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“Patrones de actividad de zorros en presencia de perros guardianes de ganado”

Seminario de Título entregado a la Universidad de Chile en cumplimiento parcial de los requisitos para optar al Título de Bióloga con mención en Medio Ambiente

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Se informa a la Escuela de Pregrado de la Facultad de Ciencias, de la Universidad de Chile que el Seminario de Título, presentado por la **Srta. Kathia Arenas Rodríguez**

"Patrones de actividad de zorros en presencia de perros guardianes de ganado"

Ha sido aprobado por la Comisión Evaluadora, en cumplimiento parcial de los requisitos para optar al Título de Bióloga con mención en Medio Ambiente.

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BIOGRAFÍA

Desde que era una niña la curiosidad me llevó a tratar de aprender lo más posible de todo tipo de cosas; no pasó mucho tiempo hasta que me diera cuenta de que la ciencia era lo que más llamaba mi atención, y finalmente, gracias a las enseñanzas de una profesora de la educación media terminé por enamorarme de la Biología, especialmente lo que implicaba relacionarse con la fauna. Si bien mi elección por la carrera de Biología Ambiental fue prácticamente una decisión azarosa, a lo largo de la carrera me di cuenta de que es realmente algo que me emociona. Gracias al interés de ir un paso más allá, logré conocer al Profesor Javier Simonetti, quien me permitió ser parte del Laboratorio de Conservación Biológica, donde además de aprender a generar estrategias para la conservación de la biodiversidad, me impulsaron a pensar críticamente. Finalmente, aunque siento que este camino recién está empezando y me queda mucho por recorrer, espero continuar aportando con conocimiento basado en evidencia a la conservación de la fauna.

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RESUMEN

Diversas actividades humanas pueden afectar a la fauna silvestre en distintas dimensiones. Entre estas actividades, la ganadería es una fuente de conflictos humano-vida silvestre debido, entre otros factores, a la depredación de ganado por carnívoros silvestres. Para evitar la depredación, se emplean métodos letales y no letales que pueden modificar la distribución espacial y/o temporal de la fauna. Los Perros Guardianes de Ganado (PGG) son uno de los métodos no letales con mayor efectividad, sin embargo, debido al posible rol de depredador tope que adquieren en la comunidad, podrían tener impactos sobre elementos de la fauna; el efecto de los perros en el uso del tiempo de especies nativas ha sido poco estudiado. Bajo este contexto, este estudio buscó determinar los posibles efectos de la presencia de PGG sobre los patrones de actividad de los zorros nativos *Lycalopex griseus* y *L. culpaeus*, depredadores de ganado ovino, principalmente corderos, en la región de Magallanes. A partir de registros de ambas especies de zorros en cámaras trampa dispuestas en estancias con y sin PGG en Isla Riesco, Chile, entre 2016 y 2018, se construyeron sus patrones de actividad en presencia/ausencia de PGG y bajo distintas condiciones ambientales, como la cobertura vegetal, la fase lunar y la temperatura ambiental. Ambas especies evitan temporalmente los momentos del día de alta actividad de los PGG y, en consecuencia, ocurre mayor sobreposición temporal entre especies nativas. Pese a la sobreposición, el uso de PGG permite alejar a los depredadores del ganado, evitando en consecuencia la depredación y cacería en retaliación, con beneficios económicos y para la conservación.

ABSTRACT

Diverse human activities can affect wildlife in different dimensions. Among these activities, livestock is currently a source of human-wildlife conflicts due, largely, to predation upon livestock by wild carnivores. Lethal and non-lethal methods are used to prevent predation, which can modify the spatial and/or temporal distribution of wildlife. Livestock Guarding Dogs (LGDs) are one of the most effective non-lethal methods, however, due to the possible top predator role acquire in the community, LGDs could impacts wildlife; the effect of dogs on wildlife daily activity patterns has been poorly studied. In this context, our aim was to determine the possible effects of LGDs presence on the activity patterns of native foxes *Lycalopex griseus* and *L. culpaeus*, two sheep predators, mainly lambs, in the Magallanes region. Based on information from camera traps arranged in ranches with/ without LGDs in Isla Riesco, Chile, between 2016 and 2018, we constructed the activity patterns of both species in presence/absence of dogs and under different environmental conditions such as vegetation cover, moon phase and environmental temperature. We found that both species avoid times of day of high LGDs activity and consequently, greater temporal overlap occurs between native species. However, even under this overlap, the use of LGDs allows the predators to move away from the livestock, possible preventing livestock predation and benefiting both, the economics of ranchers and the conservation of these native predators.

INTRODUCTION

Numerous human activities affect wildlife in different ways and dimensions, such as the spatial and the temporal dimensions of the niche (Nickel et al. 2020). Livestock raising is often related to the emergence of conflicts with native fauna, mostly due to predation of livestock by wild carnivores which leads to retaliatory hunting of the carnivores involved (Inskip & Zimmermann. 2009, Katel et al. 2014). To solve this conflict, different lethal and no-lethal methods have been used to reduce livestock losses (Moreira-Arce et al. 2018); although the latter methods do not lead carnivores to death, they can have impacts such as spatial displacement of native fauna, or in some cases, can induce changes in their activity patterns to avoid possible encounters and confrontations with potential predators or competitors such as the Livestock Guardian Dogs (LGDs) used to protect livestock from predators (Shamoon et al. 2018, Nickel et al. 2020).

Among the non-lethal tools, the use of LGDs is considered one of the most effective deterrents in the medium and long term (Allen et al. 2016, Moreira-Arce et al. 2018). LGDs have been used as livestock companion, preventing them from dispersing and at the same time, preventing predators from coming into direct contact with the guarded animals (Andelt 1992, Smith et al. 2020). The possible role of top predator that LGDs may adopt in the communities they are introduced (Van Bommel & Johnson 2016), and the resulting "*landscape of fear"* they could provoke for target and non-target species, can have consequences on the spatial and temporal distribution of native fauna, being the spatial dimension the most studied so far (Van Bommel & Johnson 2014, Allen et al. 2016).

LGDs presence and vocalizations could lead wildlife to avoid them temporally, but information related to this dimension of species' niche haven been poorly studied (Frey et al. 2017, Gaynor et al. 2018, Shamoon et al. 2018). Responses such as a decrease in time spent by wildlife in areas protected by LGDs (Gehring et al. 2010, Ugarte et al. 2021)

or an increase in time spent on vigilance have been detected for different wild species in LGDs presence such as hares and big herbivores (Van Bommel & Johnson 2016, Say-Sallaz et al. 2019, Ugarte et al. 2021).

How animals use time and space might also be affected by various environmental variables. Environmental temperature, for example, can determine animal behavior since individuals try to avoid thermal stress (Moyes & Schulte. 2007); temperature can also affect the availability of native prey and other resources depending on the season of year (Ugarte et al. 2019). On the other hand, vegetation structure can be also a conditional for predators' presence; higher vegetation density or cover, such as thickets or forests serve as a refuge and hiding place for carnivores and could work as a trap for preys, livestock included, due to a higher probability of predator's attack (Cozza et al. 1996, Mattiello et al. 2012). Finally, night luminosity, provided by the different lunar phases, has the potential to reduce or increase nocturnal activity of different species, as high luminosity can aid in the detection and capture of prey in the case of carnivores, or being detected as prey when they share space with larger carnivores (Linley et al. 2020).

LGDs have been used as a tool to prevent sheep predation by wild carnivores such as Culpeo (*Lycalopex culpeaus)* and Chilla (*L. griseus)*, two species with mainly crepuscular and nocturnal habits, and in the case of Chilla, even diurnal habits (Iriarte & Jaksic 2012). it has been postulated that nocturnal habits in *L. culpaeus* are due to human disturbance, some records indicate that they can be nocturnal even in areas without anthropogenic intervention in Argentinian Patagonia (Monteverde & Piudo, 2011). Moreover nocturnal, and diurnal habits in *L. griseus* have been observed in both, disturbed and natural areas (Gálvez et al. 2021) which prevents to make a clear distinction, if it exists, between daily activity patterns of foxes in areas with and without anthropogenic presence.

Most of the activity patterns of these two species have been recorded in protected areas (Monteverde & Piudo. 2011, Osorio et al. 2020) or in areas with different amounts of natural coverage (Galvez et al. 2021), however there is little information available regarding foxes' activity patterns in livestock systems, as well as systems with the implementation of a management strategy such as LGDs. Under this context, this study aims to analyze the possible effects of LGDs presence on the daily activity patterns of *L. culpaeus* and *L. griseus*, based on the hypothesis that if LGDs triggers a landscape of fear, foxes will modify their activity patterns to avoid encounters with them, decreasing the probability of direct confrontation. In addition, we aim to assess the possible influence of environmental variables such as temperature, vegetation cover and moon phase upon the use of time of these native fox species, as well as to recognize the influence of the livestock system on the activity patterns of both foxes by comparing their activity patterns with previous studies in other systems.

MATERIALS AND METHODS

Study Area

This study was carried out in Isla Riesco, Magallanes region, Chile. To assess daily activity patterns of native foxes in relation to LGDs presence, we conducted a natural experiment (Diamond 1986) that comprises a total of five sheep ranches, which differed in the use of LGDs as a tool to control livestock predation. Two ranches used LGDs: Estancia Anita Beatriz (52°51.984'S, 71°33.271W) and Estancia Adela (52°51'00.93''S, 71°30'37.90''W), while Fundo Ankel (52°49.954'S, 71°25.500'W), Caledonia (52°50'23.57''S, 71°29'54.54''S) and Emiliana (52°49'54.66''S, 71°28'28.35''W) have not adopted LGDs for sheep protection. All sampled properties share a vegetation composed of Magellanic subpolar forest, mainly with *Nothofagus* species, shrublands, peatlands and

grasslands for livestock use (Yusti-Muñoz & Simonetti, 2021); the proportion of the area covered by each vegetation type does not differ among properties (Kruskal-Wallis rank sum test, X^2=0.19, P=0.99).

