PARTIAL REPORT

"Use of the Andean Bear and Puma for the Elaboration of a Model of Connectivity between the NNP of Tamá, Cocuy, Pisba and the FFS of Guanenta in Eastern Colombia"

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Content

Abstract

Introduction: Nowadays, the ecological connectivity within protected areas or reserve networks is practically a requirement for the preservation of populations, ecological processes, and thus, for the diversity occurring within them. Nonetheless, given the current and historical methods of land use, protected areas are more isolated and the patches of vegetation become smaller and more fragmentized with time. In the eastern mountain range of Colombia, there are no published works that evaluate the ecological connectivity between protected areas (PAs). In addition, there are not any works that have evaluated the implications PAs have on a demographic level. this is of the utmost importance in the current context and a priority for the conservation of the species with ample ecological requirements and ample areas of actions.

Objective: The objective of this work is to evaluate the distribution and functional connectivity of large mammals – considered umbrella species – threatened and of conservational value. These include the spectacled bear (*Tremarctos ornatus*), and the puma (*Puma concolor*), found in the Natural National Parks (NNP) of Tamá, Cocuy, Pisba and the

Fauna and Flora Sanctuary (FFS) of Guanenta Alto Río Fonce, in the departments of Santander, Boyacá and Norte de Santander.

Methodology: 120 sample units were selected of dimensions of 2 x 2 km, distributed in the NNP of Tamá, Cocuy, Pisba and the FFS of Guanenta Alto Río Fonce, additional to four intermediate areas in the departments of Boyacá, Norte de Santander and Santander. In each unit, expeditions were led in search of evidence of the presence of these species, either by direct observations or by signs of their presence (faeces, footprints). Simple stations of camera-traps were installed, with a Bushnell Trophy Cam Agressor HD,in 24-hour mode, with 3 videos per shot, 15 seconds per video, a 15-second interval, without bait, separated at least by 1.5 linear kilometres between stations, between January and April of 2019. These were monitored every 1.5 months until the end of September of 2019. Outside of the protected areas, farmers were hired and trained (> 7) to carry out monitoring activities for each of the stations of the camera-traps every 1.5 months. Afterwards, by using the software of maximum entropy MAXENT 3.4.1, employing the cumulative method, using 500 interactions, 10 repetitions, an analysis of cross-validation, layers of variables of physical, environmental and of anthropogenic origins, a layer of BIAS, and taking into account the bias in the spatial auto-correlation of the data, and the compiled occurrences from the revision of literature, expert consultancy and the 4 months of sampling, the models of habitat suitability were elaborated for each of the species. We used the Trainor et al. equation (2013), and the statistical software R. 3.5.1 (R Core Team 2013) to establish the conversion of suitability values, i.e. areas with high suitability values will have low resistance values and vice versa, whose grade of transformation varies depending on the function and grade of resistance, in order to finally create 8 resistance matrixes for each specie. To calculate the connectivity models, we used the software Circuitscape v.4.0.3, using as an entry the layers of resistance created in the previous step, as well as perimeter nodules. In the end, eight models of connectivity were created for each specie that, by use of the raster calculator from ArcMap of ArcGis 10.4.1., were added to find the medium value and the standard deviation. As of this, the role of the protected areas was evaluated to ensure said current flows (connectivity probability) for each specie, the distribution and the spatial representation of suitable areas within PAs.

Results: 1240 pieces of occurrence data were obtained for both species, alongside recording of various individuals of the spectacled bear in 6 of the 8 areas (Tamá, Cocuy, Pisba, Guanenta, Chita, Palermo). Meanwhile, of the puma there was only one register documented, as of date; the same happened with more than 20 species of median and large mammals and flightless birds associated amongst them; *Leopardus tigrinus*, *L. pardalis*, *L. wiedii*, *Herpailurus yagouaroundii*, *Odocoileus goudotii*, *Mazama rufina*, *Dasprocta punctata*, *Cuniculus paca*, *Nasua nasua*, *Nasuella olviacea*, *Dasypus novemcinctus*, *Tamandua mexicana*, *C. taczanowskii*, *Pauxi pauxi* (in danger of extinction according to the IUCN), etc. The models of suitability showed a high value of the AIC (0.885 for *T.ornatus*, 0.875 for *P. concolor*), which reflects its predictable capacity and, at the same time, as demonstrated in the case of the *T. ornatus*, that an important area exists for the conservation of the species in the Cocuy-Chita-Pisba and Mongua complex that is not taken as an area of potential distribution according to the IUCN (Velez & García-Rangel, 2017). This given, and supported by the results of the camera-traps and fieldwork, this work would be useful to encourage the redefinition of such areas. Meanwhile, the circumstances are different for the *P.concolor*. The median value of the 10 models constructed demonstrates that the distribution is less generalized, and much more fragmented that what is shown by the IUCN (Nielsen et al. 2015), and with a large portion of it, outside of the PAs.

Discussion: The information communicated by the models of ecological connectivity makes us think that the populations of *T. ornatus* in the north-eastern Andes region are fragmented in various important sub-nuclei of conservation; Serranía del Perijá, Macizo del Tamá, the Cocuy-Pisba complex, the Guantiva-La Rusia moorland, and the NNP Serranía de los Yariguies, which should be reflected in the genetic diversity of these populations. The possible isolation and the eventual loss of individuals and connectivity should be treated as an important factor to resolve for the populations of the north-eastern Andes in Colombia, taking into account that it is considered one of the 5 most important nuclei in the country for the conservation of the spectacled bear, and with evident influence in the eastern populations of Venezuela. At the same time, it is possible that the populations of the *P. concolor* is largely under threat, given the absence of their apparition in the 114 camera-traps installed during the last 8 months, as a consequence of hunting and the loss of ecological connectivity between the areas, since there exists an acceptable level of prey availability (hoofed animals, rodents and procyonidae, these being the principal prey of the species; refer to Cáceres-Martínez et al. 2017) and other carnivores in the areas, e.g., *Leopardus* spp., *P. yagouaroundii*, *Cerdocyon thous* and *Urocyon cinereoargenteus*.

Additionally, our results refute the results of the species' distribution presented by Nielsen et al. (2015), this being a reason for which we consider that a more detailed analysis is necessary for the entire species, with the aim of delimiting more precisely the areas of distribution of the species. This information would be of utility not only for the academic community, but also for the NNP and the CAR (Autonomous Regional Corporation). Now, we are working on the draft of scientific manuscripts and new analyses to offer management and conservational tools for the CAR, NNP, and the scientific community.

