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**Anthropogenic Stressors and Felid Interactions in Southern Ecuador**

**Tesis**

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**Anthropogenic Stressors and Felid Interactions in Southern Ecuador**

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## **DEDICATORIA**

I would like to dedicate this thesis to my parents and family, who have supported me throughout my education. They have always helped me to pursue opportunities which has led me to proudly achieve this work. Lastly, I would like to dedicate this thesis to the professors, advisors, fellow students, and assistants that helped me through this process, for all their hard work and advice.

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## RESUMEN

Utilizamos cámaras trampa para investigar las interacciones y los patrones de actividad de pumas (*Puma concolor*), ocelotes (*Leopardus pardalis*), margays (*L. wiedii*) y gatos tigre del norte (*L. tigrinus*) en la Cordillera del Cóndor del sur de Ecuador. Se utilizaron modelos de regresión binomial negativa para explorar los impactos de los factores de estrés antropogénicos y las diferencias en la cobertura del suelo sobre la presencia de félidos en tres sitios de estudio adyacentes: Concesión minería Emperador, Concesión minería La Zarza y el Refugio de Vida Silvestre El Zarza. Esperábamos que las estaciones de cámaras más cercanas a los factores de estrés antropogénicos, en forma de actividades agrícolas y mineras, tuvieran menos presencia de félidos y patrones de actividad alterados. Nuestros resultados muestran una diferencia entre las actividades crepusculares y nocturnas de pumas y margays, donde se produjeron más impactos de cámaras trampa durante los períodos diurnos en el sitio Emperador. En cuanto a las covariables antropogénicas, la distancia al campamento base minero fue un predictor marginalmente significativo de la presencia del ocelote ( $P = 0,090$ ) y del gato tigre del norte ( $P = 0,051$ ) y fue un predictor significativo de la presencia del margay ( $P = 0,027$ ). La presencia de pumas se vio influida por la explotación minera y las infraestructuras ( $P = 0,009$ ), y las interacciones entre pumas y tigrillos fueron también marginalmente significativas ( $P = 0,59$ ). Encontramos una baja presencia de ocelote ( $N = 25$ ) en los tres sitios de estudio, y esto podría ser investigado más a fondo para encontrar las causas. Concluimos que las perturbaciones causadas por las actividades mineras influyen negativamente en la presencia de félidos, pero es necesaria una mayor investigación para monitorear y comprender el impacto total de estos cambios de hábitat en los félidos dentro de la Cordillera del Cóndor.

**Palabras clave:** cámara trampa, Cordillera del Cóndor, Leopardus, minería, Puma concolor

## ABSTRACT

We used camera traps to investigate the interactions and activity patterns of pumas (*Puma concolor*), ocelots (*Leopardus pardalis*), margays (*L. wiedii*), and northern tiger cats (*L. tigrinus*) in the Cordillera del Cóndor of southern Ecuador. We used negative binomial regression models to explore the impacts of anthropogenic stressors and land cover differences on the presence of felids in three adjoining study sites: Emperador mining concession, La Zarza mining concession, and El Zarza Wildlife Refuge. We expected that camera stations closer to anthropogenic stressors, in the form of agricultural and mining activities, would have fewer felid occurrences and altered activity patterns. Our results show a difference of the crepuscular and nocturnal activities of pumas and margays, where more camera-trap hits occurred during diurnal periods in the Emperador site. For the anthropogenic covariates, the distance to the mining base camp was a marginally significant predictor of ocelot ( $P = 0.090$ ), and northern tiger cat ( $P = 0.051$ ) presence and was a significant predictor for margay ( $P = 0.027$ ) presence. Pumas presence was influenced by the mining operation and infrastructures ( $P = 0.009$ ), and the interactions between pumas and margay were also marginally significant ( $P = 0.59$ ). We found a low ocelot presence ( $N = 25$ ) from all three study sites, and this could be further investigated to find the causes. We conclude that the disturbances caused by mining activities negatively influence the felid presence, but further investigation is necessary to monitor and understand the full impact of these habitat changes on the felids within the Cordillera del Cóndor.

**Keywords:** camera trap, Cordillera del Cóndor, *Leopardus*, mining, *Puma concolor*



**TABLA DE CONTENIDO**

Resumen .....	7
Abstract .....	8
Introducción .....	10
Metodología y diseño de la investigación .....	12
Análisis de datos.....	18
Conclusiones .....	26
Referencias .....	29
ÍNDICE DE ANEXOS.....	47

## CUERPO DEL TRABAJO DE TITULACIÓN

### INTRODUCTION

Mammalian predators are vital to wildlife community structure within Neotropical ecosystems because they regulate prey populations (Roemer et al. 2009) and interact with other predators of varying sizes (de Oliveira et al. 2013). For the relationship between the mesopredator and the dominant apex predators, interspecific competition is a driving interaction, as these carnivores will potentially compete for the same resources, including their territories (de Oliveria et al. 2013, Prugh et al. 2009). The impact of the carnivore interactions on the communities depends on the differing abundances between the apex predators and the greater species richness of mesopredators (Roemer et al. 2009). The hierarchies within the trophic structure of both predator types determine their direct or indirect effect on the prey populations on several trophic levels (Cruz et al. 2018, Prugh et al. 2009). The widespread impact is different between the apex predators and mesopredators, with the extent of the impact depending on the abundances and territorial ranges of these carnivore species (de Oliveira et al. 2013). Since apex predators have lower population abundances than mesopredators, they directly influence mesopredator and prey species distribution and movement behaviors (Cepeda-Duque et al. 2021, Roemer et al. 2009). Within the biodiverse forests of the Neotropical regions, the complexity of the predator interactions determines the structure and distribution of the species present in the habitats such as the felid apex and mesopredators.

*Leopardus* species such as margays (*L. wiedii*), northern tiger cats (*L. tigrinus*), and ocelots (*L. pardalis*) are Neotropical mesopredators that have shown varying degrees of niche overlap with pumas (*Puma concolor*), a common apex predator in some Neotropical habitats

(de Oliveira et al. 2010). These felids share common behaviors such as the solitary and territorial activities that follow their hierarchy structure, where the dominant felid species influence the population sizes and distribution of the smaller subordinate felids (de Oliveira et al. 2013, Roemer et al. 2009). Felid daily activity patterns vary in response to changes in their habitat (Azevedo et al. 2018). The direct impact from humans includes hunting for pelts (ocelots, margays, tiger cats) or protecting their livestock from predation (pumas) (Michalski et al. 2006, Zanón-Martínez et al. 2016). The indirect impact on felids from the expansion of anthropogenic activities, such as agriculture (crop farms, pastures), human settlements, and resource extraction (e.g., mining, petroleum, forest products), influences daily activity patterns and has resulted in the global decline of species abundance and, in some cases, local extinctions (Guerisoli et al. 2019, Michalski et al. 2006.). On the contrary, when the habitats of felids remain intact, they provide abundant vegetation cover and prey availability (Guerisoli et al. 2019, Harmsen et al. 2009). Some felids respond to anthropogenically altered habitats by changing their territory ranges due to their cautious vigilance of threats and their sensitivity to environmental changes like habitat fragmentation (Cruz et al. 2018, Massara et al. 2016). This pattern can show avoidance behaviors of the felids towards humans and heavily altered areas because extensive human influences disrupt the coexistence and competition between felid species (Cruz et al. 2018, de Oliveira et al. 2013).