Data Collection

This research is composed of two sampling periods, the first one from August to December 2016, during austral winter and spring, and the second from December 2017 to June 2018, which mainly comprises austral summer and autumn. To register foxes and LGDs daily activities, passive infrared-triggered Bushnell Trophy Cam traps were used. Camera traps were randomly allocated in active livestock fields and in all type of vegetation cover, with a distance between 500m and 1km between them. A total of 115 camera traps were set up in the whole sampling season, 55 cameras during 5 months in 2016, and 60 cameras for 7 months between 2017 and 2018. All cameras were set to take three photographs per trigger with an average delay of 5 minutes between triggers.

To determine if livestock system and LGDs presence has an effect in the activity patterns of foxes, we reconstruct the activity patterns of foxes in other areas without livestock activity and without LGDs presence to compare with the frequency of fox observations per hour was extracted from researches conducted in an area immerse in a vegetation gradient with different amounts of natural vegetation as a result of intensive agriculture and urban settlements in the central valley of La Araucanía, Chile (Galvez et al. 2021); from records from a pristine northwestern Patagonian area in Argentina (Monteverde & Piudo 2011) and from a protected area in the Andes of Central Chile (Osorio et al. 2020). Data was extracted using WebPlotDigitizer 4.5 software (Rohatgi, 2021).

Environmental variables

To test the possible effect of different environmental variables on fox activity patterns, data related to temperature and moon phase was directly extracted from camera trap photographs. In order to evidence the difference between warm and cold months, a threshold was established based on the average monthly temperature. Cold months were those with maximum daily temperature does not exceed 10°C, and warm months the remaining ones (Meteoblue, 2021). Data was gathered from reports generated by the Climate and Resilience Research Center (CR^2) at the Cordillera Riesco weather station (S52°84'24.99'', W71°76'41.66''). This separation was made to test the effect of seasonality upon activity patterns.

The type of vegetation cover at each camera trap station was extracted by intersecting the georeferenced point of each camera trap with the land cover map from Isla Riesco (resolution of 15 m); the characterization was made in QGis 3.4 Madeira (Pérez-Hernández, unpublished data). Coverage were grouped into three categories: 1) Forest, that included all kind of *Nothofagus* forests, 2) Grasslands, mainly composed of livestock plains, and 3) Shrubland, sites dominated by bushes.

Data analysis

Culpeo and Chilla foxes does not exhibit features that could enable to recognize different individuals, at least through photoidentification. To establish their daily activity patterns in presence/absence of LGDs, we relied on the density of registers per hour of the day; for statistical analysis we considered only independent records, that is, records of one species in one trap station with at least 30 minutes between the next observation (Linkie & Ridout. 2011). Information on hour, date, species, and presence/absence of LGDs was extracted from camera pictures using package “camtrapR” from Rstudio 4.0.3 (Niedballa et al.

2016). This information together with data of environmental variables were used to construct a matrix containing: species, time in radians, presence/absence of LGD (0/1), temperature, moon phase (full and new moon) and type of vegetation cover.

To compare the activity patterns of the foxes in presence/absence of LGDs, and additionally to recognize the possible influence of environmental variables on daily activity pattern for both foxes, we calculated the overlap under different conditions, where the number of observations per hour was the response variables. Combinations are summarized in Table 1.

Table 1. Combinations of variables for foxes' activity patterns comparisons.

Comparisons
1) Each *Lycalopex* sp with LGDs vs Each *Lycalopex* sp without LGDs under different combinations of environmental variables
2) Each *Lycalopex* sp vs LGDs
3) *L. culpaeus* vs *L. griseus* in presence/absence of LGDs under different combinations of environmental variables
4) Each *Lycalopex* sp vs Each *Lycalopex* sp activity patterns from areas with different environmental and anthropogenic conditions *

*See data collection section for details.

To assess the overlap between the species under different conditions, we use the coefficient of overlapping (Δ), which goes from nil Δ=0 (no overlap between patterns) to Δ=1 (total overlap between patterns compared), and their respective confidence intervals at 95%. We used Δ_4 to compare datasets exceeding 50 samples, and Δ_1 for comparisons where one or both datasets have fewer than 50 samples; comparisons made with any series with an n<10 were not considered due to low statistical support (Ridout & Linkie, 2009). In terms of the overlap, we considered Δ > 0.8 a high overlap, 0.79 > Δ > 0.5 medium overlap and Δ < 0.5 low overlap or patterns with high differentiation (Lynam et al.

2013; Allen et al.2018). Comparisons were assessed with package “Overlap” (Ridout & Linkie, 2009) in Rstudio 4.0.3. For each comparison, statistically significant differences between the activity patterns were estimated. For this purpose, a randomization test was used to create a null distribution from 10000 bootstrap iterations of random densities of activity per hour, which was compared with the activity patterns to define whether they belong to the same distributions. This was made with the function compareCkern of the "activity" package (Rowcliffe, 2021) for Rstudio 4.0.3.

RESULTS

A total sampling effort of 13,536 trap/nights was made between both sampling season, with a total of 28,500 events of photographs of different species. Of the total events registered, 1,219 corresponded to independent records (separation of 30’ between events) of foxes and LGDs. Of these records, 27 corresponded to LGDs while the remaining 1,192 were records of foxes; with a total of 1,081 observations, Chilla exceeds ten times the 111 Culpeo observations, being more frequent under all environmental conditions. On the other hand, the low number of LGD observations may be due to the fact that each estancia has a reduced number of individuals (Anita Beatriz n=2, Adela n=3) (Table 2).

Foxes daily activity patterns in presence/ absence of LGDs

Activity patterns of Chilla fox differ in areas with presence/absence of LGDs ($\Delta 4=0.90$, $p = 0.01$). Without LGDs, Chilla exhibited a peak of activity density around midnight, while with LGDs, two activity peaks were observed (Figure 1). As with Chilla, Culpeo fox in the absence of LGDs has one strong point of high activity density that was reduced almost by half in LGDs presence ($\Delta 4=0.73$, $p = 0.01$), leading to an activity pattern almost constant throughout the day, but being more active after midnight (Figure 1).

Table 2. Number of photos obtained for each species under LGDs presence/absence and different environmental conditions.

	L. culpaeus	*L. griseus*	LGD
With LGDs	38	477	27
Without LGDs	73	604	0
Full Moon	7	61	0
New Moon	32	290	11
Warm Months	98	960	24
Cold Months	13	121	7
Grasslands	26	582	2
Shrublands	54	348	18
Forests	31	151	11
Total Photos	**111**	**1081**	**27**

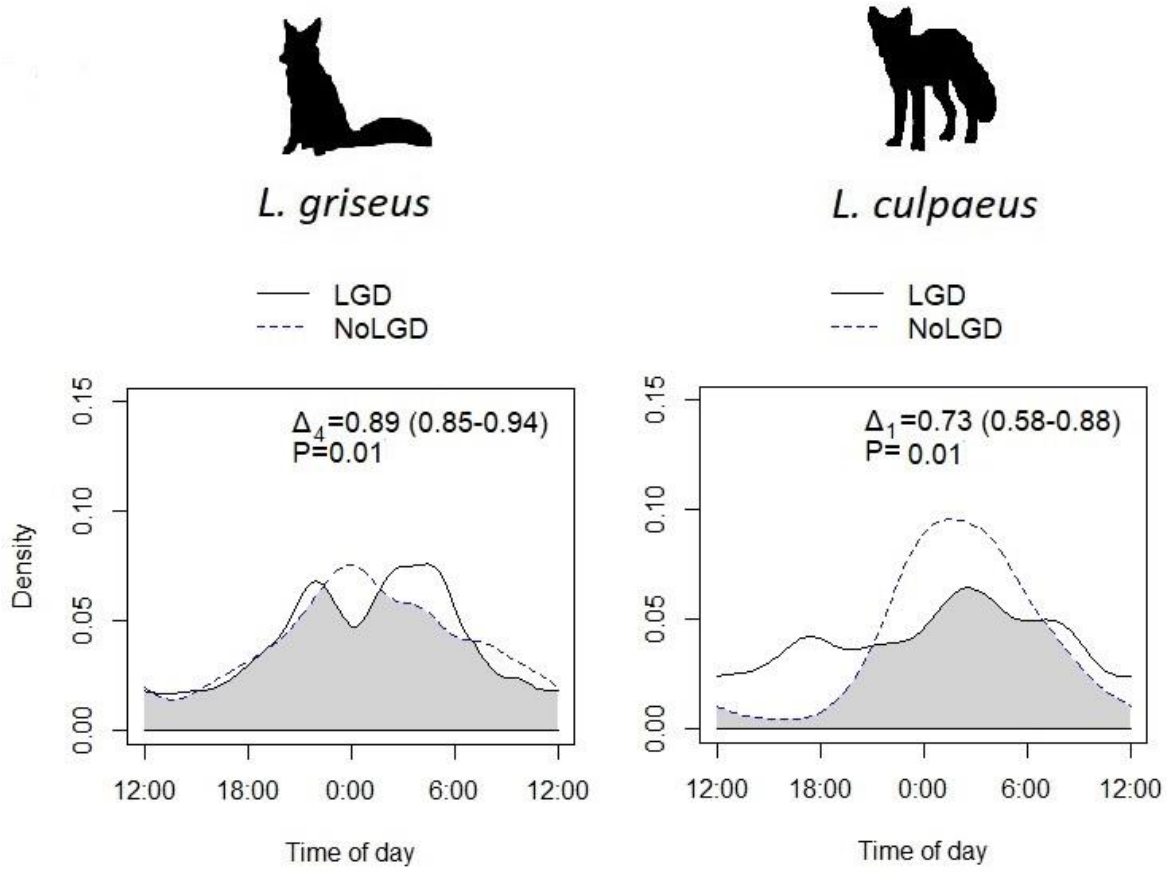

Figure 1. Comparisons of fox activity patterns in the presence/absence of LGD.

