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Research paper

Risk areas of illegal primate trafficking; estimating capture pressure and vulnerability

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Abstract

Risk areas of illegal primate trafficking; estimating capture pressure and vulnerability. We developed a model to identify and analyze the socioeconomic and spatial factors contributing to illegal primate capture in Mexico. The aim was to predict vulnerable sites and areas at significant capture pressure Focusing on primate species, we gathered data from each municipality where these species are found. Calculations showed that regions with higher socioeconomic status, such as Quintana Roo, are at highest capture pressure. We found that the most vulnerable sites were close to roads and urban settlements, and areas at risk of capture were identified as those harboring multiple primate species. These findings have significant implications for intelligence and surveillance strategies as understanding capture hotspots is crucial to mitigate indiscriminate captures and safeguard primate populations.

Key words: Capture, Pressure, Drivers, Primate trafficking, Vulnerability

Resumen

Zonas con riesgo de tráfico ilegal de primates; estimación de la presión de captura y la vulnerabilidad. Se elaboró un modelo para determinar y analizar los factores socioeconómicos y espaciales que contribuyen a la captura ilegal de primates, con el objetivo de predecir sitios vulnerables y zonas sometidas a una significante presión de captura. Centrándonos en México y sus especies de primates como caso de estudio, recopilamos datos sobre cada uno de los municipios donde se encuentran estas especies. A través de una serie de cálculos, determinamos que las regiones con un alto nivel socioeconómico, como Quintana Roo, experimentan la mayor presión de captura. Se encontró que los sitios vulnerables son los situados cerca de carreteras y asentamientos urbanos. Además, se observó que las zonas con riesgo de captura son las que albergan múltiples especies de primates. Estos hallazgos tienen implicaciones significativas para las estrategias de inteligencia y vigilancia, ya que comprender los sitios de riesgo de captura es crucial para mitigar las capturas indiscriminadas y proteger las poblaciones de primates.

Palabras clave: Captura, Presión, Elementos impulsores, Tráfico ilegal de primates, Vulnerabilidad

Introduction

Wildlife is declining rapidly as the direct consequences of human activities such as habitat destruction and wildlife crime, the trade and illegal possession of animals (Souviron-Priego 2019) andindirect consequences such as climate change and the expansion of urban and agricultural areas (Vergara-Tabares et al 2020). The illegal wildlife trade encompasses various stages, from capture and collection, to transportation, and subsequent marketing. Detecting and controlling these activities requires understanding of the economic, social, and geographical aspects on this trade of wildlife and poses serious challenges for the authorities involved (Brashares et al 2011, Mozer and Prost 2023). However, comprehensively understanding the economic, social, and geographical aspects underlying human dependence on wildlife, which supports this trade, poses challenges for authorities in detecting and controlling these activities (Brashares et al 2011, Mozer and Prost 2023). Efforts to control and reduce trafficking rely on national and international regulations and policies, and their effectiveness hinges on states' capabilities to enforce these laws. It has been documented that the increase in trafficking is attributed to low rates of detection, law enforcement, and prosecution (Challender and MacMillan 2014).

In Mexico, as in many other countries, wildlife trafficking poses significant challenges due to the lack of prioritization of environmental issues, limited allocation and scarcity of financial resources, and actions such as inspection operations and securing of protected specimens (Sosa-Escalante 2011). Such an approach is often reactive, in that interventions occur after the extraction has already taken place, resulting in irreversible environmental damage, declines in population numbers, or, in extreme cases, local or regional extinction of large animals (Symes et al 2018, Benítez-López et al 2019).

The extraction of wildlife is considered to be driven by both supply and demand. Therefore, reducing demand could effectively combat wildlife trafficking (McNamara et al 2015). Efforts to achieve this involve studying consumer behavior, motivation, values, beliefs, attitudes, and societal norms (McNamara et al 2015, Holden and Lockyer 2021). Strategies include actions aimed at persuading consumers not to purchase or consume wildlife products through campaigns (Thomas-Walters et al 2021). In combating wildlife trafficking, the dominant approach concerning supply focuses on restricting wildlife through trade bans, enforcement actions, and punitive measures against wildlife capture (Phelps et al 2014).

Individual decision-making regarding wildlife capture is determined by factors that vary over time, space, and individual preferences (Destro et al 2020). Factors driving wildlife capture globally include low economic income, subsistence needs, population expansion, cultural practices, and increasing demand in consumer cities (Harrison et al 2015, Rogan et al 2018). These socioeconomic and cultural factors determine the capture pressure that a species may face. Spatial factors also play a role, and influence the vulnerability of wildlife capture in their distribution areas, such as vegetation cover, the influence of protected areas, and accessibility to critical points such as roads and human settlements (Brashares et al 2011, Clements et al 2014, Santos and Araújo 2015).

Challender and MacMillan (2014) emphasize the importance of understanding supply/capture centers in order to to gain a deeper understanding of wildlife trafficking, although this is often challenging due to discrepancies between the seizure sites identified by authorities and the actual capture locations (Duffy et al 2016). Based on this knowledge, a model has been developed that selects hypotheses concerning the drivers of illegal capture on a global scale. This model includes socioeconomic factors that determine capture pressure and spatial factors that may influence vulnerability, aiming to identify areas at risk of capture within distribution sites. It is intended to be applied to different contexts and local species. To illustrate the model, Mexico and its primate species are used as a case study.

At a global level, one of the fauna groups significantly impacted by trafficking is primates (Nijman et al 2011). In Mexico, there are three primate species: the mantled howler monkey *Alouatta palliata mexicana*, the black howler monkey *Alouatta pigra*, and the spider monkey *Ateles geoffroyi*, all three of which inhabit the forest of southeastern Mexico (see fig. 1). However, these areas have been largely degraded, fragmented, and converted into agricultural and grazing lands (Estrada et al 2002). Historically, Mexican wild primates have been used mainly for the pet market, in traditional medicine, in entertainment, in zoos, and also as meat (Carvallo-Vargas 2002, Rodríguez-Luna et al 2009).

Applying the present model to various species may contribute to determining the origin of the trade chain risk sites, and could play a pivotal role prevention through actions such as awareness campaigns and scientific dissemination (Brashares et al 2004, Milner-Gulland and Bennett 2003). Furthermore, integrating this information into intelligence and surveillance strategies can maximize the economic resources allocated to combatting trafficking, contributing thereby to species conservation, as identifying capture sites contributes to reducing or eliminating indiscriminate captures from the supply side (Lawson and Vines 2014), thereby decreasing vulnerability to damage from extraction.

Methodology

Obtaining the information

We identified and selected the main factors facilitating the capture of wildlife globallythrough the scientific literature. We created a model that establishes two categories of driving factors based on their nature of application. The first category describes the social and economic factors that drive and promote capture, exerting pressure on the distribution sites of trafficked species. For example, economic factors determine the prevalence of wildlife capture. Similarly, population growth in areas near reserves or natural habitat can increase pressure due to greater demand for resources. The second category selected spatial factors that, when categorized, function as drivers of wildlife capture based on the characteristics of the space where the organisms subject to extraction reside. Some distribution sites are more vulnerable than others to the effects of capture due to their ecological or spatial characteristics. For example, areas with easy access due to roads or infrastructure are more vulnerable to wildlife capture (table 1). The combination of these factors applied to the distribution area of the three species of Mexican primates *(Alouatta pigra, Alouatta palliata*, and *Ateles geoffroyi)* allowed us to define 'Risk Areas', i.e., sites with the greatest pressure and vulnerability to capture.

The primate distribution maps were obtained from Enciclovida (Ceballos et al 2006) (https://enciclovida.mx) by conducting geoprocessing steps using ArcMap and QGIS software (Esri 2012, QGIS Development

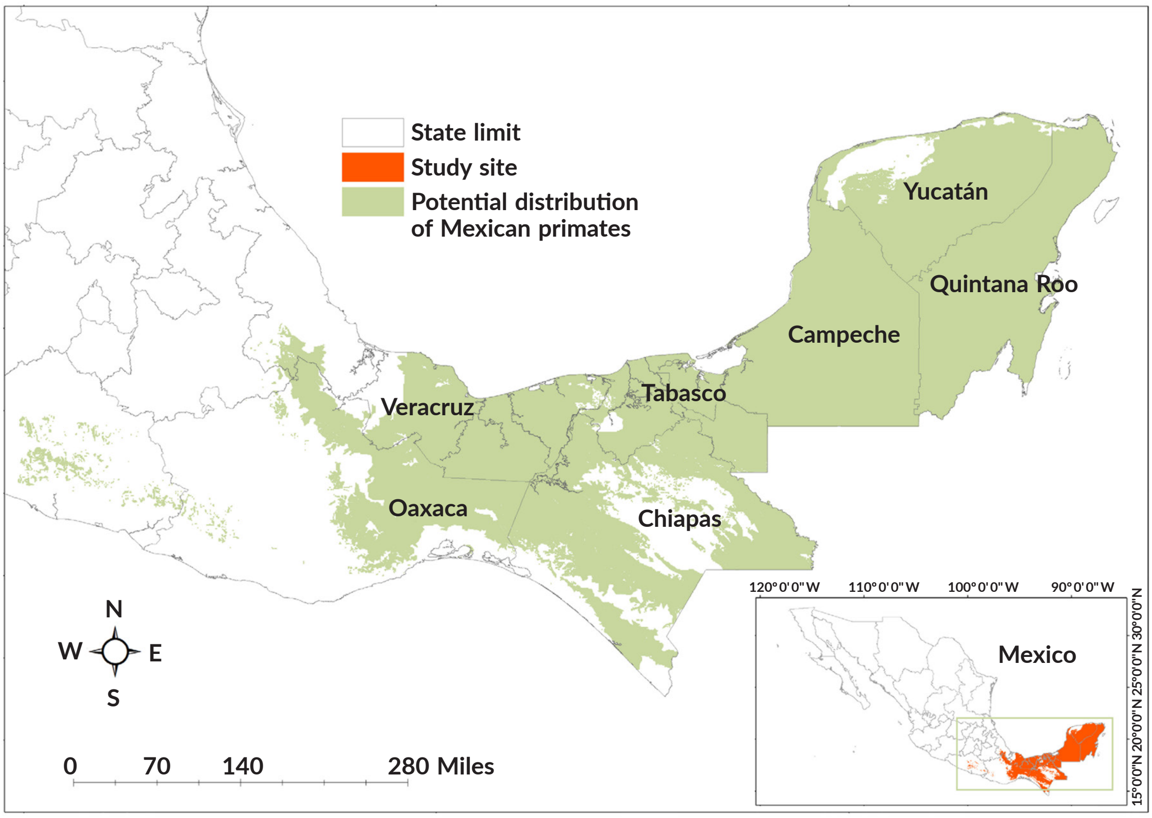

Fig. 1. The potential distribution area of the three species of primates in Mexico (*Ateles geoffroyi*, *Alouatta pigra*, *Alouatta palliata*) (own creation based on data from CONABIO and AMP, A.C.,)

***Fig. 1.** Área de distribución potencial de las tres especies de primates en México* (Ateles geoffroyi, Alouatta pigra, Alouatta palliata) *(creación propia basada en datos de CONABIO y AMP, A.C.)*

Team, 2009). Municipalities within each primate species' distribution range were then extracted. This allowed us to create a database containing the values of each pressure and vulnerability factor applied to each distribution municipality. The search for information on these values for the primate distribution municipalities proceeded as follows:

Drivers for capture pressure (socio-economic factors)

The Human Development Index and its components for 2020 were obtained from the United Nations Development Program (UNDP) website (https://www.undp.org/). These components include data on total population, total current income per capita, average years of schooling, expected years of schooling, health subindex (SS), education subindex (SE), and income subindex (SI). Information on population density was sourced from Data México (https://www.economia.gob.mx/datamexico/) and compared with the database of the '*Instituto Nacional de Estadística y Geografía*' (INEGI) (www.inegi.org.mx) to characterize the population density of the distribution points of each primate species.

