Effects of Hurricanes on bat populations in the "Sierra del Rosario" Biosphere Reserve, Cuba: a long-term monitoring study

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INTRODUCTION

The West Indies is an area of high species richness and endemism (Woods and Sergile 2001), and it is recognized as a hotspot of biodiversity for terrestrial biotas (Myers et al. 2000). Cuba is the most important island in the Caribbean hotspot, representing a high percentage of the biodiversity for the entire hotspot (Mittermeier et al., 1999). This region is characterized by high cyclonic activity; therefore, the composition and structure of its biota have been molded by hurricanes for long time (Willig et al., 2009). However, global warming likely will increase the number and intensity of tropical storms and hurricanes in this region (Goldenberg et al. 2001). The bats have potential as bioindicators of the climate change, they provide many ecosystems services, and hence reflect the status of the plant and insect populations on which they feed. The changes in their populations or activity can be related to climate change (including extremes of drought, heat, hurricanes and sea level rise), and degradation, loss and fragmentation of forests (Jones *et al*., 2009).

With 26 extant species, Cuba has the richest bat fauna in the Antilles, representing more than 45% of the entire West Indian bat fauna (see Rodríguez-Durán and Kunz, 2001). In Cuba, as other Antillean islands, the destruction of natural habitats by human and natural causes could put many bat species at extinction risk (Mancina et al., 2007a). These mammals may be particularly vulnerable to stochastic natural events such as hurricanes (Waide, 1991; Presley and Willig, 2008; Gannon and Willig, 2009; Pedersen et al., 2009). Although Cuba is frequently hit by hurricanes, studies of their effects on Cuban fauna are very scarce, and no information exit about how Cuban bat species are affected by hurricanes anywhere in the island.

Although several aspects of the biology of Cuban bats are known (Silva, 1979), their habitat requirements and long-term changes of the populations remain unexplored. Since middle 90' we began long-term monitoring of bat populations in the "Sierra del Rosario" Biosphere Reserve (see Mancina, 2004; Mancina et al., 2007b). Based on mist netting inventories and the acoustic monitoring of several vegetation patches, we have obtained information on the annual and seasonal fluctuations of the abundance of the most common species. We have also collected information on bat assemblage composition and ecological traits (use of habitat, diet, nocturnal activity, reproduction patterns, etc.). The main object of our investigations is carry on long term monitory and development a database of bat populations in "Sierra del Rosario" Biosphere Reserve. This information could be a baseline for to explore the effects of habitat modification and climate changes on the bat populations in one of Cuba's most conserved forest ecosystems.

This project had two principal aims: 1. to continue the species inventory and the long-term ecological research on the bats in "Sierra del Rosario" Biosphere Reserve and, 2. to explore the effects of the hurricanes on the bat populations of this region. In this project we compared pre-hurricane data from mist netting and acoustic surveys with information of six to 16 months after hurricane affected the reserve. The information here presented shows only the short and mid-term responses of bat populations that inhabit "Sierra del Rosario" Biosphere Reserve to hurricanes.

MATERIALS AND METHODS

STUDY AREA. This study was conducted in Sierra del Rosario Biosphere Reserve (SRBR), in the easternmost portion of the Cordillera de Guaniguanico in western Cuba (Fig. 1). The Reserve has an area of 250.7 km^2 and is characterized by predominantly tropical evergreen forest (Plate I) (Herrera *et al*., 1988). Generally, this forest exhibits two strata: a 10–20 m high tree canopy and an understory layer with plants 3–5 m high. To date only small zones of the pristine or little-altered forests remain; road openings, creation of terraces to prevent erosion, and selective logging have been the most significant habitat modifications. The climate is characterized by a rainy or wet season, May through November, and a dry season, December to April. The greatest disturbance in recent years has been Hurricanes Gustav (August 2008) and Ike (September 2008). The strong winds and rainfall drastically altered the forest structure by opening the canopy through severe defoliation, tree uprooting, and stem and branch breakage (Fig. 2).

Plate I. View of the secondary evergreen forest (July 2007, before the hurricanes).

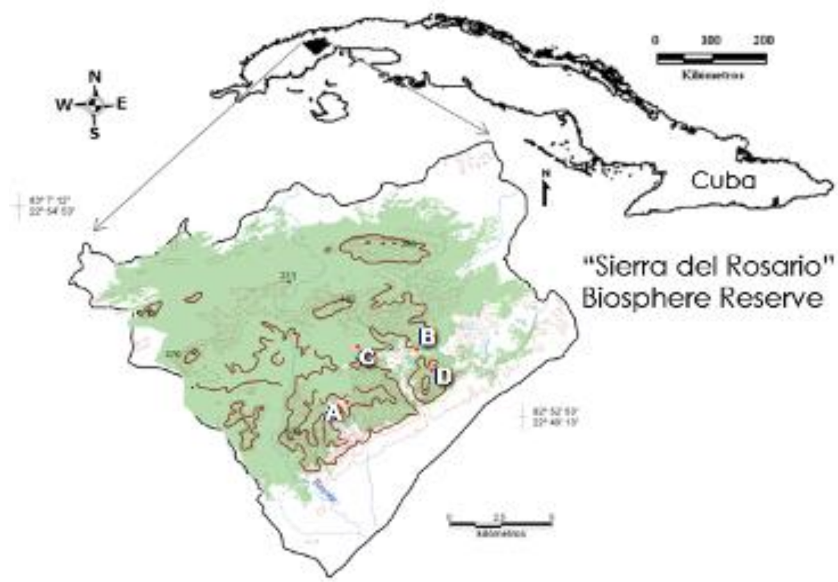

Figure 1. Location of the Sierra del Rosario Biosphere Reserve and sampled sites (red circles), labeled as: A. El Salón, B. "Sierra del Rosario" Ecological Station, C. La Serafina and D. El Taburete. The green zone represents covered area of forest vegetation.

