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# Deforestation and Primate Habitat Availability in Los Tuxtlas Biosphere Reserve, Mexico

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**Abstract** Los Tuxtlas Biosphere Reserve (LTBR) in southeast Mexico is characterized by high rates of deforestation and habitat deterioration, containing two Mexican primate species, *Alouatta palliata* and *Ateles geoffroyi.* In this study, we integrate the analysis of landscape dynamics with primate population research covering a period of 21 years (1986-2007), assessing the impacts of habitat transformation on primate populations in a study area located in the southeast region of the LTBR. We found the higher deforestation rate (1.5%) from 1986 to 2000, compared to 2000-2007 (0.5%), but reduction in primate's habitat was of 62% from 1986-2007. Land cover changes have modified the landscape in such a way that current available habitat for primates is constituted by small forest patches, immersed in a pasture matrix. A total of 37 *A. palliata* and 68 *A. geoffroyi* individuals were counted; these data were compared with information available for the same primate populations in 1987 and 2000, revealing that despite habitat loss, primate population sizes have remained relatively stable. The analysis of occupation and colonization of forests fragments by primates suggests that fragment size and connectivity are key landscape features for the persistence of primates in the region. Our results imply that strong anthropogenic pressure against primate habitat is still taking place in this portion of LTBR; and that habitat availability, as well as primate population viability in this region, are linked to political and socioeconomic factors affecting land use and production systems adopted by locals, as well as to the management efforts of the LTBR.

**Keywords** Habitat Loss, Forest Fragments, Primate Conservation

## 1. Introduction

The main threats primates face are habitat loss and fragmentation[39]. These environmental alterations are often the result of land cover changes caused by deforestation driven by human actions in order to satisfy their needs[1,6].

The amount of suitable habitat, or habitat availability, has proven to have strong effects on the feeding behaviour, population dynamics such as migration, reproduction and survival of Neotropical primates[37,41].

Los Tuxtlas Biosphere Reserve (LTBR), in southeast Mexico, contains one of the last relicts of tropical rainforest in the country; however, during the past decades deforestation led to major losses of its original vegetation[40].

Two of the three Mexican primate species, *Alouatta palliata* and *Ateles geoffroyi*, are found in LTBR. Both of these primates are considered as endangered species, mainly due to habitat loss[9,39]. Although the LTBR was declared natural protected area in 1998[10]; deforestation processes have continued since then, with higher intensity at altitudes below 990m[11], which coincides with the altitudinal range of distribution of these primates[12].

Several primatological studies have been conducted in LTBR on the effects of habitat fragmentation on primate populations, focusing on abundance, ecology and behaviour[4,13-18]. Particularly, for the southeast region of the LTBR the first primate survey was conducted in 1985[14]. By this time the landscape was already fragmented and the authors urged to look for productive alternatives compatible with the conservation of primate habitat. Recent studies in the same portion of LTBR have included landscape characteristics to the analysis of primate distribution among fragments[19-22].

Nevertheless, the quantifying of landscape dynamics and assessing changes in habitat availability through time, in order to determine trends in habitat loss and transformation, had not been addressed. Furthermore, improving the understanding of species response to landscape changes, especially those caused by land use and land cover change, is crucial for setting conservation priorities, and enabling effective landscape management[2,23,24].

In this study, we integrate the analysis of landscape dynamics with research on primate populations for a period of 21 years (1986-2007) in the southeast portion of the LTBR. We focused on two main questions: 1) how has deforestation affected habitat availability for primates, and 2) what are the effects of habitat loss on primate populations?

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We applied temporal and spatial analyses to compare the different landscape scenarios under which primate populations have been immersed. We analysed land cover changes and forest fragmentation from 1986-2007; evaluated deforestation drivers and habitat availability, and assessed the impacts of habitat transformations on primate populations. Since our study considers time periods before and after the establishment of the LTBR, we discuss the impact that this natural protected area has had so far, on the conservation of primates and their habitat.

# 2. Study Area

The study site is located in the Sierra de Santa Marta region, in the south-east portion of the LTBR, located in the state of Veracruz, Mexico (Figure 1). The study site covers an area of 3,371 ha, including the territories and landholdings of four agricultural communities (*ejido*s).