Drivers for capture vulnerability (spatial factors)

Concerning geographical drivers, data on Protected Natural Areas in Mexico were obtained from the Geo portal of of the '*Comisión Nacional para el Conocimiento y Uso de la Biodiversidad*' (CONABIO) http://geoportal.conabio.gob.mx/ and in ArcMap those distribution points that are inside and outside ANPs were displayed. For the accessibility factor, data on human settlements located within the distribution municipalities were obtained through the Geospatial Information System of the National Agrarian Registry (RAN) https://datos.ran.gob.mx/ and Data on roads were obtained from the Communication Road Network of the Ministry of Communications and Transportation of CONABIO http://geoportal.conabio.gob.mx/. In table 1, the number four used the 'distance' factor as an independent variable to measure the distance between the distribution points and the nearest settlements and roads. For the habitat disturbance factor (number five), coverage maps and changes in land use and vegetation coverage from series VI were obtained through IDEFOR: Forest Spatial Data Infrastructure https://idefor.cnf.gob.mx/mviewer/ Vegetable Coverage.

Data analysis

After obtaining the values for each municipality where each primate species is distributed, we made a series

Table 1. A model that defines risk areas based on the factors that define the drivers of pressure and vulnerability of wildlife capture.

Tabla 1. *Modelo que determina las zonas de riesgo a partir de los factores que definen los elementos impulsores de la presión y vulnerabilidad de la captura de la fauna silvestre.*

Risk areas			
Drivers	Socioeconomic factors	Hypothesis	Authors
Capture pressure	Human development Index	Higher capture is expected to occur in regions with lower rates of human development.	(Santos and Araujo, 2015)
	Municipal population density	Higher capture is expected in more densely populated regions.	(Santos and Araújo, 2015)
Capture vulnerability	Protected natural areas	Higher capture is expected in less protected regions and sites close to protected areas with large human settlements.	(Destro et al. 2012)
	Accessibility	Higher capture is expected in sites close to access points such as roads and human settlements.	(Alves et al. 2013; Benítez-López et al. 2010; Clements et al. 2014; Brashares et al. 2011)
	Habitat disturbance	Higher capture is expected in regions with more vegetation cover, which is associated with greater availability of wildlife subject to extraction.	(Santos and Araújo, 2015; Robinson and Bennett, 2004)

of formulas to corroborate the predictions of the conjectures in table 1 in order to see the behavior of each factor in relation to capture pressure and vulnerability:

Capture pressure

$$PC_i=(POB_i/IDH_i)/PC_{max}$$

where PC_i is the city capture pressure i; IDH_i the city human development index i; POB_i the city population i; and PC_{max} the maximum CP value recorded within the evaluated cities.

Capture vulnerability

$$VC_i=((SEL_i+ASE_i+CAR_i)/ANP_i+0.000001))/VC_{max}$$

where VC_i is the city capture vulnerability i; SEL_i the percentage of forest cover in the city i; ASE_i the percentage of city settlements i; CAR_i the percentage of city roads i; ANP_i the percentage of coverage within Protected Natural Areas of the city i; and VC_{max} the maximum VC value recorded within the evaluated cities.

Capture risk areas

$$ArC_i=PC_i+VC_i$$

where PC_i is the city capture pressure i; VC_i the city capture vulnerability i; and ArC_i is the city capture risk areas i.

Once the values of the municipalities with the greatest pressure and vulnerability to capture for the three primate species were obtained we calculated the 'Risk Areas' values by adding the pressure and vulnerability values for each municipality and each primate species. Subsequently, we selected 10 municipalities with the highest values of each of the three variables. From these municipalities, we categorized areas of coincidence in the results; these municipalities tended to be repeated because they are more vulnerable and face greater pressure. They were assigned a repetition value (0, 1, 2); a value of 1 indicates positivity for a site with vulnerability or pressure, and a value of 2 indicates municipalities that present both vulnerability and pressure. Once the data were obtained, each dataset was segmented in QGIS to the municipalities of distribution of the three species of Mexican primates through layers, creating a heat map using the functions 'density' and 'kernel density', followed by a 'by mask' extraction to determine the relationship between the selected municipalities, which together are defined as 'sites' (vulnerable sites and sites with pressure). Our results were also validated with information on primate trafficking in these sites. Lastly, a correlation test was conducted in R Studio (R Studio 2020) for each primate species in order to to determine the relationship between vulnerable sites and sites with pressure.

Results

We identified 85 municipalities where primates are found, these being spread out over seven states in Mexico d; Campeche (n = 7), Chiapas (n = 17), Quintana Roo (n = 10), Tabasco (n = 9), Yucatan (n = 10), Oaxaca (n = 18) and Veracruz (n = 14).

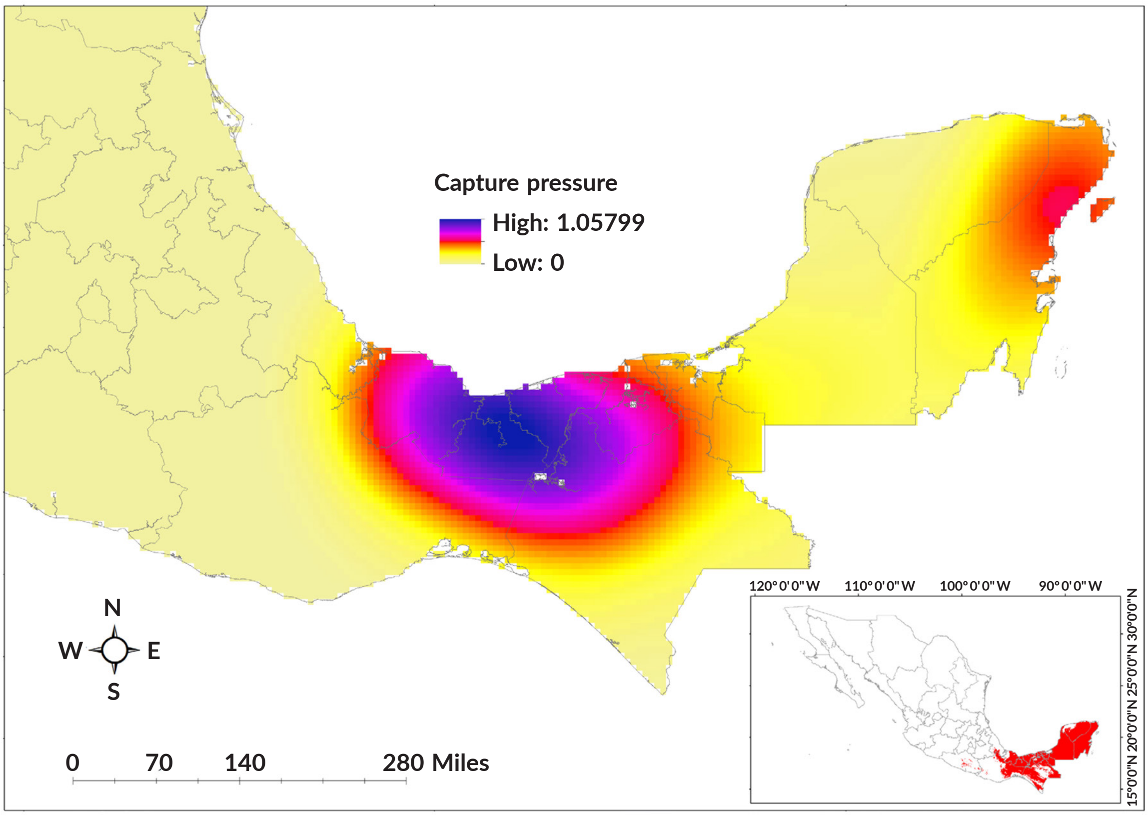

Fig. 2. Capture pressure for the three primate species in Mexico.

***Fig. 2.** Presión de captura de las tres especies de primates en México.*

Pressure

The pressure results from the formula for the three primate species range from 0.00151 to 1.10461 (mean_0.16978). The ten municipalities experiencing the greatest capture pressure for the three primate's species were located in the states of Veracruz (30 %, N = 3/10) followed by Chiapas, Quintana Roo, and Tabasco (20 %, N = 2/10), and Campeche (10 %, N = 1/10) (refer to table 1s). The municipalities with the highest pressure correspond to Quintana Roo, followed by Tabasco, Veracruz, and Chiapas (see fig. 2).

Pressure by primate species

The pressure results from the formula for the species *Ateles geoffroyi*, ranged from 0.001518 to 1 (mean_0.08656). The ten municipalities experiencing the greatest capture pressure were located in the states of Chiapas, Quintana Roo, and Veracruz (30 %, N = 3/10) and Campeche (10 %, N = 1/10), specifically, it is in the municipalities Benito Juárez (Quintana Roo), Tuxtla Gutiérrez (Chiapas), Solidaridad (Quintana Roo), Ocosingo (Chiapas), and Carmen (Campeche) where the spider monkey capture pressure is highest (fig. 1s).

Concerning the pressure results from the formula for the species *Alouatta palliata*, range from 0.03534 to 1 (mean_0.27577). The ten municipalities with the greatest capture pressure were located in the states of Veracruz (60 %, N = 6/10) and Tabasco (40 %, N = 4/10), specifically in the municipalities of Cárdenas (Tabasco), Huimanguillo (Tabasco), San Andrés Tuxtla (Veracruz), Minatitlán (Veracruz), and Cosoleacaque (Veracruz) (see fig. 2s in supplementary material).

In the case of *Alouatta pigra*, the range was 0.00525 to 1 (mean_0.10230). The ten municipalities with the greatest capture pressure were located in the states of Quintana Roo (40 %, N = 4/10), followed by Tabasco and Campeche (20 %, N = 2/10), and then Yucatán and Chiapas (10 %, N = 1/10), (refer to fig. 3s in supplementary material), specifically it is in the municipalities of Felipe Carrillo Puerto (Quintana Roo), Carmen (Campeche), and Tulum (Quintana Roo) where the capture pressure for this species is highest.