Figure 2. Photos of the vegetation of the "Sierra del Rosario" Biosphere Reserve (September 2008) after the pass of winds and heavy rains associated to the hurricanes Gustav and Ike. Note the severe defoliation and tree breakage. Photographs by courtesy of "Sierra del Rosario" Biological Station.

CAPTURE METHODS. Between March 2009 and July 2010 bats were sampled with mist-nets at four forest sites. At each site bats were sampled during the rainy season (November to April) and dry season (May to October) at least three nights in each site by season. The sampled sites were located in: La Serafina (22°51'08''N, 82°56'34''W), El Taburete (22°50'31''N, 82°55'27''W), "Sierra del Rosario" Ecological Station (SREE) (22°51'04''N, 82°55'52''W), and El Salón (22°49'39''N, 82°57'52''W). These sites were separated from each other by about 3–6.5 km (Fig. 1). Although sampling effort differed between the sites, the sampling protocols at each site before (1996-2007) and after (2009-2010) the hurricane were similar as far as possible.

We used 4–6 9 m or 12 m mist nets with 35 mm mesh set from the ground to a height of 2.5 m (Plate II a) and separated by about 30 m to capture bats. Some non phyllostomids are less susceptible to capture by mist nets but caught in harp traps (see Voss and Emmons, 1996), due to that we used a double-frame harp traps (Plate II b)(Austbat Research Equipment, Lower Plenty, Victoria, Australia) to complement the inventory of bat species in two sites (El Salón and SREE). All mist nets were open before dusk and operated until 24:00 hours and were checked every 30 min. Each individual bat captured was identified and weighed (to the nearest 0.5 g), and sex, age class (subadult or adult — Anthony, 1988), hour of capture, and reproductive condition (pregnant, lactating or non-reproductive females and the testis size in males — Racey, 1988) were recorded. All bats were marked with a numbered band on a plastic necklace (Gannon, 1993). Nearly every captured bat was kept in a cloth bag for at least one hour before being released. Each bag was inspected for fecal material. The feces were stored individually in 70% ethyl alcohol.

Plate II. Left. Captured individual of Jamaican fruit bat (Artibeus jamaicensis) while carrying a fruit of "Pomarrosa" (Syzygium jambos). Right. A trap harp set on "El Helechal", El Salón, core area of the Biosphere Reserve. Carlos A. Mancina ©.

The sampling effort was standardized each night by multiplying the length of all nets in meters (m) by the total sampling hours (hr). This allowed us to estimate species capture rate each night by dividing the number of captured individuals by sampling effort (m × hr). We did not search for roosts; therefore we have assumed that the captured individuals represented presence only of species that were foraging at these sites. Bats were classified by feeding guilds using information from Silva (1979) and Mancina *et al*. (2007).

ACOUSTIC SAMPLING. Our first aim was to complement with acoustic data the mist net inventory; because bat detectors do not distinguish among individuals calls, we did no use data to estimate abundance; rather data were used to compare relative activity levels before (2006 – 2007) and after

(2009 – 2010)the hurricanes. Due to phyllostomid bats low-intensity calls and their calls show low inter-specific variation (Vaughan et al., 2004) we only used acoustic sampling to sample insectivorous bats. We performed acoustical surveys of bats at three sites (El Salón, La Serafina and El Taburete), in the same location where we conducted the mist netting protocol. Each site was sampled in the wet and dry seasons and we recorded the activity of bats over two or three consecutive nights, from 18:00 until 6:00 each evening. We surveyed bats using the Anabat system (Plate III a), which consisted of an Anabat II ultrasonic bat detector, zero crossing analysis interface modules (ZCAIM) with a timer incorporated (Titley Electronics, Ballina, New South Wales, Australia). The bat detector was maintaining at an angle of 45° from the horizontal at 2.5 m above-ground (Plate III b). The store equipment and the timer were programmed to start recording one hour before the sunset and finishing one hour after the sunrise. Each time a bat flew past the detector (considered here as a pass), a digital file was stored in a compact flash card of 128 Mb. The equipment codified the received signals as independent files and encoded date-time information into each file.

Plate III. Left. We recording bat calls in real time during a acoustic survey in La Serafina, "Sierra del Rosario" Biosphere Reserve. Right. Fixed microphone of the Anabat bat detector. Carlos A. Mancina ©.

We captured bats to create a library of vocal signatures for comparison. The Analook software version 4.9 (Titley Electronics) was used to record and analyzes call sequences, assign species names and extract call parameters. This software includes functions for measurement and extraction of pulse parameters from entire call sequences providing the *N* and mean for each resulting in an accurate measure of the range of variation within a given species vocal signature. An index of activity was calculated for each species in each site; this method of acoustical activity index is based upon the number of recorded passes of a species during time intervals.

DATA ANALYSIS. One objective of this project was to estimate species richness of bats that inhabit the Biosphere Reserve. We computed several non parametric estimators of species richness based on our capture data, random shuffling among samples and averaging over 1000 iterations, using the program EstimateS, version 5.01 (Colwell, 1997). We applied the Pearson correlation test to explore the relationships between capture effort and number of captured individuals on the species richness. To explore the effects of the hurricanes on the bat species, we compared ecological data (e.g. capture rate, body mass, activity patterns) using similar protocols before and after the hurricane. A Kruskal-Wallis and Mann-Whitney *U*-test were used to evaluate differences in the total capture rate and of particular species across sites, and before and after the hurricanes. We limited the analysis of activity patterns to the three most abundant species of phytophagous bats; this should reduce biases associated with use of ground-level mist nets and these species providing the necessary sample sizes to accurately estimate activity patterns. Captures were pooled into 1-h intervals; for each species, intraspecific differences in temporal activity patterns were evaluated before and after the hurricanes with Kolmogorov–Smirnov tests. If not otherwise stated, data are presented as means ± 95% CIs (confidence intervals), with a significance level of $P < 0.05$.