Our study investigated the interactions between pumas and small felids using camera traps, and how variations in land cover and human activities may influence the felid presence and activity in our study area. Our analysis describes the activity patterns and occurrences of pumas, ocelots, margays, and Northern tiger cats based on observations made from camera trap data collected in the Cordillera del Cóndor area of southern Ecuador. Our main objective is to determine which environmental and anthropogenic factors have a significant effect on

the occurrences of the felid species. We expected that the camera stations closer to human activities would have fewer occurrences of all felids, especially for the communities with the highest concentration of people. However, research into the behaviors of felids avoiding predators and humans (Cruz et al. 2018) indicates that most felid occurrences appear in areas with the least alterations on the habitat.

## METHODS

This study was conducted in the Cordillera del Cóndor mountain range, in the Zamora Chinchipe province of southeastern Ecuador (Figure 1). The Cordillera del Cóndor (1400–2900 m a.s.l.) is an ecologically diverse landscape in the Tropical Andes, an area of high biodiversity that is also highly threatened (Aldrich et al. 1997). The study area (1600–2500 m a.s.l.) is comprised of lower montane evergreen forests (1400–1900 m a.s.l.) and tepuis (~1500–3000 m a.s.l.). These montane forests have a dense canopy with frequent cloud cover and high precipitation levels. The forests are home to many threatened species from similar low-elevation ecosystems (Aldrich et al. 1997). Tepuis are uplifted plateaus with high vertical walls, and flat tops, and have sandstone-restricted species of vegetation and species of animals found in high elevations (Neill et al. 2007), and sections of land containing shrub vegetation similarly found in the Andean paramos (Aldrich et al. 1997). The towns within the province overlap with sections of the Cordillera del Cóndor and contribute to the deforestation in the area from road expansions and clearing fields for livestock and crop production (Neill et al. 2007). The deforestation rate in this zone has been increasing with the development of Ecuador and the growing need for resources (Duchelle et al. 2007). Mining for precious metals (e.g., gold, silver, copper) and construction materials (e.g., stone, gravel,

timber) are also prevalent and a direct threat to this landscape (Neill et al. 2007). The management of the Cordillera del Cóndor and the reserves within has been complex because of territorial disputes between Ecuador and Peru since the 1980s and the conflicts between the exploitation of its resources and the well-being of the indigenous groups that reside there (Duchelle et al. 2007, Neill et al. 2007, Ponce et al. 2003). The involvement of indigenous groups like the Shuar has been vital to establishing compromises and improving management in the cultivation and conservation of natural resources (Duchelle et al. 2007). This area has gone through years of establishing boundaries and co-management plans between the two countries (Ponce et al. 2003).

Our study surveyed three sites: two mining concessions and a wildlife refuge. The mining concessions, Emperador and Zarza, are both owned by Lundin Gold Inc., a Canadian mining company that branched in Ecuador. Emperador consists of cloud forests and is surrounded by tepuis to the east, and nearby mining operations in Zarza to the north. Emperador is currently in the exploration phase, where topography surveys, drilling sampling, and forest clearing is occurring to prepare the concession for mining and gold production. The site also contains local dirt roads which connects the concessions and the nearest human communities, including El Zarza, Rio Blanco, and San Antonio (Figure 2). Unlike Emperador, the Zarza concession is an active mining operation that contains the mining base camp, “Las Penas” and is where the Lundin workers are temporarily living there. The camp is separated by ~five km from the mining operation concentrated in the northwestern section of the Zarza concession, which holds the quarries, processing plants, sediment ponds, heavy machinery, vehicles, and explosives used on site. The mining being conducted in this area is related to the Fruta de Norte (Fruit of the North) and where Lundin Gold began active mining operations and produced gold since November 14, 2019. The Fruta de Norte is the largest

deposit of gold in Ecuador that was discovered in 2006 and has been Lundin Gold's focus to develop the area to begin active mining from 2017-2019. The two sites are within the range of the Fruta de Norte as well as other developing concessions and protected areas like the one that is the third part of our study area (Figure 3). The refuge that borders the concessions to the west is the El Zarza Wildlife Refuge (3696 hectares) (1400–1600 m a.s.l.), which is primarily a contiguous and undisturbed cloud forest ecosystem. The El Zarza Wildlife Refuge lies within Reserva Biológica El Cóndor, a publicly protected area, regulated and monitored by park rangers (Figure 2).

### Data Collection

Our data were collected with camera traps (Bushnell, Overland Park, Kansas, USA) from April 2019 to March 2022 during an Andean bear (*Tremarctos ornatus*) monitoring study. Camera traps were rotated between the two groups (Emperador, and La Zarza with the ZWR) during four asynchronous monitoring periods. Camera trap stations in Emperador were placed in 38 1.2 km<sup>2</sup> grid cells across 5500 hectares of forest. Grid cells that were not accessible (e.g., steep cliffs, high hills, no forest trails) were excluded from the study. Twelve grid cells were not sampled and two cells (I1 and J1) was removed from the analysis because it was placed in ZWR but active during the Emperador sampling periods. Camera trap stations placement in La Zarza and ZWR did not follow a grid design but were set up on trails within the Zarza concession, and the trails along the accessible edges of the ZWR. Camera stations were placed on ideal trails with high availability to observe species richness. We placed one camera trap at each station and all station locations were selected based on the land type (montane forests and areas close to the tepuis), site topography (flat terrain, gentle, steep slopes), and accessibility (the ability of the field team to access the site). A scent lure (vanilla

extract) was used at all camera trap stations except one (Mariposas 3, located on a river) to improve the probability of a good camera capture of an Andean bear face (Molina et al. 2017). However, when hair snare corrals were installed to collect genetic samples from bears, we installed an additional camera trap for seven stations to help identify the individual bear leaving each sample. Hair snare corrals were installed at 14 stations (18%) at various times during the study period and for several weeks to several months. The camera traps were mounted on trees at an average height of one meter and were programmed to operate 24 hours/day to take a combination of photos and 30-second videos. Microsite data (e.g., elevation, habitat type) were collected at each station. Camera trap stations were checked, on average, once per month to switch the memory card, change batteries, and reposition the camera trap when necessary. Some stations were closed or moved after the initial camera trap placement because of theft or low-site quality for the target species.

### Data Analysis

Camera trap data were processed using Microsoft Excel's Kutools add-on to extract date/time of each photo. Individual photos were tagged for felid species type (*L. wiedii*, *L. tigrinus*, *L. pardalis*, and *Puma concolor*) and grouped into hits, the occurrence of the individual(s) lasting as long as the subject(s) remain in view and separated by the lapse of five minutes when it was out of the view of the cameras. Hits from stations with two cameras were grouped when the animal appeared in both cameras simultaneously. When the animal only appeared in one camera trap it was treated as a separate hit (Tobler et al. 2008). We used R (R Core Team et al. 2019) packages (*bayestestR* (Makowski et al. 2019), *chron* (James et al. 2020), *circular* (Agostinelli et al. 2022), *sm* (Bowman et al. 2021)) with the felid species hits (measured as kernel densities) and the estimate of the probability of them occurring at a

specific time of day, to graph the daily activity patterns of the four felid species (Fig. 4). We adjusted for the uneven camera trap effort by standardizing the data, using the estimated rate of camera trap days for each station as an offset variable within the models.