Vulnerability

The vulnerability results from the formula for the three primate species range from 0.00000000355263 to 2.99411 (mean_0.145820). Of the ten sites where vulnerability to capture is greatest for the three primate species, the municipalities of Oaxaca and Tabasco (30 %, N = 3/10) are highest, followed by Veracruz (20 %, N = 2/10) and Quintana Roo and Chiapas (10 %,

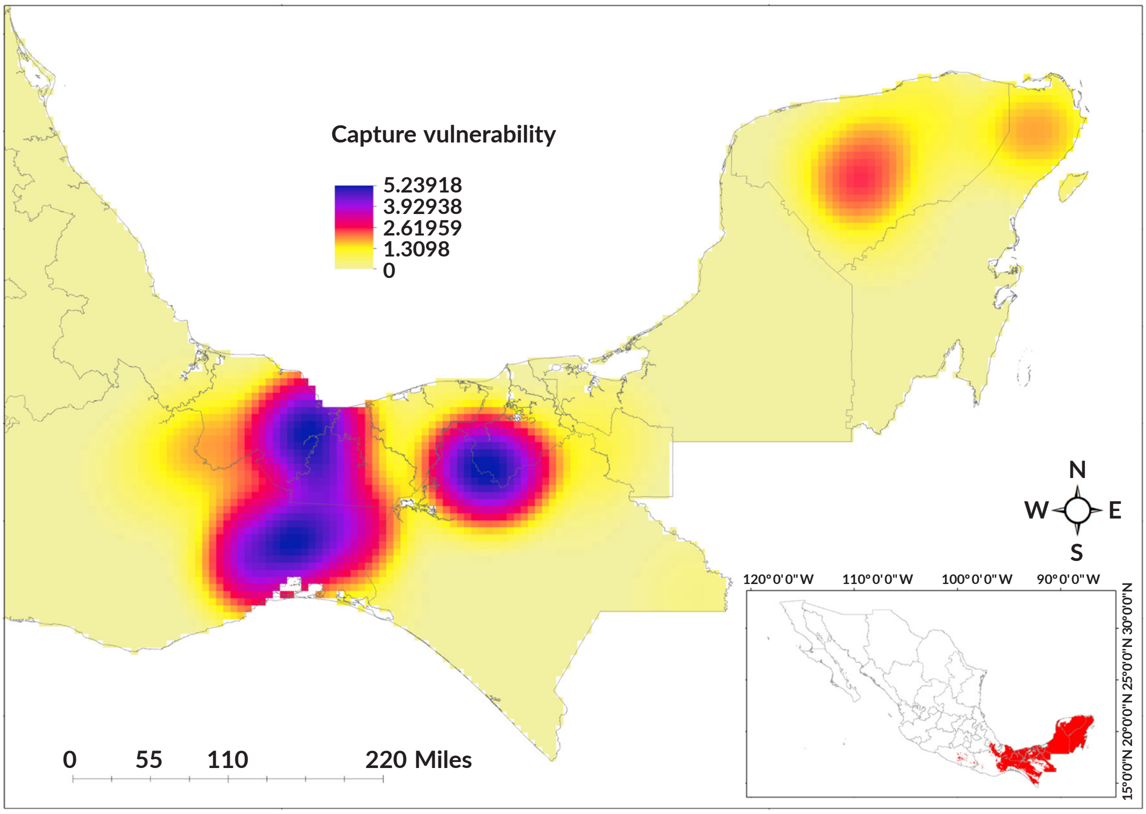

Fig. 3. Capture vulnerability for the three primate species in Mexico.

Fig. 3. *Vulnerabilidad a la captura de las tres especies de primates en México.*

N = 1/10) (fig. 3). However, the site with the greatest vulnerability according to the three hypotheses presented corresponds to Santa María Chimalapa (Oaxaca), Tacotalpa (Tabasco), and Cosoleacaque (Veracruz) (table 2s in supplementary material).

Vulnerability by primate species

The vulnerability results from the formula for *Ateles geoffroyi*, range from 0.000000002 to 1 (mean_0.20635). The ten municipalities undergoing the highest capture vulnerability were located in municipalities of the states of Oaxaca (40 %, N = 4/10), followed by Veracruz and Yucatán (20 %, N = 2/10), and Tabasco and Quintana Roo (10 %, N = 1/10) (fig. 4s in supplementary material), specifically taking into account the municipality of Santa María Mixtequilla (Oaxaca), Homún (Yucatán), and Ciudad Ixtepec (Oaxaca) as the municipalities with the greatest vulnerability to spider monkey capture. Regarding *Alouatta palliata*, its range is 0.0000098 to 2.39012 (mean_0.54). The ten municipalities with the greatest capture vulnerability were located in Tabasco (40 %, N = 4/10), followed by Veracruz (30 %, N = 3/10), Oaxaca (20 %, N = 2/10) and Chiapas (10 %, N = 1/10) (refer to fig. 5s in supplementary material). The vulnerability to capture for the species *Alouatta palliata* was highest in Santa María Chimalapa (Oaxaca), Cosoleacaque (Veracruz), Tacotalpa (Tabasco), Amatán (Chiapas), and Chinameca (Veracruz). For *Alouatta pigra* its range is 0.0000019 to 1 (mean_0.14489). The ten municipalities with greatest capture vulnerability were the municipalities in Yucatán (50 %, N = 5/10), followed by those in Tabasco and Chiapas (20 %, N = 2/10) and Quintana Roo (10 %, N = 1/10) (see fig. 6s in supplementary material). The vulnerability to capture for the *Alouatta pigra* species was highest in Puerto Morelos (Quintana Roo), Emiliano Zapata (Tabasco), Peto (Yucatán), Sotuta (Yucatán), and Tacotalpa (Tabasco).

Areas at risk of primate capture

Vulnerability and pressure generate risk areas for the three species of primates with the highest risk of capture, and correspond mostly to the municipalities of Tabasco (40 %, N = 4/10), followed by Veracruz and Quintana Roo (20 %, N = 2/10) and Oaxaca and Chiapas (10 %, N = 1/10) (fig. 4). The results of the risk area formula show a range of 0.002554696 to 3.05243 (mean_0.5159). The site with the greatest vulnerability, according to the three hypotheses presented, corresponds to Santa María Chimalapa (Oaxaca), Tacotalpa (Tabasco), and Cosoleacaque (Veracruz). In these risk areas, the presence of the three species is distributed as follows: *Alouatta palliata* 44.4 %, *Ateles geoffroyi*

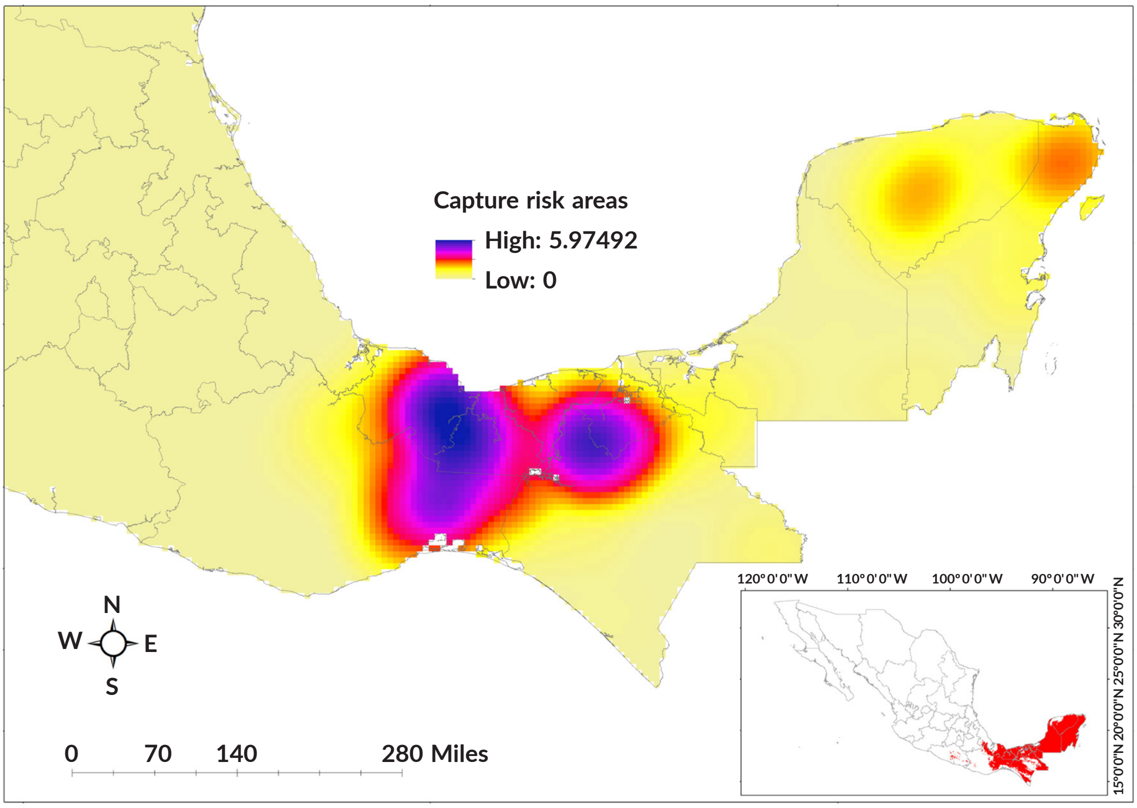

Fig. 4. Capture risk areas for the three primate species.

Fig. 4. *Áreas de riesgo de captura para las tres especies de primates.*

38.9 % and *Alouatta pigra* 16.7 % (table 2).

The municipalities with areas of coincidence correspond to Cosoleacaque (Veracruz), as it was identified as one of the sites with the greatest risk of pressure and vulnerability for both *Ateles geoffroyi* and *Alouatta palliata*. Similarly, Tacotalpa (Tabasco) emerged as a high-risk site for all three primate species, particularly for *Alouatta palliata*, showing both vulnerability and pressure (table 3).

According to the correlation tests (table 4), *Ateles geoffroyi* showed a moderate negative correlation between pressure and vulnerability (-0.28), indicating that as pressure on the species increases, vulnerability decreases. This could be due to the species' ability to evade capture in high-pressure areas. The value of 0.02 suggests that this relationship is statistically significant, making it reasonable to conclude that there is a real interaction between these variables. For *Alouatta palliata*, the relationship between pressure and vulnerability is almost negligible (-0.06), implying that there is no significant association between these variables. This species may not be differentially affected by capture pressure. The value of 0.7993 indicates that this relationship is not statistically significant, which confirms the lack of a strong association between pressure and vulnerability in this species. For *Alouatta pigra*, there is a slight negative correlation (-0.23), implying that as pressure increases, vulnerability tends to decrease, although this relationship is weak. Regarding the *P*-value of 0.2057, the relationship is not statistically significant, so it cannot be confidently stated that this correlation reflects a real pattern (see fig. 7s, 8s, and 9s in supplementary material).

Discussion

Pressure

The state with the highest capture pressure for the three species of primates is Quintana Roo, followed by Tabasco, Veracruz, and Chiapas. Quintana Roo encompasses the distribution area of *Ateles geoffroyi* and *A. pigra*. This region shows high levels of human population density and low levels of HDI. According to sociocultural documentation, it is a highly touristic area, currently experiencing significant demographic growth, estimated at 118.28 %, as the result of tourist-urban occupation (Pérez-Villegas and Carrascal 2000). Brashares et al (2011) mentioned that the threat to biological diversity in Africa is high and is attributed to the dense human population. Furthermore, this pressure may be exacerbated by sociocultural contexts

Table 2. Ten risk areas with the highest risk of capture for the three primate species.

Tabla 2. Las diez zonas de riesgo con mayor riesgo de captura para las tres especies de primates.