RESULTS AND DISCUTION

Bat Species Richness

A. MIST NETTING

We captured 1437 bats in the Reserve, of which 55 (3.8%) were recaptures (Plate IV), for 1382 individuals belonging to 15 species and five families (Table 1). The members of the family Phyllostomidae were predominant, representing 94% of all bat captured. The remaining non-phyllostomid individuals included 84 aerial insectivores of the families Mormoopidae (5.3%), Vespertilionidae (0.4%), Molossidae (0.2%) and Natalidae (0.07%). The insectivorous species, including a member of the subfamily Phyllostominae, could be considered rare, since each species contributed individually with less than 3% of the total captures (Table 1). Three phyllostomid species accounted for 87% of all individuals captured; numerically, *Artibeus jamaicensis* was the most common species and accounted for 35.6% of the total, followed by *Monophyllus redmani* (31.29%) and *Phyllonycteris poeyi* (19%).

Table 1. List of species, number of capture individuals, relative abundance and status of bats at "Sierra del Rosario" Biosphere Reserve, Cuba.

Family	Species	N	Ab.	Status[1]
Phyllostomidae				
Phyllostominae	*Macrotus waterhousei minor* Gundlach, 1865	1	0.07	RA
Brachyphyllinae	*Brachyphylla nana* Miller, 1902	56	4.05	RA
Phyllonycterinae	*Phyllonycteris poeyi* Gundlach, 1861	265	19.2	CM
	Erophylla sezekorni sezekorni Gundlach, 1861	4	0.3	RA
Glossophaginae	*Monophyllus redmani clinedaphus* Miller, 1900	432	31.2	CM
Stenodermatinae	*Artibeus jamaicensis parvipes* Rehn, 1902	492	35.6	CM
	Phyllops falcatus falcatus (Gray, 1839)	48	3.4	RA
Mormoopidae				
	Mormoops blainvillei Leach, 1821	7	0.5	RA
	Pteronotus macleayi macleayi (Gray, 1839)	11	0.8	RA
	Pteronotus quadridens quadridens (Gundlach, 1840)	40	2.9	RA
	Pteronotus parnelli parnelli (Gray, 1843)	15	1.1	RA
Natalidae				
	Chilonatalus micropus macer (Miller, 1914)[2]			RA
Vespertilionidae				
	Eptesicus fuscus dutertreus (Gervais, 1837)	4	0.3	RA
	Lasiurus pfeifferi (Gundlach, 1862)	2	0.14	RA
Molossidae				
	Molossus molossus tropidorhynchus Gray, 1839	1	0.07	RA
	Tadarida brasiliensis muscula (Gundlach, 1862)	3	0.2	RA
		1382		

1. We categorized species as rare (RA) or common (CM), based on species richness, it considers a species to be rare if its relative abundance is less than the average relative abundance of species (for this study < 6.25) in an assemblage (see Willig *et al*., 2007).
2. Only captured with harp traps.

Plate IV. Recaptured individual of Leach´s single leaf bat (Monophyllus redmani) with the body covered of yellow pollen of Blue Mahoe (Talipariti elatum). "Sierra del Rosario" Biological Station, November 2009. Raimundo López-Silvero ©.

We found that number of species captured was not related with the sampling effort (r= 0.14, CI 95%: -0.03-0.31, $p > 0.05$), however, the number of species increased with the number of captured individuals each night (r= 0.59, CI 95%: 0.45-0.69, $p < 0.0001$). Although the accumulative number of species increased with the total number of captures in the reserve (r= 0.94, CI 95%: 0.92-0.96, $p < 0.0001$), these were not enough to reach the asymptote of the curve (Fig. 3). All estimators overestimated species richness, Bootstrap yielded an estimate of 16 species and agree better with our capture data. The species richness observed (15) represented 83 % of the average expected richness by six non-parametric estimators (16-19 species; Fig. 4).

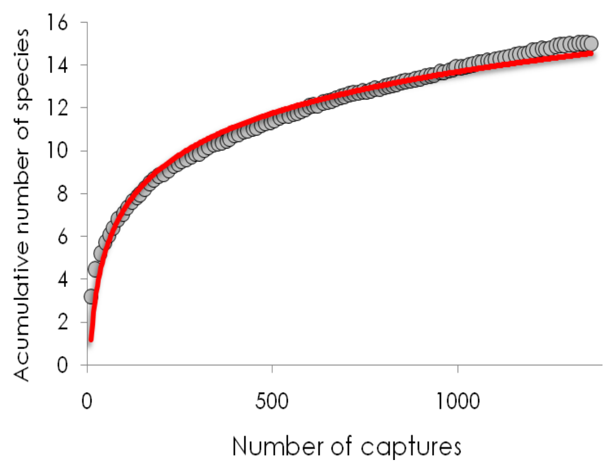

Figure 3. Relationship between the accumulative number of bat species and total number of captures in Sierra del Rosario Biosphere Reserve; only data from capture with mist net were included.

