JOURNAL OF ANIMAL BEHAVIOUR AND BIOMETEOROLOGY

RESEARCH ARTICLE
Published Online: May 9, 2025
https://doi.org/10.31893/jabb.2025006

Potential distribution of the oncilla *Leopardus tigrinus* (Carnivora: Felidae) based on high-resolution spatial data and camera traps in a national park in Peru

Nicole Briceño[a] | **Deyvis Cano**[a] ✉ | **Frank Cámara**[a] | **Bertha Campos**[a] | **Homer Sandoval**[b] | **Alex Ricra**[b] | **Nilton Rojas-Briceño**[c]

[a]Programa Académico de Ingeniería Ambiental, Universidad de Huánuco, Huánuco 10001, Perú.
[b]Parque Nacional Tingo María, Servicio Nacional de Áreas Naturales Protegidas por el Estado (SERNANP), Tingo María, Perú.
[c]Grupo de Investigación en Ciencia de la Información Geoespacial (CIGEO), Instituto de Investigación para el Desarrollo del Perú, Universidad Nacional de Moquegua, Pacocha 18610, Perú.

Abstract Potential species distribution models (SDMs) are typically evaluated over large territories via low-resolution spatial data and biased presence records. The Parque Nacional de Tingo María (National Park; PNTM, by their initials in Spanish), a small territory, presents challenges for this type of study. This study aimed to analyze the SDM of an oncilla (*Leopardus tigrinus*) and evaluate the most influential spatial data and specific distribution areas. The Maxent (Maximum Entropy) algorithm was used with 32 high-resolution spatial data layers derived from a PlanetScope multispectral satellite image, DEM, and bioclimatic, social, and infrastructure variables, resampled to 4.5 m resolution, along with 13 presence records from camera traps. The zones were overlaid to identify the species' habitat. The model has an AUC of 0.992, covering 54 hectares, favoring areas with the coldest quarter precipitation (Bio 19), dense vegetation (NDVI), and avoiding roadways and areas with lower elevations. The species is located in Buffer Zones (72.06%), Strict Protection Zones (3.93%), Recovery Zones (3.41%), Special Use Zones (0.54%), Tourist Zone I (10.66%), Tourist Zone II (0%), and Wilderness Zone (9.4%). The viability of the SDM in small spaces with precise, high-resolution data is highlighted. The current zoning of PNTM may not be sufficient to protect the critical habitats of most oncilla species.

Keywords: protected natural areas, tropical ecosystem, felines, mammals, remote sensing

1. Introduction

The oncilla, *Leopardus tigrinus* (Schreber, 1775), is a carnivorous mammal of the Felidae family that inhabits a wide variety of altitudes, from 200 to 3,000 m above sea level, and prefers premountain areas and lowland tropical forests (Torres et al., 2020). Its distribution spans northern Mexico, along the Gulf and Pacific coasts, through Central America, northern Argentina and northwest Uruguay (López Ortiz, 2020). However, the lack of detailed information about its presence in some regions has led to its classification as a "vulnerable" (VU) species, according to the International Union for Conservation of Nature (Payan & de Oliveira, 2016; Gutiérrez, 2023). Its main threats are habitat loss, poaching, and other human activities, contributing to its fragmentation in conservation areas (González-Maya et al., 2022). The limited information about its distribution makes managing and conserving its local populations more complex (Martínez-Calderas et al., 2015; de Oliveira et al., 2024). In this sense, the Parque Nacional de Tingo María (PNTM) plays a crucial role in its conservation, as it is a protected area strategically located near urban and rural zones. Although its size is relatively small (4,777 hectares), the park's proper management has allowed the conservation of species such as the oncilla (Zuloaga-Obregón & Gabriel-Campos, 2023). Furthermore, the PNTM demonstrates that it is possible to reconcile biodiversity conservation with economic activities such as sustainable tourism, benefiting local communities and wildlife (MINAM, 2024).

Species distribution models (SDMs) are key tools in conservation and are employed at the regional, continental, and global levels (Benavides Rios et al., 2024; Mateo et al., 2011). These models are based on bioclimatic data and species presence records from global databases (Pliscoff & Fuentes-Castillo, 2011) and have become fundamental for decision-making in conservation, especially in the context of accelerated environmental change. Advances in remote sensing have allowed the collection of high-quality spatial data on biological, climatic, and physical indicators (Veneros et al., 2020), improving the available information's spatial and temporal resolutions. In addition, integrating of technologies such as camera traps has optimized wildlife monitoring, providing more accurate data on species presence (Nazir & Kaleem, 2021; O'Connell et al., 2011). The lack of detailed knowledge about the distribution of the oncilla within the PNTM concerns its conservation. Therefore,

 Received: February 2, 2025| Accepted: March 22, 2025

SDMs, which use species presence data and predictive environmental variables, are essential to improve the knowledge of their suitable habitat (Gil & Carbó, 2017; Elith & Leathwick, 2009). Among the available algorithms, the maximum entropy (Maxent) model stands out for its high predictive accuracy (Carpio Amancha, 2020; Fitzgibbon et al., 2022). Maxent has been widely used to model species in large areas, such as countries and regions (Benavides Rios et al., 2024; Mateo et al., 2011) and generally relies on large-scale bioclimatic information and species records from global databases (Sánchez et al., 2024). However, few studies use high-precision monitoring methods, such as camera traps or high-resolution remote sensing images, which allow for a more detailed assessment of smaller areas (Hernández, 2023). Given the small size of PNTM, it is essential to use SDMs, such as Maxent, with high-precision local data. The combined use of camera traps and high-resolution remote sensing data will provide detailed information on wildlife and ecological patterns in the park, thus improving the management and conservation of this valuable ecosystem (Molloy, 2018).

Therefore, this study aimed to model the potential distribution of the oncilla (*L. tigrinus*) in the PNTM using presence data and high-resolution predictive variables obtained from camera traps, satellite images, and digital elevation models. The environmental variables influencing its distribution were identified, and the potential distribution of Zonas within the PNTM was determined. This will provide helpful information to the governmental body responsible for park management to ensure proper conservation of the areas occupied by this species, which is endangered within PNTM.

2. Materials and Methods

2.1. Study area

The PNTM is located in the Huánuco region, in central Peru, between coordinates 9°26'17.54" S & 76°04'37.57" W and 9°18'55.57" S & 75°57'56.98" W, with an altitudinal range from 650-1927 m.a.s.l. (Figure 1). It is situated approximately 6 km from the city of Tingo María, which has a population of 72,225 inhabitants engaged in recreational and tourism activities within the park (INEI, 2017). One of the most prominent geological formations of the PNTM is the "Bella Durmiente" (sleeping beauty), a mountain range whose profile resembles a reclining female figure. The park's climate is tropical humid, with relative humidity ranging from 80% to 90%, an annual average temperature between 22°C and 26°C, and an average annual precipitation of 3500 mm (SERNANP, 2021).