Municipality	State	Risk areas	Presence of species
Santa María Chimalapa	Oaxaca	3.05	*Ateles geoffroyi* y *Alouatta palliata*
Tacotalpa	Tabasco	2.46	*Alouatta pigra*, *Ateles geoffroyi* y *Alouatta palliata*
Cosoleacaque	Veracruz	2.35	*Ateles geoffroyi* y *Alouatta palliata*
Chinameca	Veracruz	1.7	*Ateles geoffroyi* y *Alouatta palliata*
Puerto Morelos	Quintana Roo	1.62	*Alouatta pigra* y *Ateles geoffroyi*
Cárdenas	Tabasco	1.6	*Alouatta palliata*
Teapa	Tabasco	1.49	*Ateles geoffroyi* y *Alouatta palliata*
Huimanguillo	Tabasco	1.44	*Alouatta palliata*
Amatán	Chiapas	1.12	*Alouatta palliata*
Felipe Carrillo Puerto	Quintana Roo	1.1	*Alouatta pigra* y *Ateles geoffroyi*

Table 3. Areas of coincidence of the three primate species for: 1, vulnerability or pressure; 2, vulnerability and pressure.

Tabla 3. Zonas de coincidencia de las tres especies de primates para: 1, la vulnerabilidad o la presión; 2, la vulnerabilidad y la presión.

Municipality	State	*Ateles geoffroyi*	*Alouatta palliata*	*Alouatta pigra*	Total
Santa María Chimalapa	Oaxaca	1	1	0	2
Puerto Morelos	Quintana Roo	1	0	1	2
Chinameca	Veracruz	1	1	0	2
Tabasco	Teapa	0	2	0	2
Huimanguillo	Tabasco	0	2	0	2
Juan Rodríguez Clara	Veracruz	0	2	0	2
Cárdenas	Tabasco	0	2	0	2
Tizimín	Yucatán	0	0	2	2
Campeche	Carmen	1	0	1	2
Palenque	Chiapas	1	0	1	2
Othón P. Blanco	Quintana Roo	1	0	1	2
Minatitlán	Veracruz	1	1	0	2
San Andrés Tuxtla	Veracruz	1	1	0	2
Tacotalpa	Tabasco	1	2	1	4
Cosoleacaque	Veracruz	2	2	0	4

wherein spider monkeys have been reported to have contact with people, seeking food through imprinting behaviors (Duarte-Quiroga and Estrada 2003). Instances have been documented where monkeys are present in hotels and exploited by entrepreneurs as tourist attractions, with visitors begin charged to touch them or or take photos with them, and illegal sale taking place on the streets (Orams 2002, Arroyo-Rodríguez et al 2017).

The species with the highest presence in the sites with the highest capture pressure align with the abundance of species in Mexico reported by Rodríguez-Luna et al (2009), where *Ateles geoffroyi* has the highest estimated number of individuals (~38,453), followed by *A. palliata* (~14,000), and finally *A. pigra* (~2,815).

In addition to empirical data on primate population trends, *Ateles geoffroyi* has been reported as one of the most valued groups at a nutritional level in different traditional Neotropical societies (Voss and Fleck 2011). In Mexico, its use as food and medicine has been reported (Carvallo-Vargas 2002) and, in some isolated cases, its use as bait for consumption, medicine, and/or shrimp fishing has been reported, although it is currently uncommon due to legal restrictions on

Table 4. Correlation tests for the species *Ateles geoffroyi*, *Alouatta palliata* and *Alouatta pigra*.

Tabla 4. Pruebas de correlación para las especies Ateles geoffroyi, Alouatta palliata *y* Alouatta pigra.

Species	Correlation (r)	*p*-value
Ateles geoffroyi	-0,28	0,02
Alouatta palliata	-0,06	0,7993
Alouatta pigra	-0,23	0,2057

hunting and the reduction of primate communities (Pinto-Marroquin et al 2021). Duarte-Quiroga and Estrada (2003) reported that the spider monkey was the most affected primate species in the pet market.

In the case of howler monkeys, although they are one of the most consumed species in the Neotropics (Urbani and Cormier 2015), in Mexico it has been documented that they are not usually kept as pets because they are considered difficult to tame since they are less docile and low flexibility in their diet than spider monkeys (Duarte-Quiroga and Estrada 2003, Pinto-Marroquin et al 2021), likewise, their lack of use as medicine and food could be related to difficulties handing them (Urbani and Cormier 2015).

Ateles geoffroyi has the first place in pressure in Quintana Roo, and the second place with the greatest pressure for this species is in Chiapas, specifically in the communities belonging to the municipality of Tuxtla Gutiérrez. Various seizures have been reported there, especially in recent years, leading local media to indicate that the capital functions as a bridge for illegal trafficking. The presence of transnational gangs trafficking in animals extracted from this area and from Guatemala has also been documented, serving as a corridor for traffickers of wild animals destined for illegal markets in the United States and Mexico (El Sol de Chiapas 2024, Infobae 2023).

The results regarding the areas of greatest pressure are related to the records obtained from Enciclovida (Ceballos et al 2006) concerning the distribution of the *Ateles geoffroyi* species. Spider monkeys predominate in Quintana Roo, representing 27.27 % of the total records, followed by Campeche (24.24 %), and then Tabasco (18.18 %). However, population density was not considered, which would undoubtedly provide key information to understand the impacts of trafficking in these sites. Rosa et al (2007) found that in Brazil, seahorse densities were lower in areas where they were traded, which reinforces the need to expand this type of study on drivers, taking into account population density factors.

The formulas combine the conjecture that in these places, there will be lower rates of human development, poverty/lower sources of income, and more densely populated areas. Although methodologically there is a contradiction in these two conjectures because the most populated places do not always correspond to sites with lower development rates, they are based on a global context that wildlife is the main source of meat and income for people in developing countries (Brashares et al 2011) with the potential for alternative livelihoods that depend more on the exploitation of biodiversity (Benítez-López et al 2019).

In the context of Mexico, it has been reported that the Mayans in this area consumed many species, including monkeys, for at least 1,500 years (Hamblin 1984). Currently, they are occasional prey, that is, they do not appear with the same frequency as other vertebrates (Urbani and Cormier 2015). The global drivers cannot always be adapted to local contexts, for example, Brashares et al (2004, 2011) mention how most household assets increase as household wealth grows, presenting an opposing hypothesis. This model does not aim to test the hypotheses presented, but rather, based on them, to identify these sites. However, despite the hypothesis presented regarding HDI and economic values, this study found that wealth, rather than poverty, was the main driving factor of capture, coinciding with a study from Brazil by Santos and Araujo (2015), where they show in their results that the highest incidence of human impact was located in more developed areas, where there is a low incidence of poverty and high HDI, supported by Destro et al (2012) who indicates that places with greater movement of financial funds have more illegal sales of wildlife and varies according to the species traded.

Vulnerability

The site with the highest capture vulnerability for the three primate species corresponds mostly (30 %) to the municipalities of Oaxaca and Tabasco, followed by Veracruz with 20 % and Quintana Roo and Chiapas (10 %). In this area of Oaxaca, *Alouatta palliata* and *Ateles geoffroyi* have been recorded despite the inaccessibility of the site (Briones-Salas and Sánchez-Cordero 2004). However, high levels of wildlife trafficking and deforestation are reported, causing the forest to become fragmented. In addition to these geographical characteristics that drive vulnerability, it has been documented in sociocultural contexts that in this area there is great capture pressure due to local people's beliefs of its medicinal properties (Pérez-García et al 2010). Other issues that reinforce the hypothesis of this site being one of the most vulnerable include the presence of solitary monkeys, as reported by local hunters, and the increase in accessibility to the monkeys' habitat due to new road constructions in the area, which could increase capture (Ortiz-Martínez and Rico-Gray 2007). The drivers that were selected in this study coincide with the results obtained because many roads and paths favor the capture of animals and poaching, making it is more convenient to transport animals in vehicles and market them in public markets, in addition to facilitating access and escape for poachers (Shepherd et al 2007, Alves et al 2013, Destro et al 2020).

It can be observed that for *Ateles geoffroyi* and *A. pigra*, Yucatán is a state with high vulnerability, even though the capture of these two species has become rare in the communities due to the cultural change in contemporary hunters (Santos-Fita et al 2012). However, the analyses suggest that infrastructure may have a negative impact on the abundance of primates. When analyzing the sites with the greatest vulnerability by species, it was found that the municipalities of Homún (Yucatán) for *Ateles geoffroyi*, Peto, and Sotuta for *A. pigra* present high densities of human settlements and connections of roads and highways, without areas of conserved forest that are protected natural areas. This coincides with the hypotheses of global contexts where Benítez-López et al (2010) mention that mammal population densities decrease due to their proximity to infrastructure, which could be related to the reduced visibility of infrastructure in forested areas.

Chiapas is a site that presents vulnerability for the species *A. pigra* and *A. palliata*. This latter species is in fourth place in the table of the ten most vulnerable sites, and *A. pigra* in Marqués de Comillas is in place seven, while in place eight is the municipality of Salto de Agua. The absence of vulnerability for the municipalities of Chiapas in *Ateles geoffroyi* could once again have a relationship with the distribution records of this species, However, there are media reports where monkeys were found in overcrowded conditions inside plastic boxes on buses bound for Tabasco, so the figures do not contemplate this type of demand contexts where spider monkeys may also be being extracted from these sites, as documented in the gray literature.

Cosoleacaque is a municipality in Veracruz that presents high levels of vulnerability, and its analysis coincides with the hypothesis that capture levels will be higher in sites close to protected areas with large human settlements. However, it is necessary to know the current context of the sociocultural drivers that could influence this as these sites and their surroundings have not generated sufficient information on primate uses inside and outside protected areas. Newspaper records establish that the protected natural areas of Veracruz, Chiapas, and Oaxaca are classified as some of the most dangerous and have been exposed to problems derived from drug trafficking (Alvarado et al 2017). This is important and should be considered within all aspects that could relate the nature of a global hypothesis to a local context, and also to an open window to evaluate this issue within the perspective of safety and conservation for certain species that are distributed in these areas, including primates. However, in other contexts, it has been documented that 'Illegal hunting has decreased due to the presence of these criminal groups in the area' (Carpio-Domínguez 2021).

Capture risk areas

Of the ten sites where there is the greatest pressure and vulnerability to capture for the three species of primates, the majority (40 %) correspond to the municipalities of Tabasco, followed by Veracruz and Quintana Roo with 20 %, and Chiapas and Oaxaca (10 %). It has been observed that the municipalities with the largest area of coincidence correspond to Cosoleacaque (Veracruz), since for *Ateles geoffroyi* and *Alouatta palliata*, it was one of the sites that turned out to have the greatest risk of pressure and vulnerability. Likewise, Tacotalpa (Tabasco) was shown to be a site with a higher risk of capture for all three species of primates, and specifically for *Alouatta palliata*, it showed vulnerability and, in turn, risk of pressure for the capture of primates.

In Tabasco and Veracruz, vulnerability and pressure reside in an area of coincidence. According to several authors, *A. pigra* and *A. palliata* share a distribution zone in limited areas within southern Tabasco, Veracruz, and southern Campeche, as well as at the limits of their distributions in Chiapas and Tabasco (Baumgarten and Williamson 2007). Likewise, the municipality of Santa María Chimalapa in Oaxaca represents the highest levels of vulnerability, and due to its high numbers, it also represents an area of capture risk for the three primate species.