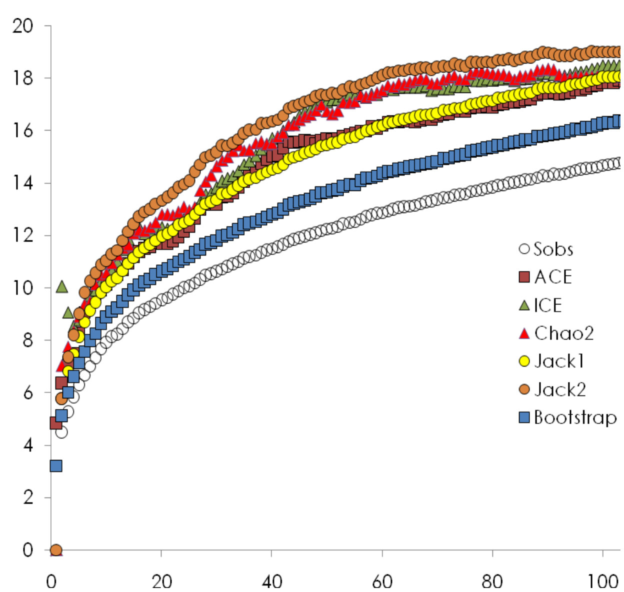

Figure 4. Estimates of species richness for bat community at "Sierra del Rosario", Biosphere Reserve, Cuba. The different symbols indicate the observed richness (white circles) and the estimated species richness based in six non-parametric estimators on our capture data.

B. ACOUSTIC SAMPLING

A total of 19954 recorded minutes of calls from free-flying bats was analyzed. Nine species belonging to the families, Mormoopidae, Molossidae and Vespertilionidae, were identified (Table 2) (Plate V). *Nyctinomops laticaudatus* only was detected by acoustic methods, and this is a new record for the occidental region of the Cuba. Three mormoopid species (*Pteronotus macleayi*, *Pteronotus quadridens* and *Mormoops blainvillei*) showed the highest levels of activity and representing more than 90% of all recorded call. The species number recorded in each site varied between nine (El Salón) and six species (La Serafina) (Fig. 5). In all sites the mormoopid bats presented the higher activity levels, although we observed a replacement in the most recorded species. The overall level of bat activity differed significantly among sites, the activity levels were significantly higher in "El Salón" than other two sites (Kruskal-Wallis Test, $H= 16.5$, $p < 0.001$).

Table 2. List of insectivorous bat species recorded by acoustic methods and number of bat passes in three sites on "Sierra del Rosario" Biosphere Reserve, Cuba.

		Number of bat passed counted	% of total
Mormoopidae	*Mormoops blainvillei* Leach, 1821	1320	22.06
	Pteronotus macleayi macleayi (Gray, 1839)	2280	38.1
	Pteronotus quadridens quadridens (Gundlach, 1840)	1868	31.2
	Pteronotus parnelli parnelli (Gray, 1843)	180	3.01
Vespertilionidae	*Eptesicus fuscus dutertreus* (Gervais, 1837)	115	1.92
	Lasiurus pfeifferi (Gundlach, 1862)	5	0.08
Molossidae	*Molossus molossus tropidorhynchus* Gray, 1839	25	0.42
	Tadarida brasiliensis muscula (Gundlach, 1862)	177	2.96
	Nyctinomops laticaudatus yucatanicus (Miller, 1902)	15	0.25

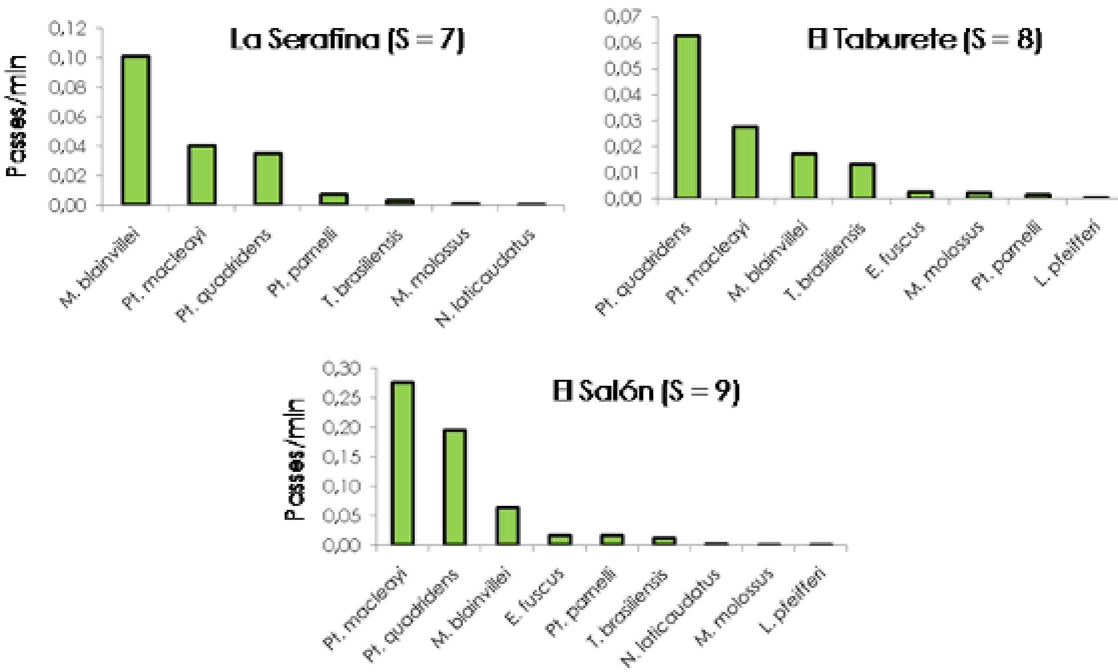

Figure 5. Activity level (passes/min) of insectivorous bats on three sites in the “Sierra del Rosario” Biosphere Reserve, Cuba. Note that species on abscissa have different ordination and the ordinates present different scales.

