

Wild felid species richness affected by a corridor in the Lacandona forest, Mexico

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Abstract

Wild felid species richness affected by a corridor in the Lacandona forest, Mexico.— Wild felids are one of the most vulnerable species due to habitat loss caused by fragmentation of ecosystems. We analyzed the effect of a structural corridor, defined as a strip of vegetation connecting two habitat patches, on the richness and habitat occupancy of felids on three sites in Marqués de Comillas, Chiapas, one with two isolated forest patches, the second with a structural corridor, and the third inside the Montes Azules Biosphere Reserve. We found only two species (*L. pardalis* and *H. yagouaroundi*) in the isolated forest patches, five species in the structural corridor, and four species inside the Reserve. The corridor did not significantly affect occupancy, but due to the low detection rates, further investigation is needed to rule out differences. Our results highlight the need to manage habitat connectivity in the remaining forests in order to preserve the felid community of Marqués de Comillas, Chiapas, México.

Key words: Habitat fragmentation, Connectivity, Neotropical felids, Corridor, Landscape ecology

Resumen

Los efectos de la presencia de un corredor en la selva Lacandona, en México, en la riqueza de especies de félidos silvestres.— Los félidos silvestres se encuentran entre las especies más vulnerables ante la pérdida de hábitat causada por la fragmentación de los ecosistemas. Se analizó el efecto de la presencia de un corredor estructural, definido como una franja de vegetación que conecta dos fragmentos de hábitat, en la riqueza y ocupación de félidos en tres sitios de Marqués de Comillas, en Chiapas: uno comprende dos fragmentos de bosque aislados, otro presenta un corredor estructural y el último se encuentra dentro de la reserva de la biosfera Montes Azules. Se encontraron cuatro especies en el interior de la Reserva, cinco en el corredor estructural y únicamente dos (*L. pardalis* y *H. yagouaroundi*) en los fragmentos de bosque aislados. La presencia del corredor no afectó de forma significativa a la ocupación, pero debido a la baja tasa de detección, se necesita seguir investigando para descartar diferencias. Nuestros resultados resaltan la necesidad de manejar la conectividad del hábitat en los bosques remanentes para lograr la conservación de la comunidad de félidos en Marqués de Comillas, en Chiapas, México.

Palabras clave: Fragmentación del hábitat, Conectividad, Félidos neotropicales, Corredor, Ecología de los paisajes

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Introduction

Habitat loss is a consequence of exponential growth of human populations around the world. Habitat destruction typically leads to fragmentation, the division of habitat into smaller and more isolated portions of land, separated by a matrix of human-transformed land cover (Haddad et al., 2015). Ecosystem fragmentation causes changes in landscape configuration. The implicit fragmentation also has well-documented consequences related to edge effects, such as increases in access for poaching, and dispersion of invasive species and decreases in the genetic flow of some species (Laurance & Useche, 2009). One of the most popular approaches to improve landscape connectivity is structural corridors, defined from a human perspective as habitat strips connecting habitat patches (Tellería, 2016). Structural corridors are crucial to connect populations that would otherwise be isolated, and they mitigate the effects of fragmentation (Bennett et al., 2004).

Wild felids are particularly prone to the effects of fragmentation because of their intrinsic ecological traits, such as large food requirements and wide-ranging behavior (Ripple et al., 2014). They are therefore an interesting wildlife group to study, not only because of their susceptibility to such effects but also because of their key ecological roles within ecosystems (Zanin et al., 2014). This study was conducted in the Lacandona rainforest, where five species of wild felids occur: jaguar (*Panthera onca*), cougar (*Puma concolor*), ocelot (*Leopardus pardalis*), margay (*L. wiedii*) and jaguarundi (*Herpailurus yagouaroundi*) (Garmendia et al., 2013). The populations of these five species are currently declining right throughout their distribution range (IUCN, 2016). The aim of this research was to analyze the effect of a structural corridor on the richness and occupancy of wild felids in a tropical rainforest area.

