Panthera Onca Corridors: A Spatially Explicit Analysis of Habitat Change Drivers and Potential Conservation Areas in the Bajo Magdalena, Colombia*

Correo electrónico: giselle.toro@urosario.edu.co

Coinvestigadora, Facultad de Ciencias Naturales y Matemáticas de la Universidad del Rosario, Bogotá Colombia.

Maria Paula Otero***
Correo electrónico: mariap.otero@urosario.edu.co

Docente de la Universidad del Rosario, Bogotá, Colombia. Correo electrónico: carlosh.valderrama@urosario.edu.co

Francisco Javier Escobedo*****
Correo electrónico: franciscoj.escobedo@urosario.edu.co

Received: June 25, 2020
Accepted: September 28, 2020

Cómo referenciar / How to cite
Toro-Garay, G. H.; Otero, M. P.; Valderrama-Ardila, C.; Escobedo, F. J. (2021). Panthera Onca Corridors: A Spatially Explicit Analysis of Habitat Change Drivers and Potential Conservation Areas in the Bajo Magdalena, Colombia. Trilogía Ciencia Tecnología Sociedad, v. 13, n. 24, 89-107. https://doi.org/10.22430/21457778.1641
Abstract: The distribution range of Jaguar (*Panthera onca*) is being reduced due to multi-scale habitat conversion, intensive hunting, illegal trafficking, habitat fragmentation, and the construction of highways and other infrastructure. Because of the decrease in population, this species’ listing has changed from vulnerable to a threatened category. Due to the ecological importance of this species, organizations like *Red Colombiana de Seguimiento de Fauna Atropellada* have proposed the establishment of wildlife corridors. But little is known as to recognize the driving forces in these habitat changes and where these corridors should be established. To address this lack of information, we determined the spatial extent to which the current distribution and access to *P. onca* habitat is being driven by deforestation, armed conflict, agriculture expansion, urbanization and the construction of highways in the Bajo Magdalena area of Colombia. We then identified potential areas for proposing conservation corridors. To do this, we used available geospatial information on *P. onca* distribution in the *Corporación Autónoma Regional* areas in the municipalities of Puerto Salgar, Caparrapí and Guaduas, as well as transportation network, administrative unit, and deforestation data from 2010 to 2018. We also calculated habitat distances to population centers and the distribution of *P. onca* relative to roads. Our findings suggest that urban population and highways affect 83% of the total area of its distribution; deforestation increased by 47.9 km$^2$ in the 105.24 km$^2$ study area with 5.6 km$^2$ alone left as *P. onca* habitat. We concluded that conservation initiatives must be implemented inside *P. onca*'s distributional range and buffer zones. Urbanization and the construction of highways were highly influential variables associated with the loss of *P. onca* habitat. Further, we propose that precautions along the principal road that connects Puerto Salgar and Guaduas should be taken into consideration to maintain the genetic flow and movement of the *P. onca* population as it affects 87 km of this proposed corridor.

**Keywords:** *Panthera onca*, highways, biological corridor, deforestation.
Resumen: el rango de distribución de Panthera onca se ha reducido debido a la transformación de hábitat a gran escala, caza intensiva, tráfico ilegal, fragmentación y la construcción de carreteras e infraestructuras. Como consecuencia, la población de jaguares ha disminuido, lo que ha generado que la especie haya cambiado de categoría vulnerable a especie amenazada. Debido a la importancia ecológica de esta especie, organizaciones como la Red Colombiana de Seguimiento de Fauna Atropellada han propuesto el establecimiento de corredores de vida silvestre. Pero se sabe poco sobre qué está impulsando estos cambios de hábitat y dónde deberían establecerse estos corredores. Para abordar esta falta de información, determinamos en un grado espacial la distribución actual y el acceso al hábitat de P. onca y evaluamos si estos factores están siendo impulsados por deforestación, conflicto armado, expansión agrícola, urbanización y construcción de carreteras en el área del Bajo Magdalena en Colombia. Con estos resultados identificamos áreas potenciales para proponer corredores de conservación. Para hacer esto, utilizamos la información geoespacial disponible sobre la distribución de P. onca en las áreas vigiladas por la Corporación Autónoma Regional en los municipios de Puerto Salgar, Caparrapí y Guaduas, así como la red de transporte, la unidad administrativa y los datos de deforestación de 2010 a 2018. También calculamos las distancias del hábitat a los centros donde se encuentra la población y la distribución de P. onca en relación con las carreteras. Nuestros hallazgos sugieren que la población urbana y las carreteras afectan el 83 % del área total de su distribución; la deforestación aumentó en 47.9 km² en el área de estudio de 105.24 km² con 5.6 km² solo en el hábitat de P. onca. Por tanto, concluimos que las iniciativas de conservación deben implementarse dentro del rango de distribución y las zonas de amortiguamiento de P. onca. En particular, la urbanización y la construcción de carreteras fueron variables muy influyentes asociadas con la pérdida del hábitat de P. onca. Además, se deben tomar en cuenta precauciones a lo largo de la carretera principal que conecta Puerto Salgar y Guaduas para mantener el flujo genético y el movimiento de la población de P. onca, ya que afecta a 87 km de este corredor propuesto.