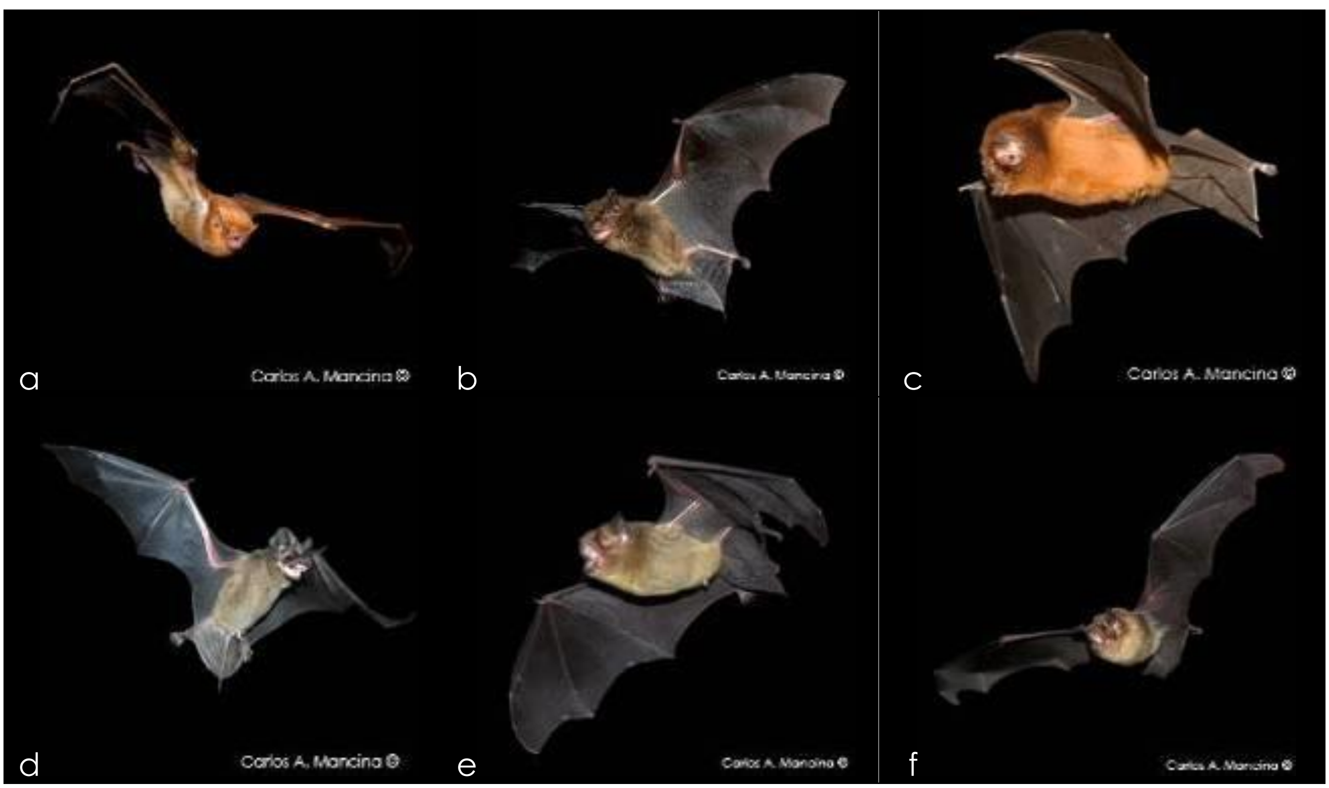

Plate V. Nine species of insectivorous bats of "Sierra del Rosario" Biosphere Reserve. a. Cuban red bat (Lasiurus pfeifferi), b. Big brown bat (Eptesicus fuscus), c. Blainville´s leaf-chinned bat (Mormoops blainvillei), d. Brazilian free-tailed bat (Tadarida brasiliensis), e. Parnell´s mustached bat (Pteronotus parnelli), f. Sooty mustached bat (Pteronotus quadridens), g. Waterhouse´s leaf-nosed bat (Macrotus waterhousei), h. Palla´s mastiff bat (Molossus molossus), and i. Cuban funnel-eared bat (Chilonatalus micropus). Carlos A. Mancina ©.

REMARK. Accurate species lists and abundance estimates are essential to carry out effective forest management and conservation of bat diversity. Based on mist netting data we did not reached the asymptote of the accumulative curve of species. Similar to other neotropical sites, this only could be achieved with the combination both capture (mist net and trap harp) and acoustic methods. Due to our long-term inventory studies on "Sierra del Rosario" we have detected 17 bat species. This high species richness (65% of all Cuban species) point out to this region as important area for the conservation of Cuban bats.

RESPONSES TO HURRICANES

A. MIST NETTING

We observed that total capture rate of bats in the reserve did not differ before and after the hurricanes Gustav and Ike (Mann-Whitney test, $U = 805$, $p > 0.09$; Fig. 6 a). The four sites studied show similar capture rate before (Kruskal-Wallis ANOVA by Ranks, $H = 7.4$, $p = 0.06$) and after ($H = 1.34$, $p = 0.7$) the hurricanes. In each sampled sites the total capture rates were not significantly different (Mann-Whitney test, all to $p > 0.07$) before and after the storms; although in all sites the rate had tendency to increase after the hurricanes (Fig. 6 b).