Comparison of foxes vs. LGDs activity patterns

Chilla vs LGD showed statistically significant differences (*L. griseus* Δ_1=0.63, p < 0,01; *L. culpaeus* Δ_1=0.74, p = 0.11); patterns of Chilla and LGDs showed to be opposite, being the fox more active when LGDs reduced their activity (Figure 2). In contrast, Culpeo fox was active throughout the day but exhibiting lower activity with a small activity peak after midnight (Figure 2).

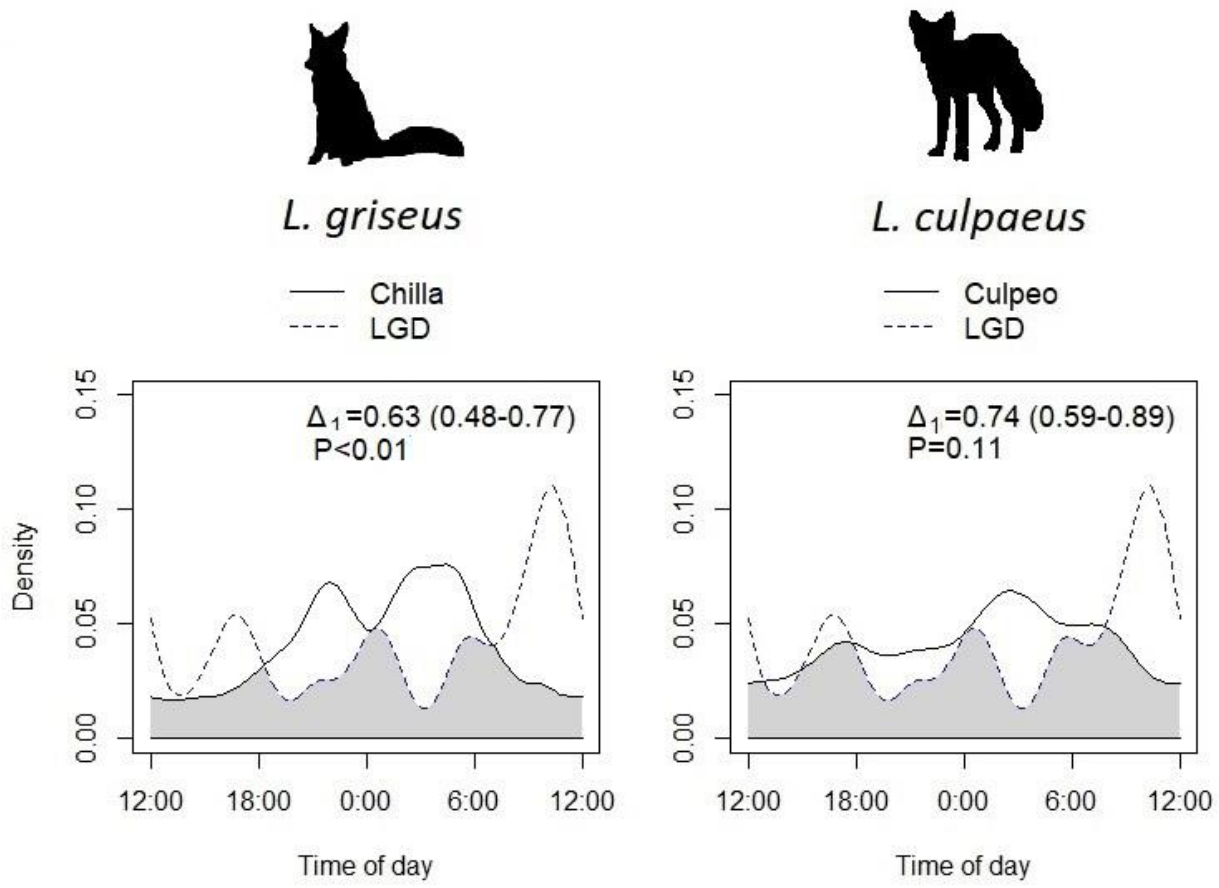

Figure 2. Comparison between daily activity pattern of native foxes and LGDs in Isla Riesco.

Comparison of L. griseus vs. L. culpaeus activity patterns

Statistically significant differences were only detected between both species in the absence of LGDs (without LGDs Δ_4=0,809, p = 0,013; with LGDs Δ_4=0,853, p = 0,710). Differences mainly accounted to the higher density of observation of Culpeo and Chilla around the midnight without LGDs, while in LGDs presence, a more fluctuating pattern across the day was observed for both species resulting in non-differences between them (Figure 3).

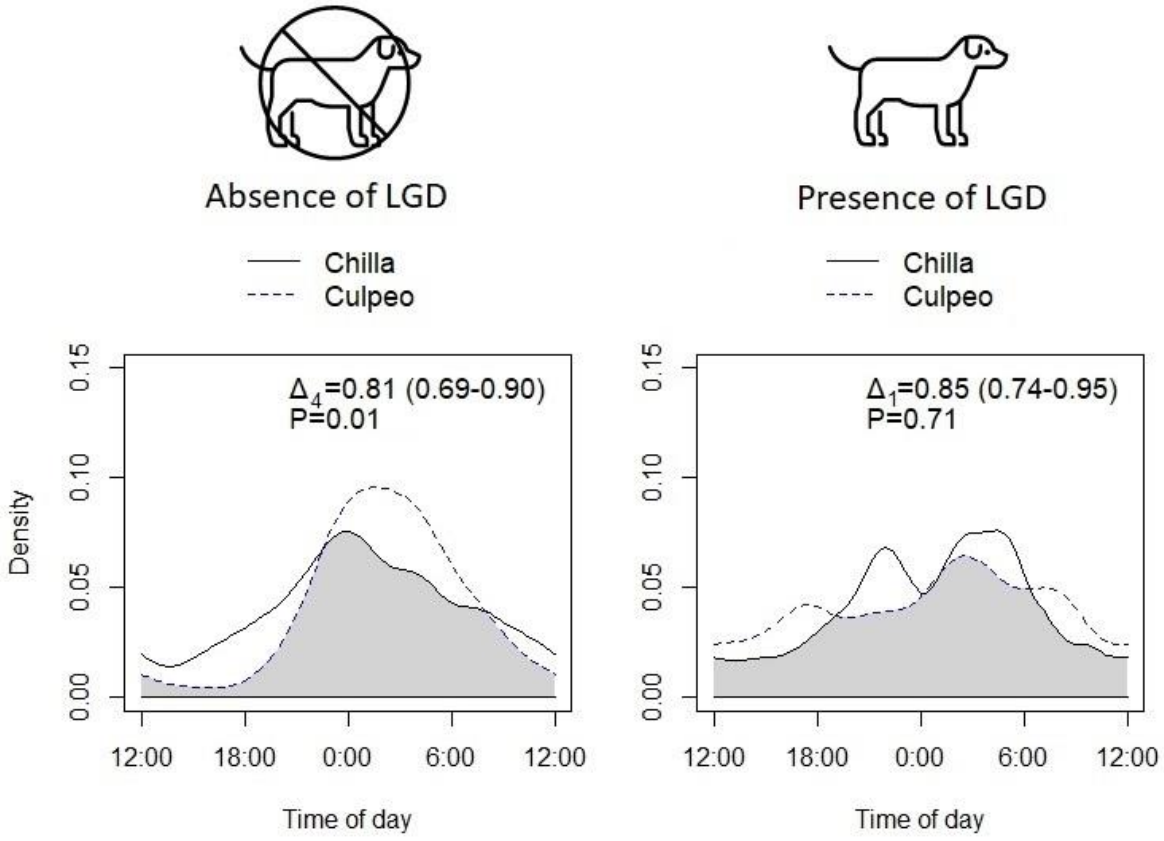

Figure 3. Comparisons between activity patterns of foxes in presence/absence of LGD.

Comparison of local daily activity patterns of foxes with previous studies

Local activity patterns of foxes in Isla Riesco were compared to patterns obtained for other localities without livestock ranching, and without LGDs. When comparing data from Isla Riesco, with that from the central valley of La Araucania, an area with intensive agriculture (Galvez et al. 2021), statistically significant differences were found for both species (*L. griseus* Δ_4=0,809, p <0,0001 ; *L. culpaeus* Δ_4=0,816, p = 0,023); for Culpeo fox, non-statistically significant difference were found between data from Isla Riesco and the patterns reported for protected areas in Argentinean Patagonia (Monteverde & Piudo, 2011) (Δ_4=0,829, p = 0,143) and Chilean Andes (Osorio et al. 2020) (Δ_4=0,859, p = 0,349) (Figure 4).

