**Bat abundance, diversity and distribution patterns in relation to habitat characteristics of Mayan forest**

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Deforestation and its impact on climate and diversity is a major concern throughout the world. Fauna such as birds, mammals and herpetofauna are often used as indicators of forest health due to the direct relationship between species abundance and diversity and forest disturbance. In the Neotropics, bats have been cited as good indicators of forest health because both abundance and diversity of bat species was lower in disturbed forest (Estrada et al., 1993; Medellin et al., 2000). However, more recent studies suggest that bats can adapt to mosaic landscapes due to their ability to travel between different habitat when feeding, provided that corridors of old growth forest persist (Estrada & Coates-Estrada, 2002; Bernard & Fenton, 2007). Moreover, bats (and birds) living in mosaic landscapes play a major role in forest regeneration in relation to seed dispersal (Medellin & Gaona, 1999) and reducing insect biomass and associated damage to new leaves (Morrison & Lindell, 2012).

The Yucatan Peninsula of Mexico contains naturally fragmented forest and savannah due to variation in rainfall patterns (Montiel et al., 2006). In addition, the tradition farming techniques of the indigenous Mayan communities have resulted in a mosaic landscape of old growth forest, regenerating forest of varying ages and farmland. Much of the wildlife appears to be adapted to this changing habitat with little variation in bird (Smith et al., 2001) butterfly (Vester et al., 2007) and herpetofaunal (Luja et al., 2008) diversity between old growth and regenerating forest. Bat abundance in the Yucatan Peninsula of Mexico is very high due to large areas of tropical forest containing an extensive system of caves, and sink holes (cenotes) that act as roost sites MacSwiney et al., 2007). Bat diversity persists throughout the mosaic landscape of the Yucatan, although the abundance of frugivorous bats is reported to be higher in old growth forest with large fruiting trees (Montiel et al., 2006). The abundance of frugivorous bats in relation to large trees, may be attributed to both roost site and food availability. A study of two common species of frugivorous bat (*Sturnira lilium* and *Artibeus intermedius*) in the buffer zone of Calakmul Biosphere Reserve in Mexico found that although both species were commonly found in both secondary and primary forest, *Sturnia lilium* would only roost in large trees found in primary forest (Evelyn & Stiles, 2003).

The Calakmul Biosphere Reserve in the south of the Yucatan Peninsula is an UNESCO World Heritage Site of Culture and Nature due to the forest of outstanding biodiversity that surrounds multiple ancient Maya ruins sites, including the city of Calakmul that contained up to 150,000 people during the height of its power between 250BC – 900AD. The tropical semi-deciduous forest in Calakmul Biosphere Reserve is unusual in that areas close to Mayan Ruins contain unusually high densities of large fruiting trees (the result of Ancient Mayan agro-forestry) in comparison to other areas (Ross & Rangel, 2011). As there are no rivers or streams in the reserve, forest structure is also heavily affected by distance from the limited number of lakes in the reserve known as aguadas. In addition, there is a steady increase in mean annual precipitation from the north to the south of the reserve that has a notable effect on tree species composition and forest structure.

Over 20,000 people live in and around Calakmul in traditional Mayan villages where the major source of income is agriculture. Data from a range of taxa suggest that the forest/farm matrix surrounding the reserve

can still maintain high biodiversity providing that corridors of primary forest remain. However, the direct relationship between habitat variables and the abundance and diversity of bats has yet to be documented. This current study aims to investigate the abundance and diversity of bats in the core and buffer zone of the Calakmul Biosphere Reserve in relation to forest structure, distance to water and vicinity to Mayan ruins.

**Methods**

Data collection will be carried out in 4 different locations with the Calakmul Biosphere Reserve (Figure 1). These camp locations have been chosen due to their accessibility during the wet season and because they cover the full geographical and vegetation range of the reserve. Each camp will contain four 2km long transect lines for data collection that have been mapped using a GPS unit. Five sample sites for habitat surveys will be located along each transect line at 500m intervals, giving rise to 80 sample sites across the 4 research locations in the reserve. Each sample site will consist of a 20m x 20m area adjacent to the transect line. These sample sites are used for habitat surveys to provide a corresponding set of habitat variables for each bat survey location (by linking each mist net location to the nearest habitat plot). Each site will be marked, and the GPS location recorded.