Material and methods

The study was carried out at three sites (fig. 1) located in the Lacandona rainforest, one of the most biodiverse areas in Mexico (Lira-Torres et al., 2012). Two of the sites were located within the municipality of Marqués de Comillas, which supports 15.7% of the total area of the Lacandona rainforest (204,000 ha). This is a highly fragmented area, where agriculture and livestock activities occupy 52% of the territory (Bezaury-Creel & Gutiérrez-Carbonell, 2009). Habitat fragmentation has created spatially heterogeneous landscape patterns. Marqués de Comillas is divided into common lands called 'ejidos', and this study was developed at four ejidos: Reforma Agraria, Adolfo Lopez Mateos, Zamora Pico de Oro and La Corona (fig. 1). The third site was located at the southern part of the Montes Azules Biosphere Reserve (MABR), which protects 331,200.00 ha of the Lacandona rainforest. Contrary to Marqués de Comillas, the reserve has a continuum of tropical rainforest that has been protected since 1978 (Ortiz-Espejel & Toledo, 1998).

We carried out a camera-trap survey in the Lacandona forest to record wild felid presence. We selected two sites with different landscape configuration, focusing on the presence-absence of a structural vegetation corridor. The first site consisted of two forest patches isolated by an anthropogenic matrix, without corridor connections (16° 22' 18"–16° 20' 33" N, 90° 42' 22"–90° 40' 32" W). Three landscape elements were identified in this site: (1) a forest patch in La Corona (17.27 km²), (2) a matrix in between, and (3) a forest patch in Zamora Pico de Oro (17.84 km²) (figs. 1A, 2A). There is a 1 km linear distance between patches. The mean distance between camera-trap stations and population settlements was 2.31 km (± 1.04). The camera-trap stations were on average 6.2 km (± 0.94) from the MABR.

The second site is located within the ejidos of Reforma Agraria and Adolfo Lopez Mateos (16° 15' 95"–16° 13' 41" N y 90° 49' 25"–90° 48' 45" W). It consists of two forest patches connected by a structural corridor. Here, we defined four landscape elements: (1) a forest patch of Reforma Agraria (23.85 km²), (2) a structural corridor (defined as corridor in Muench, 2012), (3) a matrix surrounding the corridor, and (4) a forest patch of Adolfo Lopez Mateos (75.77 km²) (figs. 1B, 2B). There was a minimum distance of 2.14 km between patches and the mean distance to population settlements was 2.86 km (± 1.08). The camera-trap stations were placed an average of 3.8 km (± 1.34) from the MABR.

We set four camera-traps on each of the seven landscape elements. The cameras were located according to a systematic arrangement, spaced 1 km from each other (fig. 2). Only the corridor cameras were spaced 500 m from each other, due to spatial limitations. Both study sites in Marqués de Comillas (figs. 2A, 2B) were sampled from 28 I 2012 to 15 XII 2012. The minimum distance between both camera-trap arrays was 16.2 km, reducing the likelihood to capture the same individual felids in the different camera-trap arrays.

The third site was used as a control. It was located inside the MABR Biosphere Reserve Montes Azules, where 15 camera-traps were located, in the circuits Miranda, La Granja and Sabana II, located to the south of the reserve. The distance between cameras was 500 m (fig. 2C). These camera-traps were active from 30 VIII 2013 to 20 V 2014. The average distance to population settlements was 2.36 km (± 0.58). This site is at least 15.6 km far from the other camera-trap systems, and there is also a fast-flowing river between the reserve and Marqués de Comillas, so we can consider this site independent from the other two.

Owing to equipment restrictions, we used four different models of camera-traps (Bushnell trophy cam, Primos truth cam 35, Wildview extreme, and Stealth Cam STC-U838NXT). Nevertheless, each site had the same proportion of each model to standardize the sampling between sites. The sampling efforts at each site were: 842 camera-trap days for the isolated patches site, 1,664 camera-trap days for the corridor site, and 1,016 camera-trap days for the reserve.