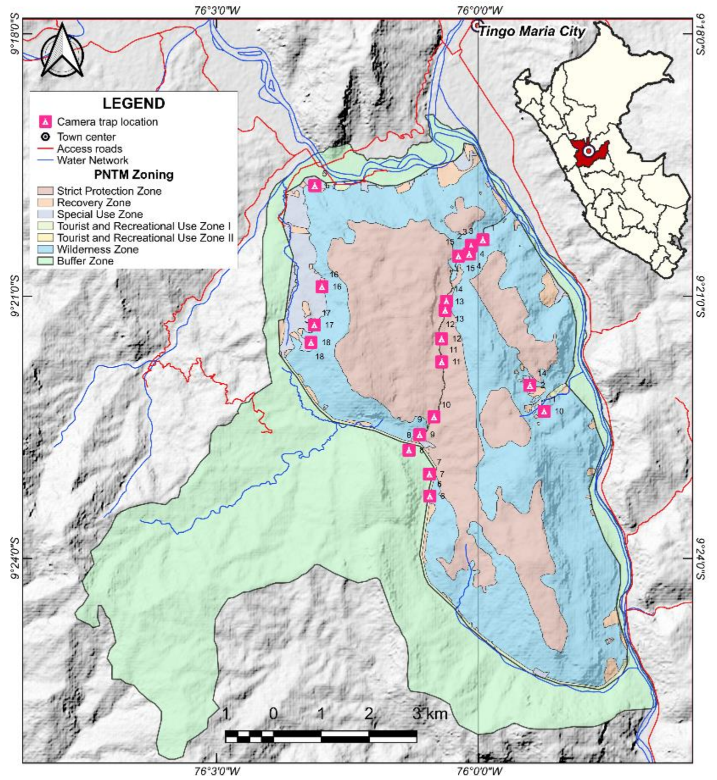

Figure 1 Location map of the PNTM study area.

2.2. Data collection for the presence of L. tigrinus within the PNTM

To estimate the distribution of *L. tigrinus*, field data collection was carried out via camera traps following these steps: (i) a physical topographic map of the PNTM was printed; (ii) with the help of park rangers, safe and accessible areas for monitoring the species were identified; and (iii) 19 random sampling points were selected, with a minimum separation of 500 m between points. Before setting up the camera traps, the sampling point coordinates (GPSs) were recorded. These camera trap points were monitored from January to September 2024.

The setup characteristics included: (i) camera traps were placed approximately 60 cm high on accessible trees near trails; (ii) cameras were configured according to their specifications, including time, photo, and video formats; date; and temperature sensors. During each data collection, memory cards and batteries were replaced approximately every two months to download data for analysis in the laboratory.

The data were incorporated into QGIS software version 3.34.9 in the laboratory to obtain geographic locations. The data were then organized in Excel format and a CSV file containing three columns: species name (*L. tigrinus*), longitude (x), and latitude (y), with all the data separated by commas. A search at the Global Biodiversity Information Facility revealed no previous reports of this species in the study area.

Spatial data sources for PNTM zoning were obtained from the conservation zoning of the PNTM areas generated by SERNANP (SERNANP, 2024). The distribution of this species within the national park was evaluated using a shapefile.

2.3. Data sources used as environmental variables

This study utilized 32 environmental variables (Table 1), 19 of which are bioclimatic variables obtained from the WorldClim Climate Geodatabase (https://www.worldclim.org), with a spatial resolution of 30 s (1 km). Concerning the Euclidean distance, four variables were generated based on vector data for paths, roads, populated centers, and water sources. Three topographic variables (elevation, slope, and aspect) were derived from the digital elevation model (DEM) obtained from Landviewer (https://eos.com/landviewer/?lat=-8.1191&lng=-79.0355&z=11), with a resolution of 4.5 m.

Six variables were derived from PlanetScope satellite images (https://www.planet.com/nicfi/), including the normalized difference vegetation index (NDVI) as an indicator of vegetation density in each pixel, the normalized difference water index (NDWI) to monitor the presence of water bodies and vegetation moisture status, and the spectral bands (red, green, blue, and NIR). All the environmental variables were standardized to a spatial resolution of 4.5 m (native resolution of PlanetScope images) in the UTM WGS84 Zone 18S coordinate system via QGIS software version 3.34.9.

2.4. Selection of environmental variables

Collinearity between environmental variables can cause overfitting issues, increasing uncertainty and reducing the predictive capacity of the model (Júnior & Nóbrega, 2018). To address this, the values of the 32 environmental variable layers were extracted from the coordinates of the georeferenced records of *L. tigrinus* through the Point Sampling Tools plugin in the QGIS software. The optimal number of groups was subsequently determined through cluster analysis via Euclidean distances in the Statgraphics program, generating a clustering dendrogram that reflected some correlations between the variables (Mori et al., 2020). This analysis resulted in the formation of groups of internally correlated variables.

According to the results of the Maxent model, scores for the 32 environmental variables were calculated by subtracting the training gains of all the variables from the training gains of each variable individually. On this basis, the one with the lowest score was selected for each group of variables. Finally, 12 variables were selected: blue band, paths, roads, DEM, water source, NDVI, NDWI, NIR, orientation, temperature seasonality (Bio 4), annual temperature range (Bio 7), and precipitation of the coldest quarter (Bio 19) (Figure 2).

2.5. Maxent modeling approach and potential distribution changes

Potential distribution models were generated via a machine learning algorithm based on the maximum entropy principle (Phillips et al., 2006), implemented in the open-source software Maxent version 3.4.4. For model development, 75% of the georeferenced records were used for training, and the remaining 25% were used for validation and were randomly selected. The algorithm was run with 10 replicates and 1000 iterations, using random partitions based on the bootstrap method, with a convergence threshold of 0.00001 and a maximum of 10,000 background points. The remaining settings were left at their default values since Maxent automatically adjusts functions based on the number of samples available for the model (Merow et al., 2013).

Model validation was performed via the area under the curve (AUC) method, obtaining a value of 0.992, which was calculated from the receiver operating characteristic (ROC) curve. According to the AUC values, model performance is classified into five levels: excellent (> 0.9), good (0.8 - 0.9), acceptable (0.7 - 0.8), poor (0.6 - 0.7), and invalid (< 0.6) (Araújo et al., 2005). A notable advantage of this method is its threshold independence, ensuring a more objective evaluation.

The cloglog output format generated a continuous map with probability values between 0 and 1, representing habitat suitability or the relative probability of species presence. These values were reclassified into four categories: "high" (> 0.6), "moderate" (0.4 - 0.6), "low" (0.2 - 0.4) as potential habitat, and "nonpotential" (< 0.2) (Meza Mori et al., 2022). The values were transformed into a range from 0-100% to facilitate interpretation. Figure 3 summarizes the procedures used to obtain the potential distribution of *L. tigrinus.*

Table 1 Variables considered for the potential distribution modeling of the oncilla.