The covariates chosen to test our felid hit data were structured after a similar study investigating the activity patterns of margays (Horn et al. 2020) with the effects of vegetation changes and anthropogenic variables. Our covariates that were statistically analyzed were related to the impact of human communities and agriculture, mining, and roads and we were able to compare and measure any changes or expansions in the covariates during 2019–2021 (since land data from 2022 was not yet available). We used the ArcGIS ver 10.8.2 (ESRI Redlands, California) Spatial Analyst Tool to extract Euclidean distances from camera trap stations to the closest occurrence of anthropogenic activities and landscape features (Horn et al. 2020, Vancutsem et al 2021). We then used these results to develop covariates for distance from the camera stations to towns (DtTS), mining base camp (DtMBC), mining infrastructure (DtMI), bodies of water (DtW), pastures and other cultivated fields (DtPCF), and roads (DtR). The mining-related covariates were separated because of the differences between site characteristics. The operation layout of the Zarza concession had the operation and camp distant from each other, so that the mining operation would not inconvenience the living conditions of the workers at the mining base camp. As well for the agricultural covariate we know that the cultivated fields for crops and pastures for livestock are different agriculture activities, and can influence the felids differently (livestock grazing v.s. prey species that eat crops). But we could not separate them into two covariates for no contextual information was noted by the field group to tell the two apart, so together they remained.



To test the effect of landcover changes, first we calculated the Normalized Difference Vegetation Index (NDVI) of each site by downloading the vegetation index of the area, from April 2019–2022, produced by the NASA Earth Observations (NEO) (Horn et al. 2020). From the 36 raster layer files of the vegetation index, we determined the direct NDVI value (range = 0–1; open fields = 0, altered and natural; 1 = dense forest cover) of each station, then took the average NDVI of each year to summarize the NDVI value during the monitoring period. We also factored in changes in land use within the study area and generated an adjusted variable from the NDVI. To make the modified variable we used separate layers from a study of the annual forest cover changes for the years 2019–2021 (Vancutsem et al. 2021), and to calculate the average change in land cover for each site we subtracted it from the averaged NDVI. There were no layers available for 2022 for these sites, so we could only estimate the NDVI-adjusted (NDVI<sub>a</sub>) for the years 2019, 2020, and 2021.

We tested the covariate effect on felid presence using the Poisson and Negative Binomial models and checked each model for overdispersion of the data. The results of the Chi-sq test showed that the Poisson model was over-dispersed, thus we chose the Negative Binomial model. We used the R packages *cmna* (Howard et al. 2017), *MASS* (Venables et al. 2002), *msm* (Jackson et al. 2011), and *pscl* (Jackman et al. 2020) to create the generalized linear regression models. We then used the regressions to compare the occurrence of pumas with the occurrence of each *Leopardus* species. We tested for over and under-dispersion of both models to decide goodness-of-fit. To prevent errors from occurring when calculating model estimations, we removed the covariates: DtR (distance to roads) since it was highly correlated with other covariates and never showed any significance in prior model tests. This was done by running and creating a correlation table between covariates and removing any with values that represent a highly correlated positive or negative relationship. We kept the

covariates most likely to be significant for all felid species: NDVIa (NDVI-adjusted), DtWB (distance to water bodies), DtPCF (distance to pastures/cultivated fields), and DtTS (distance to towns), and that were too impactful to remove despite high correlations: DtMBC (distance to the mining base camp), and DtMOI (distance to mining operation/infrastructure). For the *Leopardus* species models, we included puma occurrence as a variable (PUMA) to test the effect of puma presence on each species. We adjusted our generalized linear regression models and included different covariates to test the impact of anthropogenic influence and landcover type on felid occurrence, and the impact of puma presence on *Leopardus* species (Table 1).

## RESULTS

We collected data from a total of 79 camera stations (Emperador, N = 42, Zarza, N = 27, and ZWR, N = 10) for 18 681 camera trap nights (Emperador = 7 347, Zarza = 8 698, and ZWR = 2 636 (Table 3) during four asynchronous monitoring periods (Emperador = April–August 2019, November 2021–March 2022; Zarza and ZWR = April–July 2019, December 2019–September 2020). Data collection between the three study sites was uneven primarily due to the global COVID-19 pandemic and the suspension of access to the Zarza and ZWR study sites from April–October 2020. However, we kept this data for analysis as numerous hits for all species occurred during the monitoring shutdown, from April 2020–September 30, 2020. To adjust for this uneven sampling between the study sites, we decided to analyze the total felid hits throughout the entire monitorings and not by study site for the generalized linear regression models. We detected pumas on 112 occasions, ocelots on 25 occasions, margays on 72 occasions, and northern tiger cats on 77 occasions. We were unable to identify 36 *Leopardus* hits to the species level so we excluded these from the analysis. Regarding

other felid species, we had one hit from a jaguarundi (*Herpailurus yagouaroundi*). People have seen the species in the area, but the reason why we only saw it once could be due to our sampling methods that focused on trails (jaguarundis are known to avoid trails) (Gil-Sánchez et al. 2021) or other factors we were unable to measure with the current study. We also noticed the lack of jaguars (*Panthera onca*) in the camera traps data despite reported sightings of this species in the area. We calculated the capture rate for each species (hits per 100 camera trap days) (Table 4). We removed the J1 station (two margay occurrences) from the analysis, due to misplacement of the station in the wrong study area (Figure 5). We found that pumas had the highest overall capture rate (0.59), while margays and northern tiger cats had similar lower rates (0.37, 0.41) and ocelots had the lowest capture rate (0.13) of our focus felids (Table 4).

### Activity Patterns

From our analysis of the felid hits, we viewed that the activity periods of the felids of our study area follow the behavior ecology commonly seen in each species. The probability of seeing the felids during crepuscular periods (both matutinal and vespertine hours) is highest, followed by nocturnal behaviors, and lastly, felids showed fewer diurnal tendencies (Figure 5). Calculations of the daily activity periods showed that pumas were generally active both day and night but had low activity periods from 6:00 to 13:00, and peak activity periods from 20:00 to 21:00. However, when we looked at puma activity in the three study sites separately, there is a notable difference. In Emperador, pumas showed a more diurnal behavior (6:00–18:00), whereas in Zarza and ZWR they were more active at night (18:00–6:00). The activities of ocelots were lowest from 12:00 to 2:00 and 9:00 to 16:00, with two peaks of activity from 5:00 to 6:00 and 19:00 to 20:00, meaning that they are crepuscular, with both

matutinal and vespertine tendencies. However, ocelots had a low number of hits ( $N = 25$ ), which limits what we can interpret about the activity patterns for this species. Margays had the lowest activity periods from 8:00 to 15:00, and the highest from 20:00 to 21:00. Their activity declined from 21:00 to 8:00, meaning that the species is active at vespertine and nocturnal periods. The northern tiger cats had the lowest activity period from 8:00 to 16:00 and the highest activity period from 20:00 to 3:00, like the margay, with both vespertine and nocturnal active behaviors (Figure 5).

From what we observed in margays and northern tiger cats, their distribution of hits matches their high crepuscular tendencies, which is similar in the three sites, and their low diurnal activities. However, pumas were different with more hits during the day occurring in Emperador, while in Zarza the hits followed the crepuscular behavior. Ocelots behaved similarly, but because of the limited number of hits, we proceed cautiously when interpreting these results. Though it is also noted that as understood in the ecology of margays, the activity patterns show that they are more diurnal actives (diurnal hits occurring more in Emperador) than northern tiger cats, this matches the slight difference between the two species (Figure 6).