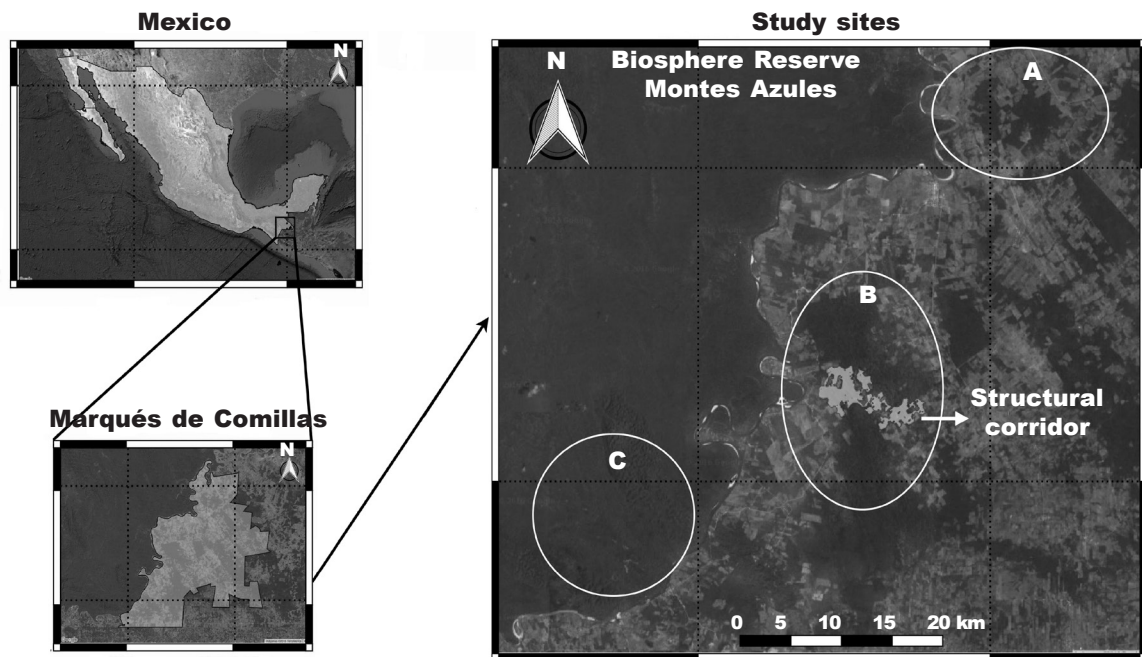


Fig. 1. Study area, Marqués de Comillas, Chiapas, and its location in Mexico. The study sites where the camera-traps were located are shown in the lower panel: A. Isolated *ejidos* Zamora Pico de Oro and La Corona, site of the two isolated forest patches; B. Connected, *ejidos* Reforma Agraria and Adolfo Lopez Mateos, site of forest patches connected by a structural corridor (in white); C. Reserve, southern part of the Montes Azules Biosphere Reserve, site of the continuum rainforest.

Fig. 1. Zona de estudio, Marqués de Comillas, en Chiapas, y su ubicación dentro de México. En el panel inferior se muestran los sitios donde se colocaron las cámaras trampa: A. Aislado, *ejidos* Zamora Pico de Oro y La Corona, sitio de los dos fragmentos de bosque aislados; B. Conectado, *ejidos* Reforma Agraria y Adolfo López Mateos, sitio de los fragmentos de bosque conectados mediante un corredor estructural (en blanco); C. Reserva, parte meridional de la reserva de la biosfera Montes Azules, sitio con bosque húmedo continuo.

All of the picture records were considered sufficiently clear to avoid false positives. To be able to compare species richness at each site, regardless of the camera-trap effort, we used rarefied species accumulation curves and extrapolations (Gotelli & Coldwell, 2001; Magurran, 2004). The history of detection of felid species at each camera-trap was used to estimate occupancy at each site. To calculate these parameters we used the single-season occupancy models of software PRESENCE 11.5 (MacKenzie et al., 2002). For these models we assumed occupancy (Ψ) was alternately constant or dependent on the presence-absence of the structural corridor and presence of the reserve. Likewise, detection probability (p) was alternately considered constant, variable over time, or dependent on the presence of the structural corridor or reserve. We ran a total of 16 models for each felid species. The best model was chosen based on the Akaike Information Criterion (AIC), where the smaller values indicate a higher likelihood (Burnham & Anderson, 2002).