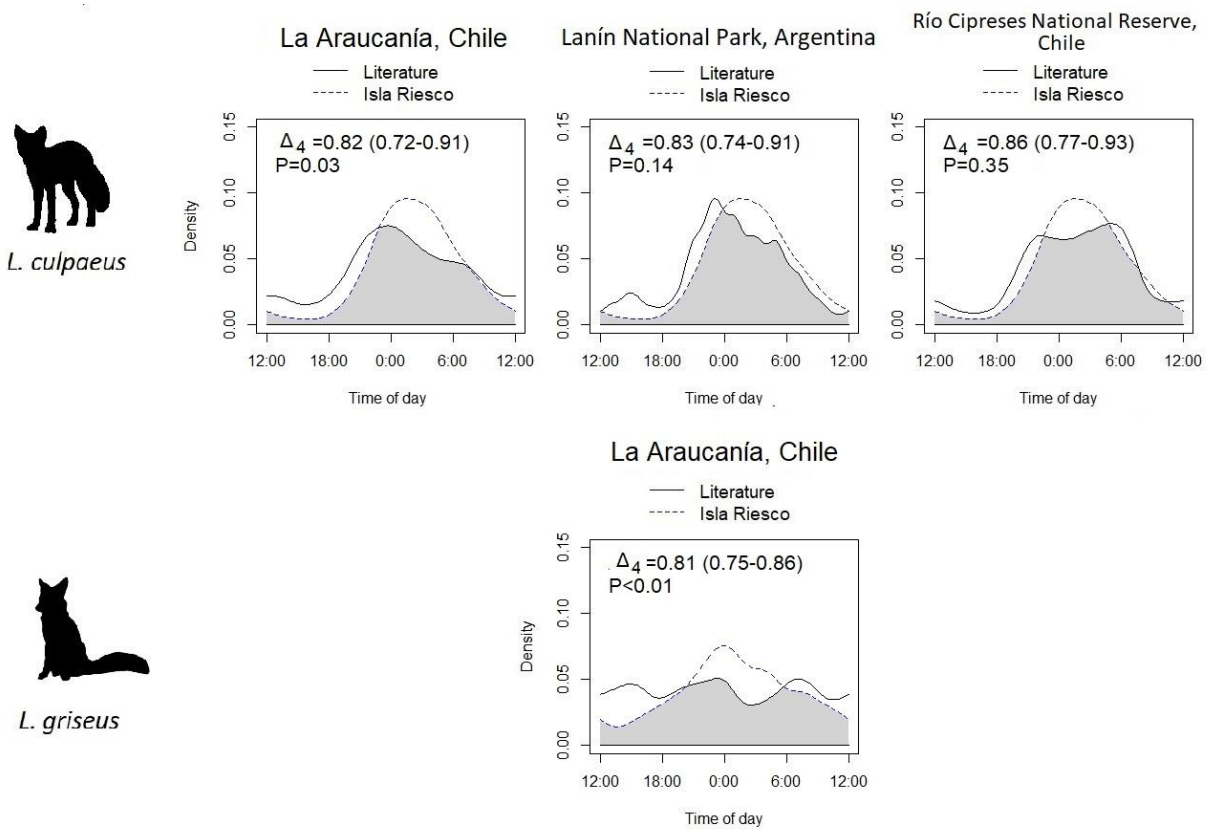

Figure 4. Comparison of activity patterns between an LGDs-free environment and patterns previously recorded in the literature.

Environmental variables

Environmental variables were not relevant for most comparisons of Chilla activity patterns with/without LGDs (Table 3). For Culpeo fox, it was possible to make few pattern comparisons, since, as with cold temperature months and full moon, data was insufficient for statistical analysis (n > 10).

Table 3. Coefficient of overlap for the comparison of fox species in areas presence/absence LGDs under different environmental conditions. p- values < 0.05 are statistically significant and highlighted in bold.

Condition	*L. griseus*		*L. culpaeus*	
	Δ	P-Value	Δ	P-Value
New Moon	0,88	0,16	0,63	**0,06**
Full Moon	0,67	0,07	-	-
Shrublands	0,89	0,32	0,71	0,12
Forests	0,88	0,63	-	-
Grassland	0,88	**0,04**	0,64	0,21
Shrublands in New Moon	0,85	0,71	-	-
Forests in New Moon	0,78	0,63	-	-
Grassland in New Moon	0,82	0,18	-	-

When comparing the activity patterns of each fox species in a different moon phase without considering the effect of LGDs, *L. griseus* showed different behaviors depending on the lunar phase (Δ_4=0,825, p = 0,032) (Figure 5a). At new moon, the pattern presented a peak of activity around midnight, but during full moon oscillations along the day occurred. Regarding *L. culpaeus,* no marked differences were observed (Figure 5a).

By the other side, *L. griseus* showed differences between patterns in grasslands in presence/absence of LGDs. In pastures with LGDs, Chilla fox split out its activity peak into two distinct periods, while Culpeo fox concentrated its activity between midnight and dawn (Figure 5b). Finally, no significant differences were obtained when evaluating the possible synergic effects of vegetation cover and moon phase on fox activity patterns. (Table 3).

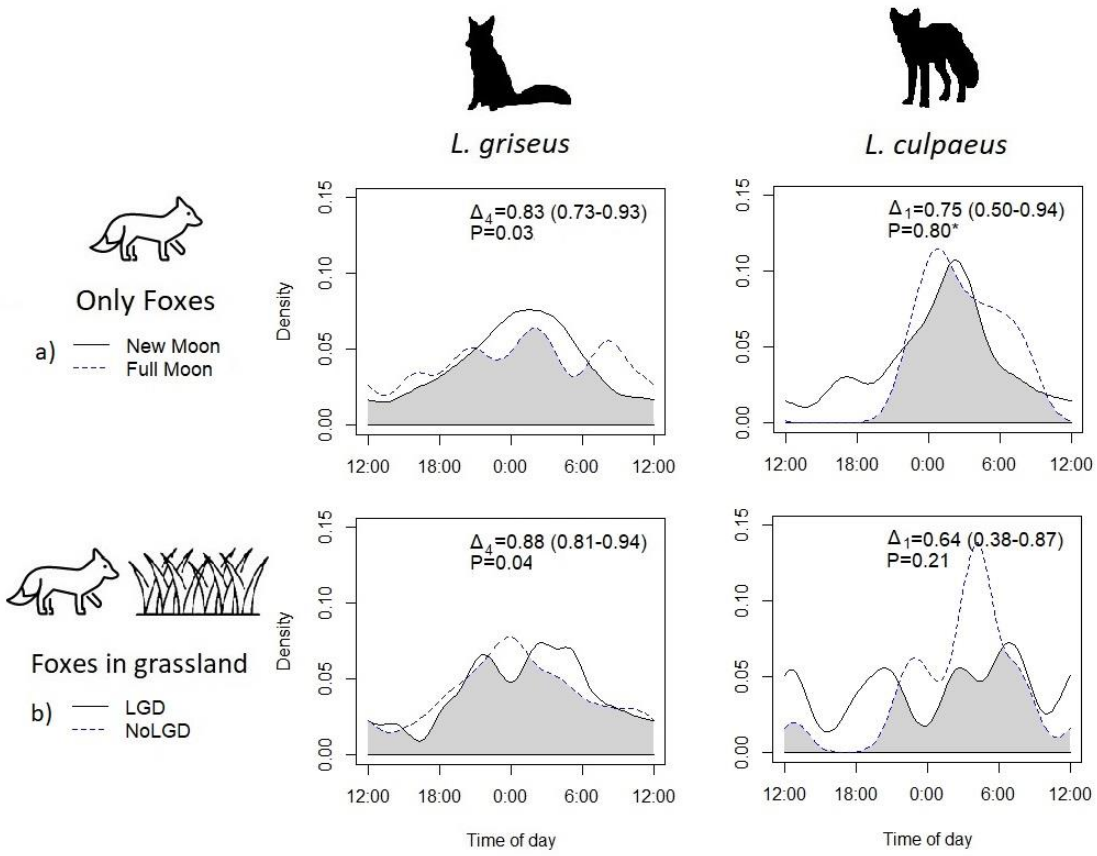

Figure 5. Comparisons of fox activity patterns in the presence/absence of LGD in different environmental conditions.

For the comparison of LGDs vs. *Lycalopex* spp., both species presented statistically significant differences in the forests (Table 4); in this cover, foxes showed higher activity densities between 06:00 and 18:00, when LGDs seems to be less active.

Table 4. Coefficient of overlap and p-value for comparisons made between foxes and LGD under different vegetation cover conditions. p values < 0.05 are significant and highlighted in bold.

Condition	*L. griseus* vs LGD		*L. culpaeus* vs LGD	
	Δ	p-Value	Δ	p-Value
Shrublands	0,77	0,49	0,82	0,83
Forests	0,23	**<0.01**	0,34	**<0.01**

For Comparisons between foxes, new moon phase did not affect their activity patterns; in the case of the full moon, data was not enough to make comparisons between the species (Table 5). For grassland and shrubland, significant differences were obtained between activity patterns in the absence of LGDs, but in the presence of dogs these differences were not significant and a high overlap between species were observed (Figure 6).

Table 5. Coefficient of overlap and P-value of comparison between foxes in presence/absence of LGD in different environmental conditions. P values < 0.05 are significant and highlighted in bold.

Condition	Absence of LGD		Presence of LGD	
	Δ	P-Value	Δ	P-Value
New Moon	0,79	0,27	0,76	0,54
Shrublands	0,76	**0,03**	0,87	0,99
Forests	0,84	0,66	0,73	0,16
Grassland	0,67	**0,03**	0,78	0,93

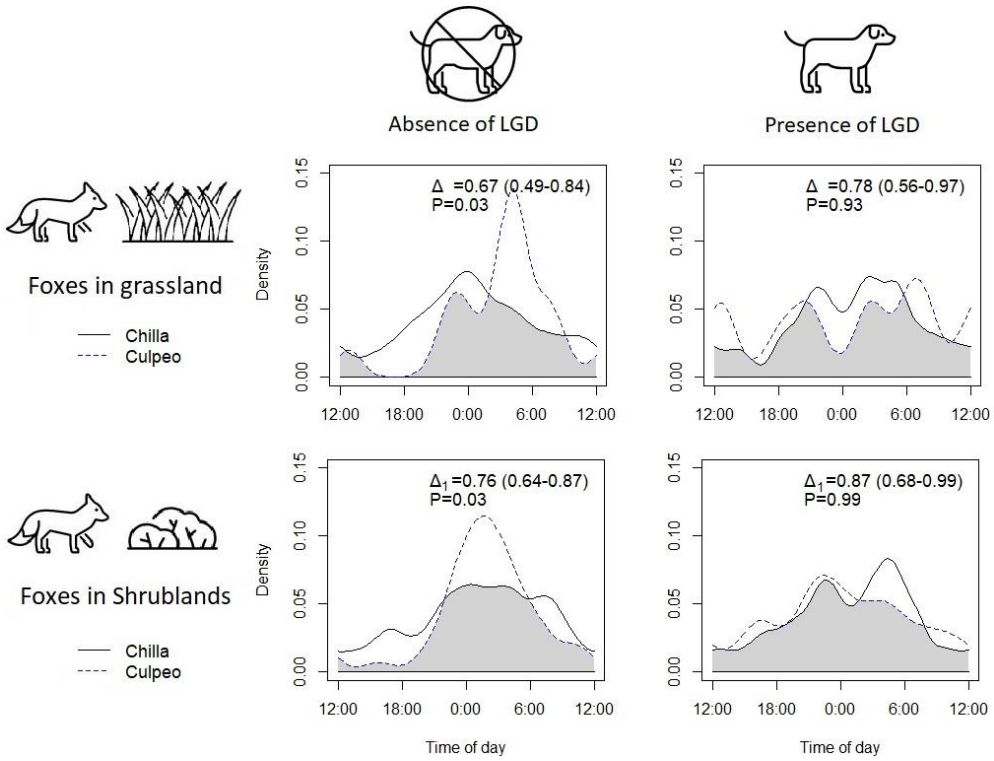

Figure 6. Comparisons between species of foxes in presence/absence of LGD and under different vegetation type cover effect.