The following step is systematizing and analysing the information obtained from the camera-traps. With the data collected from the 114 units of camera-traps, distributed in the 8 areas (4 NNP and 4 intermediate areas), a matrix of detections will be constructed in order to determine the probability of occupation, the detectability, the error and the standard deviation. We will then evaluate the effect of the co-variables employed, and determine the explicit spatial occupation using the unmarked package of the statistical software R. Finally, the following will be established: 1) The degree of functional connectivity of the cells; and 2) The percentage of occupation of the cells, employing the software R. To evaluate the data correlation, we will use the Shapiro-Wilk test and Pearson's coefficient of correlation. Thus, this will generate an input for the decision-making process based in the research of the establishment and/or the prioritization of the protected areas between these areas, which allows improving their connectivity and, at the same time, to conserve key areas for the maintenance of the populations of *T. ornatus*, and *P. concolor*, additional to the fauna and ecosystems associated.

1. Data collection

We looked through the data base, *Information System of the Biodiversity in Colombia (SIB Colombia)*, and consulted experts, while also examining global data bases, such as GBIF and VertNet, in search of biological georeferenced registers related to the spectacled bear (*Tremarctos ornatus*), and the puma (*Puma concolor*), at a global, national and local level (Santander, Norte de Santander, and Boyacá). This information could be used to evaluate the relationship between the occurrence of these species and the physical and environmental variables, and thus, be able to assign them a value within the matrix of resistance. However, we were **only able to obtain information on 81 georeferenced locations for Colombia**, and a set of 745 items of characteristic, verified data that confirmed the presence of the two species, specific to Colombia. Additionally, we collected 166 items of data provided by the Conservation Research Laboratory from the University of Arizona.

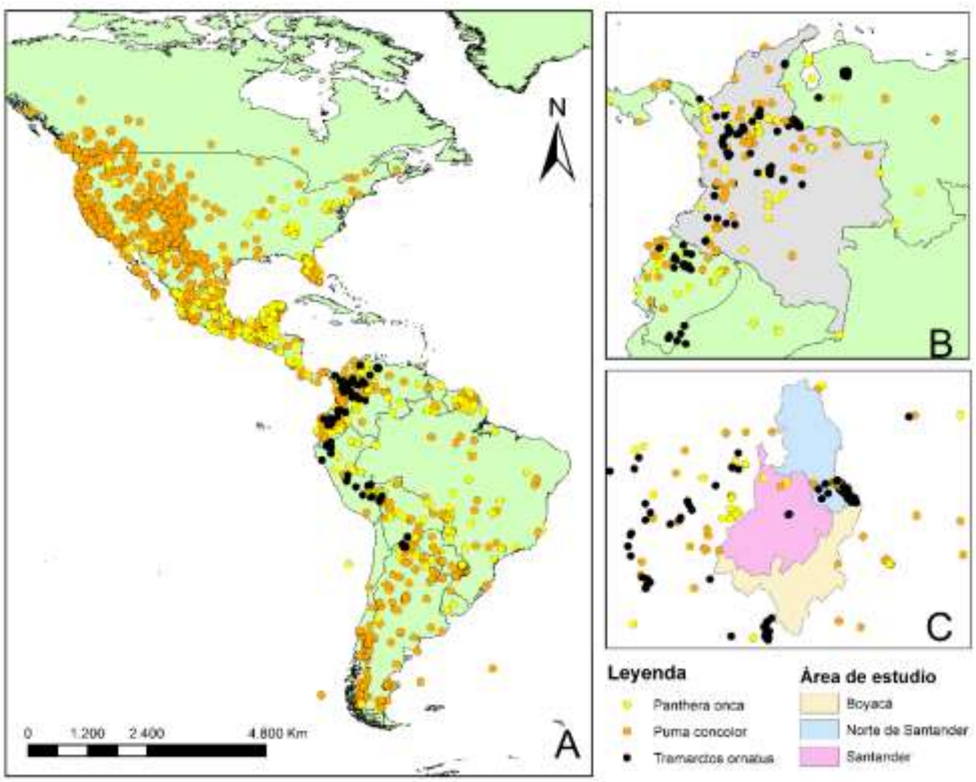

Figure 1. Data distribution of the presence of the spectacled bear, puma and jaguar in **A.** South America; **B.** Colombia; **C.** Study areas (Santander, Boyacá, Norte de Santander). The majority of the data confirming the presence of the three species in the study areas correspond

to a set of characteristic data taken in the field. Data of the confirmed presence of the three species in the study area is few or non-existent.

2. Camp phase and meetings with the NNP

Table No.1 General schedule of activities

POLYGON	NUMBER OF CAMERAS	DATES
NNP TAMÁ	20	7 - 19 of January
INTERMEDIATE BLOCK 1_MIRALINDO	7	21- 24 of January
INTERMEDIATE BLOCK 2_MOORLAND OF CHITA	10	31 of January - 3 of February
INTERMEDIATE BLOCK 3_MOORLAND OF OCETA	7	9-11 of February
NNP COCUY	-	18 - 20 of February
SSF GARF	2	21 - 22 of February
NNP COCUY	3	26-28 of February
NNP PISBA	20	28 feb - 16 of March
NNP COCUY	9	18 - 28 of March
FFS GARF	10	1 - 14 of April
CORPOBOYACA: PALERMO	20	>19 of February
CAS	16	To be defined

In total, 114 hours were installed in all the sampling area.

Each sampling station was installed in a sampling unit (cells of 2 2 km2), following the ensuing parameters:

- There could only be one camera per quadrant.
- Each camera had to be separated at least 1 lineal kilometre for the following camera-trap
- The cameras were set in video mode, with a duration of 15 seconds, and intervals of equal time span, with a normal or automatic sensor, in a 24-hour mode.