Variable	Description
Bio 1	Annual mean temperature
Bio 2	Mean diurnal temperature range
Bio 3	Isothermality (Bio2/Bio7 x 100)
Bio 4	Temperature seasonality (standard deviation x100)
Bio 5	Maximum temperature of the warmest quarter
Bio 6	Minimum temperature of the coldest quarter
Bio 7	Annual temperature range (Bio5 − Bio6)
Bio 8	Mean temperature of the wettest quarter
Bio 9	Mean temperature of the driest quarter
Bio 10	Mean temperature of the warmest quarter
Bio 11	Mean temperature of the coldest quarter
Bio 12	Annual mean precipitation
Bio 13	Precipitation of the wettest month
Bio 14	Precipitation of the driest month
Bio 15	Precipitation seasonality (coefficient of variation)
Bio 16	Precipitation of the wettest quarter
Bio 17	Precipitation of the driest quarter
Bio 18	Precipitation of the warmest quarter
Bio 19	Precipitation of the coldest quarter
NDVI = (NIR-RED)/(NIR+RED)	Normalized Difference Vegetation Index
NDWI = (NIR-GREEN)/(NIR+GREEN)	Normalized Difference Water Index
Band 2	Reflectance in the blue visible spectrum (450 to 495 nm)
Band 3	Reflectance in the green visible spectrum (495 to 570 nm)
Band 4	Reflectance in the red visible spectrum (620 to 750 nm)
NIR	Near-infrared
DEM	Elevation (m) above sea level
Slope	Terrain slope expressed in %
Aspect	Cardinal direction of the slope
Paths	Distance from pixels to access paths
Roads	Distance from pixels to nearby roads
Town Centers	Distance from pixels to nearby populated centers
Water	Distance from pixels to nearby water sources

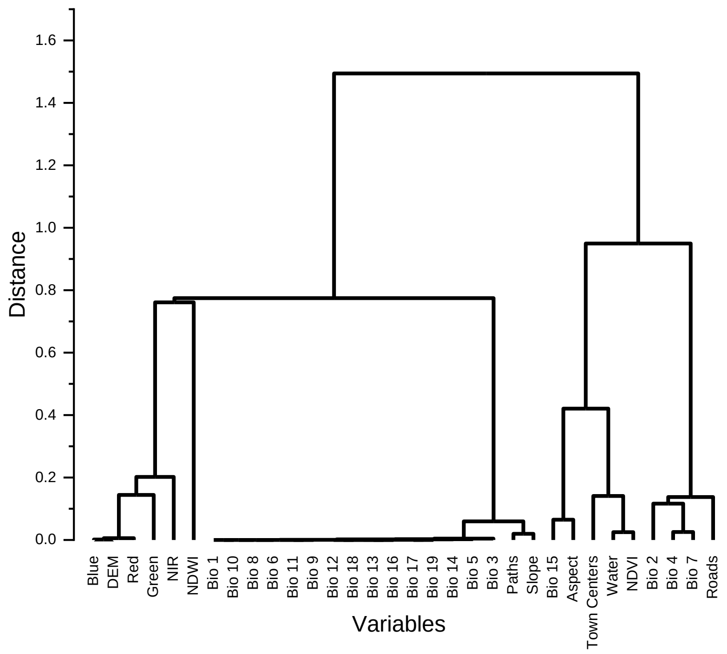

Figure 2 Dendrogram of cluster analysis using Euclidean distances.

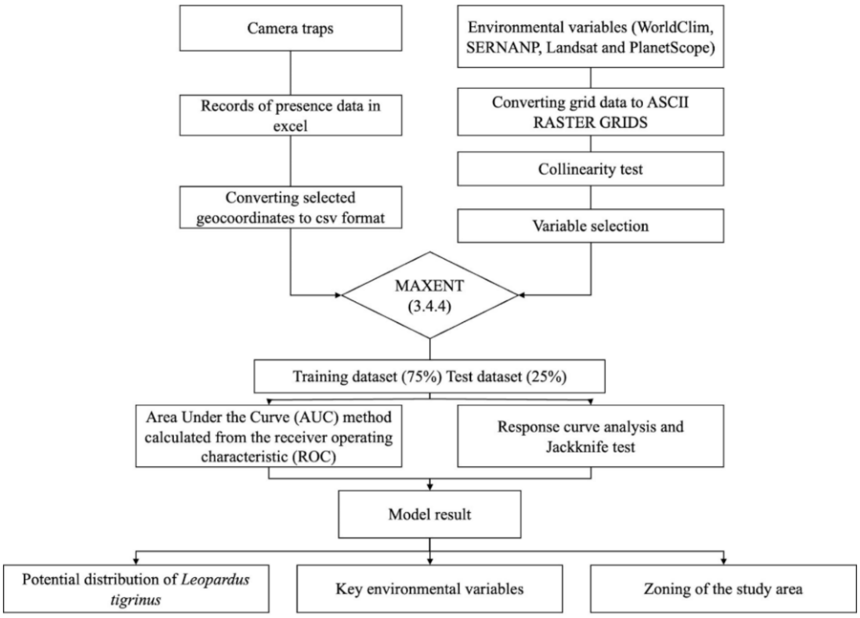

Figure 3 Flowchart of the procedures used to determine the potential distribution of *L. tigrinus.*

3. Results

3.1. Records evaluated through camera traps

The results for *L. tigrinus* within the PNTM, recorded through camera traps, are shown in Figure 4. This figure includes 4 of the 13 images obtained from 19 camera traps installed over nine months (from January to September).

In Figure 5a and Figure 5b, the records show that all observations were made exclusively during nighttime hours. Therefore, the 13 records obtained from the camera traps were used to construct the SDM. Additionally, the images identified adult individuals in motion; however, it was impossible to determine whether they were identical specimens or to identify their sex. A more exhaustive analysis of the videos and photographs could provide additional information.

To improve model accuracy, when repeated records were detected in the same cameras, their location was adjusted by shifting at least 3 pixels to increase data variability.