DISCUSSION

LGDs through aggressive behaviors, such as barking and chasing, as well as through their whole-body odor (Gehring et al. 2010, Allen et al. 2016, Ugarte et al. 2019), might generate a landscape of fear capable of induce modifications in the way native fauna use the time or behave (Farías et al. 2012, Van Bommel & Johnson. 2016), hence, its presence could modify daily activity patterns of target species such as native carnivores. Our results showed that *L. culpaeus* and *L. griseus* changed their activity patterns probably as a mechanism to avoid times of the day when a larger and intimidating species like LGDs are more active (Guntiñas et al. 2021).

LGDs presence not only led to changes in daily patterns of each fox species, they also caused both species to temporarily overlap; nevertheless, this temporal overlap seems to

be compensated by avoiding each other in terms of space when LGDs are present. At the site scale (camera trap station), in the absences of LGDs foxes co-occurred in 45% of the traps stations, in contrast with 25% in LGDs presence (Fisher Test P-value=0,06). Our results suggest that foxes without LGDs, could share space but not times of the day, however, when they faced a top-predator surrogate, they are being forced to overlap their daily use of time, possible trying to avoid encounters and confrontations between them by using space in different ways (Carothers & Jaksic 1984). However, at the landscape scale, both, temporal and spatial overlapping still occurred as expected for *Lycalopex* species living in areas without marked altitudinal differentiation (Jaksic et al. 1983).

When comparing our daily patterns with those from other localities, Culpeo fox without LGDs have similar activity patterns to those recorded in protected areas from Chile and Argentina (Monteverde & Piudo, 2011, Gálvez et al. 2021), suggesting that foxes in livestock production areas without the protection of guarding dogs are using time as they do in their natural range when human are absence. From our results, it is worth noting that changes in foxes patterns in livestock systems are mainly explained by LGDs presence, thus highlighting the role of protection dogs as behavioral disruptors for wild carnivores (Miller & Schmitz, 2019).

Regarding environmental variables, although the type of vegetation cover alone does not seem to generate differences in the probability of detection (Peñaranda et al. 2022), sites with low vegetation cover, like grasslands, in the absence of LGDs, caused Culpeo fox to experience a pronounced activity peak during the morning. Young et al. (2019) reported that LGDs tend to be closer to sheep in the early morning, when predators are more active, and sheep are less attentive and possibly more vulnerable to predation (Squires 1975), thus preventing predators to approach less attentive livestock; in this sense, it is possible that the high activity of Culpeo in the morning without LGDs, could result in high

sheep predation. In addition, by using open spaces such as pastures that despite being places of easy escape, both for predators and prey, could facilitated hunting when prey is inactive (Ugarte et al. 2019).

Previous research also states that lunar phase and season of the year could generate changes in species activity patterns due to luminosity variation between different phases (Linley et al. 2020), and to feeding sources availability in different times of year (Hatton et al. 2015); in our case, lunar phases and cold/warm season did not trigger significant differences in foxes' daily activity, despite having 71% of records at night This could be possible explained by the fact that in our study, LGDs could be exerting a predominant effect on the form native carnivores are active along the day, thereby reducing the influence that other variables could have on their behavior.

Being a non-lethal method to control livestock predation, LGDs are considered as biodiversity friendly (Smith et al. 2020), however, they could not be totally innocuous. Our results showed that LGDs presence have repercussions on the way carnivores are active along the day, even leading to overlap between similar species like *Lycalopex* foxes; however, the temporal avoidance of areas with a fear-evoking agent such as LGDs, could result in less opportunity for livestock predation by these species, thus reducing producers' economic losses and the need to use retaliatory hunting upon wild carnivores (Miller & Schmitz, 2019) thus contributing to the co-existence with wild carnivores species in areas destinated to livestock production.

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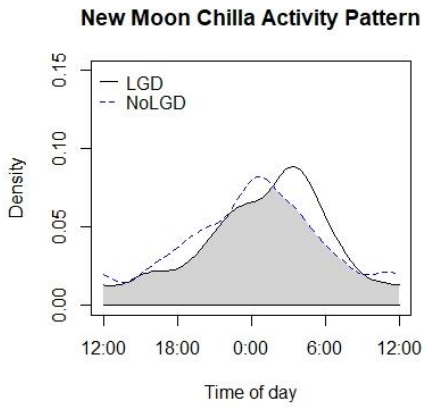
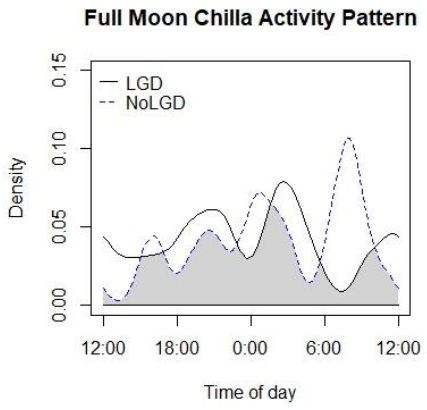
APPENDIX

Appendix Table 1. Activity patterns of foxes with presence/absence of LGD in different lunar phases.

<table>
<tr><td colspan="2"> 
</td><td colspan="2"> 
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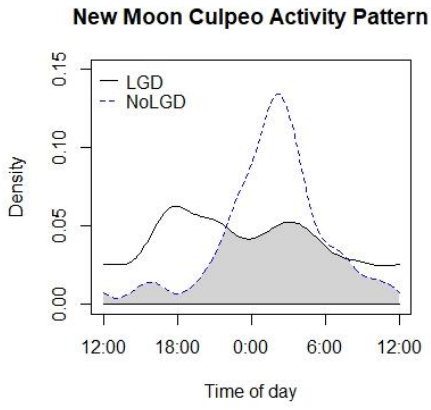
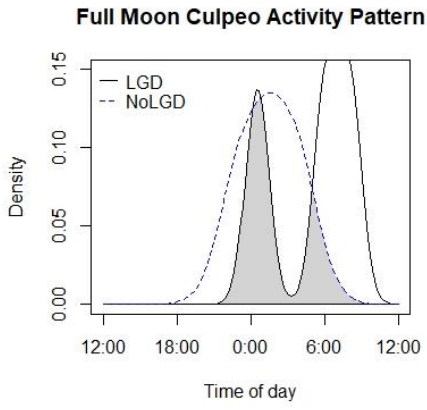
<tr><td colspan="2"> 
</td><td colspan="2"> 
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<tr><td>Δ_1=0.63</td><td>P-Value=0.06</td><td>Δ_1=0.44</td><td>P-Value=0.42*</td></tr>
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* Comparisons between datasets n < 10 that have little statistical support.

Appendix Table 2. Activity patterns of foxes with presence/absence of LGD at different temperatures.

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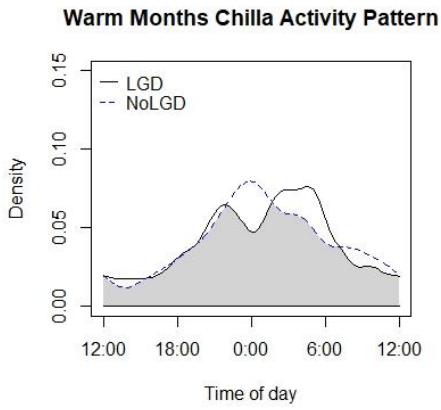
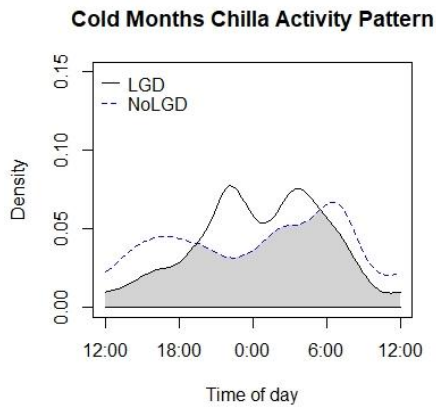
<tr><td colspan="2"> 
</td><td colspan="2"> 
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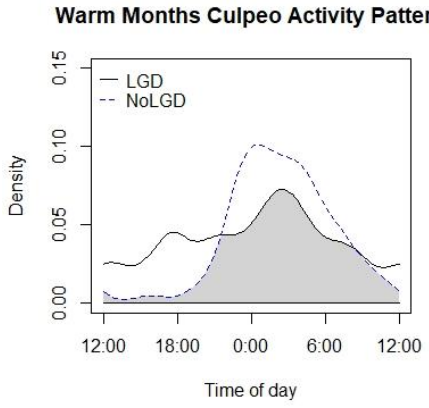
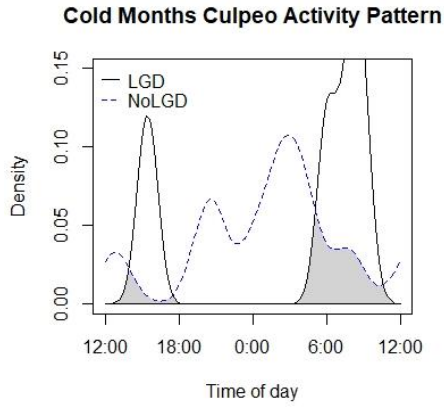
<tr><td>Δ_4=0.89</td><td>P-Value=0.01</td><td>Δ_4=0.78</td><td>P-Value=0.10</td></tr>
<tr><td colspan="2"> 
</td><td colspan="2"> 
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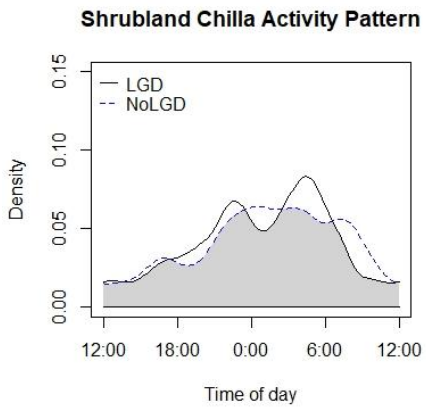
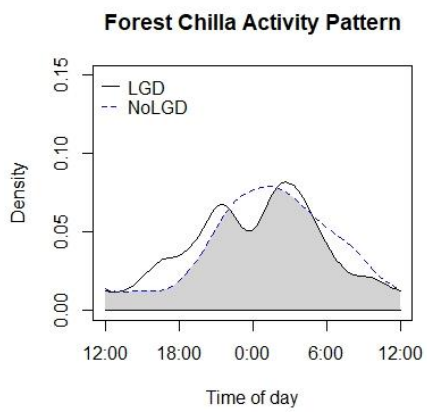
<tr><td>Δ_1=0.72</td><td>P-Value=0.01</td><td>Δ_1=0.22</td><td>P-Value=0.04*</td></tr>
</table>