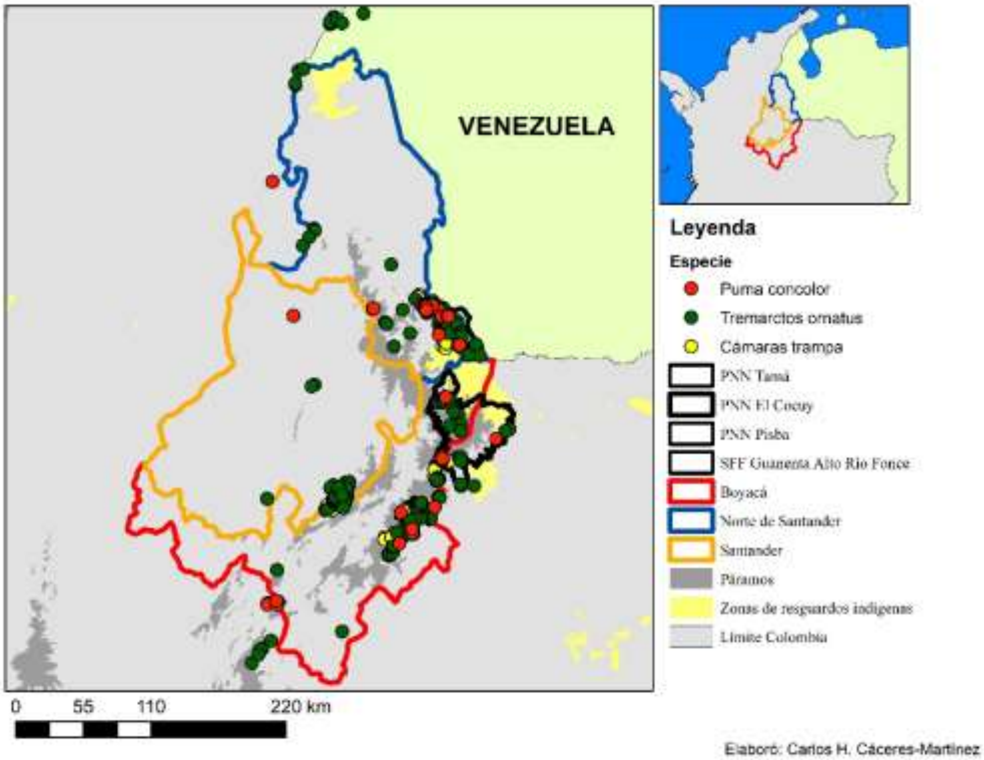

Figure 2. Distribution of cameras and sampling units in the NNP Tamá, Pisba, the FFS GARF, and intermediate areas: Miralindo, Chita, Mongua and Palermo, in the departments of Boyacá, Norte de Santander.

Figure 3. Field trip to the Orocue sector with functionaries from the NNP Tamá for the installation of the camera-traps. Toledo, Norte de Santander.

Figure 4. Installing the camera-traps with the team from the FFS GARF and local guides. Encino, Santander.

Figure 5. Installing camera-traps with the team of the NNP El Cocuy and local guides. El Guican, Boyacá.

Figure 6. Installing camera-traps with the team of the NNP Pisba. Socha, Boyacá.

3. Development of final models of habitat suitability

For this stage of the project, we used the collected data during the revision of available literature, data bases (GBIF, VertNet, SIB), additional consultancy to experts, as well as data taken from the fieldwork carried out for 4 months in the 8 sampling areas: NNP Tamá, Cocuy, Pisba and the FFS of Guanenta Alto Río Fonce and four additional localities (Miralindo, Chita, Mongua, Palermo).

For the development of the models, we used the software of maximum entropy Maxent 3.3.3e (Philips et al. 2006), using the tool SDMtoolbox v2.4,2 for ArcMap 10.4, climatic variables from Worldclim/Bioclim (Fick et al. 2017): BIO1 = Annual Mean Temperature, BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp)), BIO3 = Isothermality (BIO2/BIO7) (* 100), BIO4 = Temperature Seasonality (standard deviation *100), BIO5 = Max Temperature of Warmest Month, BIO6 = Min Temperature of Coldest Month, BIO7 = Temperature Annual Range (BIO5-BIO6), BIO8 = Mean Temperature of Wettest Quarter, BIO9 = Mean Temperature of Driest Quarter, BIO10 = Mean Temperature of Warmest Quarter, BIO11 = Mean Temperature of Coldest Quarter, BIO12 = Annual Precipitation, BIO13 = Precipitation of Wettest Month, BIO14 = Precipitation of Driest Month, BIO15 = Precipitation Seasonality (Coefficient of Variation), BIO16 = Precipitation of Wettest Quarter, BIO17 = Precipitation of Driest Quarter, BIO18 = Precipitation of Warmest Quarter, BIO19 = Precipitation of Coldest Quarter, all taken at one kilometre of resolution, environmental variables, biomes, vegetation covering, and ecosystems taken from the map of the forest of 2017 provided by the IDEAM and the Map of Continental, Coastal and Marine Ecosystems of Colombia (MEC, in Spanish) at a scale of 1:100.000 (IDEAM 2017), topographic variables: altitude, slope at a 1km of resolution, anthropic variables (distance to rivers, populated centres or highways standardized at one kilometre); a variable of probability of human access was calculated from the tracks and rivers computed from the toolbox for the identification of priority areas of WCS (Ríos-Franco et al. 2013); and lastly, fractals were employed, from images SENTINEL 2 obtained from the Copernicus Global Land Service that represent the grasslands, cultivation fields, trees, bare ground, snow, moss, scrub, urban zones and bodies of water. Finally, we carried out a bias analysis given the distribution of the sampling, using the Gausian Kernel Destiny of Sampling Localities function, incorporated in the SDMtoolbox, and it was used as a standardized raster layer for the Bias analysis.

For the elaboration of the model, we used the default values from Maxent 3.3.3e, applying the cumulative method and the statistical Jackknife method to measure the degree of importance of the variables, with the aim of eliminating the variables that do not contribute to the AUC or to the gain of the model. 10 replicas were created using the Crossvalidate method and 500 interactions. To evaluate the specificity of the model, we used the operative curve characteristic of the receptor (ROC).

In the end, the two best models were developed for each species.

3.1 Spectacled bear (*Tremarctos ornatus*)

Out of the 1159 items of occurrence data, the model used 225 items of data for training, and 25 pieces of data for the test.

As shown in the following graphic, our models predicts quite well the distribution of the spectacled bear in the study area.

