

Activity patterns by two colour morphs of the vulnerable guiña, *Leopardus guigna* (Molina 1782), in temperate forests of southern Chile

Patrones de actividad de dos morfos de coloración de la vulnerable güiña, *Leopardus guigna* (Molina, 1872), en bosques templados del sur de Chile

FELIPE HERNÁNDEZ^{1*}, NICOLÁS GÁLVEZ^{1,2}, ALESSANDRO GIMONA³, JERRY LAKER¹ & CRISTIÁN BONACIC¹

¹Fauna Australis Wildlife Laboratory, School of Agriculture and Forestry Sciences, Pontificia Universidad Católica de Chile, Santiago, Chile

²Pontificia Universidad Católica de Chile, Department of Natural Sciences, Villarrica Campus, Centre for Local Development (CEDEL), Villarrica, Araucanía, Chile

³The James Hutton Institute, Aberdeen, Scotland

*E-mail: fhernandeu@uc.cl

ABSTRACT

Here we provide the first analysis of activity patterns exhibited by spotted and melanistic colour morphs of the vulnerable guiña *Leopardus guigna*, in a forest landscape of southern Chile. Camera traps showed guiñas were mainly active at night (64% of photos). Melanistic guiñas were more nocturnal (82% of photos) than the more common spotted cats (57%). Spotted guiñas were more active on cloudy and moonless nights. Our study provides novel findings about the behavioural plasticity of guiña in different ambient conditions, and the relative advantage to each colour morph to persist in an increasingly human-dominated landscape.

KEYWORDS: Behavioural patterns, phenotypes, *Leopardus guigna*

RESUMEN

Entregamos el primer análisis de patrones de actividad exhibidos por morfos moteados y melánicos de la vulnerable güiña *Leopardus guigna*, en un paisaje de bosque del sur de Chile. Cámaras trampas mostraron que las güiñas estuvieron mayoritariamente activas en la noche (64% de fotos). Las güiñas melánicas fueron más nocturnas (82% de fotos) que las moteadas más comunes (57%). Las güiñas moteadas estuvieron más activas en noches nubladas y oscuras. Nuestro estudio provee nuevos resultados sobre la plasticidad conductual de la guiña en diferentes condiciones ambientales, y la ventaja relativa de cada morfo para persistir en un paisaje cada vez más dominado por el ser humano.

PALABRAS CLAVES: Patrones conductuales, fenotipos, *Leopardus guigna*

Activity patterns in animals are linked to endogenous biological rhythms that track environmental variables (e.g., Kolowski *et al.* 2007). Environmental factors interact with the appearance of some morphological traits such as body colouration, particularly in mammals (e.g., Caro 2005). Understanding the interplay among environmental factors and behavioural/morphological features may reveal the mechanisms by which some species adapt to, and survive

in changing landscapes. Adaptive predatory behaviour patterns have been observed in large (e.g., *Panthera tigris*, Kawanishi & Sunquist 2004) and medium-sized (e.g., *Leopardus pardalis*, Di Bitetti *et al.* 2006) felids. These patterns support the idea of a temporal synchronization of activity with prey base as well as the association between environmental factors (e.g., ambient light) and hunting efficiency (Penteriani *et al.* 2013). Considering that

concealment from prey or predators is a primary function of coat colouration (Caro 2005), a spotted pattern may aid concealment in dappled sunlight conditions, whereas melanism (black coat) probably offers enhanced crypsis in dark, closed habitats (Kitchener *et al.* 2010). However, the ways in which small wild cats (< 10 kg) exhibit behavioural and morphological adaptations to cope with environmental conditions remain scarcely explored, probably due to the practical limitations to observing cryptic, and often rare, species in their natural environment (Macdonald & Loveridge 2010).

The guiña, *Leopardus guigna* is one of the smallest (1.2-2.2 kg) felids in the world (Nowell & Jackson 1996). It is endemic to temperate rainforests of southern Chile and Argentina (30-50° S 70-75° W, Redford & Eisenberg 1992). Guiñas occur in both spotted and melanistic coat colour morphs (Sunquist & Sunquist 2002). They have been described as nocturnal/crepuscular (Dunstone *et al.* 2002a; Sanderson *et al.* 2002; Delibes-Mateos *et al.* 2014), inhabiting continuous and fragmented forests (Gálvez *et al.* 2013). However, there is still much unknown about the behavioural and morphological patterns displayed by the species, since only isolated records exist (e.g., Altamirano *et al.* 2013).

We describe and compare the daily activity patterns displayed by spotted and melanistic guiñas, and the association between moonlight and nocturnal activity of both colour morphs.