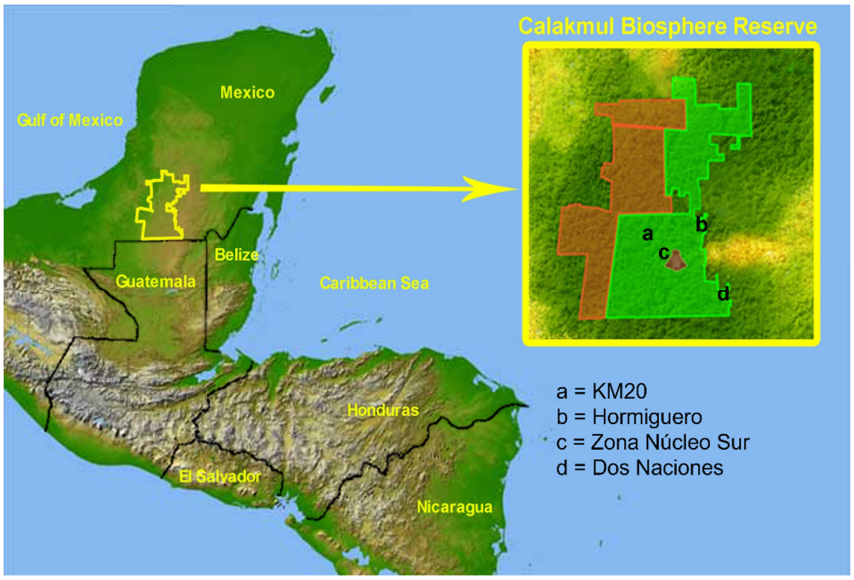



Figure 1: Location of research camps in Calakmul

Bat mist nets surveys will run 6 nights per week at each research camp using a suitable existing clearing along each of the four 2km sample routes close to one of the habitat plots with enough space to erect five 6m long mist nets 2.5 meter high. The location of each mist net site will be marked and the GPS location recorded to ensure that replicate surveys are conducted in the same location. Mist netting with be conducted between 7:00pm and 1am, but as data collection may be affected by rain, the exact opening and closing time of the nets will be recorded each session. The nets will be checked every 15 to 20 minutes during the first 3 hours of sampling and every 30 minutes for the last three. All the bats will be extracted from the nets following standardized protocols so as to minimize the stress and will be kept in a capture bags for 30mins, maximum.

This time will vary depending on the size of the bat and the sex; pregnant females will be measured and released. Bats will be weighed, sexed, reproductive status, the length of the forearm, feet and leg will be measured. Bat species will be identified using relevant field guides (e.g. Reid, 2009). In addition, ANABAT recorders will be used to record bat echolocation at each mist net location as a means of collecting data on species that may be present, but are unlikely to de captured in the nets (e.g. insectivorous bats with fine-tuned echolocation able to detect the nets and avoid capture).

Habitat surveys will be conducted in each of 20m x 20m survey sites to investigate tree diversity and forest structure. The number of saplings (trees with circumference <15cm and a minimum height of 3 metres) will be counted for each plot. For each tree in the plot with a circumference >15 the species and DBH of the tree, and whether the tree is alive or dead will be recorded on datasheets. For each tree with a circumference >30cm, height of the tree will also be recorded on datasheets. DBH will be measured using 50m tape measures and tree height will be calculated using SUUNTO clinometers (tree height can be estimated based on the distance of the observer from the base of the tree and the angle from the observer to the top of the tree). The DBH and length of each fallen tree within the plot will also be recorded. Forest structure measurements include understorey vegetation, canopy cover and leaf litter depth. To measure understorey vegetation, the plot will be bisected to produce the four quadrants. A 3m pole marked in 0.5m segments will be used to record the number of vegetation touches on the pole in each 0.5m segment every 1m along these bisecting tapes. The openness of the canopy will be measured by taking a reading with a canopy scope from the centre of each of the four quadrants and one from the centre of the overall 20m X 20m square. Leaf litter depth will be recorded in each of the 4 quadrants and in the centre of the plot using a ruler to give 5 separate leaf litter measurements (mm) per plot.

**Suggested Reading**


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