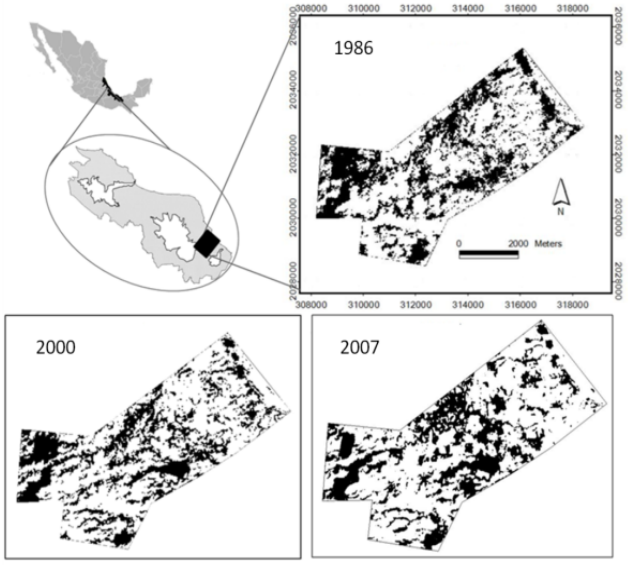


**Figure 1.** Study site location and forest cover in 1986, 2000 and 2007. Left oval: Los Tuxtlas Biosphere Reserve, Mexico

### 2.1. Landscape History

Human occupation in the Sierra de Santa Marta region dates from pre-Hispanic times, approximately 1500 years ago[25]. However, the *ejidos* located in the study area were founded between 1964 and 1970[26], encouraged by government land reform and agricultural development policies.

The main productive activity during the early settlement period of the *ejidos* was *milpa* agriculture where several useful plants are intercropped in small land clearings; at that time, cattle ranching was not part of the traditional production systems[27].

In the early 1980, the agrarian policies focused on the promotion of cattle ranching in the region, conferring local farmers with financial credits for livestock production. This initiated severe impacts on the environment as well as landscape transformation[28]. In 1992, changes in the agrarian law allowed the certification, privatization and sale of *ejido* lands. As a consequence, the agrarian frontier expanded, causing further environmental perturbation[29].

Today's main productive activity is extensive cattle ranching[30]. The natural landscape is highly fragmented, consisting of a pasture matrix and small patches of tropical forest vegetation, which remain sources of valuable products for the survival of local human populations, such as fuel-wood, timber, medicine and food. Moreover, forest patches also provide habitat for primates.

# 3. Methodology

### 3.1. Primate Population Sampling

Surveys of primate populations were carried out from March to June 2009. All vegetation fragments bigger than 0.5 ha were visited and thoroughly inspected. Each survey trek started at 5:00 am and ended at 4:00 pm. Once a primate group was located, we registered: geographic position, species, group size and composition. We compared the survey results with previous reports from 1986 and 2000 in the same area[14,21].

### 3.2. Remote Sensing Analysis

We applied remote sensing of satellite images to evaluate deforestation and forest fragmentation from 1986-2007. Imagery used included three scenes: a Landsat 5 TM from 1986, a Landsat 7 ETM from 2000, and a SPOT 5 from 2007. To compare changes in forest cover between these images, we used the minimum surface of vegetation considered as a fragment of 0.5 ha, which could be detected by both type of satellite images.

We collected 103 GPS ground-truth points in the field, describing vegetation types and land use. Subsequently, we used the GPS points to classify land use and land cover using supervised classification techniques. Classified images were then used to analyze changes in forest cover, fragment size, connectivity and deforestation rates using GIS software ArcGis 9 (ESRI®) . We estimated deforestation rates with a standardized deforestation indicator:

$$dn = \left(\frac{S2}{S1}\right)^{1/n} - 1 \quad (1)$$

Where $dn$ = deforestation rate, $S2$= forest cover in time two, $S1$= forest cover in time one, and $n$ = number of years between time one and two[31].

We used Patch Analyst 3.1 to determine landscape metrics (size, shape, and distance to nearest village and to the nearest fragment) of forest fragments. Connectivity was measured employing the connectivity index:

$$CI = Dnf + Pc - J \quad (2)$$

Where $CI$= connectivity index, $Dnf$= distance to the nearest fragment, $Pc$= presence of corridors, $J$= journey (Table 1).