The study was conducted in the foothills of the Andes in the Araucanía district of southern Chile. Vegetation cover is primarily deciduous forest dominated by the genus *Nothofagus* at lower altitudes and deciduous forest mixed with the conifer *Araucaria araucana* at higher altitudes (> 900 m). The study area covered 1,739 km² across an elevation gradient ranging from 230 m a.s.l. in the agricultural valley to > 1200 m a.s.l.

Between January 2008 and March 2009, we continuously surveyed 27 forest sites. From 2006 to 2010, additional non-continuous surveys were conducted in 100 sites, deploying similar sampling efforts throughout yearly seasons. Surveys were carried out using a combination of analogue (Trailmaster®) and digital cameras (Reconyx®, Stealthcam®). Cameras were placed along trails and tracks (< 20 cm above ground), programmed to operate 24 hours a day, and visited every 20-25 days. An independent event at a camera site was defined as an image with positive guiña recorded with at least a 1 h interval from the next detection. Guiña daily activity patterns were described by pooling independent photos from all study sites, assuming that even sampling efforts were deployed through seasons during both continuous and non-continuous surveys. Photo classification

accounted for variation on sunrise (i.e., 0800 h) and sunset (i.e., 1900 h) times, dividing photos into day (0900-1759 h), night (2000-0659 h), dawn (0700-0859 h) and dusk (1800-1959 h). We estimated moon luminosity by calculating a nocturnal illumination index ($I_{\text{norm}}(t)$), using moon time duration, moon phase and local cloud cover (Schwitzer *et al.* 2007). Nonparametric kernel density estimation was used to estimate the probability density function of guiña activity pattern (Linkie & Ridout 2011). We compared the activity patterns displayed by spotted and melanistic morphs using the overlap coefficient Δ_1 , which ranges from 0 (no overlap) to 1 (complete overlap). This coefficient has been reported to perform appropriately for small sample sizes (i.e., smaller sample had < 50 photos of guiña). The precision of Δ_1 was determined by the calculation of confidence intervals as percentile intervals from 1,000 bootstrap samples (Linkie & Ridout 2011). To explore if moon luminosity was differentially associated with the nocturnal activity displayed by both colour morphs, we conducted a two-sample Kolmogorov-Smirnov test and a Wilcoxon ranked sum test. Statistical analyses were carried out with the R software 2.15.2 (R Development Core Team, 2012), using the package overlap for the kernel density estimation (Meredith & Ridout 2014). Totalling 11,908 camera-trap days, stations ($n = 127$) recorded 78 independent photos (hereafter photos) of guiñas. The spotted morph (56 photos, 72%) was more commonly recorded than the melanistic (22 photos, 28%). The spotted cats were photographed at more stations than melanistic ones (30 vs. 15 sites). Guiñas were more active during night time, accounting for 50 nocturnal photos (64%). Eighty two percent of the photos of melanistic guiñas were taken at night, 9% during the day and 9% during dawn/dusk. For the spotted cats, 57% of the photos were taken at night, 25% during daytime and 18% during dawn/dusk; thus, records of spotted guiñas were more evenly distributed throughout the 24 h daily cycle than those of melanistic guiñas, and we observed only a moderate overlap between the activity patterns of the two morphs: $\Delta_1 = 0.68$ (0.50-0.84) (Figure 1a). Nocturnal records of spotted cats mostly coincided with cloudy and darkest nights (75% of photos associated to $I_{\text{norm}}(t) < 1$), whereas those of melanistic cats were more frequent during nights that were brighter (55% of night melanistic photos occurring with $I_{\text{norm}}(t) > 1$) (Figure 1b). The Wilcoxon ranked sum test ($W = 820$, $p = 0.024$) indicated a differential level of moon luminosity over the nocturnal activity displayed by the two guiña colour morphs, and the Kolmogorov-Smirnov test ($D = 0.3785$, $p = 0.054$) was also on the borderline of significance.

Our results suggest that guiñas are mostly nocturnal, similarly to other small neotropical felids (e.g., *Leopardus geoffroyi*, *L. colocolo*) (Cuéllar *et al.* 2006; Lucherini *et al.* 2009), and partially differ with previous studies from radio-collared guiñas in southern localities (i.e., suggesting asymmetrical and nocturnal/crepuscular daily activity

patterns — Dunstone *et al.* 2002a; Sanderson *et al.* 2002). Prior findings have suggested that guiña active behaviour may correspond with peak activity of small mammals (Sanderson *et al.* 2002), which are the species' main prey items (up to 82%, Dunstone *et al.* 2002b). Even though the periodicity of activity patterns of small mammals was not assessed during our study, perhaps the mostly nocturnal melanistic guiñas may be taking advantage of their enhanced crypsis during night time, facilitating their hunting on nocturnal rodents (Allen *et al.* 2011). On the other hand, spotted guiñas may take advantage of their disruptive coat camouflage during daytime as well and, therefore, of the opportunity to prey on day-active prey-items like birds, secondary prey items within guiña's diet (24%, Dunstone *et al.* 2002b).