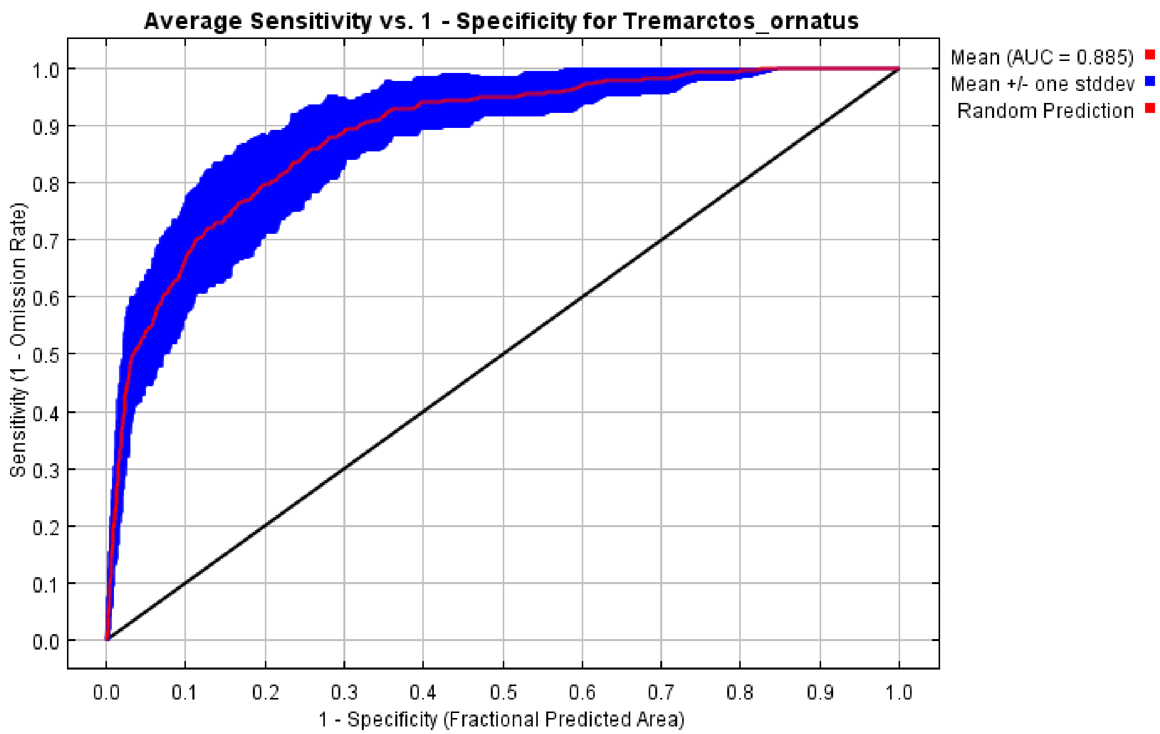

Figure 7. Specificity curve for the data of *Tremarctos ornatus*

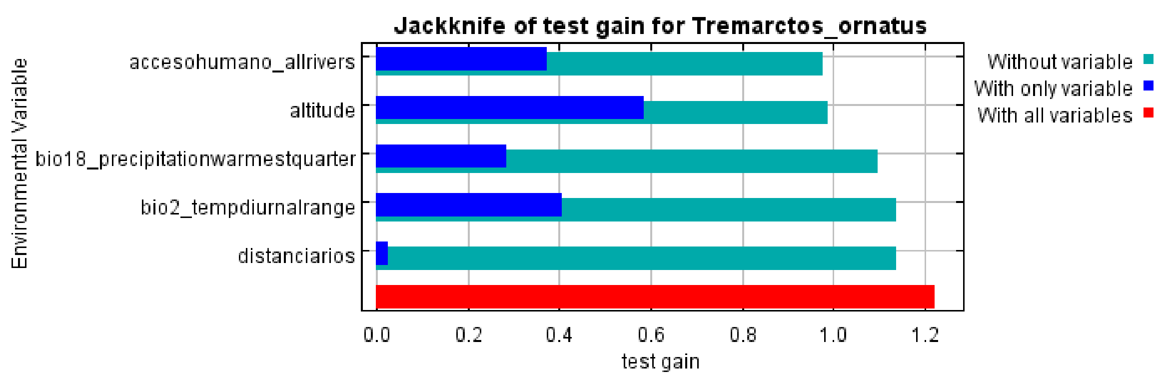

Figure 8. Test for the value of importance of the variables, employing the Jackknife method.

The variables of human access, altitude and bio18 were the ones that contributed the most to the positive return derived from the model.

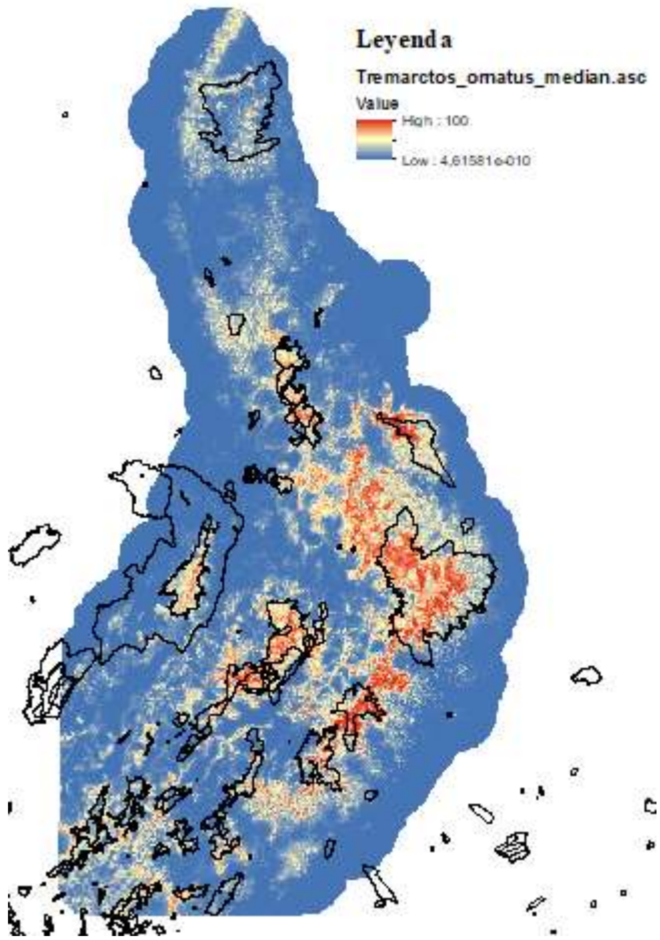

Figure 9. Distribution model (median) of *Tremarctos ornatus* in the study area. The more vibrant patches of red represent the most suitable habitats.