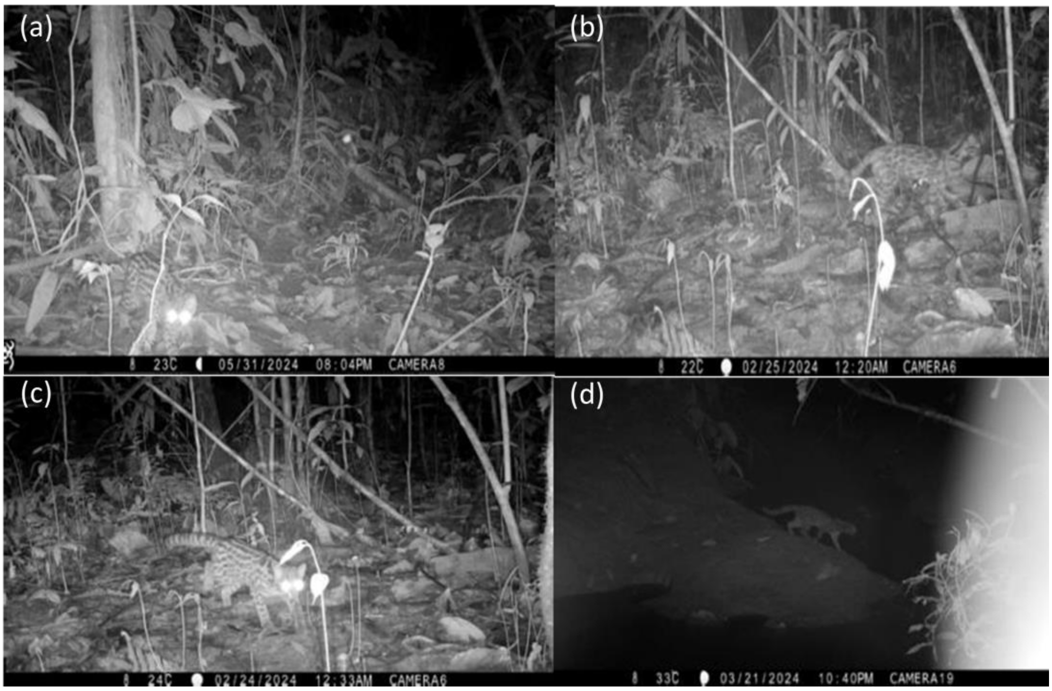

Figure 4 Photographs of the oncilla (*L. tigrinus*) captured by camera traps.(a) Location of camera 8 (UTM coordinates: X = 388732, Y = 8963046), (b and c) records from camera 6 (UTM coordinates: X = 389172, Y = 8962080), (d) capture by camera 19 (UTM coordinates: X = 388073, Y = 8963584).

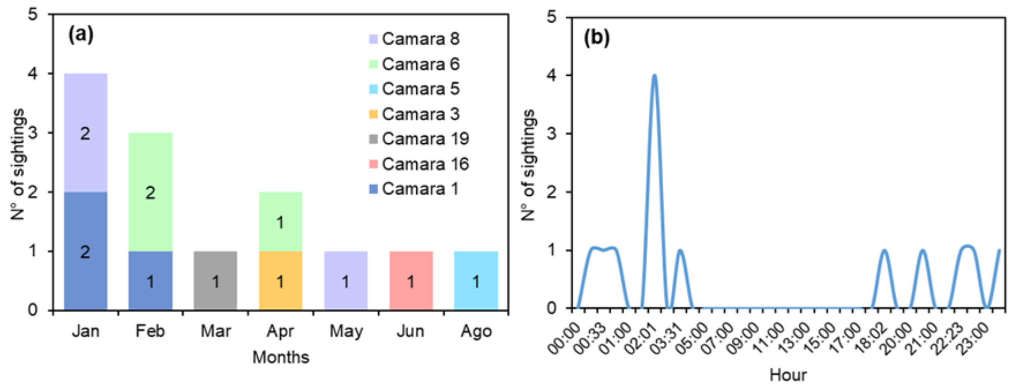

Figure 5 (a) Monthly frequency of *L. tigrinus* sightings recorded by camera traps. (b) Hourly distribution of *L. tigrinus* sightings obtained through camera traps over 24 hours.

3.2. Results of the analysis and validation of potential species distribution modeling (SDM)

3.2.1. Response curves

These curves reflect how each variable influences the probability of the presence of the oncilla, keeping the other variables constant at their average values. Figure 6 shows how the variables represented on the x-axis affect the probability of presence of the oncilla, as shown on the y-axis, which ranges from 0 to 1. This representation aims to understand changes in habitat suitability when only one variable is modified while the others remain unchanged. For example, for the elevation variable, it is evident that at low x-axis values, the probability of species presence is high, and the standard deviation (represented in blue) shows low variability. However, as elevation increases, the probability of the presence of the oncilla decreases significantly, with variability increasing within the studied range.

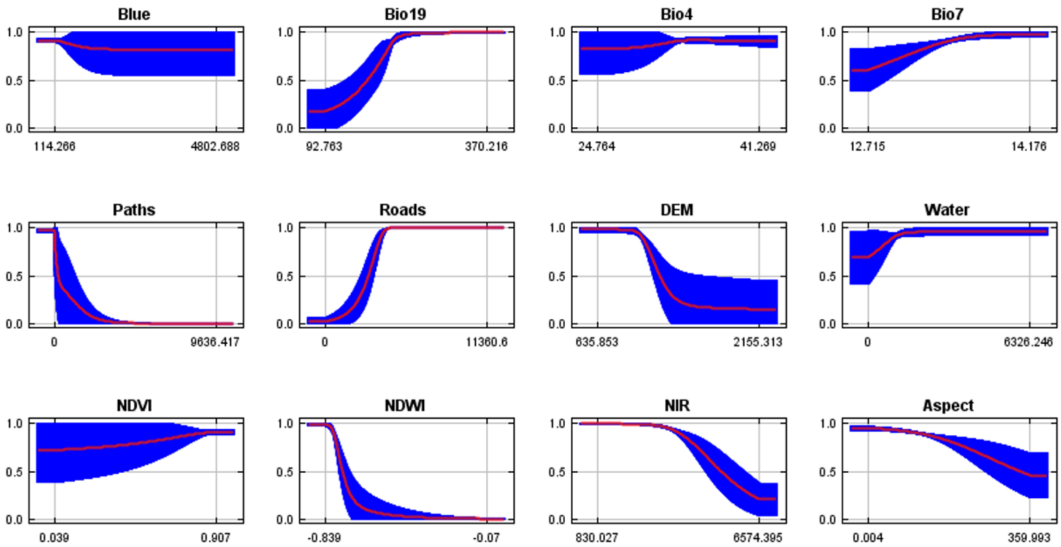

Figure 6 Average response curves generated from the 10 replicated Maxent model runs (in red) and their standard deviations (in blue). These curves illustrate the relationships between the probability of *L. tigrinus* presence and the environmental variables considered in the analysis.

3.2.2. Jackknife test

This test identified the environmental variables that had the most significant influence on the distribution of *L. tigrinus* (Figure 7). The results indicate that the environmental variable with the most valuable information individually is "paths," as its inclusion contributes significantly to the model. On the other hand, the variable that most reduces gain when excluded is "Bio 7" (annual temperature range). This suggests that temperature plays a key role in the species' distribution, highlighting its ecological importance.

Finally, it is determined that the modeling showed excellent performance, with an AUC value of 0.992, validated with 75% of the data for training and 25% for testing, using 10 replicates and 1000 iterations through the Bootstrap method. These results indicate a high predictive capacity of the model, ensuring an objective evaluation of its performance.