Palabras clave: Panthera onca, carreteras, corredor biológico, deforestación.
INTRODUCCIÓN

Colombia es un país crítico para la conservación del jaguar debido a que es el puente intercontinental entre las piscinas genéticas mesoamericanas y sudamericanas, pero debido a la conversión del hábitat a gran escala, la caza intensiva, el tráfico ilegal, la fragmentación, la construcción de carreteras e infraestructura, los jaguares en Colombia se consideran una especie amenazada (Figel et al., 2019; Quigley et al., 2017). Los jaguares desempeñan un rol funcional en que mantienen la integridad y las funciones del ecosistema, por lo tanto, los esfuerzos de conservación son importantes, pero a pesar de los esfuerzos que se han realizado, sus poblaciones siguen disminuyendo (Boron et al., 2019).

Hay varios posibles factores detrás de este cambio. Las regiones tropicales tuvieron las tasas más altas de deforestación durante 2000-2012 que es resultado de varios factores complejos incluyendo conflictos humanos-conejos así como la pérdida de conectividad del paisaje (Figel et al., 2019). Esto es particularmente relevante para los jaguares ya que son el principal carnívoro terrestre en las Américas y usualmente se desplazan a través de hábitats de tierra baja con alta cantidad de vegetación tropical, bosques tropicales secos, manglares costeros, y prados herbáceos de tierra baja (Figel et al., 2019; Gese et al., 2018). Sin embargo, *Panthera onca* es uno de los depredadores menos adaptados a la fragmentación del hábitat. Este especie también tiene una fuerte asociación con los ríos y áreas de tierra húmeda, que proveen presas o refugio. A pesar de que los bosques no son el hábitat principal de los jaguares, sí los usan como corredor para moverse a lo largo de su territorio y conectar con otras poblaciones de jaguares (Castillo Martínez, 2016).

En los últimos años, la presión antropogénica ha aumentado y afecta la capacidad de los jaguares para conectar con otras poblaciones y encontrar presas. Según Figel et al., (2019), la cantidad de jaguares ha disminuido en el 54 % en su rango, que ahora abarca 18 países desde México hasta Argentina. Esta disminución indica que la capacidad de los jaguares para moverse y dispersarse debido a las paisajes humanizados es dificultosa a pesar de su adaptabilidad, debido a que los corredores forestales se han fragmentado, donde estos fragmentos contienen pequeñas, poblaciones aisladas (Haag et al., 2010; Figel et al., 2019; Gese et al., 2018; Payán et al., 2010). Los jaguares sin embargo requieren grandes áreas y si no, tienen bajos índices de reproducción y densidad, lo que los hace vulnerables a la extinción (Boron et al., 2018; Quigley et al., 2017).
Moreover, intensive hunting, illegal trafficking, habitat fragmentation, the construction of highways and infrastructure are also some of the biggest threats to jaguar habitat (Marchini & Macdonald, 2012). Even though studies of habitat loss and conservation of *P. onca* have been conducted to identify potential areas for conservation and educational activities within the urban and rural communities inside areas of the Sistema Nacional de Áreas Protegidas, SINAP (National System of Protected Areas), the geographical distribution of jaguars outside protected areas is still unknown (Boron et al., 2018; Petracca et al., 2014). Moreover, studies have not identified the exact areas of movement and their area, thus making it more difficult to understand habitat conditions and population distribution, frontiers, and parameters (Figel et al., 2019). Given all these changes and impacts to habitat, measures in these tropical regions must be taken in order to preserve and conserve the jaguar (Boron et al., 2018; Rabinowitz & Zeller, 2010).