Ultimately, the model can be extrapolated outside of the sampling area, demonstrating the importance of other protected areas, e.g. PNR Sisavita, Mutiscua, Arboledas, Pamplona, the absence of others, e.g. NNP Iguaque, and the possible presence in PAs such as the NNP Catatumbo, additional to the isolation of the populations.

3.2 Puma (*Puma concolor*)

Out of the 81 points of occurrence, the model used 35 items of data for training and 4 items of data for the test.

According to the AUC, our model predicts quite well the distribution of the puma in the study area, although there is a higher standard deviation in the data, since, evidently, these are fewer than those obtained for the spectacled bear.

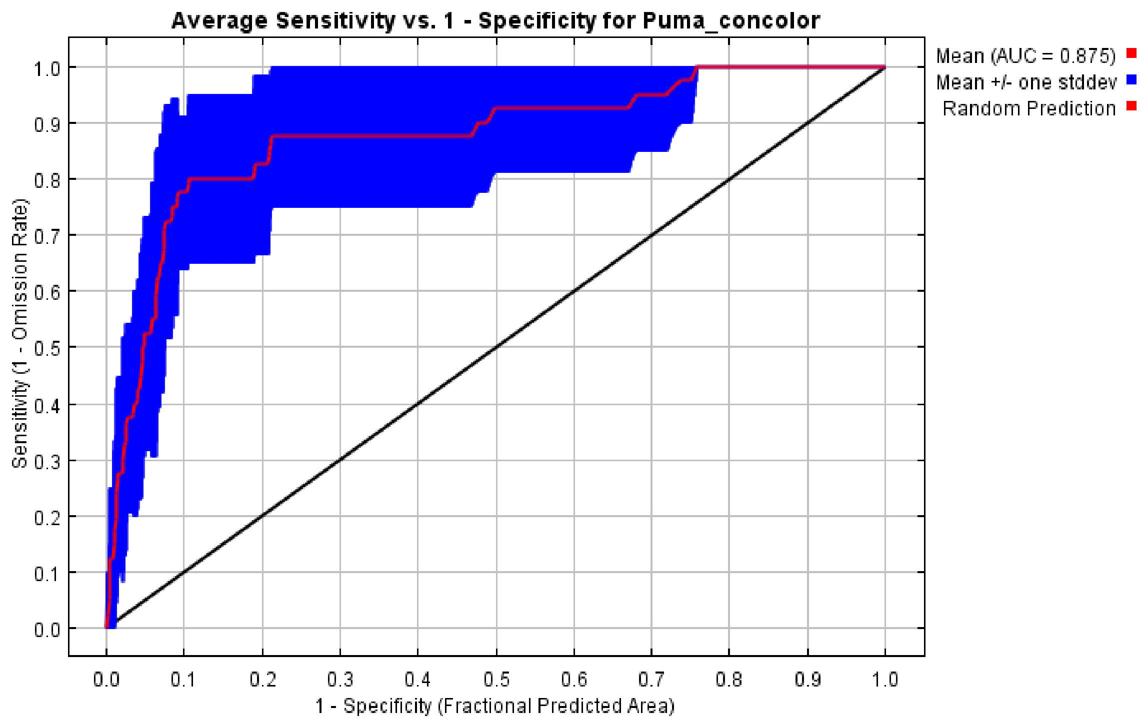

Figure 10. Specificity curve for the data of *Tremarctos ornatus.*

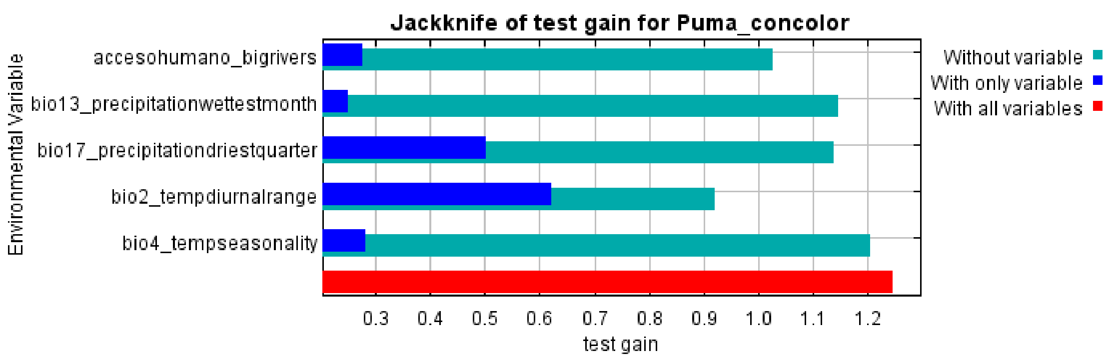

Figure 11. Test for the value of importance of the variables, employing the Jackknife method.

The variables of human access and bio 2 were the ones that contributed the most to the positive return derived from the model.