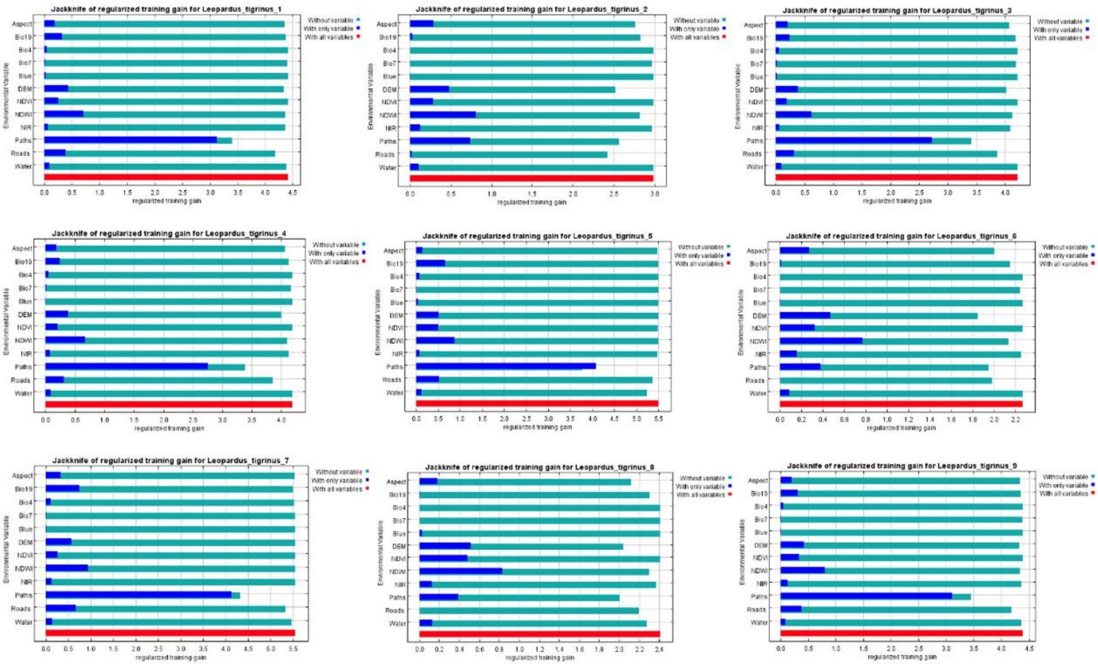

Figure 7 The jackknife test results for regularized training gain in the Maxent models for the oncilla (*L. tigrinus*) in the PNTM. Gain is shown in three scenarios: without the variable (green bars), with only the variable in question (blue bars), and with all variables included (red bars).

3.3. Ecological interpretation of influential environmental variables and zoning

3.3.1. Most influential environmental variables

The variables with the most significant contribution to the model were the precipitation of the coldest quarter (Bio 19, Figure 8a) and the normalized difference vegetation index (NDVI, Figure 8b). This finding indicates that *L. tigrinus* adapted to climatic conditions characterized by relatively high precipitation during the coldest quarter and preferred areas with relatively high vegetation density.

Moreover, the model reveals that the species avoids areas near highways but less significantly avoids paths used by park rangers and the local population. This suggests that areas near these trails may be frequent (Figure 8c). Additionally, a preference for areas at lower altitudes is highlighted, as observed in the elevation variable (DEM, Figure 8e).

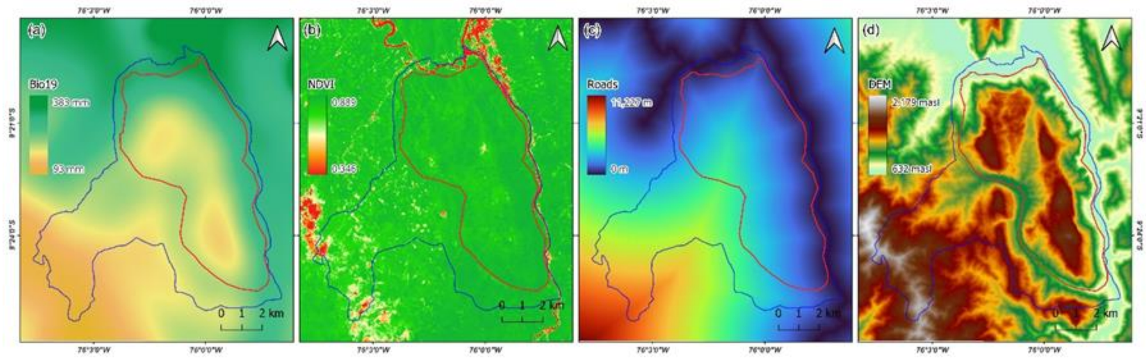

Figure 8 Most influential environmental variables.

3.3.2. Zoning of the PNTM

Figure 9 shows the potential distribution of *L. tigrinus* under current conditions, which can be classified into four habitat suitability ranges: "nonpotential" (< 0.2), "low" (0.2 - 0.4), "moderate" (0.4 - 0.6), and "high" (> 0.6). According to PNTM zoning, the most significant proportion of zones where the species is distributed is in the buffer zone, covering 72.06% of its surface. Additionally, the oncilla occupies other zones, such as Tourist Use Zone I (10.66%), the Wilderness Zone (9.4%), the Strict Protection Zone (3.93%), the Recovery Zone (3.41%), and, to a lesser extent, the Special Use Zone (0.54%).

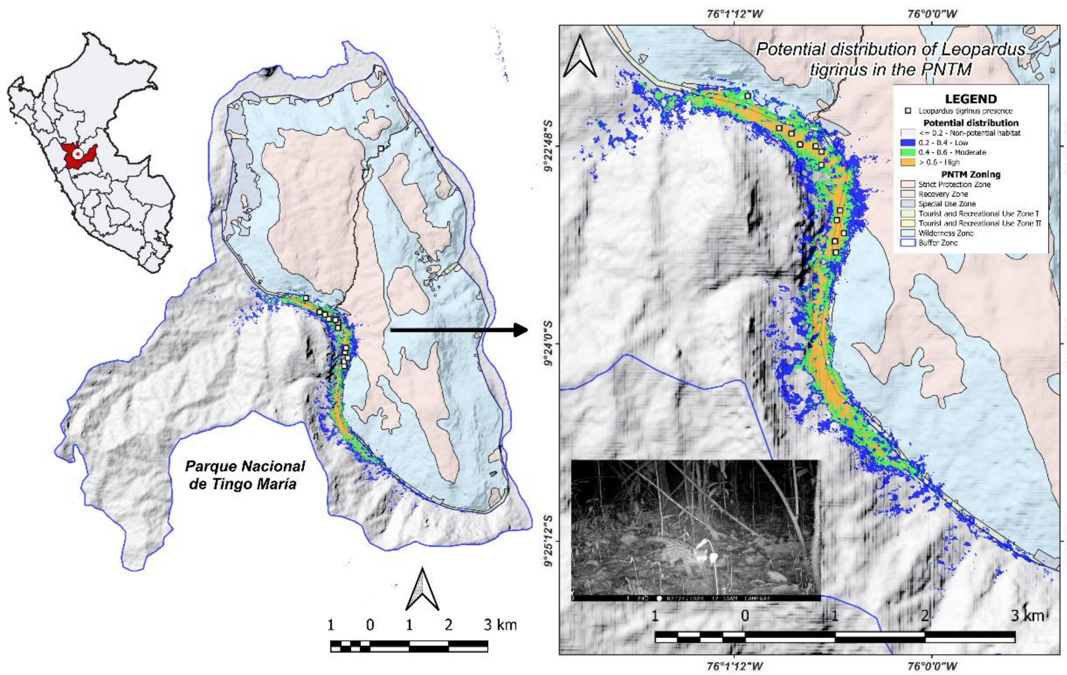

Figure 9 Current potential distribution of the oncilla (*L. tigrinus*) in the PNTM, generated with the Maxent model, camera traps, and high-resolution environmental variables. The values represented correspond to the probability of species occurrence in different park zones.