### Significant Covariates

The results of the negative binomial model for pumas were that the distance to the mining operation and infrastructures (DtMOI) has a statistically significant effect on puma presence ( $P = 0.009$ ). The ocelot model showed the distance to the mining base camp (DtMBC) was just a marginally significant predictor of ocelot hits ( $P = 0.090$ ) (Table 5.a.). The model for the margay showed a puma presence (PUMAS;  $P = 0.059$ ) was a marginally significant covariate, but that DtMBC ( $P = 0.027$ ) was significant covariate (Table 5.b.). The northern tiger cat showed as well that the DtMBC was marginally significant ( $P = 0.051$ )

(Table 5.c). For the results of whether pumas have a negative correlation with any of the *Leopardus spp.*, the negative binomial model of ocelot ( $P = 0.512$ ) and northern tiger cat ( $P = 0.636$ ) showed that no such negative relationship existed between them, at least according to the data at hand (Table 5.a. and c.).

## DISCUSSION

This study provides information on felid activity patterns and presence in the three study sites in the Cordillera del Cóndor- Emperador mining concession, La Zarza mining concession, El Zarza Wildlife Refuge, in relationship to landcover features, anthropogenic stressors, and for the *Leopardus* species the relationship with puma presence. Our key findings for the activity patterns of felids were a variation between sites for pumas and margays and diurnal activities for pumas, ocelots, and margays in Emperador. We also found that some anthropogenic stressors, particularly distance to the mining base camp was a predictor of hits for all three *Leopardus* species. Pumas seem to be more influenced by distance to the mining operation and infrastructures, and margays can be influenced by the puma presence. These results could be relevant within the greater Cordillera del Cóndor, and other Neotropical landscapes with intense mining and deforestation.

Activity patterns for the margay and northern tiger cat were as expected; vespertine and nocturnal activities are common for both species, as found in other studies (Horn et al. 2020, Marinho et al. 2018, Oliveira-Santos et al. 2012, Pérez-Irineo et al. 2017, Vanderhoff et al. 2011). However, we saw a marked difference in puma activity between the three sites, with diurnal puma activity in Emperador and crepuscular and nocturnal in Zarza and ZWR. Uneven sampling between the three study sites may account for the hits being slightly higher

in Zarza (N = 51) than Emperador (N = 43), and ZWR having the lowest (N = 18) (Figure 6), but these three sites are also different in significant ways. Emperador had three towns and numerous cultivated fields near the camera trap stations. La Zarza had both a mining base camp and operations occurring to the east and north. El Zarza Wildlife Refuge to the west, is a protected area with no agricultural or mining activities inside the reserve. Pumas are known to be flexible in their activity periods related to matching prey activity patterns (Azevedo et al. 2018, Cepeda-Duque et al. 2021) and in their adaptive responses to anthropogenic factors such as habitat loss, poaching, and hunting (Guerisoli et al. 2019, Zanón-Martínez et al. 2016).

In the case of ocelots, they show crepuscular activities like in other studies. Still, we observed a surprisingly lower number of hits than was expected, limiting what we can interpret about their activity patterns. It should be noted that the interpretation of low or high hits of certain species does not mean singular or numerous individuals of a felid species that was camera captured. High felids hits could be interpreted differently, from an individual felid that is circling around their territory frequently or it could mean that there are multiple individuals passing through the camera trap's view. Reasons for low felid hits could be from low felid abundance, they are avoiding certain areas, or that they are difficult to observe in camera traps. Without a detailed camera trap method to create an individual identification index, we can not interpret the results to explain what is occurring here. We can speculate the reasons from our review on the felid ecology such as how one explanation could lie in the structure of the felid hierarchy, where smaller felids are subordinate to larger felids, and the abundance of pumas as influencers (de Oliveira et al. 2010, de Oliveira et al. 2013). Certain anthropogenic stressors may have a more significant impact, but the limited data for the test models preclude us from drawing any conclusions.

The results of the negative binomial models indicated that distance to the mining base camp was a significant predictor for ocelots, margay, and northern tiger cat presence but not puma presence. Mining impacts biodiversity-rich areas like Cordillera del Cóndor, with the overlap of mining operations and protected areas. Mining camps typically consist of extraction sites, heavy and potentially loud equipment, refinement buildings, vehicles, and numerous personnel (Kolowski et al. 2010, Finer et al 2008). Mining contributes to deforestation by opening forests for roads and clearing forests to build and expand extraction points (Finer et al 2008, Sonter et al. 2017). For pumas, deforestation can indirectly affect them because it alters the distribution of prey and lowers the availability of large prey, resulting in pumas avoiding heavily disturbed areas or to change their diet to focus on smaller animals (Magioli et al. 2021). This trend is supported by similar studies that showed that, while each species has some tolerance to human disturbances, even if their habitat is altered, their presence in this type of deforested areas declines (Gil-Sánchez et al. 2021, Massara et al. 2016). In other studies, margays are sensitive to deforestation as their habitat preference is close to the forest edges with partial canopy coverage (Hodge et al. 2014). Also, ocelots are sensitive to deforestation, as it affects the wide territorial ranges within their habitat (Massara et al. 2016). On the other hand, northern tiger cats are sensitive to habitat loss but specifically, the effect it has on the prey activity patterns and availability (Marinho et al. 2018).

Indeed, our study showed that the camera trap stations closest to the mining base camp had low occurrences of ocelots, margays, and northern tiger cats. However, we had stations around the mining base camp that saw multiple felid species throughout the monitoring periods. That was something we expected to see only in stations around undisturbed or less impacted areas like the refuge or the southern part of La Zarza (Figure 4). Also what we expected and did see was that in the variety of felid species present at La Zarza stations, we

can see that camera traps with closer DtMOI we only see one or two of the felid species (Figure 4). It is interesting to see that stations that view multiple felid species are camera traps within both Zarza sites and stations that view one or two of the felid species are more in Emperador (Figure 4). The differences in characteristics between sites should be studied further, as it shows variations between the felid presence and how frequently at certain stations we have hits of each species or a lack of them. Though what could also be further investigated in explaining the presence and activity differences between sites is preference differences within the species. In another study on the daily activity patterns of pumas, they also saw differences of diurnal activities between sites. The researchers were able to identify individuals by their sex and saw that there is a difference between diurnal and crepuscular activities, with females being more active during the day than males (Azevedo et al. 2018). This is an example of how important an individual identification index is within the studies of activity patterns and how this study can be improved with the basis of what we found.

For the last of the significant covariates from the negative binomial model, in the relationship between pumas and the *Leopardus* species, only margay showed a negative association with puma presence. Looking at the results and distribution throughout the camera trap stations, stations with higher puma presence were less likely to have margay presence. This result is supported by other studies that show that small predators will avoid larger predators due to intraguild competition and prey size preference (de Oliveira et al. 2013). Pumas tend to prefer medium-sized mammals which match the size of a margay, as well pumas are flexible in their daily activities and can adapt to follow the activity patterns of their prey species (Azevedo et al. 2018). Although there is no evidence that pumas actively hunt margays (de Oliveira et al. 2013, Dias et al. 2019, Massara et al. 2016), pumas could still pose a significant threat to this small felid. We saw a clear overlap between pumas and margays



activities at crepuscular periods (Figure 7), and from our review of other studies there have been reported killings of other *Leopardus* species of similar size, even jaguarundis, by pumas through competition and encounters when their territories or active periods overlap (de Oliveira et al. 2013). A potential reason why puma presence was not a significant predictor of the presence of northern tiger cats could be that they do not meet the prey preference of pumas as they seek large-medium sized prey (Azevedo et al. 2018, Cepeda-Duque et al. 2021, Santos et al. 2019), while the northern tiger cats, being the smallest (1.5–3.0 kg) of the three *Leopardus* species (Oliveira-Santos et al. 2012). For the ocelots, other studies have shown an overlap with the apex predator and no negative relationship between the pumas and ocelots (de Oliveira et al. 2010). However, the lack of significance between puma and ocelot occurrence could result from the few ocelot records during the monitoring, as we see an extremely high overlap of activity patterns between pumas and ocelots from the few hits we had (Figure 7). This could be explained by the few ocelot hits, preventing us from viewing a similar negative relationship with the pumas from other studies (de Oliveira et al. 2010, Herrera et al. 2018). We cannot say for sure if there is simply no intraguild competition without a more extensive sampling we can only make that speculation.