However, the lack of information about jaguar distribution and poor landscape-level planning in Colombia can affect conservation strategies (Zárrate-Charry et al., 2018). Therefore the conservation of forested areas and wetlands (Boron et al., 2018) is key to better understand *P. onca* distribution, populations, corridors and how they overlap (Thornton et al., 2016). Furthermore, the fact that Colombia was at war for 50 years with guerrilla groups, means that some of the habitat areas have never or been little studied until 2016 (Zárrate-Charry et al., 2018; Boron et al., 2018; Boron et al., 2019). Due to the ecological importance of this species, organizations like Red Colombiana de Seguimiento de Fauna Atropellada (RECOSSA) have proposed the establishment of wildlife corridors. But again, little is known as to what is driving these changes and where corridors could be established. The overall objective of this study is to spatially analyze the extent to which the current distribution and access to *P. onca* habitat is being affected by different anthropogenic activities and if they are being driven by either deforestation, armed conflict, agriculture expansion, urbanization and the construction of highways in the Bajo Magdalena area of Colombia.
METHODOLOGY

Area of study

Colombia covers an area of 1.1 million km² (Castro-Nunez et al., 2017) and is a mega biodiversity hotspot that hosts a variety of ecosystem types such as forest ecosystems that covers about 52.20% of its area and 6% of the forest cover of Latin America. Colombia has different types of landscapes such as hills (35%), mountains (26%), valleys, and plains (20%) (Ramírez Delgado et al., 2018). Even though, this species can be found across the Amazonia, the Orinoquia, the biogeographic Chocó, the Caribbean, and the inter-Andean valley regions, which represent 33% of the country area, they are rarely found in the Andean region, but some isolated populations are present in in Yacopí, Puerto Salgar, Caparrapí and Guaduas, which correspond to Bajo Magdalena area, located at 5°25'42.1"N 74°34'45.6"W (Figure 1) (Castillo Martínez, 2016).

Figure 1. Study area

Source: Own elaboration.
Accordingly, we selected the Bajo Magdalena region as our study area because the population of jaguars is being affected by rapidly occurring anthropogenic changes such as small-large urban and rural areas, increasing human populations, agriculture activities, infrastructure developments, such as major roads and other drivers related to deforestation (Castillo Martínez, 2016). Moreover, *P. onca* population is decreasing in Bajo Magdalena due to many isolated populations that are still increasing (Castillo Martínez, 2016). Therefore, is important to establish corridors between these isolated populations to maintain the jaguar's corridor and the genetic drift between them by implementing conservation strategies.

As part of this analysis, we used information from the Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Departamento Administrativo Nacional de Estadística (DANE), and Instituto Nacional de Vías (Invías). We also estimated deforestation based on global coverage provided by Hansen et al., (2014). This data was used in vector format (. * Shp), and was reprojected to the MAGNA SIRGAS system-3116 (Table 1) to allow subsequent analyses. We used Qgis V.3.4 software to calculate the vector layers for the municipalities of Caparrapí, Puerto Salgar, and Guaduas, to determine the *P. onca* distribution in Bajo Magdalena, with this information we measured the total area.

| Variable type         | Variable Description                        | Year      | Unit   | Source                                      |
|-----------------------|--------------------------------------------|-----------|--------|---------------------------------------------|
| Municipality          | Municipalities of Colombia                 | 2018      | KM²    | Castillo Martínez, 2016                     |
| Deforestation         | Deforestation rates in Colombia            | 2003-2018 | KM²    | Hansen et al., 2014                         |
| Population            | Population density                         | 2015      | Number | DANE, 2018                                  |
| Jaguar Population     | Population density                         | 1957-2016 | Number | Castillo Martínez, 2016                     |
| Jaguar Distribution   | Area of distribution or movement           | 1957-2016 | KM²    | Castillo Martínez, 2016                     |
| Armed conflict        | Presence of armed groups in the area       | 2000-2020 | 1 presence and 0 absence                   | Prem et al., 2020 |
| Urban infrastructure  | Urban constructions, little towns          | 2019      | KM²    | DANE, 2018                                  |
| Roads                 | Maps of roads                              | 2019      | KM²    | (The National Institute of Roads)          |

**Table 1. Variables used for explaining jaguar distribution and area, and deforestation patterns**

**Source:** Own elaboration.
We analyzed the distance and distribution of the species using data from Table 1 and deforested areas adjacent to urban areas in the study area. Specifically, we studied 19 urban areas in Bajo Magdalena with an area of influence of 5 km, and we divided these areas into 5 buffer rings of 1 km each to determine the distance to the *P. onca* territory.