* Comparisons between datasets n < 10 that have little statistical support.

Appendix Table 3. Activity patterns of foxes with presence/absence of LGD in different vegetation covers.

<table>
<tr><td colspan="2"> 
</td><td colspan="2"> 
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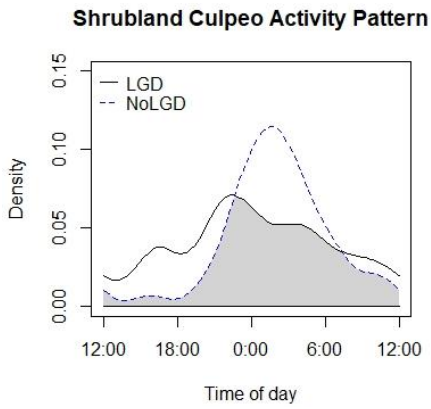
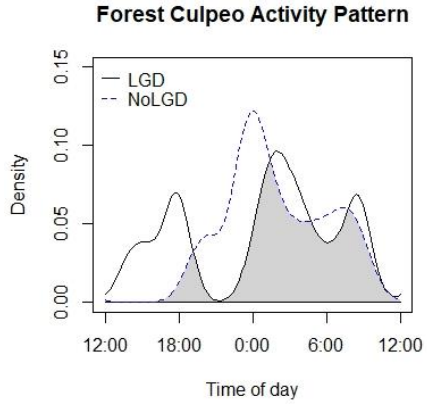
<tr><td colspan="2"> 
</td><td colspan="2"> 
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<tr><td>Δ_1=0.71</td><td>P-Value=0.12</td><td>Δ_1=0.63</td><td>P-Value=0.24</td></tr>
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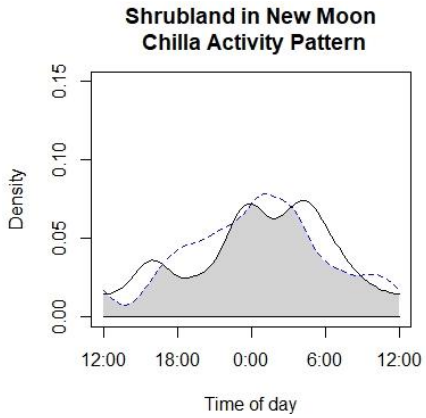
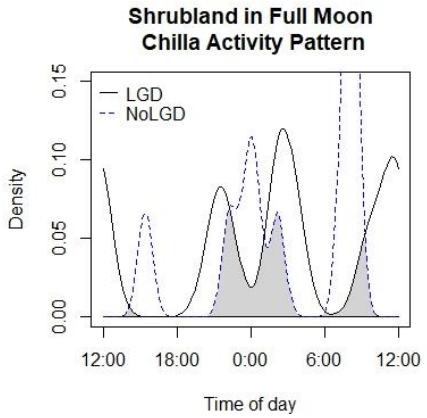
Appendix Table 4. Activity patterns of foxes with presence/absence of LGD in different vegetation cover and different lunar phases.

<table>
<tr><td colspan="2"> 
</td><td colspan="2"> 
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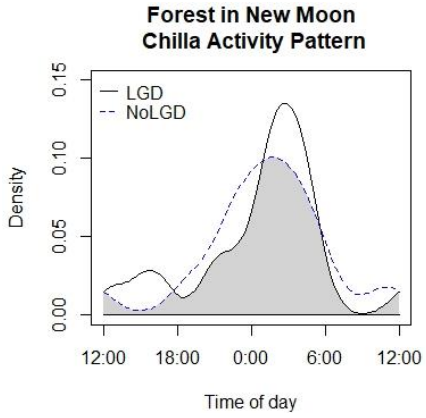
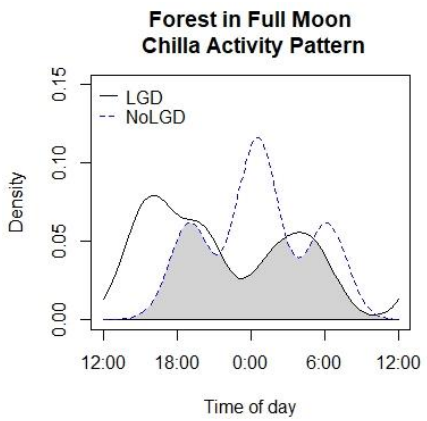
<tr><td colspan="2"> 
</td><td colspan="2"> 
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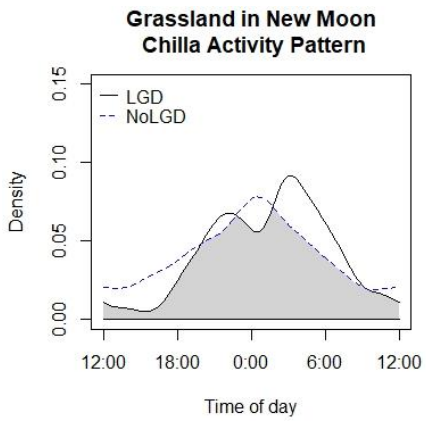
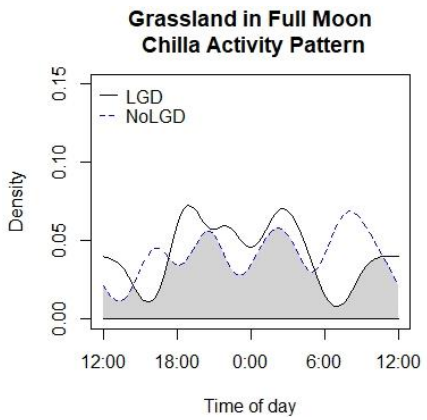
<tr><td colspan="2"> 
</td><td colspan="2"> 
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<tr><td>Δ_4=0.82</td><td>P-Value=0.18</td><td>Δ_1=0.74</td><td>P-Value=0.60</td></tr>
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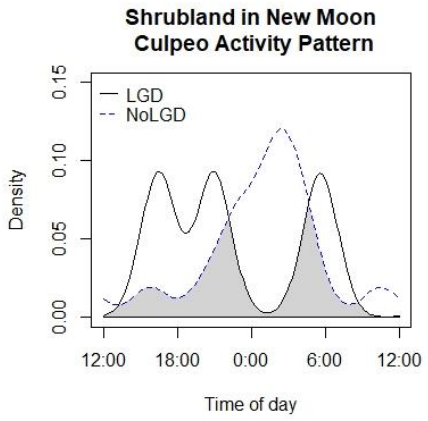
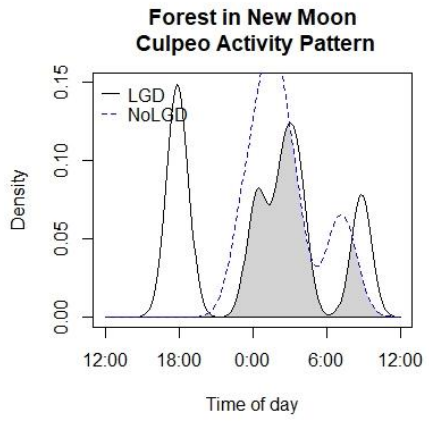
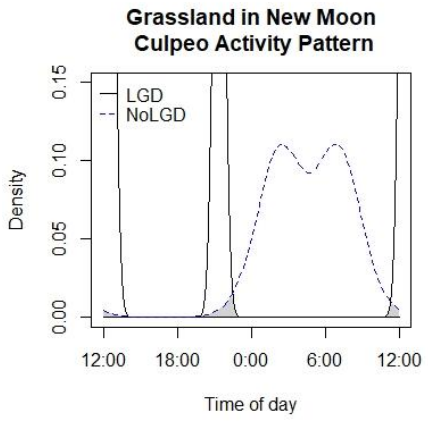


Δ_1=0.44	P-Value=0.15*



Δ_1=0.53	P-Value=0.40



Δ_1=0.01	P-Value=0.33

* Comparisons between datasets n < 10 that have little statistical support.

Appendix Table 5. Activity patterns of foxes in different lunar phases in environments with/without LGD.