The increased activity of spotted guiñas during cloudy and moonless conditions resembles the negative influence of moonlight on the activity of other felids (e.g., *L. pardalis*,

P. leo) (Di Bitetti *et al.* 2006; Packer *et al.* 2011). Brighter nights may hinder concealment for guiñas. Similarly, small mammals commonly avoid activity during moonlit nights, suggesting a potential degree of synchronization in this predator-prey relationship (e.g., Clarke 1983). A note of caution must be stated regarding the potential role of unmeasured environmental variables on the perception of ambient light by this species (e.g., canopy cover). The higher activity of melanistic cats during moonlit nights (supposed to generate highest contrast in the background) could be confounded by canopy structure patterns in the temperate forests. Probably, dense vegetation cover would impede moonlight from reaching the forest floor, not causing a meaningful effect of luminosity on felid nocturnal behaviour.

Our study provides novel findings about the behavioural patterns showed by guiñas in Chile. Differences in daily and nocturnal activity patterns between spotted and melanistic

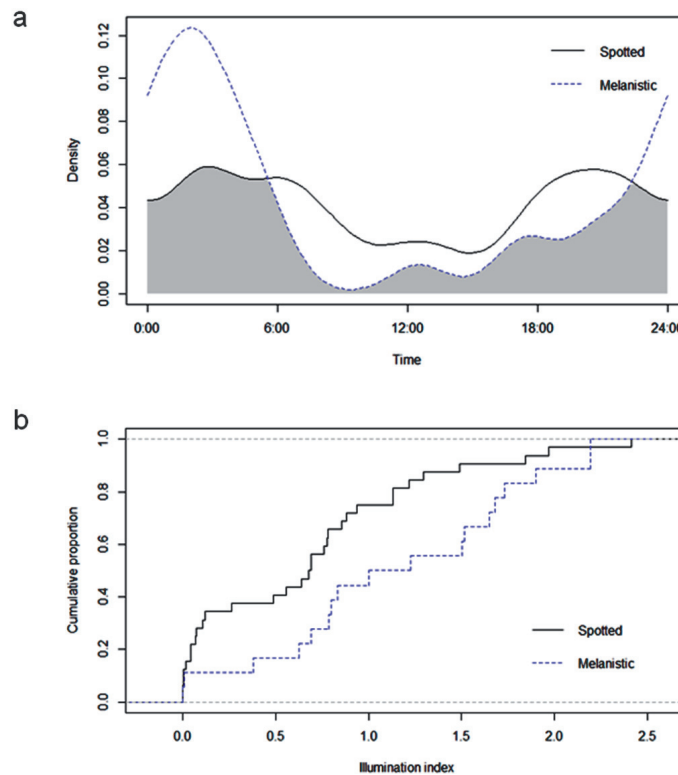


FIGURE 1 (a) Density estimates of the daily activity patterns of spotted ($n = 56$) (solid line) and melanistic ($n = 22$) (dashed line) guiñas. Activity overlap between both morphs is represented by the shaded area. Photos were divided into day (0900-1759 h), night (2000-0659 h), dawn (0700-0859 h) and dusk (1800-1959 h); and (b) cumulative proportion of night time photos of spotted ($n = 32$) (solid line) and melanistic ($n = 18$) (dashed line) guiñas through nocturnal illumination index ($I_{norm}(t)$), recorded by camera traps in the Andean Araucanía of southern Chile

FIGURA 1 (a) Estimadores de densidad de patrones de actividad diarios de guiñas moteadas ($n = 56$) (línea sólida) y melánicas ($n = 22$) (línea discontinua). Traslapo de actividad entre ambos morfos es representado por el área sombreada. Clasificación de fotos consideró la variación en tiempos de salida (i.e., 0800 h) y puesta (i.e., 1900 h) del sol, dividiendo las fotos en día (0900-1759 h), noche (2000-0659 h), amanecer (0700-0859 h) y atardecer (1800-1959 h); y (b) proporción acumulada de fotos nocturnas de guiñas moteadas ($n=32$) (línea sólida) y melánicas ($n=18$) (línea discontinua) a través de índice de iluminación nocturna ($I_{norm}(t)$), registradas por cámaras trampa en la Araucanía andina del sur de Chile

guiñas reflect the behavioural plasticity displayed by both morphs in distinct ambient conditions. They suggest interesting insights about the relative advantage to each colour morph to persist in an increasingly human-dominated landscape, such as the temperate forests of southern Chile.

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