This latter analysis shows a scenario that intensifies with the combination of drivers and the presence of more than one species, coinciding with Abernethy et al (2013), who mention that sites also become more vulnerable to fragmentation and loss of forest cover, resulting in an intensification of catches and consequently increasing in the rate of ecological change. According to the correlation tests, the *Alouatta* species do not show a positive relationship between pressure and vulnerability, which could suggest that ecological factors protect them from being captured even under pressure from socio-ecological factors. Sites with less pressure could be related to more vulnerable habitats or those less accessible to traffickers, which seems especially relevant for *Ateles geoffroyi*. A pattern can be observed in the results since the spider monkey is also usually more vulnerable in places where there is less vegetation, which may have a relationship with what has been reported about howler monkeys, as they can be found in forest fragments and in disturbed habitat, although success depends at least in part on the pressures of hunting (Estrada et al 2002; Muñoz et al 2006). Like other *Alouatta* species, *A. pigra* can be found in fragmented and disturbed forests (Estrada et al 2002, Shepston 2007). The results highlight the role that disturbed landscapes play in extraction, agreeing with various authors who mention that the lowest trade volumes originated in undisturbed sites (Demmer and Overman 2001, McNamara et al 2015).

The results also reinforce the hypothesis of Destro et al (2020) who demonstrated, on a large scale, that spatial factors, not socioeconomic factors, were the most important drivers of illegal bird harvests. This driver methodology shows us that establishing global drivers to a local context will not always support conjectures. When reinforced or otherwise refuted, it must be seen in light of the information from sociocultural contexts and historical records to establish a better discussion of the findings.

For example, the results on pressure mention Quintana Roo, while vulnerability has little representation. However, it is important to pay attention to all sites with high levels of capture vulnerability because Quintana Roo has witnessed notable development of tourism, leading to require the loss of more than 12,700 ha of semi-evergreen forest to establish infrastructure for hotel supply, as well as roads, housing, and tourist facilities (Pérez-Villegas and Carrascal 2000), which could also be placed in a vulnerable area. In Quintana Roo, contrary to what could be expected regarding pressure, the high presence of protected natural areas can be observed. Although the findings could suggest that protected areas are safe from exploitation, it is said that the greater the concentration of ANP the greater the illegal capture due to a greater supply of specimens compared to unprotected sites, revealing a possible fragility of federal authorities (Destro et al 2020). Under scenarios of increased human settlement and access to forests, along with population growth, captures of primates in southern Mexico are expected to increase in the short term. Analyzing these sites individually for each driver shows observe that the risk areas are sites devoid of vegetation. This coincides with some authors who report that the main anthropogenic pressures for primates are changes in soil cover and the expansion of road networks (Estrada et al 2019), these changes acting in synergy with all drivers.

Based on the combination of factors that drive capture pressure and vulnerability, our results show us the complex and highly variable correlation between economy, geography, politics, and culture, coinciding with Brashares et al (2011) and Abernethy et al (2013) who mentions that wildlife consumption is immersed in a network of dynamic and interactive factors whose variability impedes efforts to identify a unifying theory for wildlife use. This model highlights global factors which, in combination, can be adapted to a national context to identify areas at higher risk of capture and may have various implications and applications. By including spatial factors such as road accessibility and proximity to human settlements, the predictive capacity in areas where illegal capture is likely to occur would be strengthened, enabling the creation of strategies to improve the authorities' ability to allocate surveillance and prevention resources more efficiently. Likewise, socioeconomic factors allow for the assessment of whether communities are subject to being provided with economic alternatives to reduce their dependence on wildlife trafficking. This model is a first step in isolating the causes and establishing a solution based on the driving factor. For instance, conservation programs can be developed to target communities near high-risk areas through education and the strengthening of management capacities in protected areas.

Under a scenario of illegality, the isolated hypotheses selected in this model have the advantage of predicting capture areas. However, in this methodology, the hypotheses are not directly tested they do not include methods to measure high and low capture rates. The method proposes the integration of socioeconomic and spatial factors, offering a more holistic view that considers their interaction to improve the identification of capture areas. The use of a simple formula, compared to methods that do not take this combination into account and that use complex modeling, can be applied with an approach adaptable to specific local contexts, and could be generalized to other species and locations, adjusting the variables to each country and species distribution.

Likewise, by applying this novel methodology to other threatened species and getting experts from all the groups of most trafficked organisms to collaborate with decision-makers, intelligence work can be developed to support trafficking efforts despite limited resources. Finally, outreach efforts in the sites of greatest pressure and vulnerability could be a measure to counteract perceptions about primate extraction from the point of view of prevention, from the perspective of community-based conservation involving the local populations (Norconk et al 2020).

Finally, considering that the species face different levels of threat and show varying results in terms of pressure and vulnerability, some conservation strategies are proposed based on the results. For *Ateles geoffroyi*, since there is a significant relationship between pressure and vulnerability, it would be prudent to actively monitor areas of high pressure. These areas, which may have characteristics that facilitate evasion from capture, h could be leveraged by protecting these habitats. Additionally, surveillance in low-pressure areas should be implemented to reduce vulnerability, as they could become critical points for trafficking if preventive measures are not taken.

For *Alouatta palliata*, the absence of a significant relationship suggests that the species might be less affected by direct capture pressure. Therefore, strategies should focus on habitat protection, as any significant alteration could increase its vulnerability. For *Alouatta pigra*, although there is no significant correlation, it is important to monitor low-pressure areas where capture risks may increase as high-pressure areas become saturated. The creation of protected natural areas could help reduce vulnerability in regions where there is human pressure or habitat fragmentation.

It has been suggested to expand the model and delve deeper, to include cultural factors that identify which factors predominantly influence capture and assess their interaction in future strategies. Likewise, increasing the understanding of the changing contexts at each site can enhance the specificity needed to design more targeted and specific conservation policies, considering the perception of primates, traditions, and economic contexts of the sites beyond the numbers. If exotic pet ownership is rooted in traditional cultural attitudes, then understanding the origin of the tradition may be useful in providing explanations that discourage this and help identify those factors that are most influential in illegal captures, according to the species (Norconk et al 2020).

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Author contributions
Zaira Esparza-Rodríguez wrote the first draft of the manuscript. **Wesley Dáttilo** performed a portion of the statistical analysis, and all authors contributed to writing and revising earlier manuscript versions. All authors read and approved the final manuscript.

Conflicts of interest
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Supplementary material

This supplementary information has not been peer reviewed.

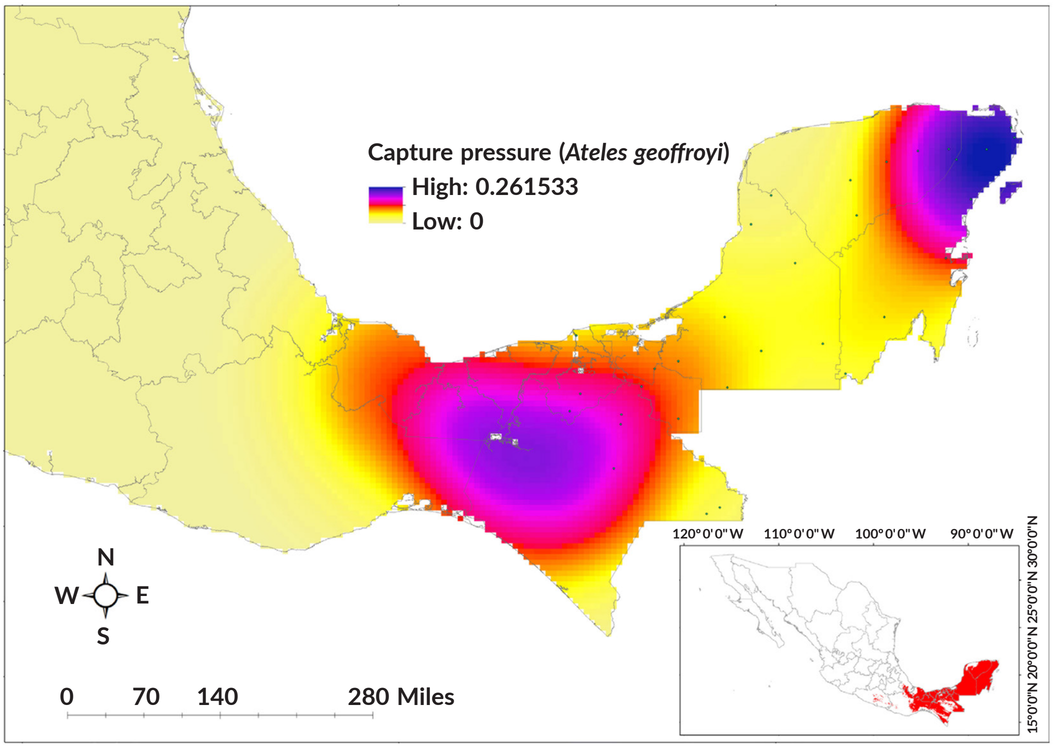

Fig. 1s. Areas of greatest capture pressure for the species *Ateles geoffroyi*.

Fig. 1s. *Zonas de mayor presión de captura para la especie* Ateles geoffroyi.

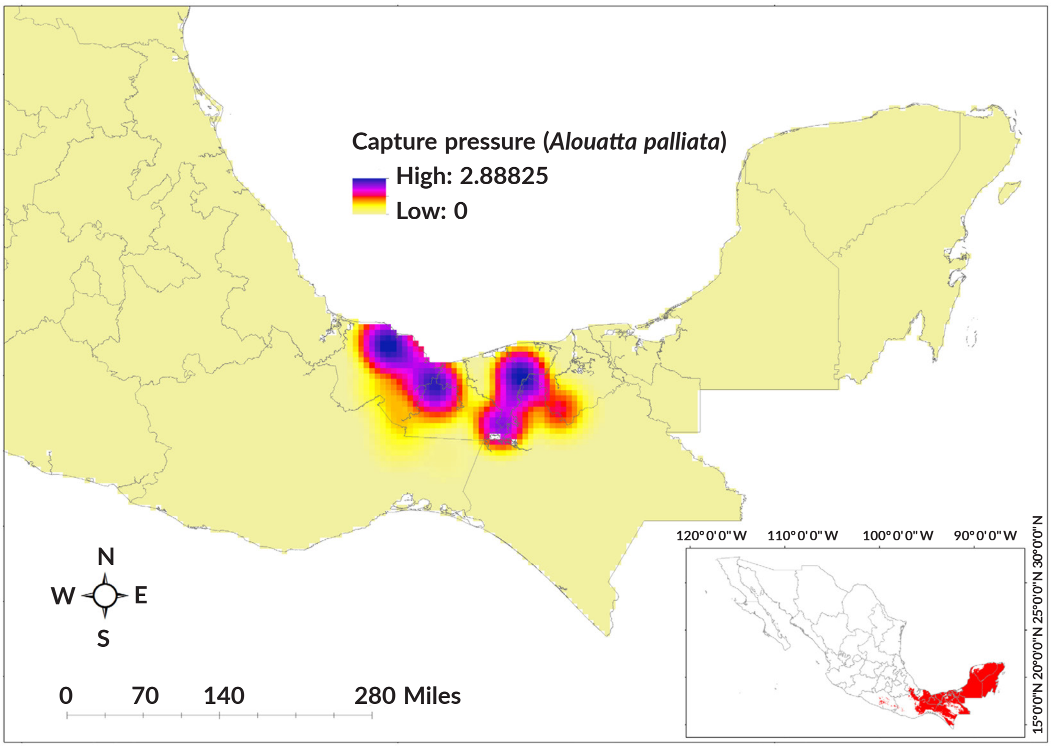

Fig. 2s. Areas of greatest capture pressure for the species *Alouatta palliata*.