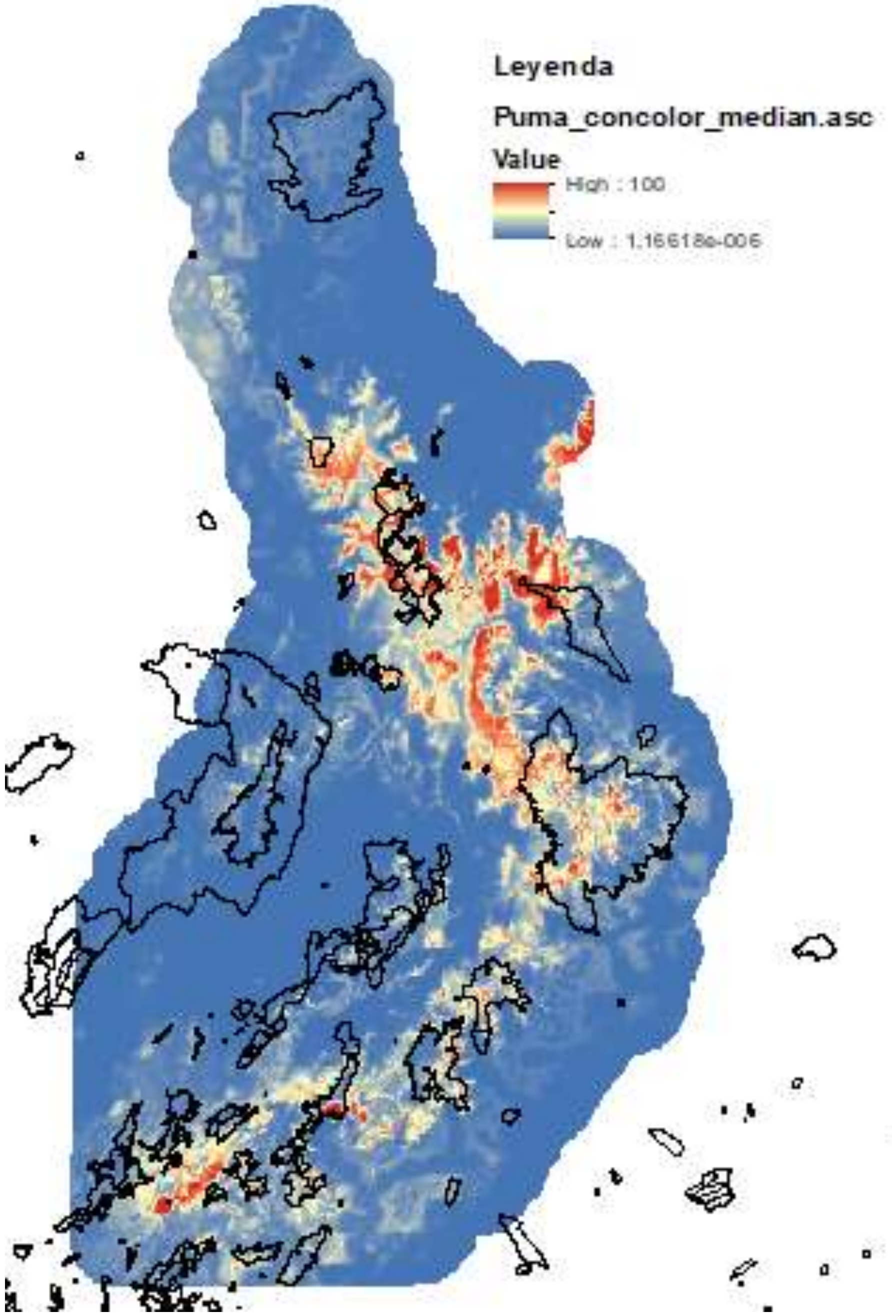

Figure 12. Distribution model (median) of *Puma concolor* in the study area. The more vibrant patches of red represent the most suitable habitats.

4. Results from camera-traps

Figure 13. Spectacled bear photographed in the FFS Guanenta Alto Río Fonce, in the department of Santander.

Figure 14. Spectacled bear photographed in the NNP Tamá, in the department of Norte de Santander.

Figure 15. Spectacled bear photographed in the NNP Pisba, in the department of Boyacá.

Figure 16. Spectacled bear photographed in the NNP El Cocuy, in the department of Boyacá.

5. Discussion

Variables such as ecosystems, biomes and vegetation coverings – aside from being explicative – they did not form part of the final model, since their geographical limit constrained the model. Meanwhile, the layers of fractionals, obtained from images from SENTINEL 2, through the Copernicus Global Land Service, had missing values that changed the result and thus, were removed.

The current distribution model of the spectacled bear from the UICN (Velez-Liendo & García-Rangel 2017), is quite fragmented and lacks information, we consider that this is the most complete and up to date model that is able to explain the distribution of the spectacled bear in the northern Andes region. On the other hand, the distribution model of the puma from the UICN (Nielsen et al. 2015), is overgeneralized. The first one can lead to complications due to the error type 2 (false negatives), excluding the populations of these areas from forming part of conservation programs. The second one, due to the presence of error type 1 (false positives), generalizes the distribution, overestimates the population and does not allow taking definite or specific actions for the conservation of the species.

The distribution model of *P. concolor* cannot be compared to that of the UICN, since the distribution of the puma according to Nielsen et al. (2017) covers up all of the Colombian territory, including the study area, cultivation zones, and even urban centres.

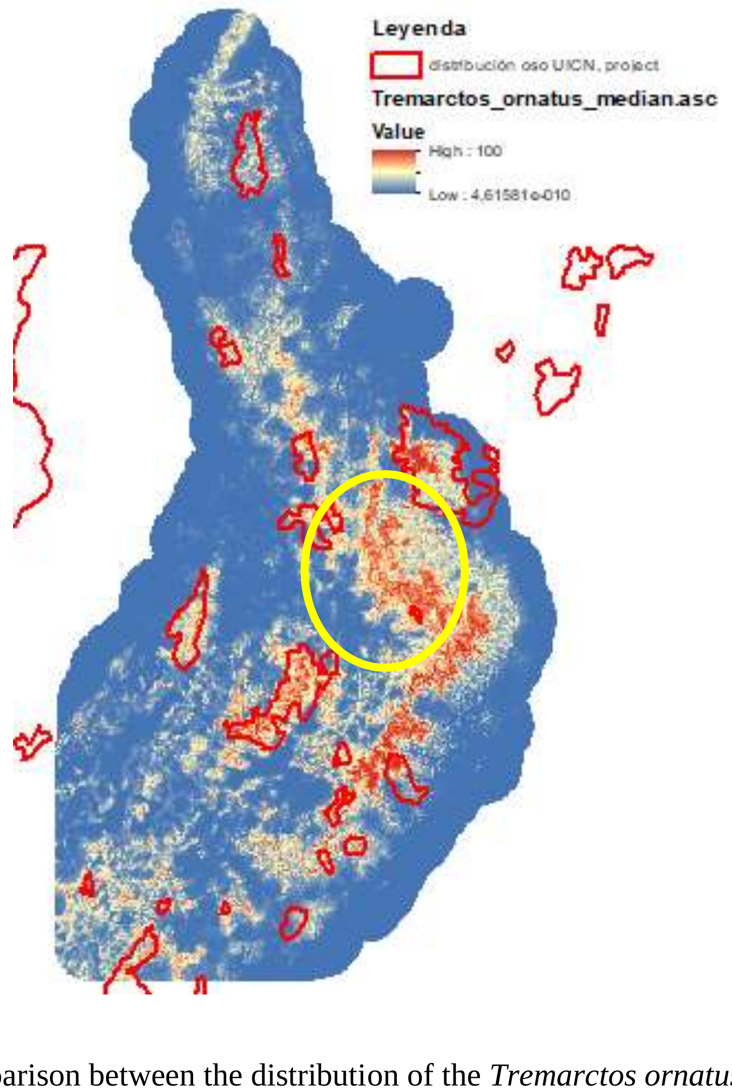

Figure 17. Comparison between the distribution of the *Tremarctos ornatus* proposed by the UICN and the model we suggest based on our analysis. The yellow polygons represent important areas that are not taken to be important parts of the distribution.

