Correa and Roa, 2005; Zuñiga et al., 2005). These results closely resemble those obtained for other stalking felid predators, which require their most profitable prey to be active in order to detect and capture them (Schaller and Crawshaw, 1980; Emmons, 1987; Harmsen et al., 2011; Foster et al., 2013).

In this study we have reported a high overlap between the activity of the guiña and that of small mammals for the first time. This suggests that the cat mainly relies on this prey in the Valdivian rainforest. We recorded a relatively low number of detections of guiñas during this short study. We recommend longer-term studies in the future to confirm whether the activity of the guiña also is closely associated with that of small mammals in other seasons and habitats. In any case, studies such as ours improve the understanding of the temporal relationships between predators and their prey, which is especially important in the case of poorly known predators like the guiña. This is necessary to design effective management strategies to conserve this vulnerable felid.

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FIGURE LEGENDS

Figure 1 Location of the Huinay Biological Reserve and Comau Fjord within the Los Lagos Region, southern Chile.

Figure 2 Activity patterns of the four species/groups represented as the percentage of independent detections (sample sizes, 'n', above each bar) occurring within each of the three periods of the 24-h light cycle in the study area.

Figure 3 Activity overlap between guiña (solid line) and prey species (dashed line): (a) small mammals, (b) chucao tapaculos and (c) black-throated huet-huet. Overlap is represented by the shaded area. Coefficient of overlap (Δ_1) and confidence intervals from 500 bootstrap samples (in brackets). The gray dashed vertical lines represent the approximate time of sunrise and sunset during the study period.

Figure 1

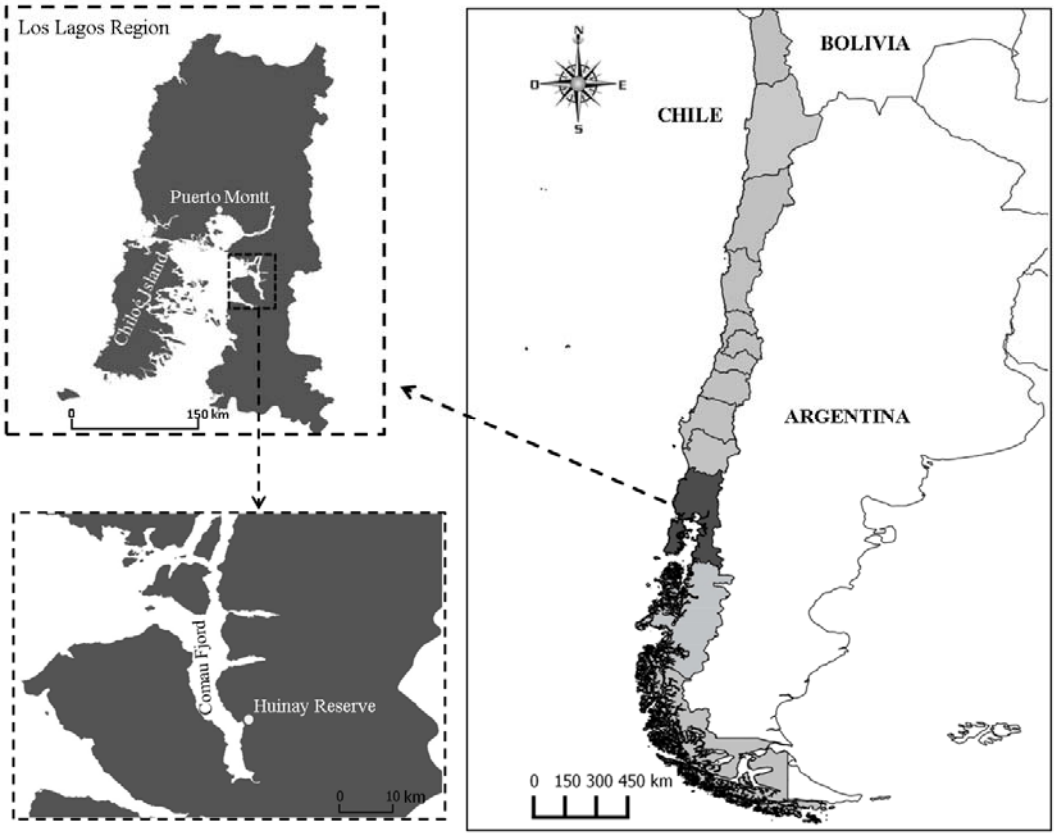

Los Lagos Region
Puerto Montt
Chiloé Island
0
150 km
Comau Fjord
Huinay Reserve
0
10 km
BOLIVIA
CHILE
ARGENTINA
0 150 300 450 km