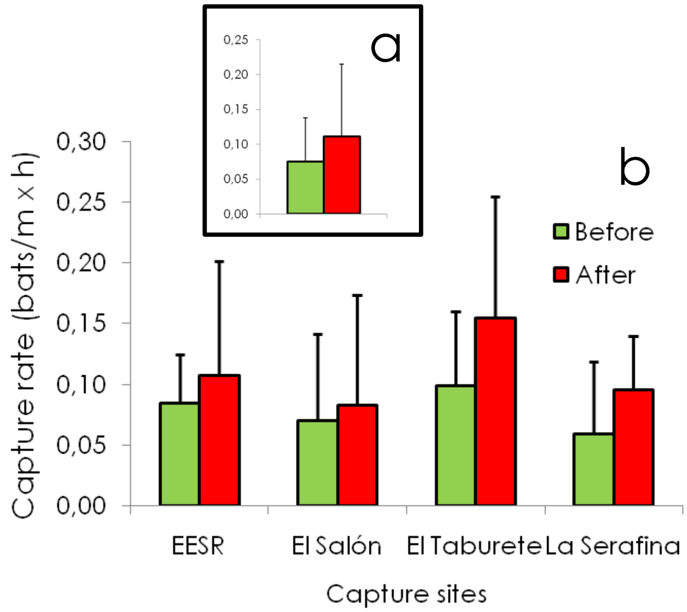

Figure 6. Capture rate of bats on four sites in Sierra del Rosario Biosphere Reserve before and after Hurricanes Gustav and Ike estimated from mist-net captures.

In the four sampled sites three species (*Artibeus jamaicensis*, *Monophyllus redmani* and *Phyllonycteris poeyi*) accounted for more than 80 % of the captures before and after the hurricane. In spite of lower capture effort after hurricane, two species: Waterhouse´s leaf-nosed bat (*Macrotus waterhousei*) and Cuban funnel-eared bat (*Chilonatalus micropus*) were capture only after the storms, although the latter was captured with the harp trap. In 1996 we found a colony of Waterhouse´s leaf-nosed bat in a small cave in the core area of the reserve, although never more an individual had been captured. The individual of Cuban funnel-eared bat (4 g of body mass) is a new record of bat species for the reserve and it represents one of localities of more elevation above sea level (470 m) where a funnel-eared bat has been captured in Cuba.

When the overall capture rate was analyzed including the species into feeding guilds (frugivores, nectarivores and insectivores), no significant difference was detected in any guild before and after the hurricanes ($p > 0.05$) (Fig. 7a). The frugivore guild on Cuba is composed of *Artibeus jamaicensis* and *Phyllops falcatus* (Plate VI), this guild is dominated by *Artibeus jamaicensis*, and captured data suggest that their population was unaffected by hurricanes on “Sierra del Rosario”. The capture rate of Jamaican fruit bat was higher after the hurricanes than pre-hurricane, although the difference was not significant ($U = 1106$, $p > 0.13$). The capture rate of this species in 2009 (between six and fourteen moths after hurricanes) was similar to higher historical rates on the region (year 2003) (Fig. 7b).

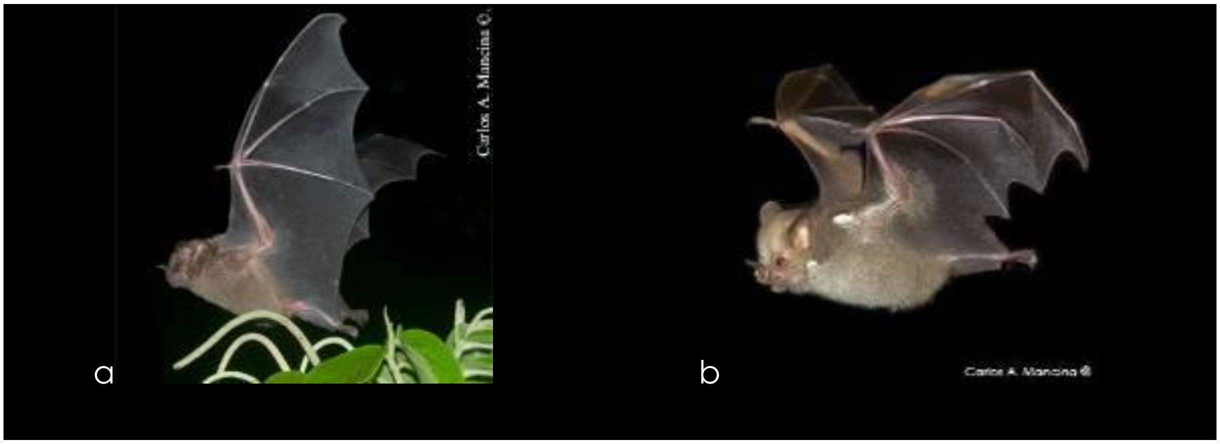

Plate VI. The two frugivorous bat species of “Sierra del Rosario”. a. Jamaican fruit bat (Artibeus jamaicensis), and b. Cuban White-shouldered bat (Phyllops falcatus). Carlos A. Mancina ©.