### 3.3. Data Analysis

Using SPSS Statistics 17.0 we ran one-way ANOVA tests to compare variables of forest fragment size, connectivity, percent of secondary vegetation, and forest cover loss among fragments that remained occupied, that were abandoned, and that were colonized by primates from 1986-2000 and 2000-2009. In addition, linear regressions were applied to test the relationship between deforestation and the distance to the nearest village as well as deforestation and fragment characteristics. The probability level at which we determined significance was P=0.05

**Table 1.** Variables and values for estimating the connectivity index (CI)

| VARIABLE | DESCRIPTION | VALUE |
|---|---|---|
| Distance to the nearest fragment (Dnf)* | 3– 30 m | 1 |
| | 31 – 50 m | 0.5 |
| | > 50 m | 0 |
| Presence of corridors (Pc) | Connects to a fragment with no other corridors | 1 x n |
| | Connects to a fragment that has corridors connecting with other fragments | 2 x n |
| | n = number of corridors with this feature | |
| Journey (J) | Presence of roads between fragments or corridors | 0.5 |

*Distances estimated according to the dispersal capacity across pasture matrix. A distance up to 30m has been considered feasible for these primates to walk[32]. Crossing distances longer than 50m will be risky and will require high expenditure of energy, lowering the probabilities for this to happen[12,16].

# 4. Results

## 4.1. Landscape Dynamics

Table 2 summarizes land cover change and deforestation rates in the study area for periods 1986-2000 and 2000-2007. Deforestation was most intense during the first period; with a significant reduction from 2000-2007; nontheles, deforestation area reamins considerable. The lower annual deforestation rate, along with a decrease in the amount of forest regrowth from 2000 to 2007, show that the landscape changes were more dynamic from 1986 to 2000 than from 2000 to 2007 (Figure 2).

**Table 2.** Percentage of land cover changes and deforestation rates from 1986-2007 in Sierra de Santa Marta, Los Tuxtlas, Mexico

| Land cover changes | 1986-2000 | 2000-2007 |
|---|---|---|
| Remained forested | 22.8% | 22.9% |
| Forest regrowth | 11.6% | 10.5% |
| Remained deforested | 46.2% | 55.1% |
| New deforestation | 19.4% | 11.5% |
| Annual deforestation rate | 1.5% | 0.5% |

## 4.2. Primate Habitat and Population

The total amount of habitat available for primates has diminished through time, and forest fragments have become smaller and more isolated (Figure 1 and Table 3). In 1986 there were 28 fragments, of which 32% were less than 10 ha and the largest fragment was 166.7 ha. By 2007, there were 25 fragments; 60% of the fragments had less than 10 ha and the largest fragment covered an area of 59.7 ha.

**Table 3.** Changes in primate's habitat in Sierra de Santa Marta, Los Tuxtlas, Mexico for 1986, 2000 and 2007

| | 1986 | 2000 | 2007 |
|---|---|---|---|
| Habitat availability (ha) | 876.9 | 332.2 | 335.5 |
| Number of Patches | 28 | 23 | 25 |
| Mean patch size (ha) ± SD | 31.3 ± 40.4 | 14.4 ± 18.3 | 12.0 ± 14.0 |
| Mean patch composition | 57.1% | 79.6% | 57.2% |
| Connectivity Index | 2.8 | 1.8 | 1.6 |
| | 1986 | 2000 | 2009 |
| *Alouatta palliata* (ind) | 40[b] | 50[b] | 37* |
| *Ateles geoffroyi* (ind) | 67[b] | | 68* |

[a]Patch composition in terms of secondary vegetation according to remote sensing.
[b][14,21]
*Present study