Results

We recorded four species in the reserve site; *L. pardalis*, *L. wiedii*, *P. concolor*, and *P. onca* (fig. 1s in supplementary material). We recorded all five species in the connected site (fig. 3, fig. 2s in supplementary material). This latter site included the landscape elements with the most felid independent captures, the patch of Reforma Agraria and the corridor, each with seven records. There were no records of felids in the matrix surrounding the corridor. In the isolated site we recorded only two species, *L. pardalis* and *H. yagouaroundi* (fig. 3s in supplementary material). These records were confined to La Corona patch; no sightings were obtained in the matrix or in the Pico de Oro patch.

The model with the lowest AIC was the null model, in which the occupancy rate and probability of detection were constant. The model with the second lowest AIC value had constant occupancy and probability of presence dependent on presence-absence of the

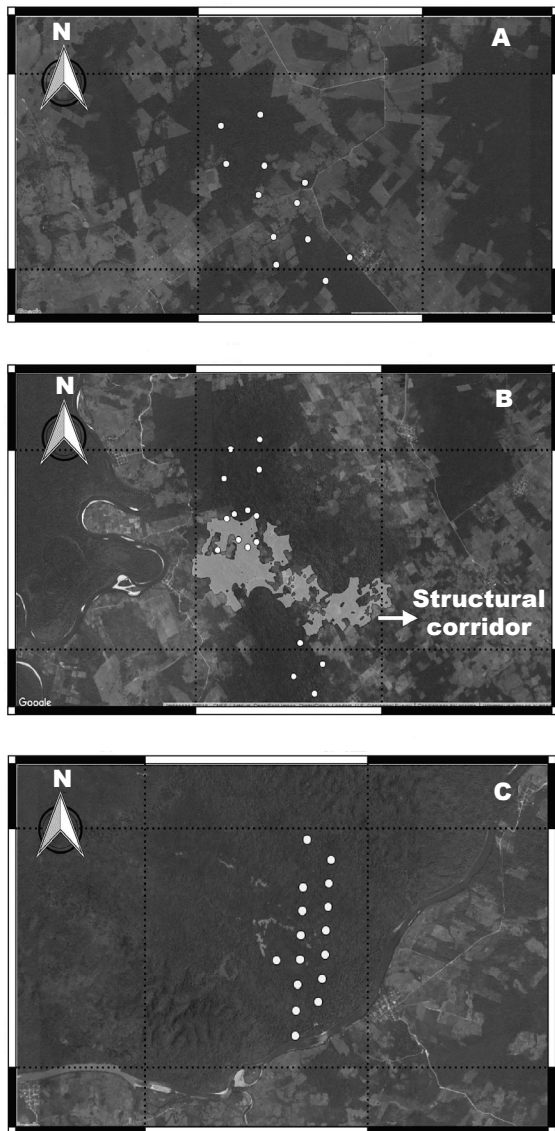


Fig. 2. Camera-trap locations. Study sites: A. Isolated, two isolated forest patches; B. Connected, two forest patches connected by a structural corridor (in white dots); C. Reserve, sampling along the paths inside the Montes Azules Biosphere Reserve, Chiapas, Mexico. Four camera-traps were located on each landscape element (corridor, matrix, patch) of the sites outside the reserve.

Fig. 2. Ubicación de las cámaras trampa. Sitios de estudio: A. Aislado, dos fragmentos de bosque aislados; B. Conectado, dos fragmentos de bosque conectados por un corredor estructural (en puntos blancos); C. Reserva, muestreo en senderos en el interior de la reserva de la biosfera Montes Azules, en Chiapas, México. Se colocaron cuatro cámaras trampa por cada elemento del paisaje (corredor, matriz y fragmento) en los sitios fuera de la reserva.

corridor; nevertheless, the fitting was insufficient to accept this model ($\Delta AIC > 3$). There was a tendency to a higher occupancy rate for *L. pardalis* than for other species $\Psi = 0.27$ (95% CI: 0.10–0.56; fig. 4). Overall, there was high uncertainty associated with occupancy estimations ranging from 0.29 (95% CI: 0.04–0.78) for *P. onca*, to 0.59 (95% CI: 0.09–0.91) for *P. concolor*.