Fig. 2s. *Zonas de mayor presión de captura para la especie* Alouatta palliata.

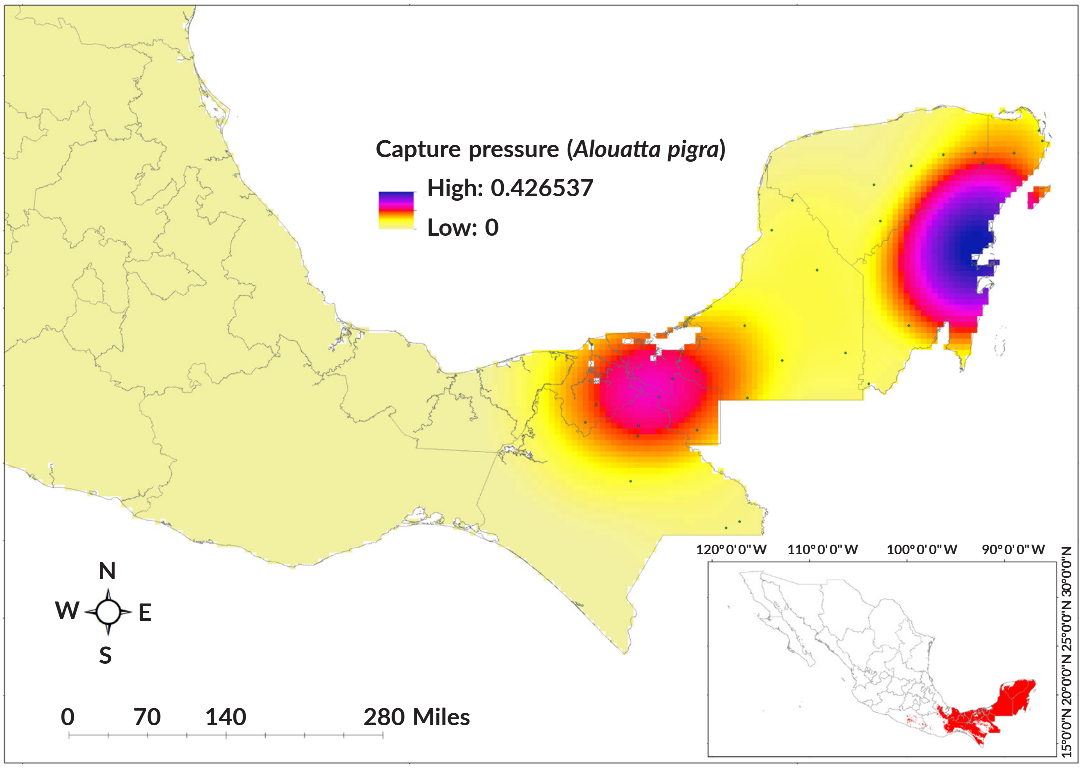

Fig. 3s. Areas of greatest capture pressure for the species *Alouatta pigra*.

Fig. 3s. *Zonas de mayor presión de captura para la especie* Alouatta pigra.

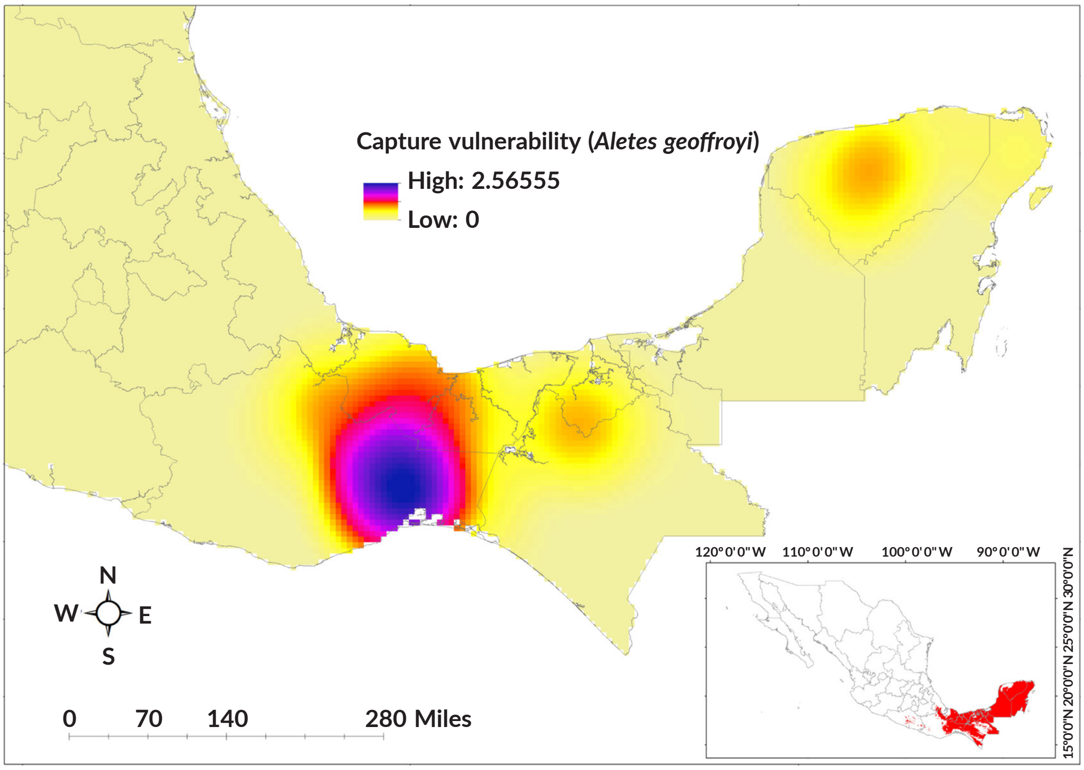

Fig. 4s. Areas of greatest capture vulnerability for the species *Ateles geoffroyi*.

Fig. 4s. *Zonas de mayor vulnerabilidad a la captura para la especie* Ateles geoffroyi.

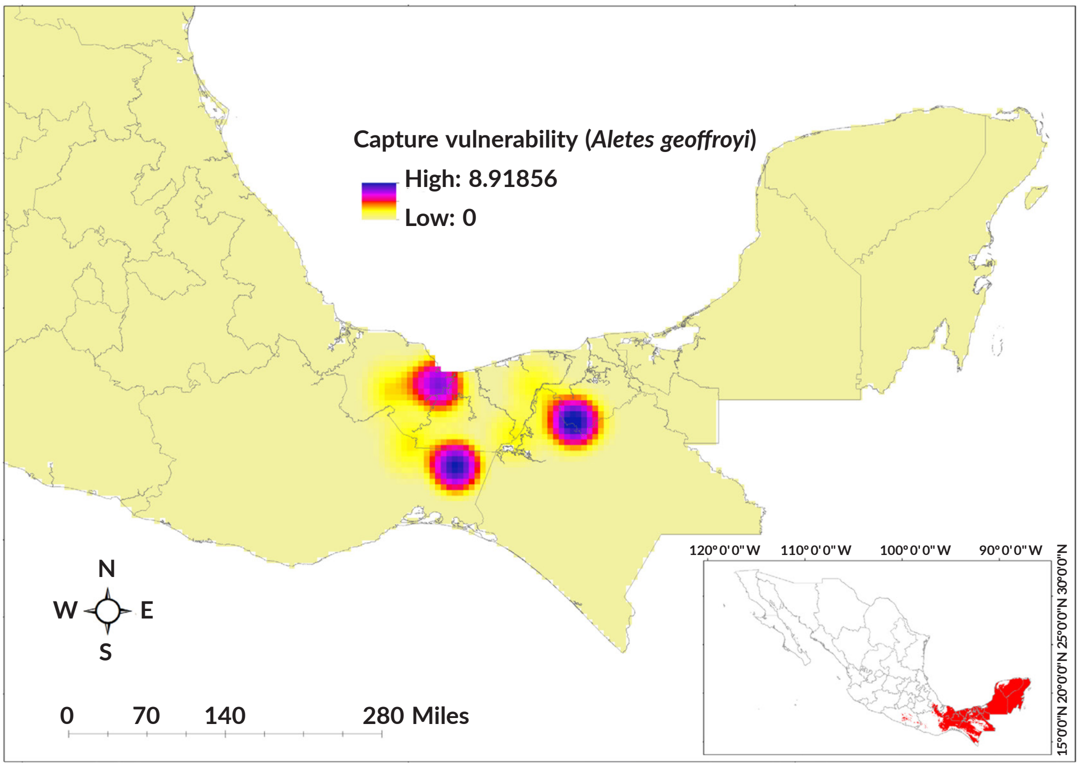

Fig. 5s. Areas of greatest capture vulnerability for the species *Alouatta palliata*.

Fig. 5s. *Zonas de mayor vulnerabilidad a la captura para la especie* Alouatta palliata.

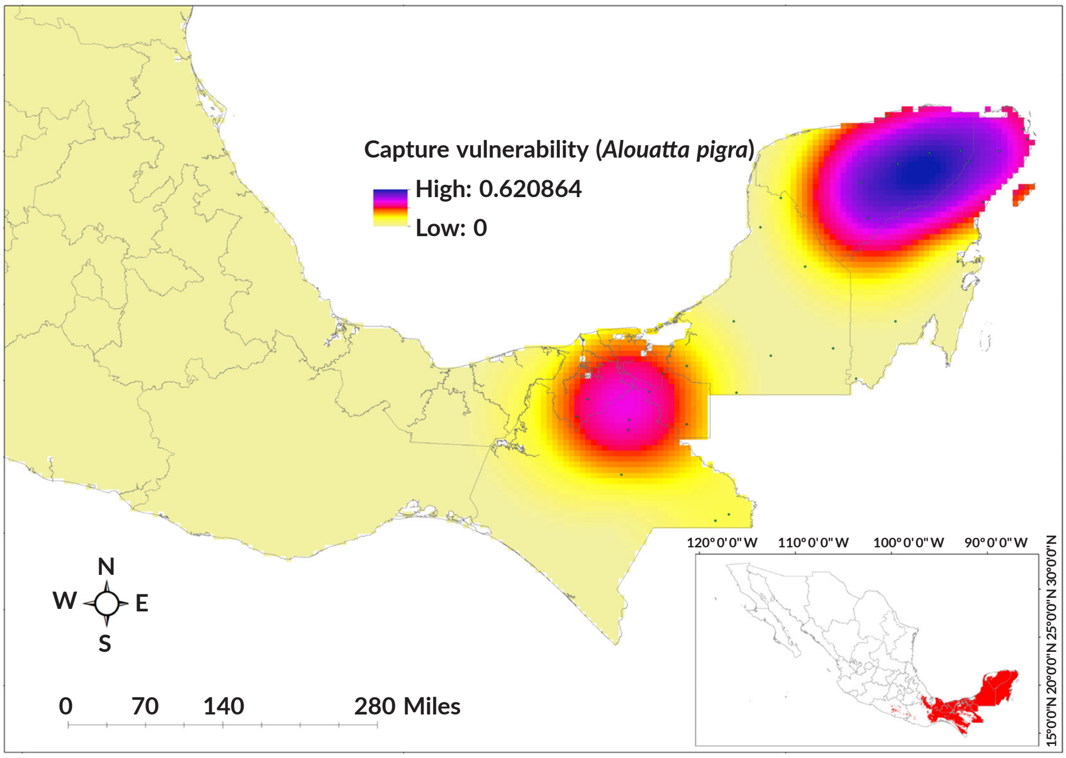

Fig. 6s. Areas of greatest capture vulnerability for the species *Alouatta pigra*.