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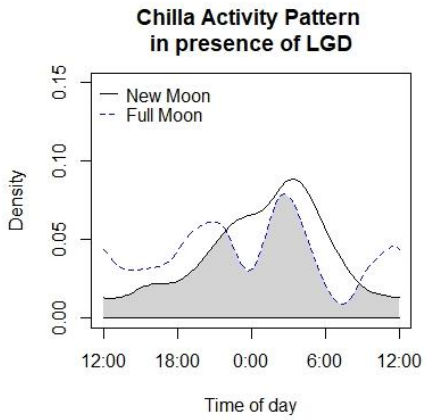
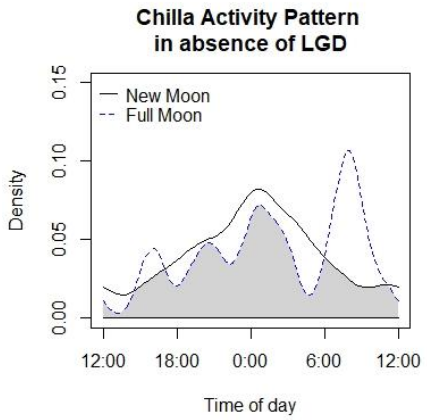
<tr><td colspan="2"> 
</td><td colspan="2"> 
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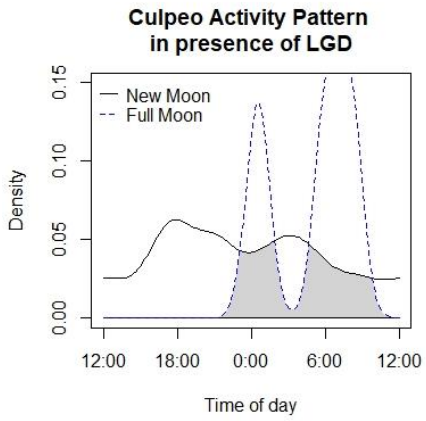
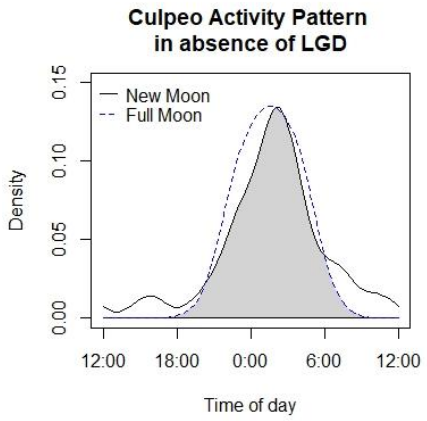
<tr><td colspan="2"> 
</td><td colspan="2"> 
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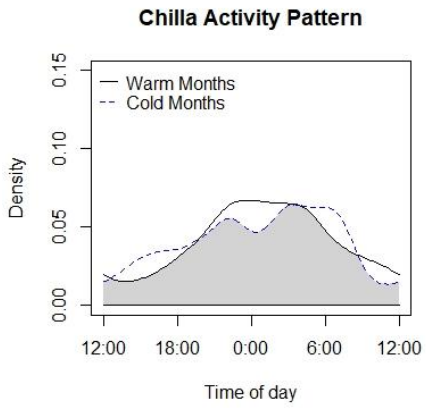
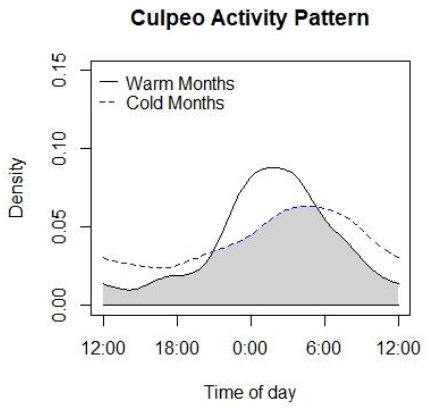
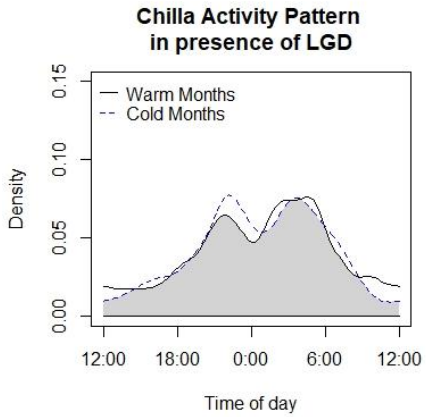
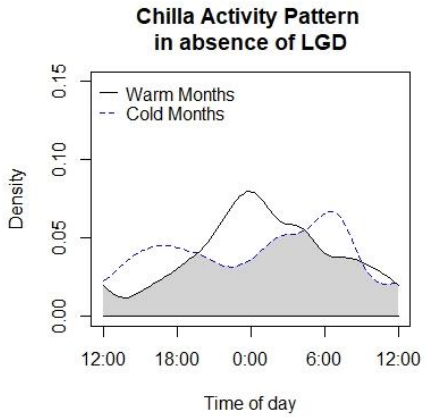
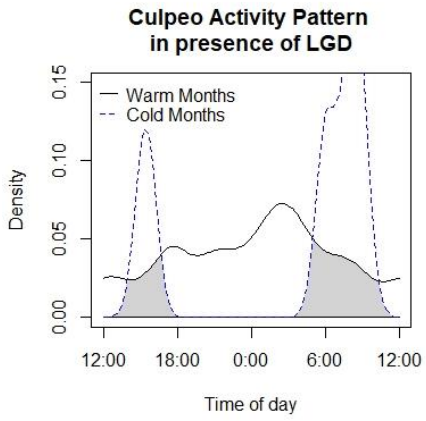
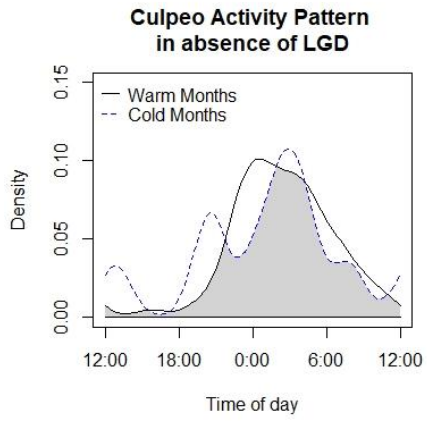
* Comparisons between datasets n < 10 that have little statistical support.

Appendix Table 6. Activity patterns of foxes at different temperatures

			
Δ_4=0.89	P-Value=0.10	Δ_1=0.81	P-Value=0.69

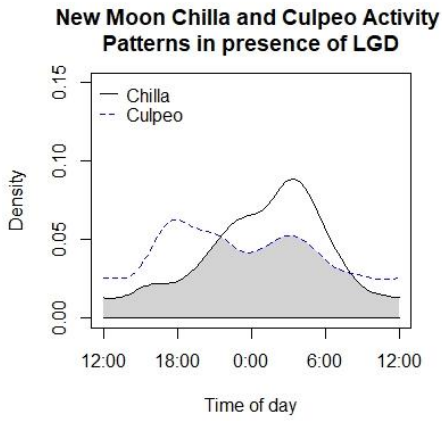
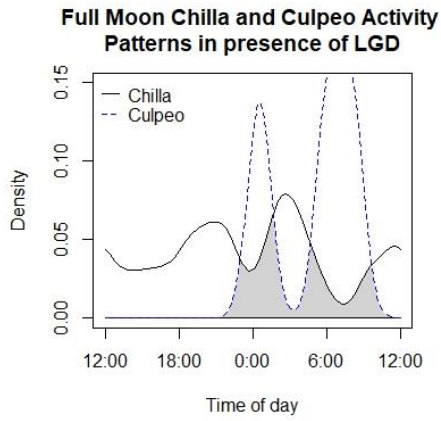
Appendix Table 7. Activity patterns of foxes at different temperatures in LGD/non-LGD environments.

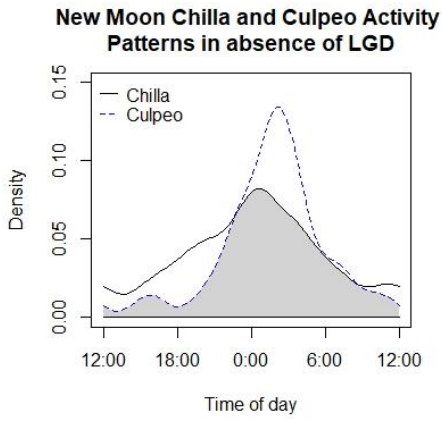
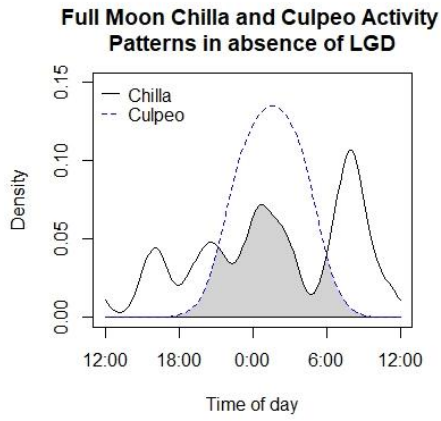
			
Δ_4=0.93	P-Value=0.99	Δ_4=0.77	P-Value=0.01

			
Δ_1=0.31	P-Value=0.01*	Δ_1=0.77	P-Value=0.47*

* Comparisons between datasets n < 10 that have little statistical support.

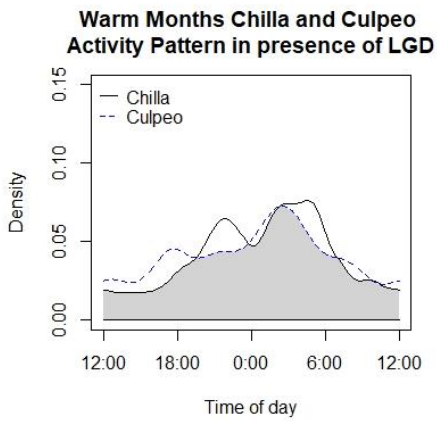
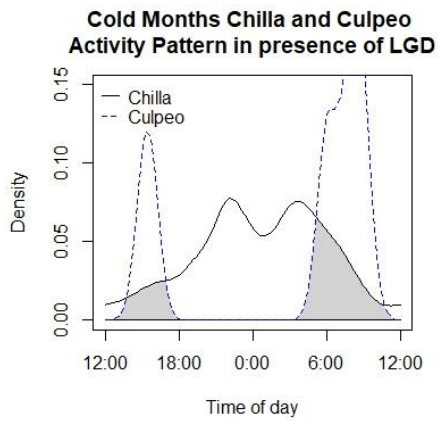
Appendix Table 8. Comparison of Chilla and Culpeo fox activity patterns in different lunar phases in environments with/without LGD.