Additionally, we also estimated the deforested area within these populations, using raster data of forest cover change during the analysis periods of 2000 and 2018, with a pixel size of 27.88 m. Roads that were associated with each municipality and the concentric rings were also accounted for in order to calculate the total area affected by transportation infrastructure. Then, we determined the total area affected by the different drivers in the 5 rings.

Finally, we also calculated the impacts on the distribution of *P. onca* in the main and secondary pathways in the study area. We used a similar method to calculate the population of the jaguars based on rings of influence using the same patterns, between 1 and 5 km among roads. We found that the rings overlapped and intersected roads into segments. This analysis generated duplication of the data; thus, to avoid this we only counted the ring of influence closest to the distribution of *P. onca*. Finally, we developed a spatial correlation statistical analysis to identify the spatial relationship between the study areas and areas that affect the distribution of the *P. onca*. To explain this, we made a database with the number of jaguar populations, and then added the number of the studied population in areas that affect the distribution of the *P. onca* to maintain the equivalent unit as the municipalities. Besides, we also used this data to evaluate the effects of roads for jaguars, deforestation, and the area of *P. onca* distribution (GeoDa software).

**RESULTS**

The total area of the distribution of *P. onca* is in the three municipalities of interest were 43.77, 30.73, and 30.72 km² in the Caparrapí, Puerto Salgar, and Guaduas municipalities, respectively. It can be noted that the difference between these areas is small, given that they are an area of great influence and importance within the ecological corridor of *P. onca*. These areas in total represent 105.2 km².
Figure 2 shows *P. onca* distribution areas (white areas), and the five rings created around the populations and populated centers of the municipalities studied. As figure 2 shows, they are conflict zones along Bajo Magdalena, especially in the central and southern zones. Therefore, we found fewer jaguar populations in the north and it extends to the east. We can also evidence that only a small fragment of the distribution is not in contact with the human population because of their distance.

**Figure 2.** Areas of influence of populations and distribution areas

*Source:* Own elaboration.

*Note:* The orange circles represent the urban population, and the other colors 5 km concentric rings around the urban center. White fragments represent *P. onca* distribution area or corridor.

The total area of distribution within each analyzed ring is shown in Table 2. According to this, the urban settlements that have the highest influence areas for the jaguar distribution are Cambras, San Ramón Alto, and Guaduero, with more than 10 km² of distribution within the direct area of the population. These results show that even at distances up to 1 km² we can find a jaguar distribution area.
Besides, it was found that out of 12 urban populations studied, 7 occupy 72% of Bajo Magdalena, and affects the distribution area of *P. onca* in the 5 km buffer zones.

| Table 2. Intersected areas with the population |
|-----------------------------------------------|
| DISTANCE (KM²)                  | POPULATION |
|---------------------------------|------------|
|                                 | 1.00 | 2.00 | 3.00 | 4.00 | 5.00 | Total |
| CAMBRAS                         | 10.207 | 9.618 | 7.42 | 3.212 | 1.711 | 32.168 |
| CAMBULO                         | 6.177 | 4.619 | 1.744 | 1.349 | 0.104 | 13.993 |
| EL DINDAL                       | 0.988 | 3.835 | 5.77 | 1.336 | 0.407 | 12.336 |
| CAPARRAPÍ                       | 5.238 | 2.315 | 0.205 |      |      | 7.758 |
| SAN RAMÓN ALTO                  | 2.426 | 1.17 | 0.35 | 1.21 | 0.054 | 5.14 |
| LA PAZ DE CAL-AMOIMA            | 1.991 | 1.17 | 1.064 | 0.78 | 0.038 | 5.043 |
| SAN PEDRO                       | 2.172 | 0.531 | 0.875 | 0.467 | 0.031 | 4.076 |
| GUADUERO                        | 1.417 | 0.531 | 0.633 | 0.666 | 0.602 | 3.849 |
| GUADUAS                         | 0.434 | 0.651 | 0.602 | 0.265 |      | 1.952 |
| PUERTO BOGOTÁ                   | 1.179 | 0.362 |      |      |      | 1.541 |
| CÓRDOBA                         | 0.164 |      |      |      | 0.164 |      |
| TATI                            | 0.019 |      |      |      | 0.019 |      |
| **Total (general)**             | 32.393 | 24.732 | 18.663 | 9.304 | 2.947 | 88.039 |

Source: Own elaboration.