Fig. 6s. *Zonas de mayor vulnerabilidad a la captura para la especie Alouatta pigra.*

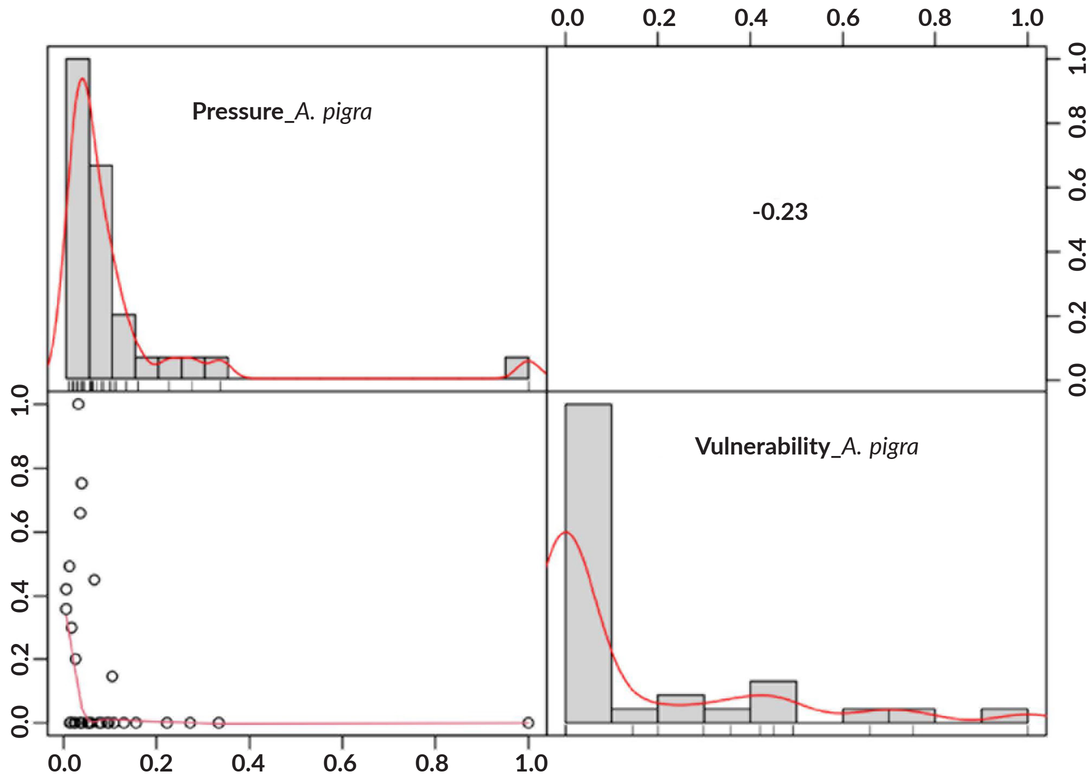

Fig. 7s. Pressure and vulnerability correlation test of the species *Alouatta pigra*.

Fig. 7s. Prueba de correlación de presión y vulnerabilidad de la especie Alouatta pigra.

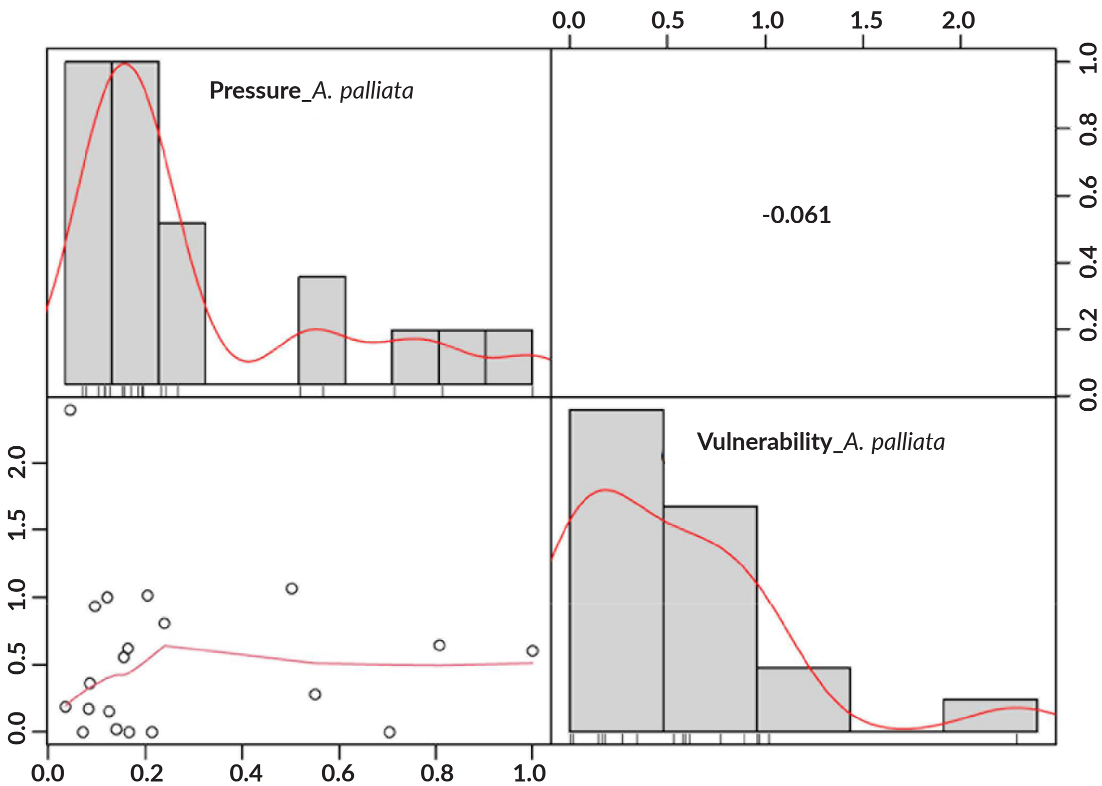

Fig. 8s. Pressure and vulnerability correlation test of the species *Alouatta palliata*.

Fig. 8s. Prueba de correlación de presión y vulnerabilidad de la especie Alouatta palliata.

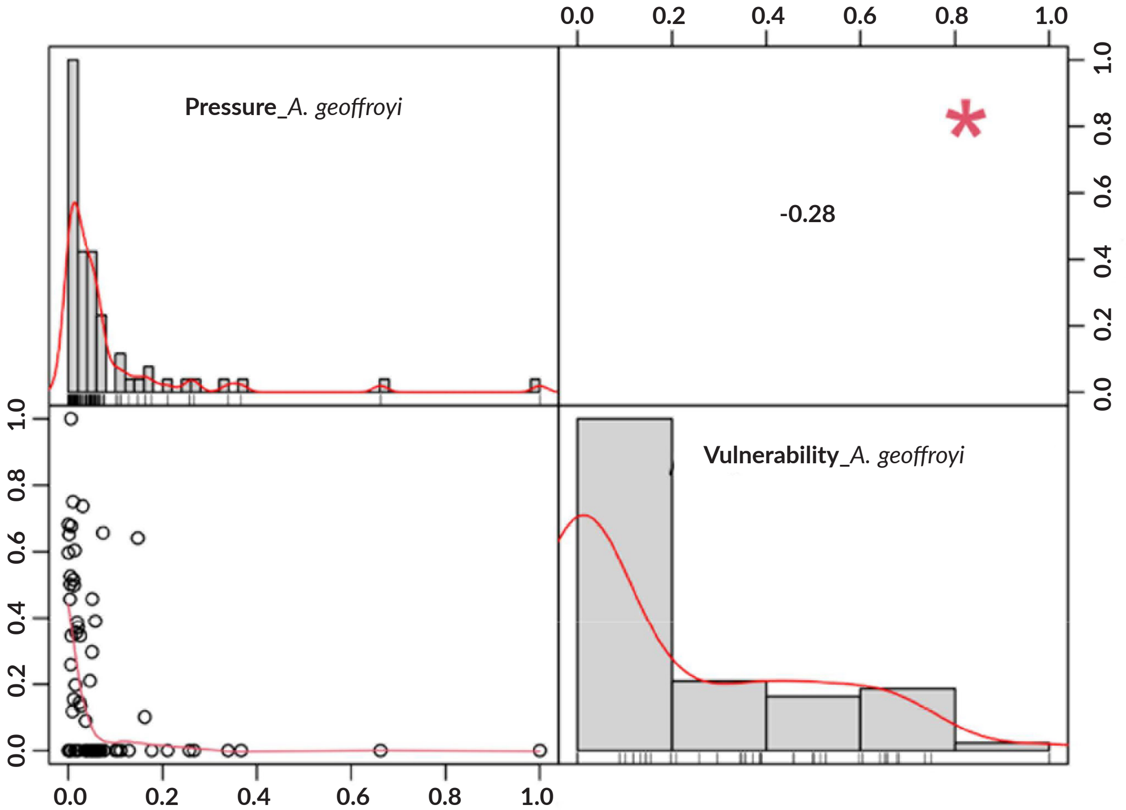

Fig. 9s. Pressure and vulnerability correlation test of the species *Ateles geoffroyi*.

Fig. 9s. *Prueba de correlación de presión y vulnerabilidad de la especie* Ateles geoffroyi.

Table 1s. Ten sites with the highest capture pressure for the three species of primates.

Tabla 1s. *Los diez sitios con la mayor presión de captura para las tres especies de primates.*

Municipality	State	Pressure
Benito Juárez	Quintana Roo	1.10461
Felipe Carrillo Puerto	Quintana Roo	1.02309
Cárdenas	Tabasco	1
Huimanguillo	Tabasco	0.91511
San Andrés Tuxtla	Veracruz	0.80754
Tuxtla Gutiérrez	Chiapas	0.71302
Minatitlán	Veracruz	0.66195
Cosoleacaque	Veracruz	0.65017
Solidaridad	Quintana Roo	0.60045
Ocosingo	Chiapas	0.39207
Carmen	Campeche	0.33393751
Tulum	Quintana Roo	0.27239196
Carmen	Campeche	0.26651315
Othón P. Blanco	Quintana Roo	0.25666173
Teapa	Tabasco	0.23972217

Municipality	State	Pressure
Macuspana	Tabasco	0.22221914
Catemaco	Veracruz	0.21416977
San Andrés Tuxtla	Veracruz	0.21059762
Tacotalpa	Tabasco	0.20474021
Palenque	Chiapas	0.17684853
Soteapan	Veracruz	0.16673068
Juan Rodríguez Clara	Veracruz	0.16421638
Minatitlán	Veracruz	0.1621585
Matías Romero Avendaño	Oaxaca	0.15588596
Centla	Tabasco	0.15580975
Cosoleacaque	Veracruz	0.14739152
San Juan Evangelista	Veracruz	0.14048944
Hopelchén	Campeche	0.12966105
Ocozocoautla de Espinosa	Chiapas	0.12861958
Jesús Carranza	Veracruz	0.12539648

Table 1s. (Cont.)