4. Discussion

Our results on the species distribution model, which uses spatial data from sources such as WorldClim, SERNANP, Landviewer, PlanetScope, and camera traps, have shown outstanding performance, achieving an AUC value of 0.992, indicating a precise estimation of the species distribution. Similar studies, such as that by Martínez-Calderas et al. (2016), reported similar values, with an AUC of 0.822 for the potential distribution of *Leopardus pardalis* in Tamaulipas and San Luis Potosí in Mexico. Using high-resolution data has proven to be highly effective for modeling the SDM of *L. tigrinus*. The results highlight the relationships between the species distributions observed through records from camera traps and high-resolution environmental variables. This has enabled a more precise determination of its ecological niche within a limited space (Merow et al., 2013; Guzmán Vera, 2018). The information obtained from camera traps, including details such as the date and time of the records, observed behavior, and even individual identification of the oncilla, enriches the model. This data allows for the integration of precise information about the species' location, improving the quality and accuracy of the SDM (Andrade-Ponce et al., 2021)

As a result, the most influential variables for determining the suitability of *L. tigrinus* were higher precipitation conditions in the coldest quarter (Bio 19) and dense vegetation (NDVI). In a similar study conducted in Colombia, Guasca (2023) also chose to select the environmental variables with the most significant impact on this species via the same approach. In the SDM used in this study, the ecological niche model helped determine whether the obtained distribution accurately reflected the actual geographical location of the species or was influenced by noise due to excessive input data. Therefore, it is essential to select only the most influential variables (Ortega-Huerta & Townsend Peterson, 2008). Out of a total of 32 variables, only 12 environmental variables were selected to model the potential distribution of the oncilla because of the high spatial correlation among some of them. This method has proven effective for optimizing the variable selection process and improving the prediction of species' potential distribution accuracy.

When modeling the distribution of *L. tigrinus*, it was observed that most of its presence was concentrated in the Buffer Zones, covering 72.06% of the distribution. At the same time, a smaller proportion is found within the protected natural area (PNTM). This situation is particularly notable, implying a well-conserved ecosystem characterized by healthy biodiversity and intact habitats (Gascon et al., 2015). However, this same situation could pose other risks, as mentioned by Payan & González-Maya (2011), where the clustering of the potential distribution of *L. tigrinus* indicates that the areas surrounding the protected area are highly fragmented, making its permanence dependent on protected zones. The species is predominantly observed during the dry season (June–September) when water scarcity drives these animals to descend to areas where water networks are available. Additionally, it has been documented that oncillas move in search of food, as their diet includes terrestrial and semiterrestrial birds such as *Columbina spp.* and *Leptotila sp.* (Columbidae), as well as *Nothura sp.*, *Crypturellus sp.* (Tinamidae), and *Aramides sp.* (Rallidae) (Marinho et al., 2018). It is also necessary to consider that *L. tigrinus* tends to inhabit these areas because of the predation of domestic animals (Pizarro, 2015; Abreu et al., 2008). In the Buffer Zone, there is a diversity of crops and a population of residents who raise many chickens (*Gallus domesticus*), providing a much more accessible food source for this species. This highlights the importance of Buffer Zones for the conservation of the species while suggesting that the oncilla uses areas within the park, albeit to a lesser extent.

In many cases, the delimitation of conservation areas is carried out without prior studies on species distributions due to legal conflicts over land ownership. This contributes to the fragmentation of the habitat of the oncilla and many other species (Santos & Tellería, 2006; Loveridge et al., 2010). A previous study conducted in the PNTM indicated that assessments with camera traps recorded four species not previously reported in the PNTM: *C. minimus, L. wiedii, L. tigrinus*, and *P. cancrivorus* (Daniel Cossios & Ricra Zevallos, 2019), which coincides with the findings of this study in capturing the presence of *L. tigrinus*. These camera traps not only facilitate the verification of recorded species but also improve the accuracy of species identification, thus reducing the probability of ambiguous identifications (Vélez et al., 2024). Furthermore, the presence of this feline species is linked to the availability of prey, such as small animals, in zones occupied by users within the Buffer Zone and the Special Use Zone of the ANP (Anderson et al., 2024).

Therefore, the findings of this study provide key information for the management and conservation of *L. tigrinus* in the PNTM, emphasizing the need for integrated strategies that strengthen habitat connectivity and minimize the effects of fragmentation. The precise identification of critical areas for the species, based on environmental data and records obtained with camera traps, allows for more effective decision-making in conservation planning. Furthermore, these results highlight the importance of considering ecological and anthropogenic factors in habitat modeling and evaluation, and their consideration in the design of management policies, ensuring the long-term viability of this species in its natural environment.

5. Conclusion

The results of this study highlight the usefulness of high-resolution spatial data and the accuracy provided by camera traps, demonstrating that it is feasible to apply these models even in small areas. The curves derived from the environmental variables effectively fit the model, achieving an AUC of 0.992. The observed distribution aligns with particular characteristics of the area that favor the habitat of the oncilla, a species currently classified as vulnerable. Among the most influential variables in the species distribution are precipitation in the coldest quarter (Bio 19), the vegetation index (NDVI), and the avoidance of areas near road and low elevations. The areas with the highest probability of species presence are concentrated mainly in the Buffer Zones (72.06%), followed by the Strict Protection Zones (3.93%), Recovery Zones (3.41%), Special Use Zones (0.54%), Tourist Zone I (10.66%), Tourist Zone II (0%), and Wilderness Zones (9.4%). These results suggest that the current zoning of the PNTM may not be sufficient to protect all critical habitats of the oncilla.

This study provides valuable information conserving this species and highlights the management measures the PNTM took. Additionally, it serves as clear evidence of the high levels of conservation in the park, which benefits the area's flora and fauna. To expand this research, obtaining more data on the species is recommended, such as identifying the number of individuals, their sex, and health status through images and videos obtained by camera traps. It would also be helpful to complement this study with research on the behavior of the oncilla, such as its activity patterns. Finally, the species that serve as prey to the oncilla should be investigated to better understand its feeding habits.

Acknowledgments

The authors thank the Servicio Nacional de Áreas Naturales Protegidas (SERNANP) staff and officials for the facilities granted for entry and stay in the PNTM. We also acknowledge the Vice-Rectorate for Research of the Universidad de Huánuco for the logistical support provided during the research.

Ethical Considerations

The authors declare that they agree with this publication, have made contributions that justify their authorship, and have complied with all relevant ethical and legal requirements and procedures.

Conflicts of Interest

There are no conflicts of interest.

Funding

The Universidad de Huánuco funded this research through a project titled "Effect of land-use change on the potential distribution of mammal species in the Regional Conservation Area (ACR) Bosque Montano de Carpish".