Discussion

Our results suggest that loss of structural connectivity has a marked effect on wild felids species richness in our study site, as observed in other sites (Haddad et al., 2015). We should also emphasize that the only two species found in the isolated patches site, *L. pardalis* and *H. yagouaroundi*, are the most generalist of the five species in the study area. In contrast, it has been reported that presence of jaguar and cougar is favored in connected habitat (Grigione et al., 2009). The margay is considered the most vulnerable felid in this group, which could also explain its absence on the isolated patches site (Payan et al., 2008). We did not record *H. yagouaroundi* inside the reserve, possibly in view of its low density, which has been previously reported (Townsend et al., 2013). When comparing occupancy between sites, there was acceptance of the null model. We attribute this result to the low detection rates, which might produce false negatives, specially for the isolated patches site. The low detection rates could also be attributed to the high mobility and low density of these felids (Dillon & Kelly, 2007; Silver et al., 2004).

Other factors may affect our results. First, the area of patches is contrasting. In fact, the Adolfo Lopez Mateos patch is three times larger than the other patches, which could account for the higher richness of felids in the connected site (Scheiner, 2003). Still, in the connected site, there were more species and more records of felids in the Reforma Agraria patch, which is only slightly larger than the patches of the isolated site. Other factors that could also play a role are the distance to the reserve, and the distance to roads and population settlements, which we considered to have negligible effects on the probability of capture. It should also be noted that the camera-trap array was different in the reserve site; cameras were placed along the trails, possibly increasing the captures of felids, which are common users of trails (Harmsen et al., 2010). However, the detection rate did not vary between sites, so we could assume that the array did not affect our results. The low variation in detectability also suggests adequate distribution of the camera-trap models, which could otherwise be a source of error (Kelly & Holub, 2008).

To conclude, our results indicate that habitat connectivity is an important landscape feature, which requires to be maintained or even increased to favor conservation of felid species richness in the Lacandon rainforest. If habitat connectivity continues to decrease due to deforestation, the species that could be the most affected, in the short term, might be *P. concolor*, *P. onca* and *L. wiedii*.