As Table 2 shows, out of 105 km² of jaguar distribution, 88 km² intersect within the 5km buffer zones. This means that 83% of the distribution area intersects the buffer areas.

Overall, we found a total of 47.9 km² of deforestation, where 5.6 km² are within the *P. onca* distribution area. However, this value is found in strategic areas for connectivity between jaguar populations.

Figure 3 shows the vector information used for the analysis of the influence of the roads, both local and inter-municipal, finding that 99.7 km² of the total are being affected by these, especially in connectivity between municipalities. Once the analysis was carried out, we found that the municipalities of Caparrapi and Guaduas have more prominent effects on *P. onca* distribution, with a 41.3 and 33.2 km² respectively. Besides, we noticed that the most troubled areas of jaguar distribution are 1-3 km² away within these municipalities, which suggests that
the roads are very close to *P. onca* population, which can explain the difficulty of jaguar interaction between two different populations due to fragmentation.

**Figure 3.** Spatial analysis from the influence of the roads

---

Table 3 shows the effects of *P. onca* distribution by ring and municipality within the intersection between roads and distribution areas of *P. onca*. As table 3 shows, 87.5 km² of the distribution area of the *P. onca* is affected by primary and secondary roads, which represents 83.1% of the total area of distribution of *P. onca*.

Table 3 shows the direct relationship among roads and their connectivity toward jaguar populations, which intersect 5 km of the total distribution area of the *P. onca* due to the spatial distribution and growth of the studied municipalities. Since these municipalities require connectivity between them, jaguar populations become isolated as a result of the construction of roads. Nonetheless, the impact, influence, and the type of road are different regarding *P. onca* distribution, and
habitat. The greatest impact among this is found in the highways or roads that connect the largest municipalities through national roads, other roads that connect urban areas and rural have a lower impact because some of them are unpaved, which allows the movement of *P. onca*, although the greater probability of being run over.

### Table 3. Intersected areas with the roads

| MUNICIPALITY     | 1.00  | 2.00  | 3.00  | 4.00  | 5.00  | Total  |
|------------------|-------|-------|-------|-------|-------|--------|
| CAPARRAPI        | 9.103 | 11.806| 13.047| 5.189 | 2.239 | 41.384 |
| GUADUAS          | 8.948 | 7.95  | 6.399 | 6.41  | 3.549 | 33.256 |
| PUERTO SALGAR    | 5.911 | 1.402 | 3.973 | 1.615 | 12.901 |
| TOTAL            | 23.962| 21.158| 19.446| 15.572| 7.403 | 87.541 |

**Source:** Own elaboration.

### Model

Table 4 shows the correlation between variables and that there is a positive relationship between the influence of jaguar populations and their distribution area in the 5 km studied, the highest values of influence on roads are between the 2 and 3 km rings, and at a greater distance, the correlation decreases.

### Table 4. Correlation between the variables studied and the area of distribution

| Variable                  | Correlation-area of distribution *P. onca* |
|----------------------------|------------------------------------------|
| Distribution area          | 1.00                                     |
| Deforestation              | 0.49                                     |
| Urban Population 1 km      | 0.95                                     |
| Urban Population 2 km      | 0.99                                     |
| Urban Population 3 km      | 1.00                                     |
| Urban Population 4 km      | 0.99                                     |
| Urban Population 5 km      | 0.95                                     |
| Roads 1 km                 | 0.54                                     |
| Roads 2 km                 | 0.78                                     |
| Roads 3 km                 | 0.87                                     |
| Roads 4 km                 | 0.00                                     |
| Roads 5 km                 | -0.20                                    |

**Source:** Own elaboration.
Then, we made a spatial statistics analysis with the Bivariant dwell index to determine the relationship within the variables, and the effects on their neighbors spatially. To do this we used the queen contiguity for the connectivity analysis in all directions. As Figure 4 shows, we made a map of significance to establish the relationship between a municipality and its neighboring municipalities to determine the variables that affect the distribution area of the jaguar in a ring of a kilometer. For 2 of the 3 municipalities studied, the low-high combination indicates that when the relationship in a municipality between the populations of the jaguar is low and the distribution area of the jaguar is high, its neighbors also have this relationship.

Figure 4. Maps connectivity and Moran index

Source: Own elaboration.

Note: a) Spatial connectivity of the Municipalities of Bajo Magdalena. b) Example of the Moran Bivariante Index between the distribution area and the population in the 1 km ring.