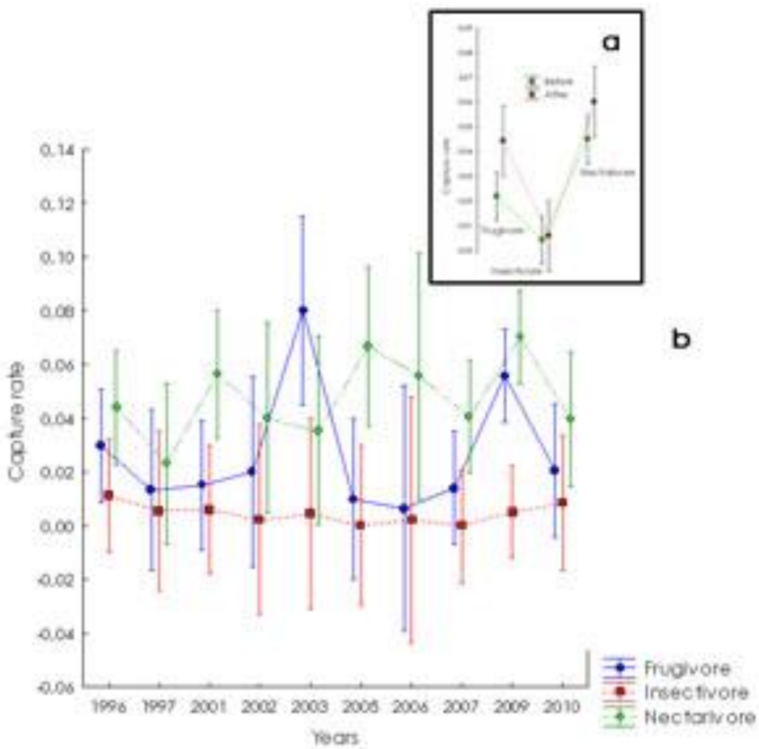

Figure 7. Annual fluctuation in the capture rate of three feeding guilds in “Sierra del Rosario” Biosphere Reserve.

Nectarivore guild is integrated by four species (*Monophyllus redmani*, *Phyllonycteris poeyi*, *Erophylla sezekorni* and *Brachyphylla nana*) (Plate VII). *Erophylla sezekorni* is the rarest phyllostomid in the study area (to date, only four individual have been captured, all pre-hurricanes). These species are obligate cave dwellers and have a generalist diet with nectar and pollen as the most important items in their diets, but they also consume insects and fruits of understory shrubs (Silva, 1979; Mancina,1998; Mancina et al., 2007). When we examined species individually, two patterns of response to the hurricanes were observed. The most common nectarivorous bat of the reserve, Leach´s single leaf bat (*Monophyllus redmani*), showed a significant increase (Mann-Whitney test, U = 835, p < 0.01) in total capture rate after the hurricane. The remaining species didn't show variation in their abundance after the hurricane (Table 3). In particular sites these species showed similar trend, although after hurricane we did not captured *Brachyphylla nana* on three of four sites (Fig. 8).

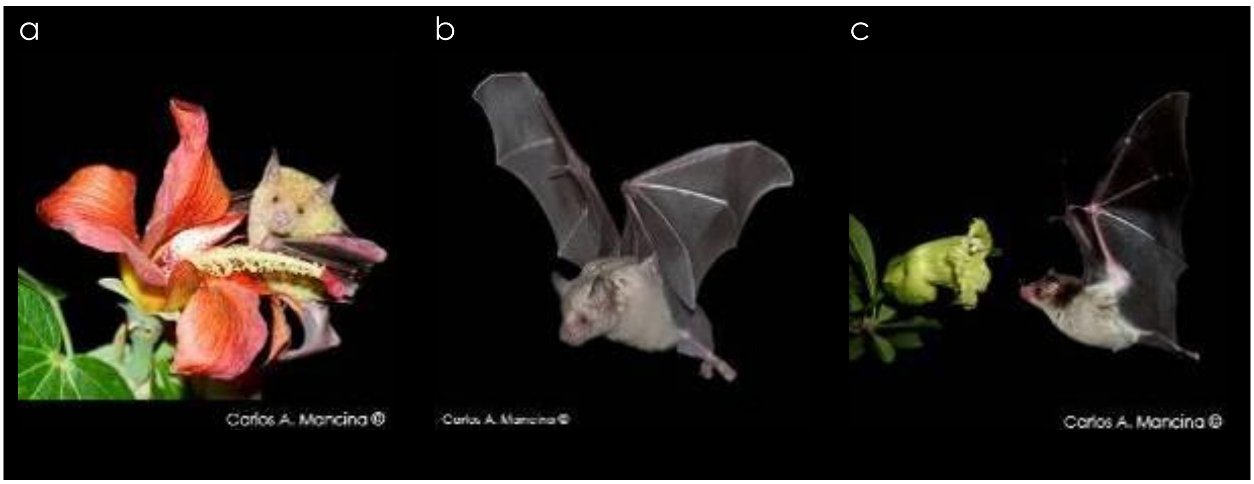

Plate VII. Three nectarivorous bats, a. Cuban flower bat (Phyllonycteris poeyi), b. Cuban fruit-eating bat (Brachyphylla nana), and Leach´s single leaf bat (Monophyllus redmani). Carlos A. Mancina ©.

Table 3. Overall capture rates (number of bats capture/meters- net hours) before (sampling between 1996 and 2007) and after (2009-2010) Hurricane Gustav and Ike.

	Before 1996-2007	After 2009-2010	U
Brachyphylla nana	0.002 ± 0.006 (CI 95%: 0.001-0.004)	0.003 ± 0.01 (CI 95%: 0-0.007)	1316 p= 0.84 (n.s.)
Phyllonycteris poeyi	0.013 ± 0.02 (CI 95%: 0.009-0.017)	0.013 ± 0.017 (CI 95%: 0.006-0.019)	1268 p= 0.62 (n.s.)
Monophyllus redmani	0.025 ± 0.03 (CI 95%: 0.017-0.033)	0.043 ± 0.03 (CI 95%: 0.029-0.057)	853 p = 0.002
Artibeus jamaicensis	0.022 ± 0.03 (CI 95%: 0.015-0.029)	0.048 ± 0.11 (CI 95%: 0.006-0.089)	1106 p= 0.13 (n.s.)
Phyllops falcatus	0.002 ± 0.007 (CI 95%: 0.001-0.004)	0.002 ± 0.006 (CI 95%: 0-0.004)	1200 p= 0.35 (n.s.)