Lastly, to mention the covariates that were not significant in our study, but important in other studies. The covariates of the towns and cultivated fields was not significant, but concentrated populations of people and their activities may influence the presence of felids. These towns (i.e., El Zarza, Río Blanco, and San Antonio) have a local population size of ~300 people each and participate in agricultural activities, from cultivating crop fields to raising livestock. While there is evidence that pumas activity patterns and population sizes are affected by human influences, pumas are flexible felids. Their avoidance of human-altered habitats depends on the extent of habitat degradation (Azevedo et al. 2018). For this

monitoring, the camera trap stations close to these three towns did not have any photos of pumas and with the little information on the communities' history with pumas, either hunting them or puma attacks on livestock, it is difficult to fully interpret these results. However, other studies show that retaliatory hunting because of conflicts occurs when people try to protect their livestock from the pumas (Cepeda-Duque et al. 2021, Michalski et al. 2006, Zanón-Martínez et al. 2016).

## CONCLUSION

Our focus was to determine which, if any, of the environmental and anthropogenic factors, as well as the interactions between pumas and the mesopredators, could significantly affect the presence of the felids. We understand that disturbances caused by human activities can dramatically alter the natural carnivore interactions and niche partitioning, but further investigation is necessary to understand the full impact on the felids within this location. The next steps for future studies would be further monitoring with an improved camera trapping method, so that an individual identification index can be created for interpreting the results better and to camera capture difficult to record felids like the jaguarundi. It would benefit to examine the site differences and investigate the effects of the anthropogenic stressors that might explain the low ocelot presence we observed in this study. This study and current data can be used as a foundation to view any changes in the presence of the felids throughout the area. The reason being that the Emperador concession is developing and will soon began active mining similar to La Zarza, so it will be important to know how the area will change, how felids and other diverse species present might respond, and to what extent. The Cordillera del Cóndor is an area of high biodiversity but is also highly impacted by deforestation and mining that will surely expand in the future. It will be important that future

conservation activities include controlling and monitoring the development of urban expansion, agricultural activities, roads, and preventing mining activities in areas that are biodiversity hot spots. Our data demonstrate the uniqueness of the area and the incredibly biodiversity of the wildlife present. This should be considered in both future studies and conservation efforts within the Cordillera del Cóndor in relation to the human activities in this area, and to know how important it is to mitigate impacts on the wildlife and landcover there.

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## TABLES

Table 1. Environmental and anthropogenic covariates used in negative binomial models to test their effect on felid occurrences. Puma presence is also included to test the influence of puma presence on ocelot, margay, and northern tiger cat occurrences.

<b>Covariate</b>	<b>Code</b>	<b>Description</b>
Land use	NDVIa	Normalized Difference Vegetation Index measured the vegetation cover at each camera trap station, ranging from 0 (open fields, altered and natural) to 1 (dense forest cover) and then calculated for forest changes for the NDVI adjustment SAT. DATA SOURCE (Horn et al. 2020).
Distance to water	DtW	Euclidean distance raster created in ArcGIS based on shapefile of water bodies (narrow streams and rivers).
Distance to towns	DtTS	Euclidean distance raster created in ArcGIS based on shapefile of nearest to the three human communities (El Zarza, Rio Blanco, San Antonio).
Distance to the mining base camp	DtMBC	Euclidean distance raster created in ArcGIS of the basecamp of the mining operation, Las Peñas (barracks, cafeteria, greenhouse nursery, gym, and soccer field).
Distance to pastures/cultivated fields	DtPCF	Euclidean distance raster created in ArcGIS based on shapefile of pastures and cultivated fields.
Distance to roads	DtR	Euclidean distance raster created in ArcGIS based on shapefile of roads (dirt and gravel roads connecting mining infrastructures and towns).
Distance to mining infrastructures	DtMOI	Euclidean distance raster created in ArcGIS of the base of the mining operation and infrastructures (quarries, jaw crusher, concentrate filtrations, sediment ponds, processing and paste plants, etc.).
Puma occurrences	PUMA	Number of hits of puma presence.

**Table 2.** Correlation table between both environmental and anthropogenic covariates. Highly correlated covariates (>0.6) are indicated in red.

<i>Covariates</i>	<i>NDVIa</i>	<i>DtWB</i>	<i>DtPF</i>	<i>DtR</i>	<i>DtTS</i>	<i>DtMOI</i>	<i>DtMBC</i>	<i>PUMA</i>
<i>NDVIa</i>	1.000	-0.188	-0.055	-0.780	-0.154	0.029	0.098	0.008
<i>DtWB</i>	-0.188	1.000	0.311	0.318	0.139	0.054	0.149	0.072
<i>DtPF</i>	-0.055	0.311	1.000	0.129	0.495	-0.452	-0.282	0.017
<i>DtR</i>	-0.780	0.318	0.129	1.000	0.065	0.126	0.084	0.017
<i>DtTS</i>	-0.154	0.139	0.495	0.065	1.000	-0.754	-0.660	0.048
<i>DtMOI</i>	0.029	0.054	-0.452	0.126	-0.754	1.000	0.961	-0.081
<i>DtMBC</i>	0.098	0.149	-0.282	0.084	-0.660	0.961	1.000	-0.101
<i>PUMA</i>	0.008	0.072	0.017	0.017	0.048	-0.081	-0.101	1.000

**Table 3.** Results of the total camera trap days by study site and year.

<b>Study Site</b>	<b>2019</b>	<b>2020</b>	<b>2021</b>	<b>2022</b>	<b>Grand Total</b>
<i>Emperador</i>	3 755	0	1 613	1 613	7 347
<i>Zarza</i>	3 507	6191	0	0	8 698
<i>Zarza Wildlife Refuge</i>	760	1876	0	0	2 636
<b>Grand Total</b>	7 022	8 067	1 613	1 979	18 681

**Table 4.** Capture rates for each felid species by study site and year. Capture rates were calculated using hits per-100 camera trap days.

CAPTURE RATE (CR)	EMPERADOR (E)				ZARZA (Z)			ZARZA WILDLIFE REFUGE (ZWR)			
	Species	2019	2021	2022	CR-E	2019	2020	CR-Z	2019	2020	CR-ZWR
<b>Puma</b>	0.69	0.31	0.61	0.59	0.32	0.69	0.59	0	0.96	0.63	0.59
<b>Ocelot</b>	0.08	0.06	0.05	0.07	0.40	0.10	0.18	0.23	0.11	0.14	0.13
<b>Margay</b>	0.21	0.25	0.05	0.18	0.64	0.52	0.55	0.46	0.27	0.32	0.37
<b>Northern tiger cat</b>	0.32	0.31	0.25	0.30	0.40	0.23	0.52	0.23	0.43	0.35	0.41