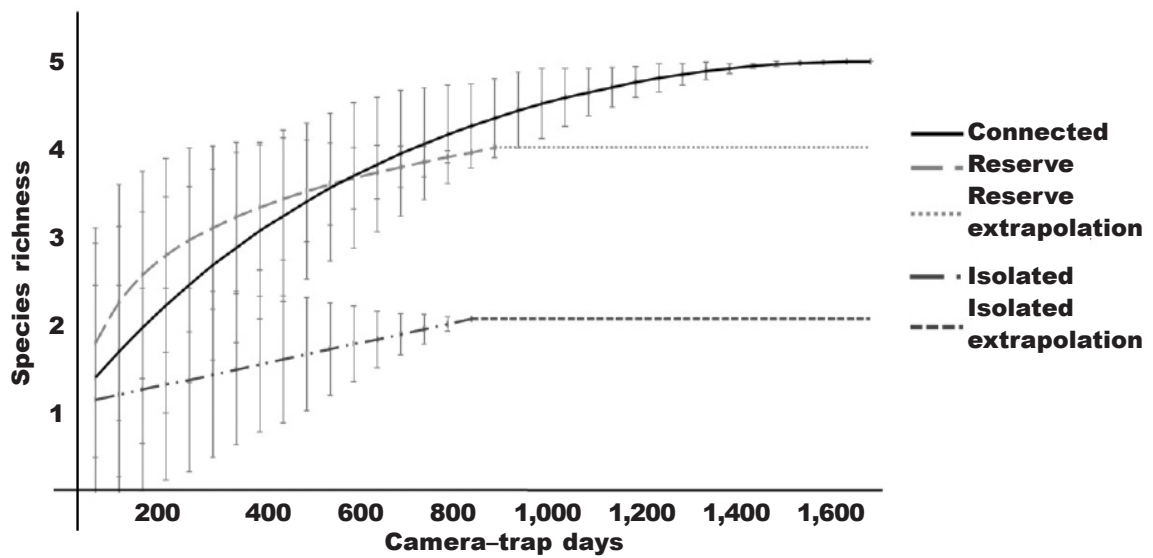


Fig. 3. Rarefied species accumulation curves of wild felids for the study sites located in Marqués de Comillas (connected and isolated) and south of the Montes Azules Biosphere Reserve (reserve), Chiapas, Mexico.

Fig. 3. Curvas de acumulación de especies escasas de félidos silvestres para los sitios del estudio en Marqués de Comillas (conectado y aislado) y al sur de la reserva de la biosfera Montes Azules (reserva), en Chiapas, México.

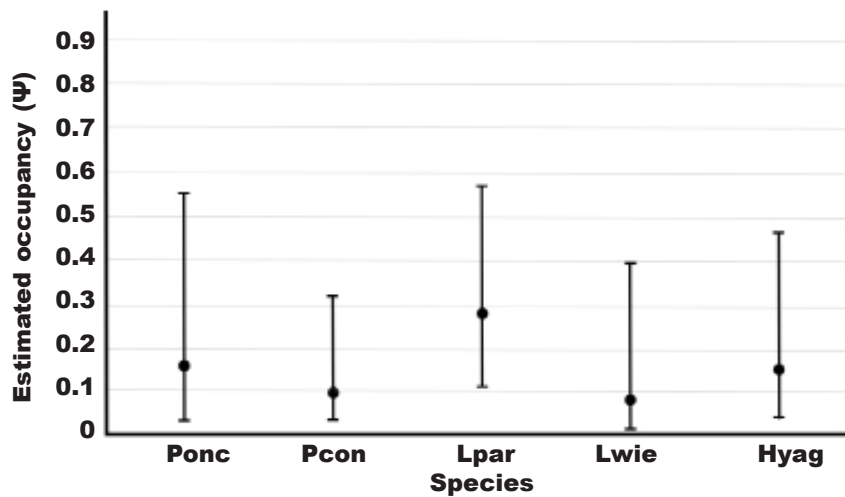


Fig. 4. Estimated occupancy of felid species in the Lacandona forest, Chiapas, México. Ponc. *Panthera onca*; Pcon. *Puma concolor*; Lpar. *Leopardus pardalis*; Lwie. *Leopardus wiedii*; and Hyag. *Herpailurus yagouaroundi*.

Fig. 4. Ocupación estimada de las especies de félidos de la selva Lacandona, en Chiapas, México: Ponc. *Panthera onca*; Pcon. *Puma concolor*; Lpar. *Leopardus pardalis*; Lwie. *Leopardus wiedii*; Hyag. *Herpailurus yagouaroundi*.