References

Abreu, K. C., Moro-Rios, R. F., Silva-Pereira, J. E., Miranda, J. M. D., Jablonski, E. F., & Passos, F. C. (2008). Feeding habits of ocelot (*Leopardus pardalis*) in Southern Brazil. *Mammalian Biology, 73*(5), 407–411. https://doi.org/10.1016/j.mambio.2007.07.004

Anderson, C., Zuckerwise, A., Wallace, R. B., Ayala, G., Viscarra, M., & Schmitz, O. J. (2024). Small felids coexist in mixed-use landscape in the Bolivian Amazon. *Animals, 14*(5), Article 5. https://doi.org/10.3390/ani14050697

Andrade-Ponce, G., Cepeda-Duque, J. C., Mandujano, S., Velásquez-C, K. L., Gómez-Valencia, B., & Lizcano, D. J. (2021). Modelos de ocupación para datos de cámaras trampa: De los conceptos a la interpretación. *Mammalogy Notes, 7*(1), Article 1. https://doi.org/10.47603/mano.v7n1.200

Araújo, M. B., Pearson, R. G., Thuiller, W., & Erhard, M. (2005). Validation of species–climate impact models under climate change. *Global Change Biology, 11*(9), 1504–1513. https://doi.org/10.1111/j.1365-2486.2005.01000.x

Benavides Rios, E., Sadler, J., Graham, L., & Matthews, T. J. (2024). Species distribution models and island biogeography: Challenges and prospects. *Global Ecology and Conservation, 51*, e02943. https://doi.org/10.1016/j.gecco.2024.e02943

Carpio Amancha, E. M. (2020). Modelos de máxima entropía y su resolución numérica mediante métodos de segundo orden con aplicación en la predicción de presencia de especies en áreas naturales [Bachelor's thesis, Escuela Politécnica Nacional]. http://bibdigital.epn.edu.ec/handle/15000/20797

Daniel Cossios, E., & Ricra Zevallos, A. (2019). Diversidad y actividad horaria de mamíferos medianos y grandes registrados con cámaras trampa en el Parque Nacional Tingo María, Huánuco, Perú. *Revista Peruana de Biología, 26*(3), 325–332. https://doi.org/10.15381/rpb.v26i3.16776

de Oliveira, T. G., Fox-Rosales, L. A., Ramírez-Fernández, J. D., Cepeda-Duque, J. C., Zug, R., Sanchez-Lalinde, C., Oliveira, M. J. R., Marinho, P. H. D., Bonilla-Sánchez, A., Marques, M. C., Cassaro, K., Moreno, R., Rumiz, D., Peters, F. B., Ortega, J., Cavalcanti, G., Mooring, M. S., Blankenship, S. R., Brenes-Mora, E., … Rodrigues, F. H. G. (2024). Ecological modeling, biogeography, and phenotypic analyses setting the tiger cats' hyperdimensional niches reveal a new species. Scientific Reports, 14(1), 2395. https://doi.org/10.1038/s41598-024-52379-8

Elith, J., & Leathwick, J. (2009). Species distribution models: Ecological explanation and prediction across space and time. *Annual Review of Ecology, Evolution, and Systematics, 40*, 677–697. https://doi.org/10.1146/annurev.ecolsys.110308.120159

Fitzgibbon, A., Pisut, D., & Fleisher, D. (2022). Evaluation of Maximum Entropy (Maxent) machine learning model to assess relationships between climate and corn suitability. *Land, 11*, 1382. https://doi.org/10.3390/land11091382

Gascon, C., Brooks, T. M., Contreras-MacBeath, T., Heard, N., Konstant, W., Lamoreux, J., Launay, F., Maunder, M., Mittermeier, R. A., Molur, S., Al Mubarak, R. K., Parr, M. J., Rhodin, A. G. J., Rylands, A. B., Soorae, P., Sanderson, J. G., & Vié, J.-C. (2015). The importance and benefits of species. *Current Biology, 25*(10), R431–R438. https://doi.org/10.1016/j.cub.2015.03.041

Gil y Carbó, G. E. (2017). Modelos de distribución y su aplicación en la conservación de mamíferos terrestres sudamericanos [Doctoral thesis, Universidad Autónoma de Madrid]. https://repositorio.uam.es/handle/10486/681434

González-Maya, J. F., Zárrate-Charry, D. A., Arias-Alzate, A., Lemus-Mejía, L., Hurtado-Moreno, A. P., Vargas-Gómez, M. G., Cárdenas, T. A., Mallarino, V., & Schipper, J. (2022). Spotting what's important: Priority areas, connectivity, and conservation of the Northern Tiger Cat (*Leopardus tigrinus)* in Colombia. PLOS ONE, 17(9), e0273750. https://doi.org/10.1371/journal.pone.0273750

Gutiérrez. (2023). Tigrillo: El pequeño gato silvestre que peligra por el Arco Minero en Venezuela. *Noticias ambientales*. https://es.mongabay.com/2023/08/tigrillo-pequeno-gato-silvestre-que-peligra-por-arco-minero-venezuela/ Accessed on 07 November 2024.

Guzmán Vera, M. (2018). *Modelos de Distribución Potencial de Especies Forestales en las Sierras de Jaén. Aplicaciones de alta resolución*. http://crea.ujaen.es/jspui/handle/10953.1/8512. Accessed on 07 November 2024.

Hernández, J. C. H. (2023). La tecnología y la conservación de especies: El poder de las cámaras-trampa. *Revista Digital Universitaria, 24(*4), Article 4. https://doi.org/10.22201/cuaieed.16076079e.2023.24.4.3

INEI. (2017). *Resultados Definitivos de los Censos Nacionales 2017 – Censos Nacionales 2017*. https://censo2017.inei.gob.pe/resultados-definitivos-de-los-censos-nacionales-2017/. Accessed on 07 November 2024.

Júnior, P. D. M., & Nóbrega, C. C. (2018). Evaluating collinearity effects on species distribution models: An approach based on virtual species simulation. *PLOS ONE, 13*(9), e0202403. https://doi.org/10.1371/journal.pone.0202403

López Ortiz, E. I. (2020). Historia de vida, distribución potencial y conectividad del tigrillo (*Leopardus wiedii)* en Michoacán [Master's thesis, Universidad Michoacana de San Nicolás de Hidalgo]. http://bibliotecavirtual.dgb.umich.mx:8083/xmlui/handle/DGB_UMICH/2829. Accessed on 18 November 2024

Loveridge, A., Wang, S. W., Frank, L., & Seidensticker, J. (2010). People and wild felids: Conservation of cats and management of conflicts. In D. W. Macdonald & A. J. Loveridge (Eds.), *Biology and conservation of wild felids* (pp. 161–195). Oxford University Press. http://repository.si.edu/xmlui/handle/10088/11074

Marinho, P. H., Bezerra, D., Antongiovanni, M., Fonseca, C. R., & Venticinque, E. M. (2018). Activity patterns of the threatened northern tiger cat *Leopardus tigrinus* and its potential prey in a Brazilian dry tropical forest. *Mammalian Biology, 89*, 30–36. https://doi.org/10.1016/j.mambio.2017.12.004

Martínez-Calderas, J. M., Rosas-Rosas, O. C., Palacio-Núñez, J., Martínez-Montoya, J. F., Olmos-Oropeza, G., & Tarango-Arámbula, L. A. (2015). Potential distribution of the ocelot (*Leopardus pardalis*) in Northeastern Mexico. *Therya, 6*(3), 545–558. https://doi.org/10.12933/therya-15-304

Mateo, R. G., Felicísimo, Á. M., & Muñoz, J. (2011). Modelos de distribución de especies: Una revisión sintética. *Revista chilena de historia natural, 84*(2), 217–240. https://doi.org/10.4067/S0716-078X2011000200008