**Table 5.** Results of negative binomial regression model for ocelot (a), margay (b), and northern tiger cat (c).

a) Ocelot

Negative Binomial Model				
<i>Coefficient</i>	<i>Estimates</i>	<i>std. Error</i>	<i>CI (95%)</i>	<i>P-Value</i>
Intercept	8.63	9.50	-9.50 – 28.51	0.364
NDVla	-8.85	6.31	-21.61 – 3.33	0.160
DtWB	0.08	0.27	-0.39 – 0.67	0.772
DtPF	-0.24	0.21	-0.67 – 0.20	0.256
DtTS	-0.34	0.37	-1.08 – 0.42	0.349
DtMBC	-0.63	0.37	-1.45 – 0.10	<b>0.090*</b>
DtMOI	0.04	0.34	-0.58 – 0.86	0.898
PUMAS	0.08	0.12	-0.22 – 0.32	0.512
log-Likelihood	-69.170			

\*p<0.1 \*\* p<0.05 \*\*\* p<0.01 \*\*\*\* p<0.001

**b) Margay**

Negative Binomial Model				
<i>Coefficient</i>	<i>Estimates</i>	<i>std. Error</i>	<i>CI (95%)</i>	<i>P-Value</i>
Intercept	-5.25	6.06	-16.85 – 6.53	0.386
NDVIa	2.23	4.34	-6.08 – 10.84	0.608
DtWB	0.26	0.20	-0.11 – 0.70	0.204
DtPF	0.02	0.15	-0.27 – 0.32	0.900
DtTS	0.07	0.26	-0.41 – 0.57	0.795
DtMBC	-0.51	0.23	-0.97 – -0.06	<b>0.027**</b>
DtMOI	-0.01	0.16	-0.31 – 0.29	0.963
PUMAS	-0.27	0.14	-0.58 – -0.01	<b>0.059*</b>
log-Likelihood	-127.428			

\* p < 0.1   \*\* p < 0.05   \*\*\* p < 0.01   \*\*\*\* p < 0.001

**c) Northern tiger cat**

Negative Binomial Model				
<i>Coefficient</i>	<i>Estimates</i>	<i>std. Error</i>	<i>CI (95%)</i>	<i>P-Value</i>
Intercept	-1.48	6.14	-13.22 – 10.56	0.810
NDVIa	-3.24	4.19	-11.82 – 5.36	0.439
DtWB	0.29	0.21	-0.11 – 0.75	0.182
DtPF	-0.12	0.15	-0.45 – 0.22	0.453
DtTS	-0.01	0.26	-0.50 – 0.48	0.959
DtMBC	-0.49	0.25	-1.01 – 0.01	<b>0.051*</b>
DtMOI	0.17	0.21	-0.22 – 0.59	0.411
PUMAS	0.04	0.09	-0.14 – 0.22	0.636
log-Likelihood	-133.431			

\*p < 0.1   \*\* p < 0.05   \*\*\* p < 0.01   \*\*\*\* p < 0.001

**Table 6.** Results of negative binomial regression model on the significance of the covariates on puma occurrences.

Negative Binomial Model				
<i>Coefficient</i>	<i>Estimates</i>	<i>std. Error</i>	<i>CI (95%)</i>	<i>P-Value</i>
Intercept	-16.47	5.24	-27.28 – -5.91	0.002
NDVIa	5.71	3.77	-1.27 – 12.77	0.130
DtWB	0.28	0.18	-0.07 – 0.67	0.122
DtPF	0.02	0.14	-0.26 – 0.29	0.905
DtTS	0.35	0.23	-0.13 – 0.85	0.121
DtMBC	-0.29	0.24	-0.74 – 0.14	0.226
DtMOI	0.54	0.21	0.16–0.94	<b>0.009***</b>
log-Likelihood	-173.301			

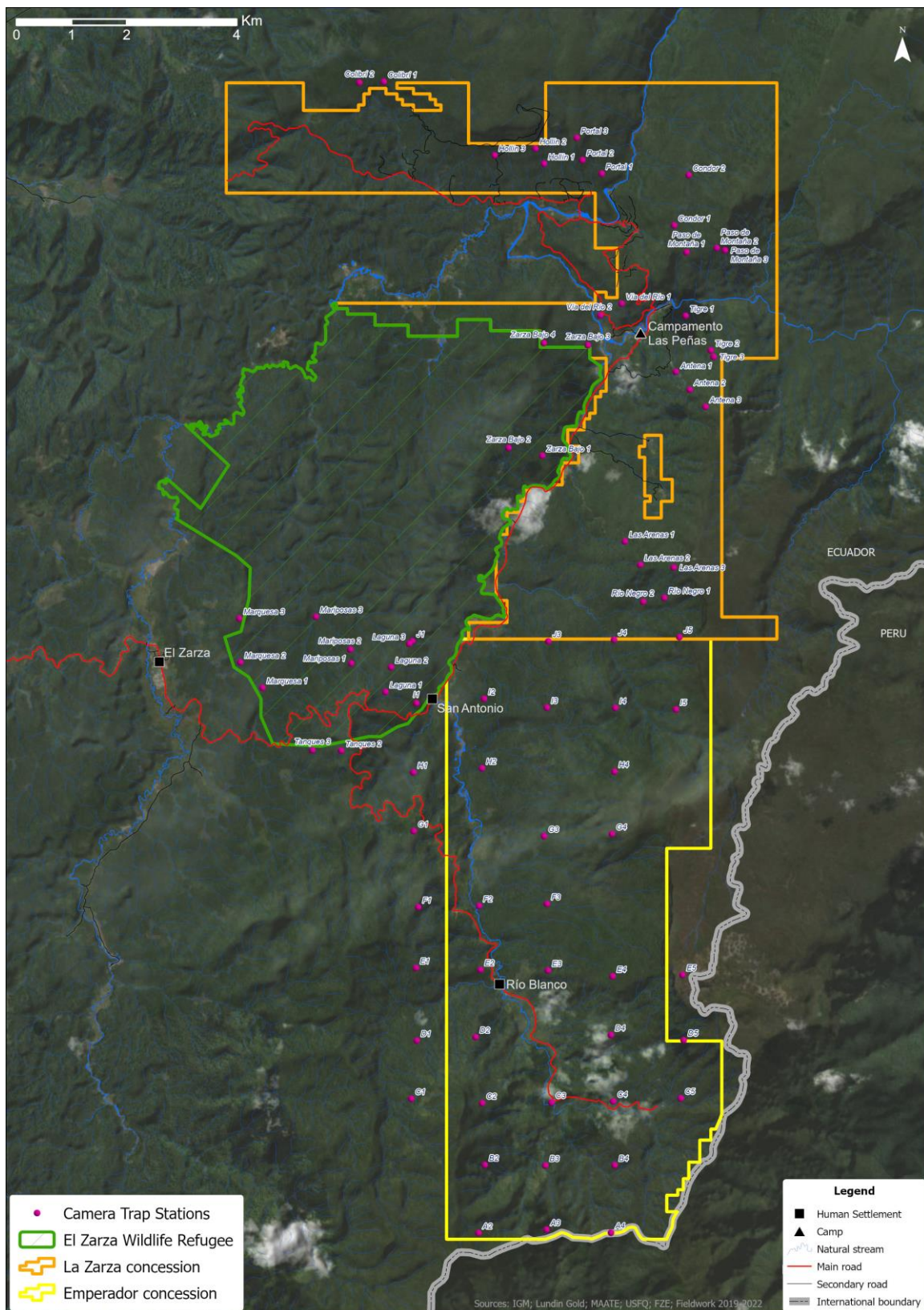
\*p < 0.1    \*\* p < 0.05    \*\*\* p < 0.01    \*\*\*\* p < 0.001