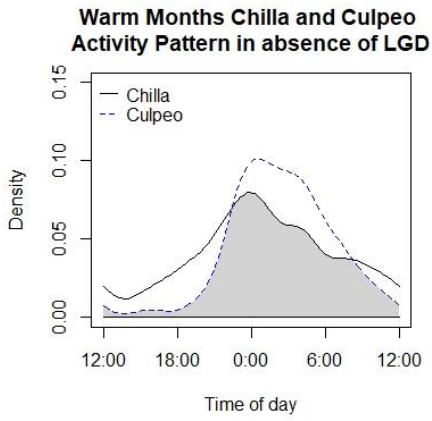
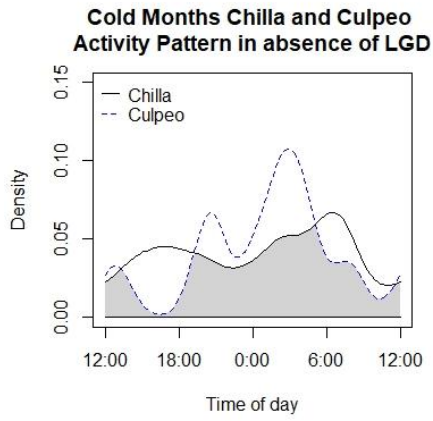
			
Δ_1=0.76	P-Value=0.54	Δ_1=0.28	P-Value=0.06*

			
Δ_1=0.79	P-Value=0.27	Δ_1=0.46	P-Value=0.30*

* Comparisons between datasets n < 10 that have little statistical support.

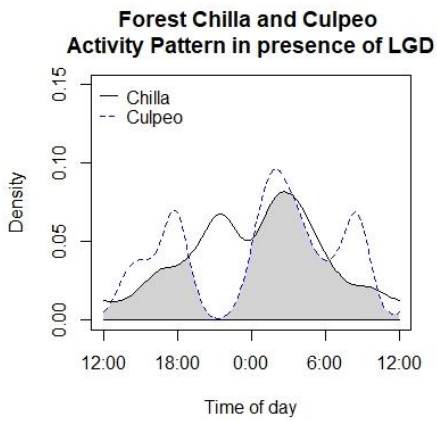
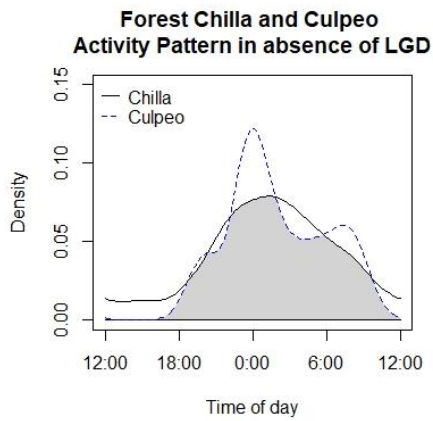
Appendix Table 9. Comparison of Chilla and Culpeo fox activity patterns at different temperatures in environments with/without LGD.

			
Δ_1=0.88	P-Value=0.96	Δ_1=0.30	P-Value=0.01*

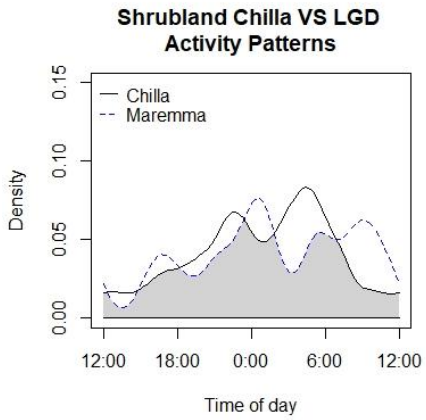
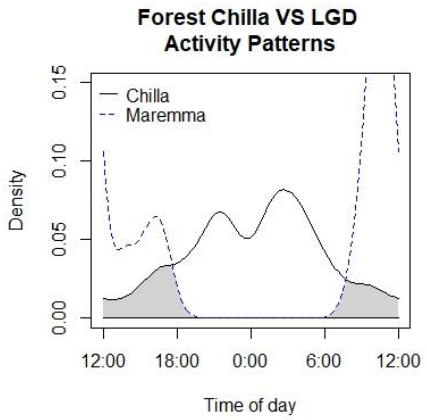
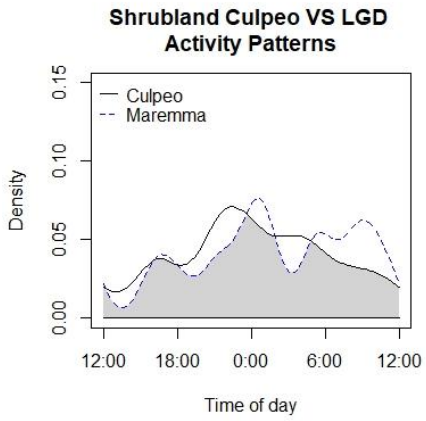
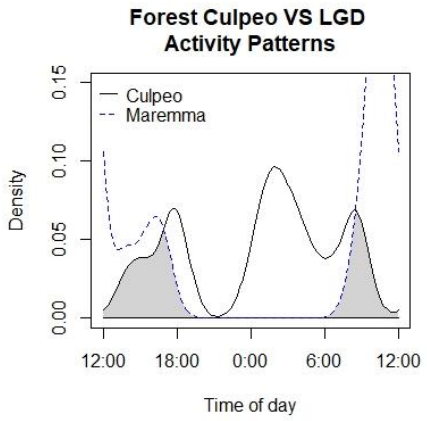
			
Δ_4=0.78	P-Value<0.01	Δ_1=0.71	P-Value=0.35*

* Comparisons between datasets n < 10 that have little statistical support.

Appendix Table 10. Comparison of Chilla and Culpeo fox activity patterns in forests in environments with/without LGD.

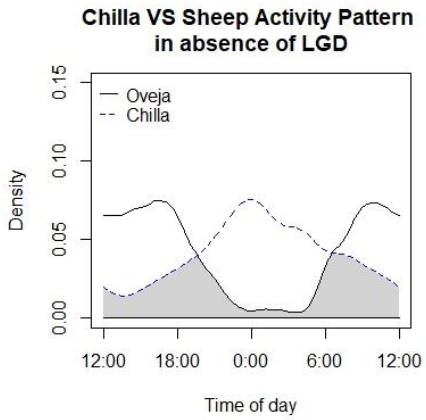
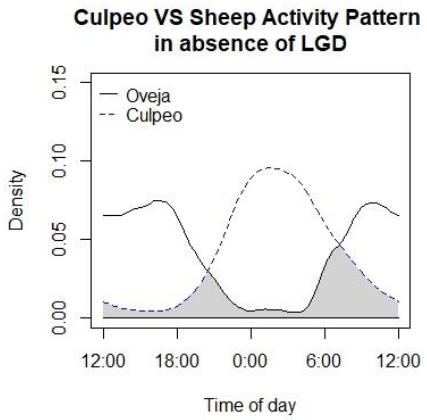
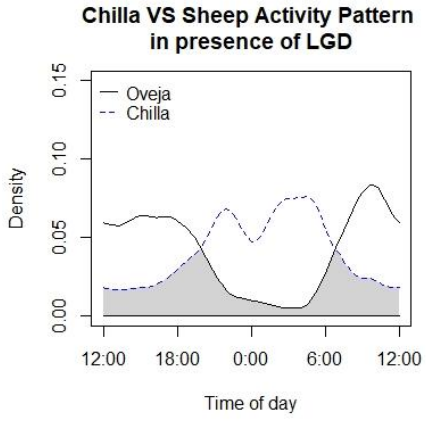
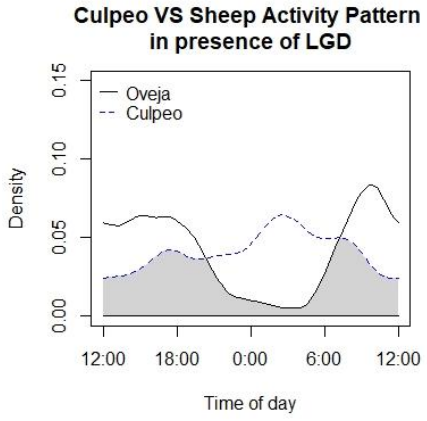
			
Δ_1=0.72	P-Value=0.16	Δ_1=0.84	P-Value=0.66

Appendix Table 11. Comparison of activity patterns of each fox vs. LGD in different vegetation covers.

<table>
<tr><td colspan="2"> 
</td><td colspan="2"> 
</td></tr>
<tr><td>Δ_1=0.77</td><td>P-Value=0.49</td><td>Δ_1=0.23</td><td>P-Value<0.01*</td></tr>
<tr><td colspan="2"> 
</td><td colspan="2"> 
</td></tr>
<tr><td>Δ_1=0.82</td><td>P-Value=0.83</td><td>Δ_1=0.34</td><td>P-Value<0.01*</td></tr>
</table>

* Comparisons between datasets n < 10 that have little statistical support.

Appendix Table 12. Comparison of activity patterns of each fox vs sheep in environments with/without LGD.

			
Δ_4=0.50	P-Value<0.01	Δ_4=0.33	P-Value<0.01
			
Δ_4=0.48	P-Value<0.01	Δ_4=0.62	P-Value<0.01