In the variables studied, there are no high-high spatial relationships, which means that the variables are not spatially related, and the distribution of *P. onca* is affected only by the variables already described, but they are not related in space. This spatial relationship is evident, despite being significant it has few observations, which can affect the result.
DISCUSSION

This study used spatially explicit analyses and available geospatial data to determine the spatial extent of *P. onca* habitat and how deforestation, armed conflict, agriculture expansion, urbanization and the construction of highways are affecting its habitat and distribution in the Bajo Magdalena area of Colombia. Our findings show that urbanization and the construction of highways were highly influential variables associated with the loss of the jaguar (*Panthera onca*) habitat, especially in the urban areas of Cambras, San Ramon Alto and Guaduero (Figure 2), which manifest an intersection with jaguars and the human settlements, which is common due to the highly transform areas (Zárrate-Charry et al., 2018). Thus, highways and different types of roads of Puerto Salgar, Caparrapi and Guaduas affect 87.7 km² of jaguar territory (Table 3). Even though jaguars intend to avoid human areas, due to landscape transformation this lack of interaction is impossible because forest and swamp areas become limited, which makes it easier to predict their connectivity with other jaguar populations and their closeness to human areas (Thornton et al., 2016; Zárrate-Chorry et al., 2018).

In addition, our results also show a correlation between variables and a positive relationship between the influence of jaguar populations and their distribution area in the 5 km studied around the urban areas (Table 4). This implies that measures need to be taken considering that habitat loss due to forest conversion such as roads and agriculture generate conflict between jaguar and humans by increasing disputes between them as a result of the reduction and difficulty of jaguar movement (Zárrate-Chorry et al., 2018, Benitez Gutiérrez, 2010; Thornton et al., 2016; Marchini & Macdonald, 2012). Through identifying the distribution area of *P. onca* we analyzed the landscape distribution between the municipalities of Bajo Magdalena. By doing this we established different categories that could influence jaguar distribution. We evaluated the presence of Natural Parks in the area, swamps, infrastructure projects (polyducts), railway, and the influence of inter-municipal buses.

As we evaluated, there is presence of jaguars in the SINAP Cuchilla de San Antonio, and there are isolated and difficult areas for jaguar to cross because of roads, infrastructure, and human settlements. Thus, we identify connections of forest areas within the riparian forest. For instance, we suggest that *P. onca* may be adapting to highly transformed areas by using them to move and avoid human
interaction (Pardo-Vargas & Payán-Garrido, 2015). As it is well known, jaguar distribution area is being affected by crops, infrastructure, and highways (Zárrate-Charry et al., 2018; Petracca et al., 2014), and their distribution and interaction with other members of the population is becoming difficult, generating isolation (Roques et al., 2016). However, there has been some evidence that the jaguar is adapting to some unconventional landscapes such as oil-palm crops (Figel et al., 2019; Pardo-Vargas & Payán-Garrido, 2015; Boron et al., 2016) and riparian forest to avoid total isolation among different jaguar populations.

Therefore, there are remote populations of jaguars in the Bajo Magdalena area, and as Figures 2 and 3 show, these areas might restrict jaguar distribution due to railways, highways and urban population in the area; yet there are some additional pressures, such as deforestation, that may restrict jaguar distribution and their fitness. Even though jaguars require a large territory, having limited access to their territory may affect the gene flow in isolated populations (Rabinowitz & Zeller, 2010). As our results in Figures 2 and 3 show, the geographic distance and the difficulty of access between populations due to habitat deterioration may cause a decline in the number of Jaguars per area (Roques et al., 2016).

Moreover, _P. onca_ is a nocturnal feline, which means that the movement and hunting take place mostly at night (Castillo Martínez, 2016). However, these roads and highways are currently used mostly in the daytime, which means they generate constant traffic noise. Thus, due to the behavior of this feline, it will not attempt to approach or travel on roads highly attended by humans, which affect jaguar habitat distribution, making the population more isolated (Roques et al., 2016). Adding to this fact, inter-municipal routes and some trucks travel with less regulation at night, which is the jaguar’s hour of mobility (Castillo Martínez, 2016). When not listening to sound, the probability that the jaguar is confident when crossing is greater, which settle them in a vulnerable position. Yet, land use and land-use change were also influential factors in the analysis. The transformation among dense forest and bush areas can change the distribution of _P. onca_ and how it relates to other jaguar populations. Infrastructure, transportation, and the human population makes them even more vulnerable. Despite the drivers of deforestation and the isolation of the jaguar population, we can establish some main factors and changes that can help preventing _P. onca_ population loss and avoid their isolation by establishing bushes and trees corridors, and palm oil crops so that they can move easily and in a larger area.
CONCLUSION