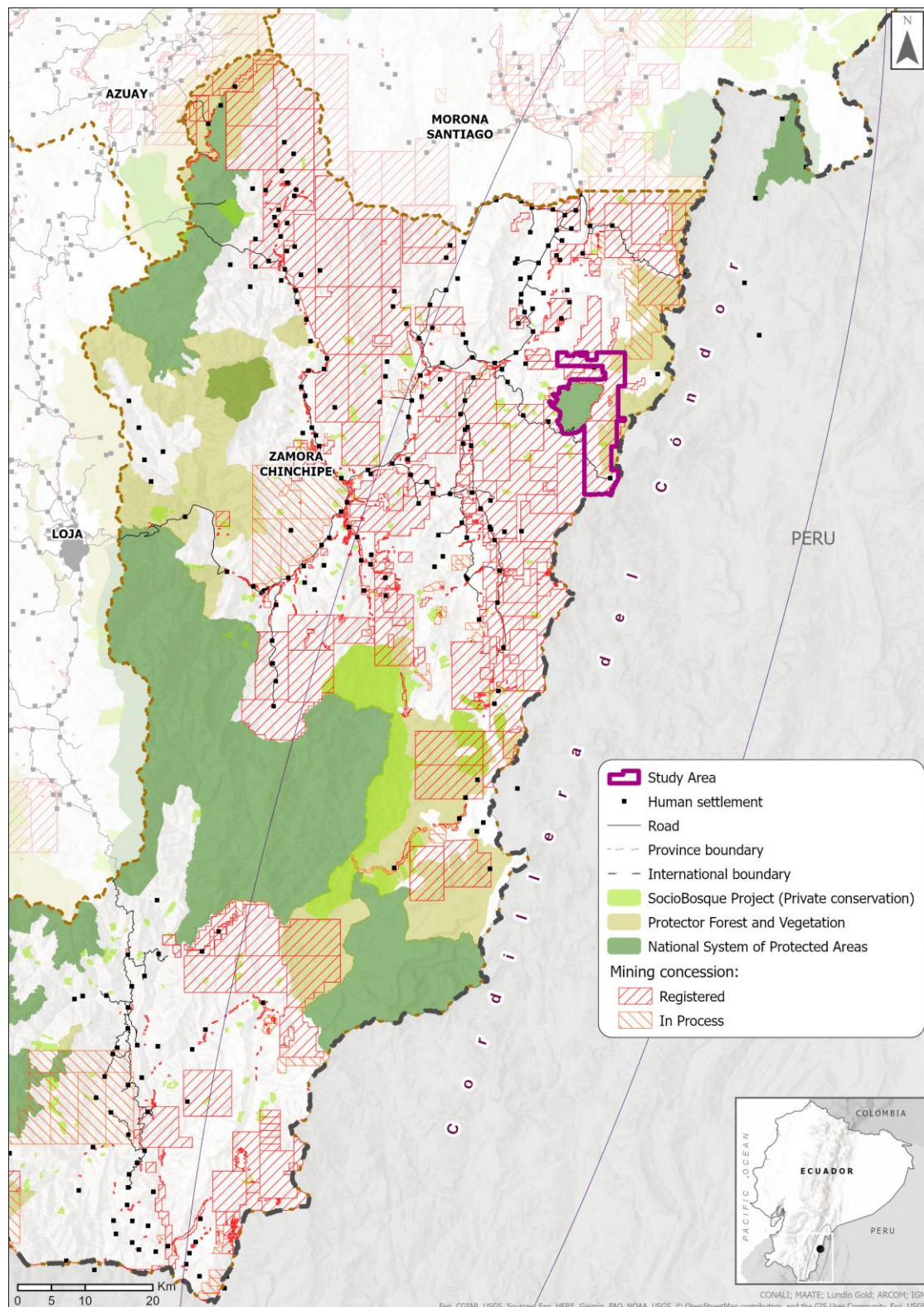
## FIGURES



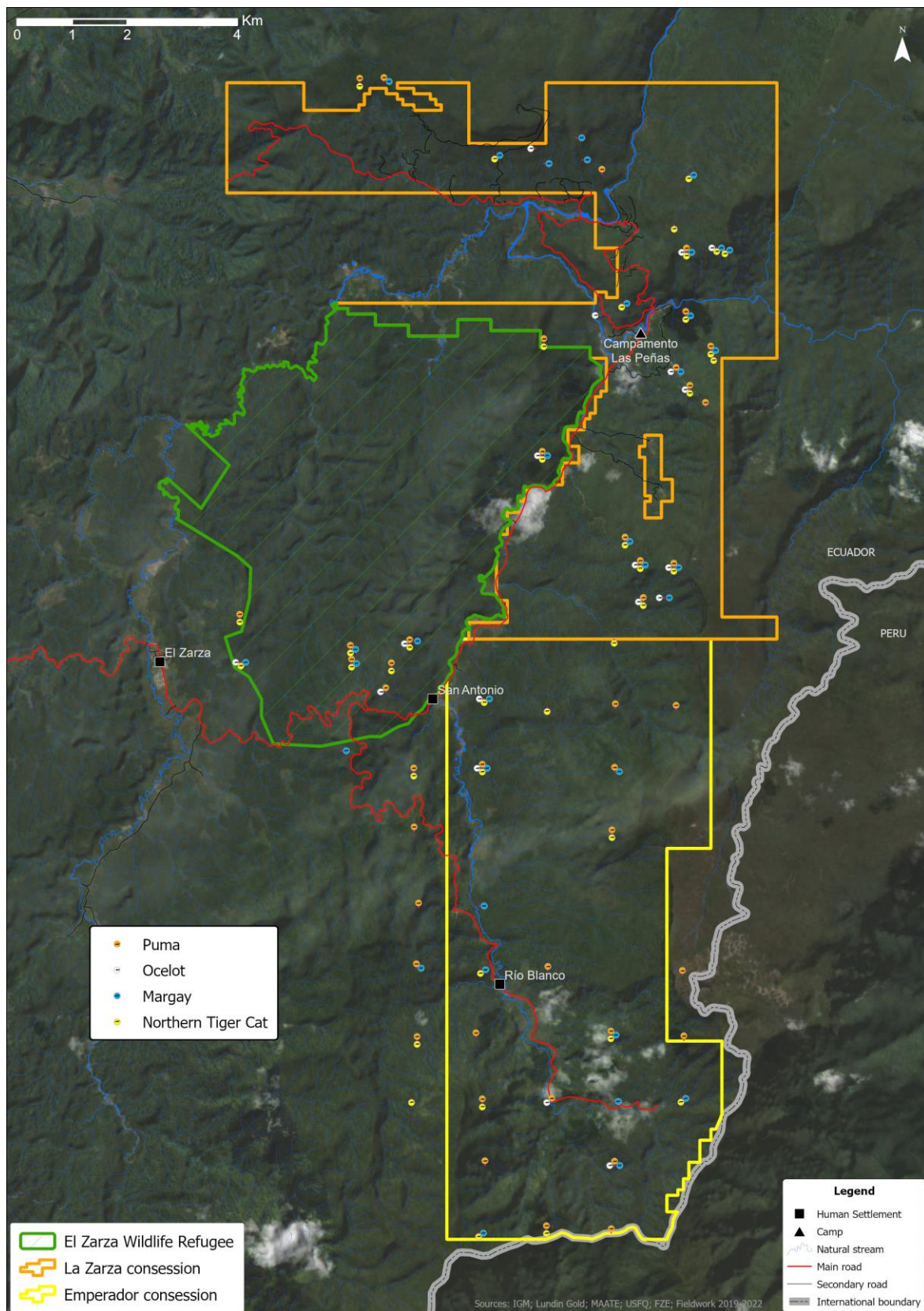
**Figure 1.** Landcover map of Ecuador with the study área (turquoise) location within Zamora Chinche province (purple line) and its location in the Cordillera del Cóndor (yellow line).