- Elaborate a connectivity model between the Natural National Parks Tamá-Cocuy-Pisba and the Fauna and Flora Sanctuary of Guanenta Alto Río Fonce, in the departments of Norte de Santander, Santander and Boyacá, using the spectacled bear (*Tremarctos ornatus*) and the puma (*Puma concolor*) as landscape species.

The final connectivity model shows that there is no existent connection between Tamá and Cocuy, and that the most important corridor for the conservation of the species is between Cocuy – the moorland of Chita – Pisba and the moorland of Siscunsí – Oceta, in the municipality of Mongua, Boyacá. While the FFS Guanenta appears to be isolated, the models look for suitable areas for the compound of moors of Sisavita – Pamplona, Mutiscua, Arboledas and Salazar de las Palmas, including the National Park La Serranía de los Yariguíes, and the Serranía del Perijá, taken to be important areas for the conservation of the meta-populations of the species, apparently isolated from the central mountain range of the country. The next step would be to identify priority areas of conservation that are not yet in any conservation scheme to maintain and augment the connectivity and/or conservation of said populations.

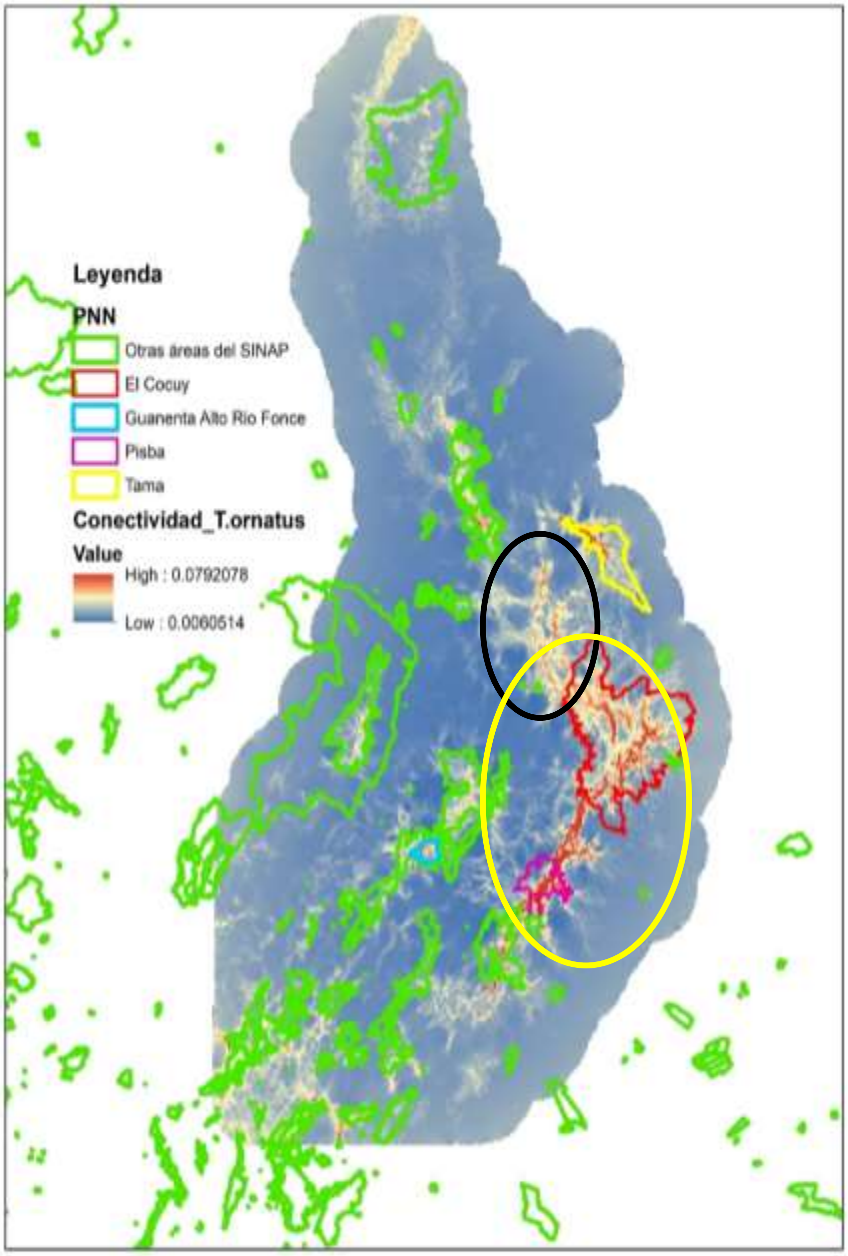

Figure 18. Model (median of the 8 connectivity models) of connectivity for *Tremarctos ornatus*.