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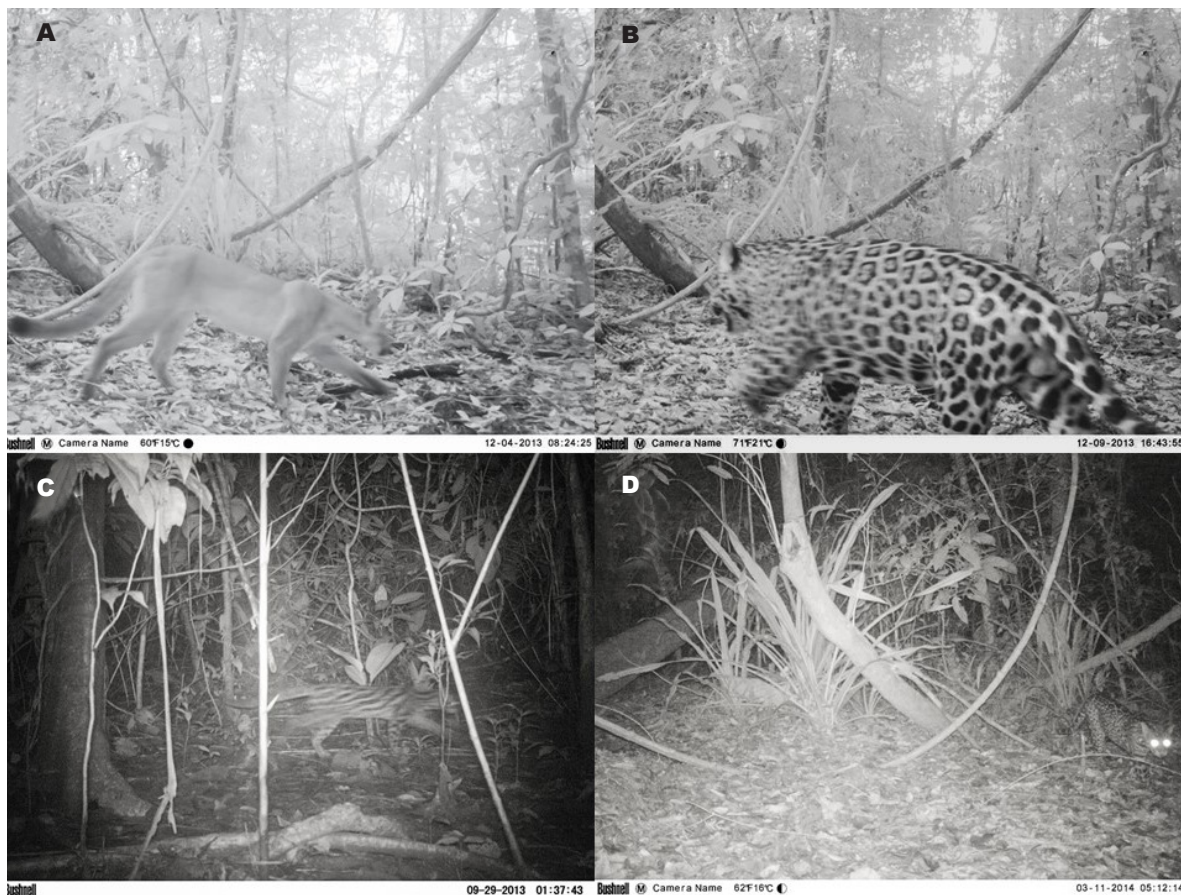
Supplementary material

Fig. 1s. Felid species recorded on the Montes Azules Biosphere Reserve, Chiapas, Mexico: A. *Puma concolor*; B. *Panthera onca*; C. *Leopardus wiedii*; and D. *Leopardus pardalis*.

Fig. 1s. Especies de félidos registradas en la reserva de la biosfera Montes Azules, en Chiapas, Mexico: A. *Puma concolor*; B. *Panthera onca*; C. *Leopardus wiedii*; D. *Leopardus pardalis*.



Fig. 2s. Felid species recorded at the connected site of Marqués de Comillas, Chiapas, Mexico: A. *Puma concolor*; B. *Leopardus wiedii*; C. *Leopardus pardalis*; D. *Panthera onca*; and E. *Herpailurus yagouaroundi*.

Fig. 2s. Especies de félidos registradas en el sitio conectado en Marqués de Comillas, en Chiapas, México: A. *Puma concolor*; B. *Leopardus wiedii*; C. *Leopardus pardalis*; D. *Panthera onca*; E. *Herpailurus yagouaroundi*.



Fig. 3s. Felid species recorded at the isolated site of Marqués de Comillas, Chiapas, Mexico: A. *Herpailurus yagouaroundi*; B. *Leopardus pardalis*.

Fig. 3s. Especies de félidos registradas en el sitio aislado en Marqués de Comillas, en Chiapas, México: A. *Herpailurus yagouaroundi*; B. *Leopardus pardalis*.