Landscape transformation and the change in land use are increasing the isolation of jaguar populations. Roads, agricultural expansion, and urban areas are some of the anticipated mechanisms of isolation among jaguars. However, due to these landscape changes, jaguars have developed a strategy by moving through highly transformed forests, mostly riparian forests, but we propose that precautions along the principal road that connects Puerto Salgar and Guaduas should be taken into consideration in order to maintain the genetic flow and movement of the *P. onca* population as it affects 87 km of this proposed corridor. Through using geospatial tools we can provide an insight into the different jaguar threat drivers by identifying conflict zones and the reasons for potential habitat loss, as well as the possibility of generating optimal ecological niche proposals and monitoring of proposed conservation plans. We concluded that conservation initiatives must be implemented inside jaguars’ distributional range and buffer zones. Finally, these analyses help to get an overview of various factors that can explain how indirect and direct factors may impact *P. onca* and its habitat, such as the change in land use and the change of area, that restricts the movement of the species.

REFERENCES

Benítez Gutiérrez, A. M. (2010). *Aproximaciones del hábitat potencial para jaguar (Panthera onca) en la Región Caribe colombiana* (Tesis de maestría). http://hdl.handle.net/11554/4515

Boron, V.; Deere, N. J.; Xofis, P.; Link, A.; Quiñones-Guerrero, A.; Payan, E.; Tzanopoulos, J. (2019). Richness, diversity, and factors influencing occupancy of mammal communities across human-modified landscapes in Colombia. *Biological conservation*, v. 232, 108-116. https://doi.org/10.1016/j.biocon.2019.01.030

Boron, V.; Tzanopoulos, J.; Gallo, J.; Barragan, J.; Jaimes-Rodriguez, L.; Schaller, G.; Payán, E. (2016). Jaguar Densities across Human-Dominated Landscapes in Colombia: The Contribution of Unprotected Areas to Long Term Conservation. *PloS One*, v. 11, n. 5, 1-14. https://doi.org/10.1371/journal.pone.0153973
Boron, V.; Xofis, P.; Link, A.; Payan, E.; Tzanopoulos, J. (2018). Conserving predators across agricultural landscapes in Colombia: habitat use and space partitioning by jaguars, pumas, ocelots and jaguarundis. *Oryx*, v. 54, n. 4, 554-563. https://doi.org/10.1017/S0030605318000327

Castillo Martínez, L. S. (2016). *Plan de conservación de los felinos silvestres del territorio CAR*. Corporación Autónoma Regional de Cundinamarca. http://hdl.handle.net/20.500.11786/35787

Castro-Nunez, A.; Mertz, O.; Sosa, C. C. (2017). Geographic overlaps between priority areas for forest carbon-storage efforts and those for delivering peacebuilding programs: implications for policy design. *Environmental Research Letters*, v. 12, n. 5, 1-11. http://doi.org/10.1088/1748-9326/aa6f20

Departamento Administrativo Nacional de Estadística. (2018). Marco Geoeconómico Nacional. https://geoportal.dane.gov.co/servicios/descarga-y-metadatos/descarga-mgn-marco-geoestadistico-nacional/

Figel, J. J.; Botero-Cañola, S.; Forero-Medina, G.; Sánchez-Londoño, J. D.; Valenzuela, L.; Noss, R. F. (2019). Wetlands are keystone habitats for jaguars in an intercontinental biodiversity hotspot. *PloS One*, v. 14, n. 9, 1-16. https://doi.org/10.1371/journal.pone.0221705

Gese, E. M.; Terletzky, P. A.; Cavalcanti, S. M. C.; Neale, C. M. U. (2018). Influence of behavioral state, sex, and season on resource selection by jaguars (*Panthera onca*): Always on the prowl? *Ecosphere*, v. 9, n. 7, 1-16. https://doi.org/10.1002/ecs2.2341

Haag, T.; Santos, A. S.; Sana, D. A.; Morato, R. G.; Cullen Jr, L.; Crawshaw Jr, P. G.; De Angelo, C.; Di Bitetti, M. S.; Salzano, F. M.; Eizirik, E. (2010). The effect of habitat fragmentation on the genetic structure of a top predator: loss of diversity and high differentiation among remnant populations of Atlantic Forest jaguars (*Panthera onca*). *Molecular Ecology*, v. 19, n. 22, 4906-4921. https://doi.org/10.1111/j.1365-294X.2010.04856.x