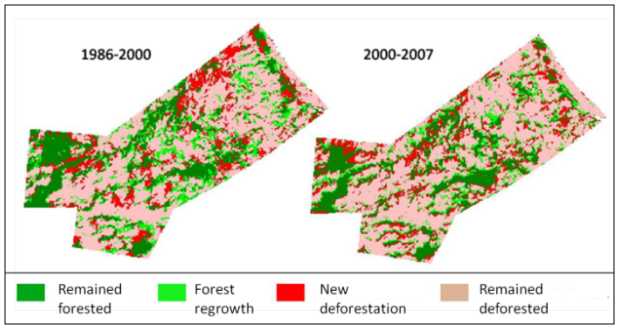


**Figure 2.** Land cover change at Sierra de Santa Marta, Los Tuxtlas Biosphere Reserve, Mexico

From 1986-2007, 12 fragments disappeared in the study area, three of which were occupied by primates; five fragments were divided into two smaller fragments and another three fragments were regenerated. According to our primate survey, by 2009 these last three patches were still unoccupied by primates. Population surveys show the presence of primate groups within patches of available habitat was fairly constant between 1986-2009, but showing colonization and abandonment among the fragments (Table 4).

For *Alouatta palliata* no significant differences in spatial characteristics were found between fragments that remained occupied or that were colonized, and fragments that were unoccupied. In contrast, the fragments that remained occupied by *Ateles geoffroyi* from 1986-2009 differ from the unoccupied ones by being larger (ANOVA: F=11.68, df=14, P=0.005) and by having better connectivity (ANOVA: F=6.63, df=14, P=0.023); also, the fragments colonized by *Ateles geoffroyi* during this period show a higher connectivity index than the unoccupied fragments (ANOVA: F=7.8, df=18, P=0.012).

Fragments that had lower number of primates in 2009 than in 1986, showed a reduction of up to 68% of their surface area. Fragments that had more primates in 2009 than in 1986, maintained their connectivity with other fragments despite the losses in their surface area.

Regression analysis indicate a positive relationship between fragment size and the amount of forest cover loss ($R^2$=0.414, P=0.001), the largest fragments being the ones with more deforestation.

**Table 4.** History of primate occupation per fragment in Sierra de Santa Marta, Los Tuxtlas, 1986-2009. S= *Ateles geoffroyi,* H= *Alouatta palliata*, X= deforested fragment

| Fragment | 1986[a] | 2000[a] | 2009* |
|---|---|---|---|
| 1 | H | | H |
| 2 | S | H | |
| 7 | S | | |
| 8 | S, H | | S |
| 9 | | H | S, H |
| 10 | S, H | | |
| 11 | | | S, H |
| 12 | S | H | S, H |
| 14 | | | H |
| 15 | | H | |
| 16 | | H | S |
| 17 | H | H | H |
| 21 | S, H | | S |
| 22 | | H | H |
| 23 | | | S |
| 24 | | x | S |
| 25 | | | H |
| 26 | S, H | x | x |
| 27 | S | x | x |
| 28 | | H | x |

[a][14,21]
*Present study

# 5. Discussion and Conclusions

The aim of this study was to determine how landscape dynamics (deforestation and fragmentation) affect primate habitat availability and how primate populations have been impacted by these changes. Deforestation rate for the study area was extremely high from 1986 to 2000, accelerating forest fragmentation during this period. The following reduction in deforestation from 2000 to 2007 allowed for some forest regrowth and the maintenance of forest fragments. The less intense deforestation from 2000-2007, could be explained by conservation strategies and policies implemented with the establishment of the LTBR in 1998, but also by the fact that the processes of certification of *ejido* lands, which started in 1992, was over in the region around 2000; moreover, human population growth remained constant[32], thus there was no further deforestation in order to claim new property.

Land cover changes have modified the landscape in such a way that currently available habitat for primates is constituted by several small patches, immersed in a "hostile" pasture matrix with no forest cover, hindering the movement of primates among fragments[33], disturbing dispersal and the subsequent formation of new groups.

The comparison between primate surveys showed that, contrary to the expected, the total primate population has remained stable, despite deforestation, fragmentation, and high percentage of habitat loss. However, a demographic analysis of both primate species in the same region, suggests that the low proportion of infants in groups of both primate species could be having a negative impact on population replacement rates[34]. Furthermore, it has been reported for this particular region, that *Alouatta palliata* groups inhabiting fragments smaller than 15 ha have a 60% of extinction probability within 30 years[18]. Since 73% of the current *Alouatta palliata* population in the study area inhabit fragments smaller than this area, coupled with the fact that the mean fragment size in 2007 was also smaller than 15 ha, the primate populations in this region are probably highly threatened.