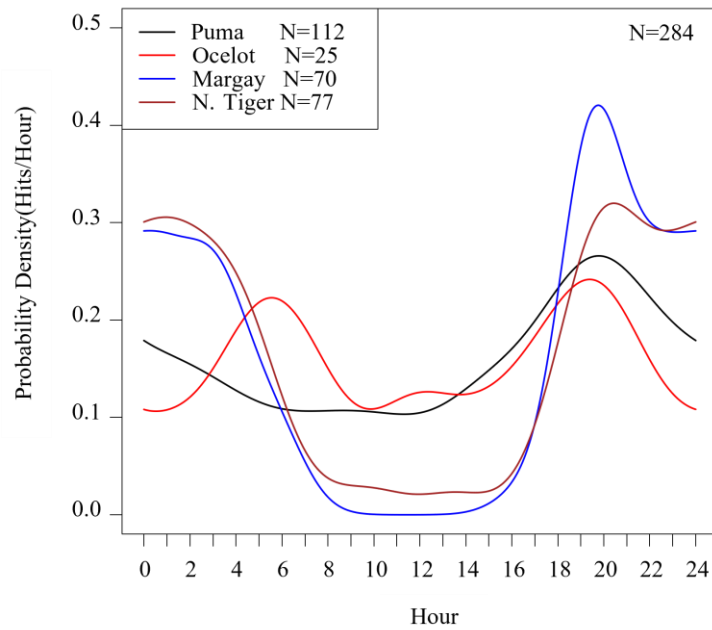
**Figure 2.** Map of camera trap locations in each of the three study sites: Zarza Concession (orange), Zarza Wildlife Refuge (green) and Emperor Concession (yellow).



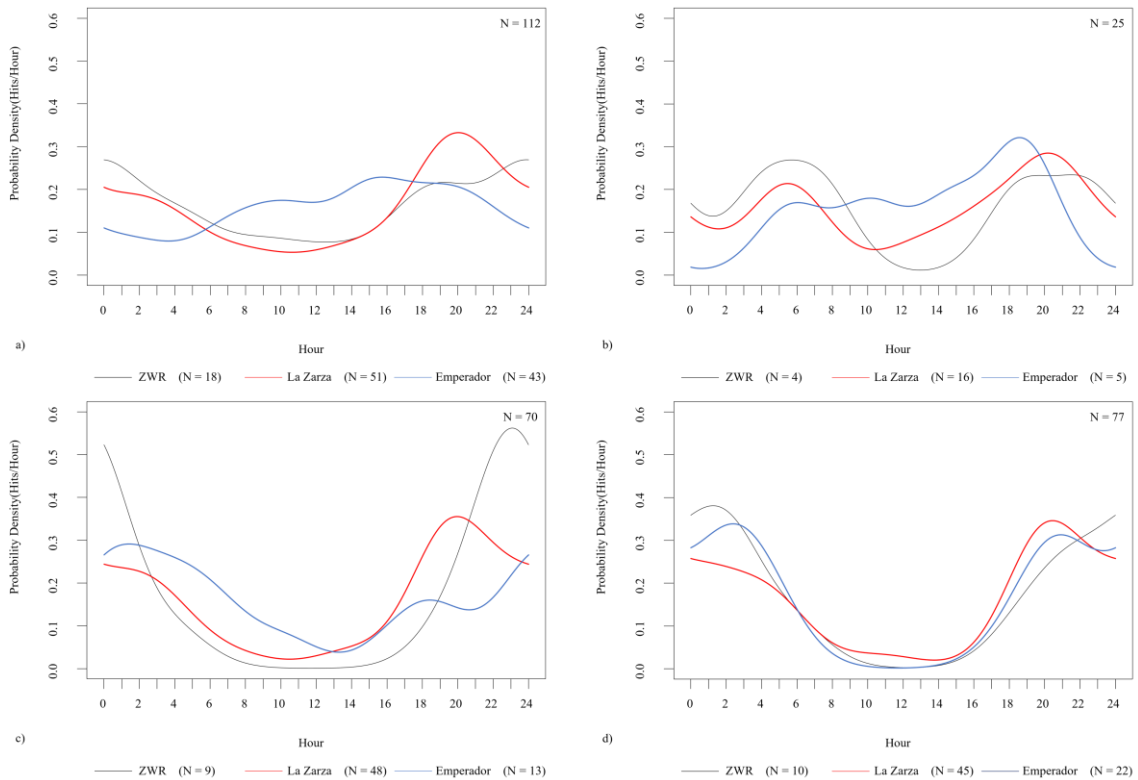
**Figure 3.** Map of the Zamora Chinchipe province, locations of the protected areas and mining concessions within the province.



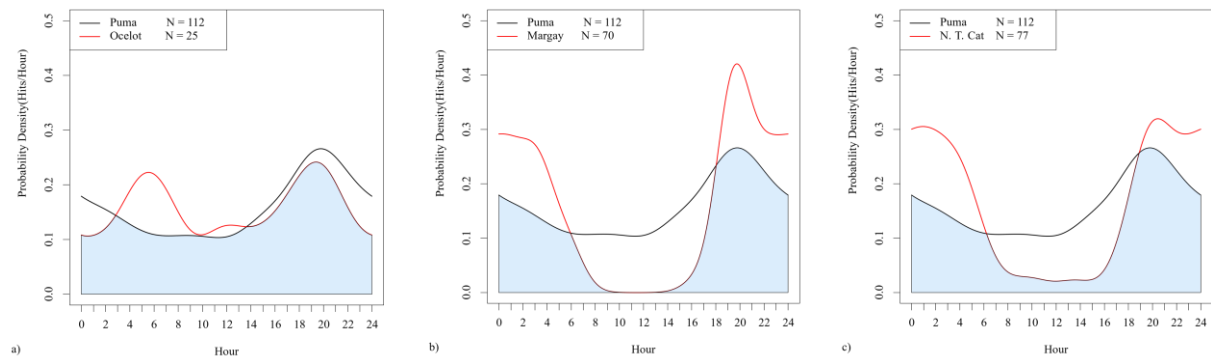
**Figure 4.** Map camera trap stations highlighting specific felid presence: puma (orange), ocelot (white), margay (blue), and northern tiger cat (yellow).



**Figure 5.** Kernel density estimates for daily activity patterns of puma (N =112), ocelot (N =25), margay (N =73), and northern tiger cat (N =77) from all three study sites.



**Figure 6.** Kernel density estimates for daily activity patterns of puma (a), ocelot (b), margay (c), and northern tiger cat (d) in two study areas, Emperor and Zarza.



**Figure 7.** Kernel density estimates of the daily activity patterns of pumas with ocelots (a), margays (b), and northern tiger cats (c). The blue area corresponds to the hours where the presence of both felids overlap.

## APPENDIX I



**Figure S1. Camera trap photos of puma (*Puma concolor*) appearances of differing quality and during both day (left) and night (right).**



**Figure S2. Camera trap photos of ocelot (*Leopardus pardalis*) appearances of differing quality and during both day (left) and night (right).**



**Figure S3. Camera trap photos of margay (*Leopardus wiedii*) appearances of differing quality and during both day (left) and night (right).**



**Figure S4. Camera trap photos of northern tiger cat (*Leopardus tigrinus*) appearances of differing quality and during both day (left) and night (right).**



**Figure S5. Camera trap photo of jaguarundi (*Herpailurus yagouaroundi*) appearance.**