Figure 2

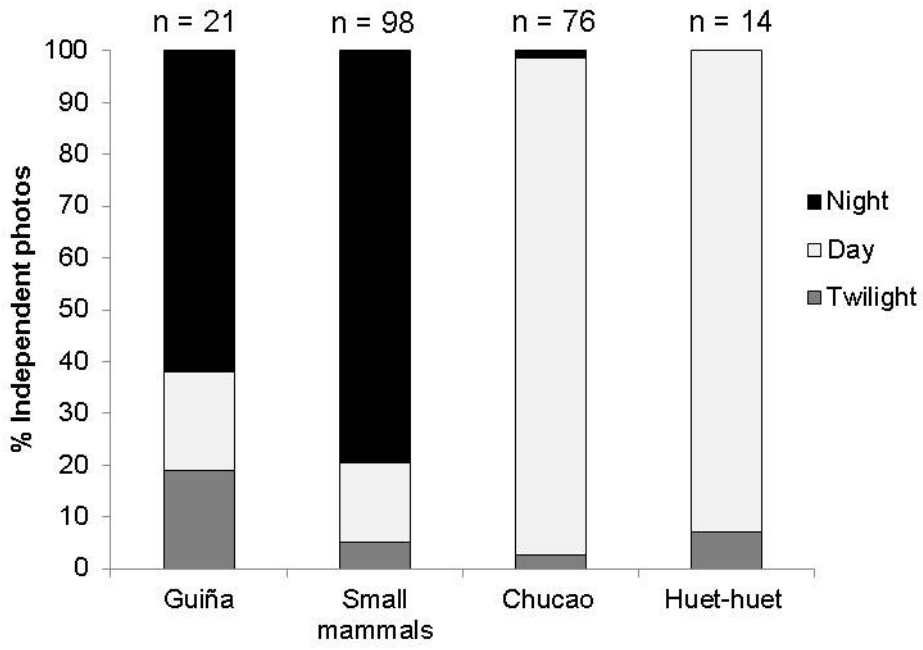
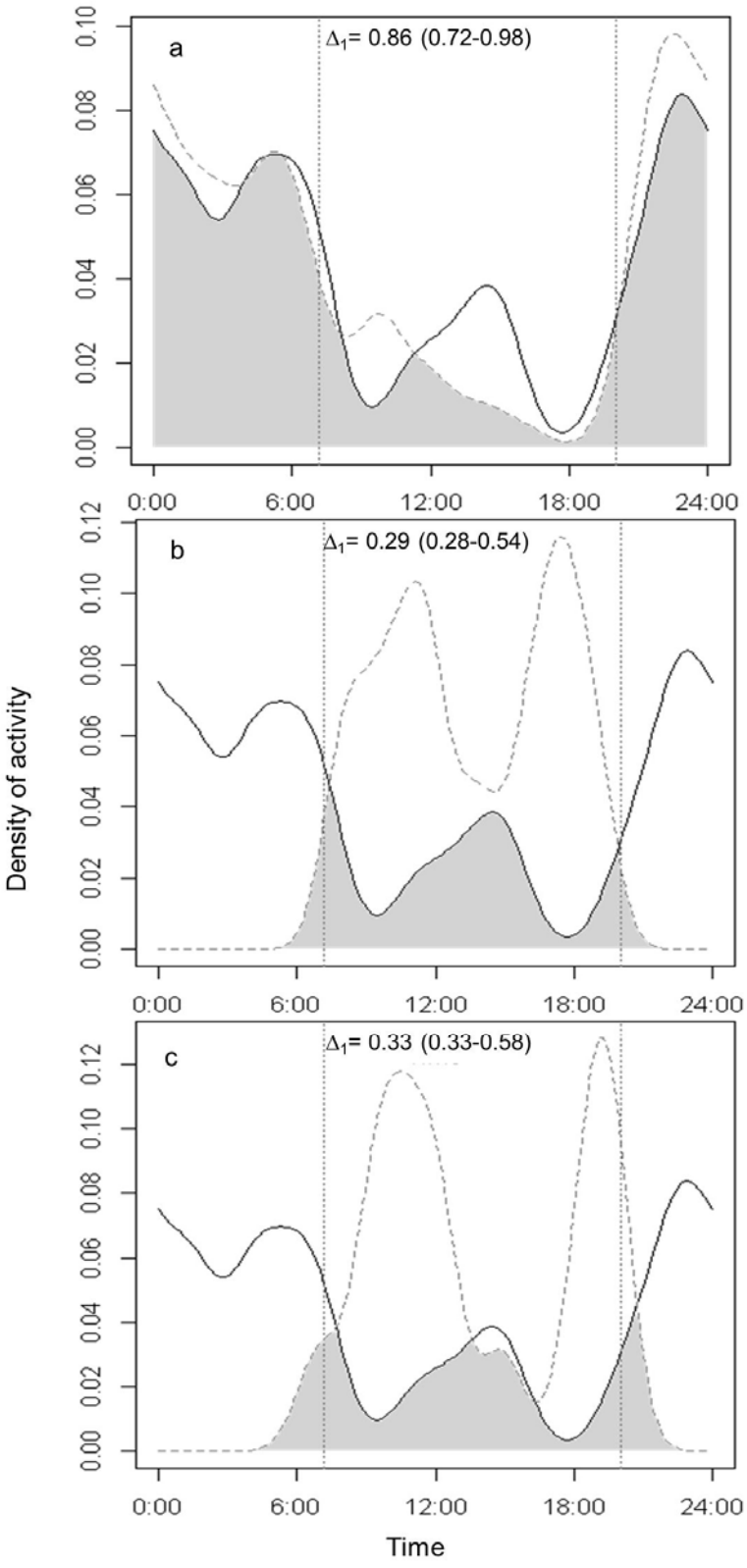

n = 21
n = 98
n = 76
n = 14
100
90
80
70
60
50
40
30
20
10
0
% Independent photos
Night
Day
Twilight
Guiña
Small mammals
Chucao
Huet-huet

Figure 3


a
Δ_1= 0.86 (0.72-0.98)
b
Δ_1= 0.29 (0.28-0.54)
c
Δ_1= 0.33 (0.33-0.58)
Density of activity
Time
0:00
6:00
12:00
18:00
24:00
0.00
0.02
0.04
0.06
0.08
0.10
0.12