The analysis of occupation and colonization of forest fragments by primates, suggests that fragment size and connectivity are key landscape features for the persistence of primates in the region, mainly for *Ateles geoffroyi*, since this primate has a larger home range than *Alouatta palliata*[16,35-36]. *Alouatta palliata* groups have been more static, probably because of their high tolerance to fragmented habitats[4,37] and their low dispersal capacity[38].

The positive relationship found between deforestation and fragment size, in addition to the tendency of *Ateles geoffroyi* to occupy and remain within the larger fragments, suggest that strong anthropogenic pressure against primate habitat is still present in this portion of Sierra de Santa Marta. Forest fragments in this part of LTBR are constantly exploited by the local people, since obtaining products, such as food and timber, is indispensable for their subsistence. In order to determine the effects of human activities on the quality of primate habitat and its impact on primate populations, it is necessary to monitor the frequency and intensity of such activities within these forest patches, and to establish if the tree species managed by humans are also key species for primates.

The design of the LTBR conservation zones did not consider the altitudinal restrictions for the presence of endangered species such as *Alouatta palliata,* establishing the core zones at higher elevation than what this primate can tolerate, leaving most of the habitat suitable for primates within the buffer zones of the LTBR, where deforestation has had its strongest impacts[11]. Our results coincide with previous authors[11,22], and advise that the strategies for primate conservation in this part of Sierra de Santa Marta must be directed to preserve the patches of forest habitat and to increase the patch connectivity within the landscape.

Primate population viability, in this part of LTBR is linked to political decisions that take place at federal, state and local levels, which influence the production and land use systems of local communities through their programs. Since habitat availability for primates is ruled by the individual decisions of land use made by local residents, the inclusion of these local communities in the management of the LTBR is crucial. Therefore, conservation of these species depends on a greater political commitment to adequately manage LTBR and to a stronger social cohesion that allows integrating habitat conservation strategies.

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# REFERENCES

[1] Francoise Burel, Jacques Baudry, "Landscape ecology: concepts, methods and applications", Science Publishers, USA, 2003.

[2] Klaus Henle, Kendi F. Davies, Michael Kleyer, Chris Margules, Josef Settele, "Predictors of species sensitivity to fragmentation", Kluwer Academic Publishers, Biodiversity and Conservation, vol. 13, pp. 207-251, 2004.

[3] Collin A Chapman, "Ecological constraints on group size in three species of neotropical primates", Karger, Folia Primatologica, vol. 55, pp. 1-9, 1990.

[4] Jurgi Cristóbal Azkarate, Joaquim Veà, Norberto Asensio, Ernesto Rodríguez Luna, "Biogeographical and floristic predictors of the absence and abundance of mantled howlers (*Alouatta palliata mexicana)* in rainforest fragments at Los Tuxtlas, Mexico", Wiley-Liss Inc, American Journal of Primatology, vol. 67, pp. 209–222, 2005.

[5] Leigh E.G Jr, Rand A.S, Windsor D. M. (eds), "The ecology of a tropical forest: seasonal rhythms and long term changes", Smithsonian Institute, USA, 1982.

[6] Ruth DeFries, Jonathan A. Foley, Gregory P. Asner , "Land-use choices: balancing human needs and ecosystem function", The Ecological Society of America, "Frontiers in Ecology and the Environment", vol. 2, pp. 249-257, 2004.

[7] Eric F. Lambin, Helmut J. Geist, Erika Lepers, "Dynamics of land-use and land-cover change in tropical regions" Annual Reviews, Annual Review of Environmental Resources vol. 28, pp.

[8] David L. Bray, Leticia Merino Pérez, Deborah Barry (Eds), "Los bosques comunitarios de México: manejo sustentable de paisajes forestales", Instituto Nacional de Ecología, México, 2007.

[9] Norma Oficial Mexicana, NOM-059-SEMARNAT -2001, "Protección ambiental, especies nativas de México de flora y fauna silvestres. Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio: lista de especies en riesgo", Secretaria del Medio Ambiente y Recursos Naturales, Mexico, Diario Oficial 30 de Diciembre de 2010.