Merow, C., Smith, M. J., & Silander Jr, J. A. (2013). A practical guide to MaxEnt for modeling species' distributions: What it does, and why inputs and settings matter. *Ecography, 36*(10), 1058–1069. https://doi.org/10.1111/j.1600-0587.2013.07872.x

Meza Mori, G., Rojas-Briceño, N. B., Cotrina Sánchez, A., Oliva-Cruz, M., Olivera Tarifeño, C. M., Hoyos Cerna, M. Y., Ramos Sandoval, J. D., & Torres Guzmán, C. (2022). Potential Current and Future Distribution of the Long-Whiskered Owlet (*Xenoglaux loweryi*) in Amazonas and San Martin, NW Peru. *Animals, 12*(14), Article 14. https://doi.org/10.3390/ani12141794

MINAM. (2024). Ministro del Ambiente destaca potencial turístico del Parque Nacional Tingo María y su aporte a la reactivación económica sostenible [Noticias]. Plataforma Digital Única del Estado Peruano. https://www.gob.pe/institucion/minam/noticias/985454-ministro-del-ambiente-destaca-potencial-turistico-del-parque-nacional-tingo-maria-y-su-aporte-a-la-reactivacion-economica-sostenible. Accessed on 07 November 2024

Molloy, S. (2018). *A Practical Guide to Using Camera Traps for Wildlife Monitoring in Natural Resource Management Projects*. https://doi.org/10.13140/RG.2.2.28025.57449

Mori, G. M., Castillo, E. B., Guzmán, C. T., Cotrina Sánchez, D. A., Guzman Valqui, B. K., Oliva, M., Bandopadhyay, S., López, R. S., & Rojas Briceño, N. B. (2020). Predictive modelling of current and future potential distribution of the spectacled bear (*Tremarctos ornatus*) in Amazonas, northeast Peru. *Animals, 10*(10), Article 1816. https://doi.org/10.3390/ani10101816

Nazir, S., & Kaleem, M. (2021). Advances in image acquisition and processing technologies transforming animal ecological studies. *Ecological Informatics, 61*, 101212. https://doi.org/10.1016/j.ecoinf.2021.101212

O'Connell, A., Nichols, J. D., & Karanth, K. U. (2011). *Camera traps in animal ecology: Methods and analyses* (p. 271). Springer. https://doi.org/10.1007/978-4-431-99495-4

Ortega-Huerta, M. A., & Townsend Peterson, A. (2008). Modeling ecological niches and predicting geographic distributions: A test of six presence-only methods. *Revista Mexicana de Biodiversidad, 79*(1), 205-216. https://www.scielo.org.mx/scielo.php?pid=S1870-34532008000100017&script=sci_abstract&tlng=en. Accessed on 08 November 2024

Payan, E., & de Oliveira, T. (2016). *Leopardus tigrinus*. The IUCN Red List of Threatened Species 2016: E.T54012637A50653881. The IUCN Red List of Threatened Species. https://dx.doi.org/10.2305/IUCN.UK.2016-2.RLTS.T54012637A50653881.en. Accessed on 07 November 2024

Payan, E., & González-Maya, J. (2011). Distribución geográfica de la Oncilla (*Leopardus tigrinus*) en Colombia e implicaciones para su conservación. *Revista Latinoamericana de Conservación, 2*, 51–59. https://www.academia.edu/download/41423379/Sobre_la_necesidad_y_pertinencia_de_la_g20160122-16376-1j65tor.pdf#page=54. Accessed on 07 November 2024.

Phillips, S. J., Anderson, R. P., & Schapire, R. E. (2006). Maximum entropy modeling of species geographic distributions. *Ecological Modelling, 190*(3), 231–259. https://doi.org/10.1016/j.ecolmodel.2005.03.026

Pizarro, J. F. (2015). Interacciones humano–oso andino *Tremarctos ornatus* en el Perú: Consumo de cultivos y depredación de ganado. *THERYA, 6*(1), Article 1. https://doi.org/10.12933/therya-15-251

Pliscoff, P., & Fuentes-Castillo, T. (2011). Modelación de la distribución de especies y ecosistemas en el tiempo y en el espacio: Una revisión de las nuevas herramientas y enfoques disponibles. *Revista de geografía Norte Grande, 48*, 61–79. https://doi.org/10.4067/S0718-34022011000100005

Sánchez, A., Marques, M. C., Cassaro, K., Moreno, R., Rumiz, D., Peters, F. B., Ortega, J., Cavalcanti, G., Mooring, M. S., Blankenship, S. R., Brenes-Mora, E., … Rodrigues, F. H. G. (2024). Ecological modeling, biogeography, and phenotypic analyses setting the tiger cats' hyperdimensional niches reveal a new species. Scientific Reports, 14(1), 2395. https://doi.org/10.1038/s41598-024-52379-8

Santos, T., & Tellería, J. L. (2006). Pérdida y fragmentación del hábitat: Efecto sobre la conservación de las especies. *Ecosistemas, 15*(2), Article 2. https://www.revistaecosistemas.net/index.php/ecosistemas/article/view/180. Accessed on 07 November 2024.

Schreber, J. C. D. (1775). *Die Säugthiere in Abbildungen nach der Natur mit Beschreibungen. Tafelband 1: Theil 1–3 und Supplement 1 u. 2: Taf. I–CLXV*. https://doi.org/10.11588/DIGLIT.3322

SERNANP. (2021). Parque Nacional Tingo María - Sernanp. https://visitaareasnaturales.sernanp.gob.pe/anps/parque-nacional-de-tingo-maria/. Accessed on 26 November 2024

SERNANP. (2024). GEO ANP - Visor de las Áreas Naturales Protegidas. https://geo.sernanp.gob.pe/visorsernanp/. Accessed on 14 September 2024

Torres, M., Jaimes-Rodríguez, L., & Lozano Flórez, J. (2020). New records of *Leopardus tigrinus* (Carnivora: Felidae) in the Department of Santander, Colombia. In *Mammalogy Notes* (Vol. 6). https://doi.org/10.47603/mano.v6n2.142

Vélez, J., McShea, W., Pukazhenthi, B., Stevenson, P., & Fieberg, J. (2024). Implications of the scale of detection for inferring co-occurrence patterns from paired camera traps and acoustic recorders. *Conservation Biology, 38*(3), e14218. https://doi.org/10.1111/cobi.14218

Veneros, J., García, L., Morales, E., Gómez, V., Torres, M., López-Morales, F., Veneros, J., García, L., Morales, E., Gómez, V., Torres, M., & López-Morales, F. (2020). Aplicación de sensores remotos para el análisis de cobertura vegetal y cuerpos de agua. *Idesia (Arica), 38*(4), 99–107. https://doi.org/10.4067/S0718-34292020000400099

Zuloaga-Obregón, J. L., & Gabriel-Campos, E. N. (2023). Cambio de uso de tierra y su impacto en la cobertura vegetal del Parque Nacional Tingo María entre los años 2006-2021. *Revista Kawsaypacha: Sociedad y Medio Ambiente, 12*. https://doi.org/10.18800/kawsaypacha.202302.A009