Municipality	State	Pressure
Amatán	Chiapas	0.12148047
Cintalapa	Chiapas	0.11120192
Isla Mujeres	Quintana Roo	0.108177
Felipe Carrillo Puerto	Quintana Roo	0.10461822
Tizimín	Yucatán	0.10453393
Tizimín	Yucatán	0.10063179
Othón P. Blanco	Quintana Roo	0.09694155
Chinameca	Veracruz	0.09632897
Palenque	Chiapas	0.09384166
Texistepec	Veracruz	0.08565871
Hidalgotitlán	Veracruz	0.08309318
Balancán	Tabasco	0.08114339
Tenosique	Tabasco	0.07632494
Escárcega	Campeche	0.07585485
Tacotalpa	Tabasco	0.07356768
Tatahuicapan de Juárez	Veracruz	0.07140542
Calkiní	Campeche	0.06858805
Pijijiapan	Chiapas	0.06637479
Tacotalpa	Tabasco	0.06598708
Catemaco	Veracruz	0.06278439
Candelaria	Campeche	0.06195191
Champotón	Campeche	0.05883553
Mapastepec	Chiapas	0.05856796
Teapa	Tabasco	0.05733388
Tulum	Quintana Roo	0.05615244
Bacalar	Quintana Roo	0.05590507
Escárcega	Campeche	0.05480243
San Fernando	Chiapas	0.05468426
Ocosingo	Chiapas	0.05344473
Bacalar	Quintana Roo	0.0517828
José María Morelos	Quintana Roo	0.05102545
Loma Bonita	Oaxaca	0.05069238
Playa Vicente	Veracruz	0.05022877
José María Morelos	Quintana Roo	0.04935883
Soteapan	Veracruz	0.04768924
Matías Romero Avendaño	Oaxaca	0.04569835
Santa María Chimalapa	Oaxaca	0.04509477
Calakmul	Campeche	0.04377194
Escuintla	Chiapas	0.03987725
Tenabo	Campeche	0.03968622
Emiliano Zapata	Tabasco	0.03887917
Villa Comaltitlán	Chiapas	0.03846593
Tenosique	Tabasco	0.03803623
Jesús Carranza	Veracruz	0.03676028

Municipality	State	Pressure
Calkiní	Campeche	0.0362701
Peto	Yucatán	0.0359633
Lázaro Cárdenas	Quintana Roo	0.03549857
Santiago Yaveo	Oaxaca	0.03534995
Lázaro Cárdenas	Quintana Roo	0.03520802
Puerto Morelos	Quintana Roo	0.03188591
Ciudad Ixtepec	Oaxaca	0.03053443
San Juan Mazatlán	Oaxaca	0.02626814
Salto de agua	Chiapas	0.02560606
Oxchuc	Chiapas	0.02514383
Texistepec	Veracruz	0.02511106
Salto de Agua	Chiapas	0.02371795
Benito Juárez	Quintana Roo	0.02309037
Tatahuicapan de Juárez	Veracruz	0.02093267
Santiago Jocotepec	Oaxaca	0.02045395
San Pedro Tapanatepec	Oaxaca	0.01849977
Marqués de Comillas	Chiapas	0.01796753
Marqués de Comillas	Chiapas	0.01721915
Asunción Ixtaltepec	Oaxaca	0.01680732
Candelaria	Campeche	0.01520506
Santo Domingo Zanatepec	Oaxaca	0.01504517
Tenabo	Campeche	0.0134798
Calakmul	Campeche	0.01336754
Santa María Chimalapa	Oaxaca	0.01321964
Sotuta	Yucatán	0.01257512
Solosuchiapa	Chiapas	0.01223022
Buctzotz	Yucatán	0.01168052
Ixtlán de Juárez	Oaxaca	0.01093795
Homún	Yucatán	0.00996094
San Miguel Chimalapa	Oaxaca	0.00905805
Mayapán	Yucatán	0.00627166
Santiago Lachiguiri	Oaxaca	0.00601612
Santa María Mixtequilla	Oaxaca	0.00549025
Calotmul	Yucatán	0.00547996
Dzitás	Yucatán	0.00525553
Sochiapa	Veracruz	0.00524803
Osumacinta	Chiapas	0.0050271
Río Lagartos	Yucatán	0.00500098
Santa María Guienagati	Oaxaca	0.0043863
Santiago Laollaga	Oaxaca	0.00394528
Dzilam de Bravo	Yucatán	0.00346064
Santiago Ixcuintepec	Oaxaca	0.0025547
Magdalena Tlacotepec	Oaxaca	0.00151831

Table 2s. Ten sites with the highest capture vulnerability for the three species of primates.

Tabla 2s. *Los diez sitios con la mayor vulnerabilidad de captura para las tres especies de primates.*

Municipality	State	Pressure
Benito Juárez	Quintana Roo	1.10461
Felipe Carrillo Puerto	Quintana Roo	1.02309
Cárdenas	Tabasco	1
Huimanguillo	Tabasco	0.91511
San Andrés Tuxtla	Veracruz	0.80754
Tuxtla Gutiérrez	Chiapas	0.71302
Minatitlán	Veracruz	0.66195
Cosoleacaque	Veracruz	0.65017
Solidaridad	Quintana Roo	0.60045
Ocosingo	Chiapas	0.39207
Carmen	Campeche	0.33393751
Tulum	Quintana Roo	0.27239196
Carmen	Campeche	0.26651315
Othón P. Blanco	Quintana Roo	0.25666173
Teapa	Tabasco	0.23972217
Macuspana	Tabasco	0.22221914
Catemaco	Veracruz	0.21416977
San Andrés Tuxtla	Veracruz	0.21059762
Tacotalpa	Tabasco	0.20474021
Palenque	Chiapas	0.17684853
Soteapan	Veracruz	0.16673068
Juan Rodríguez Clara	Veracruz	0.16421638
Minatitlán	Veracruz	0.1621585
Matías Romero Avendaño	Oaxaca	0.15588596
Centla	Tabasco	0.15580975
Cosoleacaque	Veracruz	0.14739152
San Juan Evangelista	Veracruz	0.14048944
Hopelchén	Campeche	0.12966105
Ocozocoautla de Espinosa	Chiapas	0.12861958
Jesús Carranza	Veracruz	0.12539648
Amatán	Chiapas	0.12148047
Cintalapa	Chiapas	0.11120192
Isla Mujeres	Quintana Roo	0.108177
Felipe Carrillo Puerto	Quintana Roo	0.10461822
Tizimín	Yucatán	0.10453393
Tizimín	Yucatán	0.10063179
Othón P. Blanco	Quintana Roo	0.09694155
Chinameca	Veracruz	0.09632897
Palenque	Chiapas	0.09384166
Texistepec	Veracruz	0.08565871
Hidalgotitlán	Veracruz	0.08309318
Balancán	Tabasco	0.08114339
Tenosique	Tabasco	0.07632494
Escárcega	Campeche	0.07585485
Tacotalpa	Tabasco	0.07356768
Tatahuicapan de Juárez	Veracruz	0.07140542

Municipality	State	Pressure
Calkiní	Campeche	0.06858805
Pijijiapan	Chiapas	0.06637479
Tacotalpa	Tabasco	0.06598708
Catemaco	Veracruz	0.06278439
Candelaria	Campeche	0.06195191
Champotón	Campeche	0.05883553
Mapastepec	Chiapas	0.05856796
Teapa	Tabasco	0.05733388
Tulum	Quintana Roo	0.05615244
Bacalar	Quintana Roo	0.05590507
Escárcega	Campeche	0.05480243
San Fernando	Chiapas	0.05468426
Ocosingo	Chiapas	0.05344473
Bacalar	Quintana Roo	0.0517828
José María Morelos	Quintana Roo	0.05102545
Loma Bonita	Oaxaca	0.05069238
Playa Vicente	Veracruz	0.05022877
José María Morelos	Quintana Roo	0.04935883
Soteapan	Veracruz	0.04768924
Matías Romero Avendaño	Oaxaca	0.04569835
Santa María Chimalapa	Oaxaca	0.04509477
Calakmul	Campeche	0.04377194
Escuintla	Chiapas	0.03987725
Tenabo	Campeche	0.03968622
Emiliano Zapata	Tabasco	0.03887917
Villa Comaltitlán	Chiapas	0.03846593
Tenosique	Tabasco	0.03803623
Jesús Carranza	Veracruz	0.03676028
Calkiní	Campeche	0.0362701
Peto	Yucatán	0.0359633
Lázaro Cárdenas	Quintana Roo	0.03549857
Santiago Yaveo	Oaxaca	0.03534995
Lázaro Cárdenas	Quintana Roo	0.03520802
Puerto Morelos	Quintana Roo	0.03188591
Ciudad Ixtepec	Oaxaca	0.03053443
San Juan Mazatlán	Oaxaca	0.02626814
Salto de agua	Chiapas	0.02560606
Oxchuc	Chiapas	0.02514383
Texistepec	Veracruz	0.02511106
Salto de Agua	Chiapas	0.02371795
Benito Juárez	Quintana Roo	0.02309037
Tatahuicapan de Juárez	Veracruz	0.02093267
Santiago Jocotepec	Oaxaca	0.02045395
San Pedro Tapanatepec	Oaxaca	0.01849977
Marqués de Comillas	Chiapas	0.01796753
Marqués de Comillas	Chiapas	0.01721915

Table 2s. (Cont.)

Municipality	State	Pressure
Asunción Ixtaltepec	Oaxaca	0.01680732
Candelaria	Campeche	0.01520506
Santo Domingo Zanatepec	Oaxaca	0.01504517
Tenabo	Campeche	0.0134798
Calakmul	Campeche	0.01336754
Santa María Chimalapa	Oaxaca	0.01321964
Sotuta	Yucatán	0.01257512
Solosuchiapa	Chiapas	0.01223022
Buctzotz	Yucatán	0.01168052
Ixtlán de Juárez	Oaxaca	0.01093795
Homún	Yucatán	0.00996094
San Miguel Chimalapa	Oaxaca	0.00905805
Mayapán	Yucatán	0.00627166
Santiago Lachiguiri	Oaxaca	0.00601612
Santa María Mixtequilla	Oaxaca	0.00549025
Calotmul	Yucatán	0.00547996
Dzitás	Yucatán	0.00525553
Sochiapa	Veracruz	0.00524803
Osumacinta	Chiapas	0.0050271
Río Lagartos	Yucatán	0.00500098
Santa María Guienagati	Oaxaca	0.0043863
Santiago Laollaga	Oaxaca	0.00394528
Dzilam de Bravo	Yucatán	0.00346064
Santiago Ixcuintepec	Oaxaca	0.0025547
Magdalena Tlacotepec	Oaxaca	0.00151831