[10] Comisión Nacional de Áreas Naturales Protegidas, "Programa de Conservación y Manejo, Reserva de la Biosfera Los Tuxtlas", Secretaría del Medio Ambiente y Recursos Naturales. México, 2007.

[11] Eduardo Mendoza, John Fay, Rodolfo Dirzo, "A quantitative analysis of forest fragmentation in Los Tuxtlas, southeast Mexico: patterns and implications for conservation". Sociedad de Biología de Chile, Revista chilena de historia natural, vol. 78, pp. 451-467, 2007.

[12] Alejandro Estrada, Rosamond Coates-Estrada, "La contracción y la fragmentación de las selvas y las poblaciones de primates silvestres: El caso de Los Tuxtlas, Veracruz", Universidad Veracruzana, La Ciencia y el Hombre, vol. 18, pp. 45-69, 1994.

[13] Alejandro Estrada, "Survey and census of howler monkeys *(Alouatta palliata)* in the rain forest of "Los Tuxtlas", Veracruz, Mexico", Wiley-Liss Inc, American Journal of Primatology, vol. 2, pp. 363-372, 1982.

[14] Ernesto Rodríguez Luna, John E.Fa, Francisco García Orduña, Gilberto Silva López, Domingo Canales Espinoza, "Primate conservation in Mexico", IUCN/SSC Primate Specialist Group, Primate Conservation, vol. 8, pp. 114-118, 1987.

[15] Gilberto Silva López, Francisco García Orduña, Ernesto Rodríguez Luna, "The status of *Ateles geoffroyi* and *Alouatta palliata* in disturbed forest areas if Sierra de Santa Marta, Mexico", IUCN/SSC Primate Specialist Group, Primate Conservation, vol. 9, pp. 53-61, 1988.

[16] Alejandro Estrada, Rosamond Coates Estrada, "Tropical Rain Forest Fragmentation and Wild Populations of Primates at Los Tuxtlas, Mexico" . Plenum Publishing Corporation, International Journal of Primatology, vol. 17, pp. 759-782, 1996.

[17] Jurgi Cristóbal Azkarate, Victor Arroyo Rodríguez, "Diet and activity pattern of howler mnkeys (*Alouatta palliata)* in Los Tuxtlas, Mexico: Effects of habitat fragmentation and implications for conservation", Wiley-Liss Inc, American Journal of Primatology, vol. 69, pp. 1013-1029, 2007.

[18] Salvador Mandujano, Luis A. Escobedo Morales, "Population viability analysis of howler monkeys (*Alouatta palliata mexicana*) in highly fragmented landscape in Los Tuxtlas, Mexico, Mongabay, Tropical Conservation Science, vol. 1, pp. 43-62, 2008.

[19] Victor Arroyo Rodríguez, Salvador Mandujano, "Forest fragmentation modifies habitat quality for *Alouatta palliata",* Springer, International Journal of Primatology, vol. 27, pp. 1079-1096, 2006.

[20] Victor Arroyo Rodríguez, Salvador Mandujano, Julieta Benítez Malvido, "Landscape attributes affecting patch occupancy by howler monkeys (*Alouatta palliata mexicana*) at Los Tuxtlas, Mexico", Wiley-Liss Inc, American Journal of Primatology, vol. 70, pp. 69-77, 2008.

[21] Erika M. Rodríguez Toledo, "Propuesta sobre la conexión de fragmentos como alternativa para la conservación del mono aullador (*Alouatta palliata mexicana)* en un paisaje alterado en Los Tuxtlas, Veracruz", M.Sc. Thesis, Instituto de Ecología A.C, Mexico, 2002.

[22] Alejandro Estrada, Paul A. Garber, Mary S. Pavelka, LeAndra Luecke (Eds), "New perspectives in the study of Mesoamerican primates: distribution, ecology, behavior and conservation", Springer, USA, 2006.

[23] Ruth DeFries, Francesco Roveri, Patricia Wright, Jorge Ahumada, Sandy Andelman, Katrina Brandon, Jan Dempelwolf, Andrew Hansen, Jenny Hewson, Jianguo Liu, "From plot to landscape scale: linking tropical biodiversity measurements across spatial scales", The Ecological Society of America, Frontiers in Ecology and the Environment, vol. 8, pp. 153-160, 2009.