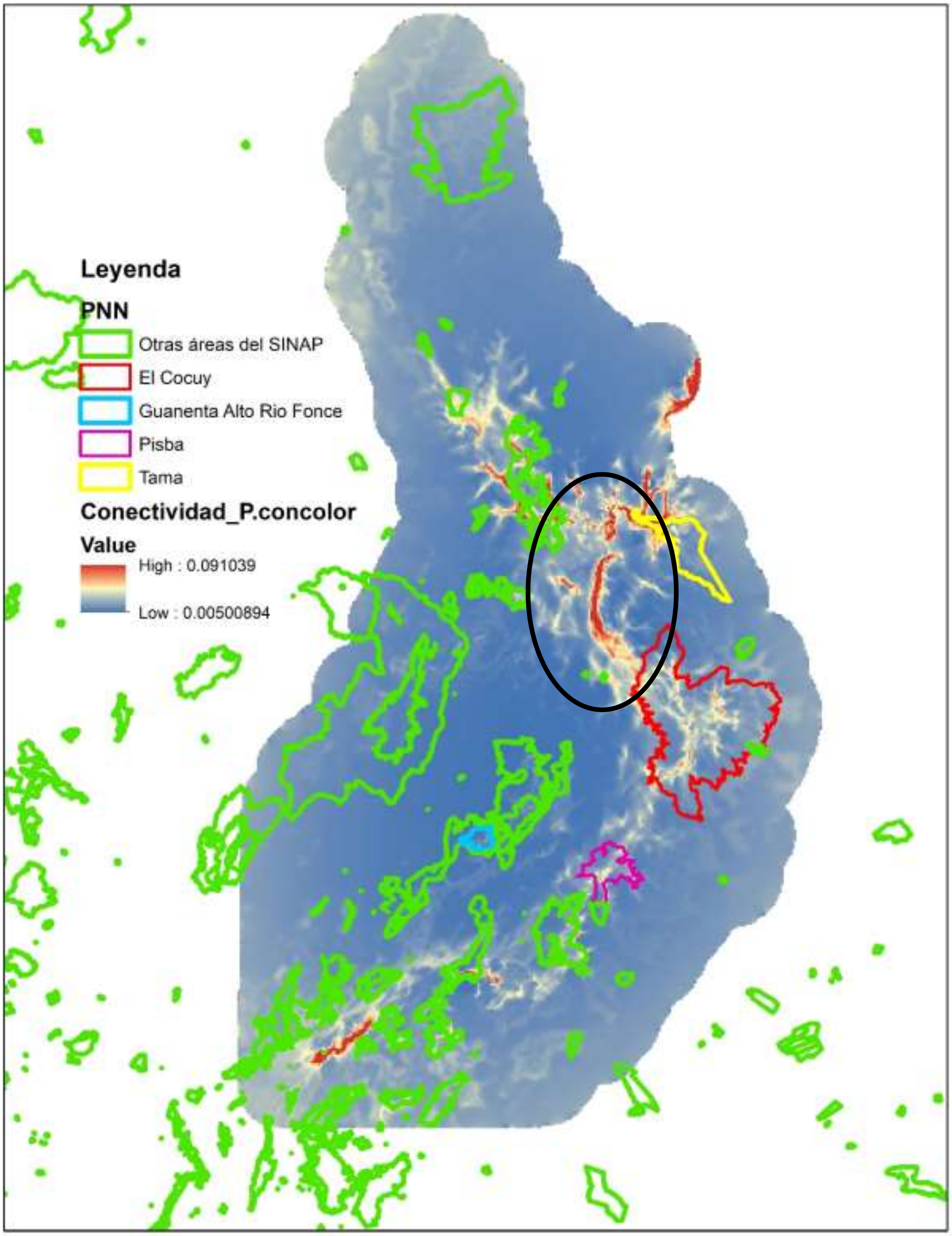

Figure 19. Model (median of the 8 connectivity models) of connectivity for *Puma concolor*. The black circle indicates important areas for the connectivity under no protection figure.

The yellow circle represents the most important corridor identified within the study area and the degree of connectivity.

The model of connectivity of *P. concolor* is much more fragmented than that of *T. ornatus*, demonstrating the low connectivity between Cocuy and Pisba and an absence of the species in the FFS Guanenta Alto Río Fonce, this being an important area for its conservation in the Macizo del Tamá, and in surrounding areas of the moor compound of Sisavita in the department of Norte de Santander, and an important range with a high current (probability of connectivity) in which there is no apparent conservation figure.

5. Conclusions

There is few scientific literature and published data for the two species object of study of this investigation. Thus, we believe this work will be a considerable contribution to the ecology, management and conservation of the target species and the ecosystems they inhabit, primarily in terms of their distribution, ecological connectivity and occupation, including the diversity of medium and large size associated mammals, due to the use of camera-traps.

The models of suitability showed a high value of AIC, conveying their capacity for prediction and, at the same time, demonstrating, in the case of *T. ornatus*, that there exists an important area for the conservation of the species in the compound Cocuy-Chita-Pisba and Mongua that is not considered as an area of potential distribution according to the UICN (Velez-Liendo & García-Rangel, S. 2017). Due to this, and supported in the results obtained from the camera-traps and the fieldwork, this work would be useful to promote the redefinition of these areas previously mentioned. Meanwhile, for the puma, the circumstances are different. The median of the 10 models demonstrate that the distribution is much less generalized and fragmented that what is shown by the UICN (Nielsen et al. 2015), and, with a large portion of it, outside of the PAs.

The information contained in the ecological connectivity models makes us consider that the populations of *T. ornatus* in the north-eastern Andes region are fragmented into various important sub-nuclei of conservation: Serranía del Perijá, Macizo del Tamá, compound Cocuy-Pisba, moorland Guantiva-La Rusia, and the NNP Serranía de los Yariguíes. This factor must be seen in the genetics of these populations, for which the possible isolation, the gradual loss of individuals, and of connectivity must be treated as an important item to be resolved for the populations of the north-eastern Andes in Colombia, taking into account that this is considered as one of the 5 most important nuclei in the country for the conservation of the spectacled bear. At the same time, it is possible that the populations of *P.concolor* are largely under threat, due to their absence in the 114 camera-traps installed during the last 8 months, as a consequence of hunting, and the loss of ecological connectivity between the areas, given that there exists an ample supply of prey and other carnivores in the area, e.g. *Leopardus* spp., *P. yagouaroundii*, *Cerdocyon thous* y *Urocyon cinereoargenteus*. Additionally, our results, reject the distribution of the species as proposed by Nielsen et al. (2015), for which we consider that a more detailed and adjusted analysis is necessary for every aspect of the species, with the aim of defining with greater precision the areas of distribution and, thus, the management and conservation courses of action. As a side note, a very important part of the biological corridor that could be delimited for the *P. concolor* is found between Tamá and Cocuy, and near the moorland of Rabanal in the limits between Boyacá and Cundinamarca, absent in the FFS Guanenta, Catatumbo and Serranía de los Mariguíes, and outside of the protected areas.

Finally, the occupation items of data obtained from the camera-traps will provide for the elaboration of a model of occupation spatially explicit, which would allow us to evaluate our following hypothesis: areas with a higher level of habitat suitability, and higher connectivity, are more likely to be occupied. This would also help to prioritize areas for conservation, by selecting specific parameters, such as: size of the patch, distance from the patch, perimeter of the patch, probability of occupation (using as a co-variable the degree of ecological connectivity) and thus, generate an input for management and planning processes for the Natural National Parks of Colombia and the Autonomous Regional Corporations.

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