Hansen, M.; Potapov, P.; Margono, B.; Stehman, S.; Turubanova, S.; Tyukavina, A. (2014). Response to Comment on “High-resolution global maps of 21st-century forest cover change”. *Science*, v. 344, n. 6187, 981. https://doi.org/10.1126/science.1248817
Marchini, S.; Macdonald, D. W. (2012). Predicting ranchers’ intention to kill jaguars: Case studies in Amazonia and Pantanal. *Biological Conservation*, v. 147, n. 1, 213-221. https://doi.org/10.1016/j.biocon.2012.01.002

Pardo-Vargas, L. E.; Payán-Garrido, E. (2015). Mamíferos de un agropaisaje de palma de aceite en las sabanas inundables de Orocué, Casanare, Colombia. *Biota Colombiana*, v. 16, n. 1, 54-66. http://revistas.humboldt.org.co/index.php/biota/article/view/367

Payán, E.; Castaño-Uribe, C.; González-Maya, J. F.; Valderrama, C.; Ruiz-García, M.; Soto, C. (2010). Distribución y estado de conservación del jaguar en Colombia. En E. Payán Garrido; C. Castaño-Uribe (editores), *Grandes félinos de Colombia* (Vol. I, pp. 23-36). Panthera Colombia.

Petracca, L. S.; Hernández-Potosme, S.; Obando-Sampson, L.; Salom-Pérez, R.; Quigley, H.; Robinson, H. S. (2014). Agricultural encroachment and lack of enforcement threaten connectivity of range-wide jaguar (*Panthera onca*) corridor. *Journal for Nature Conservation*, v. 22, n. 5, 436-444. https://doi.org/10.1016/j.jnc.2014.04.002

Prem, M.; Saavedra, S.; Vargas, J. F. (2020). End-of-conflict deforestation: Evidence from Colombia’s peace agreement. *World Development*, v. 129, 1-11. https://doi.org/10.1016/j.worlddev.2019.104852

Quigley, H.; Foster, R.; Petracca, L.; Payan, E.; Salom, R.; Harmsen, B. (2017). *Panthera onca* (errata version published in 2018). *The IUCN Red List of Threatened Species 2017*: e.T15953A123791436. https://doi.org/10.2305/IUCN.UK.2017-3.RLTS.T15953A50658693.en

Rabinowitz, A.; Zeller, K. A. (2010). A range-wide model of landscape connectivity and conservation for the jaguar, *Panthera onca*. *Biological conservation*, v. 143, n. 4, 939-945. https://doi.org/10.1016/j.biocon.2010.01.002

Ramírez Delgado, J. P.; Galindo García, G.; Yepes Quintero, A. P.; Cabrera Montenegro, E. (2018). *Estimación de la degradación de bosques de Colombia a través de un análisis de fragmentación*. http://documentacion.ideam.gov.co/openbiblio/bvirtual/023784/023784.html

Roques, S.; Sollman, R.; Jácomo, A.; Tórres, N.; Silveira, L.; Chávez, C.; Keller, C.; Mello do Prado, D.; Carignano Torres, P.; Jorge dos Santos, C.; Bernardes García da Luz, X.; Magnusson, W. E.; Godoy, J. A.; Ceballos, G.; Palomares,
F. (2016). Effects of habitat deterioration on the population genetics and conservation of the jaguar. *Conservation genetics*, v. 17, n. 1, 125-139. https://doi.org/10.1007/s10592-015-0766-5

Thornton, D.; Zeller, K.; Rondinini, C.; Boitani, L.; Crooks, K.; Burdett, C.; Rabinowitz, A.; Quigley, H. (2016). Assessing the umbrella value of a range-wide conservation network for jaguars (*Panthera onca*). *Ecological Applications*, v. 26, n. 4, 1112-1124. https://doi.org/10.1890/15-0602

Zárrate-Charry, D. A.; Massey, A. L.; González-May, J. F.; Betts, M. G. (2018). Multi-criteria spatial identification of carnivore conservation areas under data scarcity and conflict: a jaguar case study in Sierra Nevada de Santa Marta, Colombia. *Biodiversity and Conservation*, v. 27, n. 13, 3373-3392. https://doi.org/10.1007/s10531-018-1605-z