[24] Fernanda Michalski, Carlos A. Peres, "Anthropogenic determinants of primate and carnivore local extinctions in a fragmented forest landscape of southern Amazonia", Elsevier, Biological conservation, vol. 124, pp. 383-396, 2005.

[25] George E.Stuart, "New light on the Olmec", National Geographic Society, National geographic magazine, pp. 88 –115, 1993.

[26] Online Available: http://www.ran.gob.mx

[27] Leticia Durand, Elena Lazos, "Colonization and tropical deforestation in the Sierra Santa Marta, southern Mexico", Cambridge University Press, Environmental Conservation, vol. 31, pp. 11-21, 2004.

[28] Renée González Montagut, "Factors that contributed to the expansion of cattle ranching in Veracruz, Mexico", University of California Press, Mexican studies/Estudios mexicanos, vol. 15, No. 1, pp. 101-130, 1999.

[29] Elena Lazos, Luisa Paré, "Percepciones del deterioro ambiental entre nahuas del sur de Veracruz", Universidad Nacional Autónoma de México, Mexico, 2000.

[30] Lucina Hernández (Ed), "Historia ambiental de la ganadería en México", Instituto de Ecologia A.C, México, 2001.

[31] José L. Palacio-Prieto, María T. Sánchez Salazar, José M. Casado Izquierdo, Enrique Propin Frejomil, Javier Delgado Campos, Alejandro Velásquez Montes, Luis Chias Becerril, María I. Ortíz Álvarez, Jorge González Sánchez, Gerardo Negrete Fernández, Josefina Gabriel Morales, Roberto Márquez Huitzil, "Indicadores para la caracterización y ordenamiento del territorio", Instituto Nacional de Ecología, México, 2004.

[32] Online Available: http://www.inegi.org.mx/est/contenidos/Proyectos/ccpv/default.aspx

[33] Salvador Mandujano, Luis A. Escobedo Morales, Rodolfo Palacios Silva, "Movements of *Alouatta palliata* among fragments in Los Tuxtlas, Mexico", IUCN/SSC Primate Specialist Group, Neotropical Primates, vol. 12, pp. 126-131, 2004.

[34] Brenda Solórzano García, Ernesto Rodríguez Luna, "Cambios demográficos en poblaciones de primates de la región sur de Los Tuxtlas, México: análisis longitudinal 1985-2008", IUCN/SSC Primate Specialist Group, Neotropical Primates, vol. 17, pp. 1-6, 2010.

[35] Meg McFarland Symington, "Environmental determinants of population densities in *Ateles",* IUCN/SSC Primate Specialist Group, Primate Conservation, vol. 9, pp. 74-78, 1988.

[36] Oscar M. Chaves, Kathryn E. Stroner, Victor Arroyo Rodriguez, Alejandro Estrada, "Effectiveness of spider monkey (*Ateles geoffroyi vellerosus)* as seed dispersers in continuous and fragmented rain forests in southern Mexico", Springer, International Journal of Primatology,vol. 32, pp. 177-192, 2010.

[37] Laura K. Marsh (Ed), "Primates in fragments: ecology and conservation" Kluwer Academy/Plenum Publishers, USA, 2003.

[38] Salvador Mandujano, Alejandro Estrada, "Detección de umbrales de área y distancia de aislamiento para la ocupación de fragmentos de selva por monos aulladores, *Alouatta palliata,* en Los Tuxtlas, Mexico", Universidad Juárez Autónoma de Tabasco, Universidad y Ciencia, Special number II, pp. 11-21, 2005.

[39] Online Available: http://www.iucnredlist.org

[40] Rodolfo Dirzo, María C. García, "Rates of deforestation in Los Tuxtlas, a Neotropical area in Veracruz, Mexico", Society for conservation biology, Conservation Biology, vol.6, pp.84-90, 1992.

[41] Victor Arroyo Rodríguez, Pedro A.D. Dias, "Effects of habitat fragmentation and disturbance on howler monkeys: A review", Wiley-Liss Inc, American Journal of Primatology, vol. 72, pp. 1-16, 2010