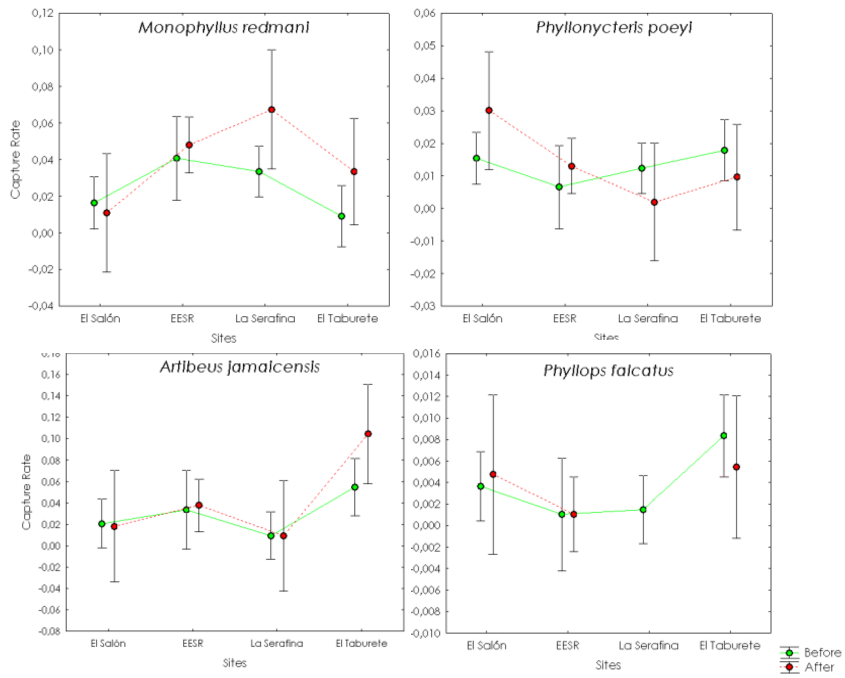

Figure 8. Capture rate of four phytophagous bats estimated from mist-net captures on four sites in "Sierra del Rosario" before and after Hurricane Gustav and Ike.

The high capture rate of *Monophyllus redmani* could be related with their diet relied more heavily on insects that other nectarivorous Cuban bats (see Mancina and Herrera, in press). Similar response to the hurricane by *M. redmani* was observed on Puerto Rico (Gannon y Willig, 1994). These authors documented that *M. redmani* was positively affected by Hurricane Hugo, its biomass and number of captured individuals increased compared to prehurricane levels, may be attributed to the rapid increase in the presence of flowering plants in the open forest understory after hurricane.

The activity patterns were indistinguishable from those observed in three most abundant phytophagous bats before the hurricanes (Kolmogorov–Smirnov 2-sample tests, $p > 0.1$) (Fig. 9). In *Monophyllus redmani* and *Phyllonycteris poeyi* the greatest differences in activity intervals involved less activity during the 1st hour of the night compared to before storms. Changes in the vegetation physiognomy (more open canopy) could be related with a reduction of activity levels of bats to avoid the risk of predation by diurnal and nocturnal birds.

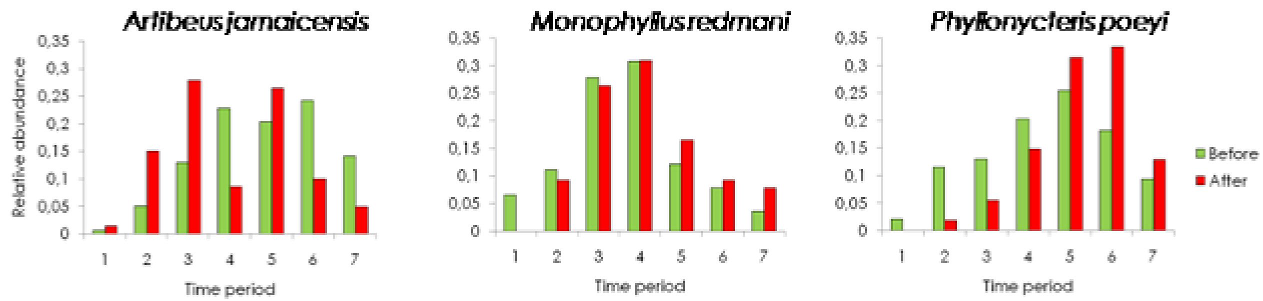

Figure 9. Temporal activity patterns for three phytophagous bats before and after Hurricane Gustav and Ike.

Insectivores are the most diverse guild on Cuba; in the reserve 11 insectivorous bats have been detected. The mean activity level before hurricanes was 0.26 ± 0.28 (CI 95%: 0.09 – 0.42) passes/min and after 0.24 ± 0.24 (CI 95%: 0.09 – 0.39) passes/min, and these differences were not significantly different (U= 78, $p > 0.05$). We found no difference in the activity levels in the three sites pre and post-hurricanes (Fig. 10 a). The mormoopid bats also were more recorded, *Pteronotus macleayi* and *P. quadridens*, exhibited similar activity; however, *Mormoops blainvillei* ($p < 0.01$) and *Pteronotus parnelli* ($p < 0.01$) showed a significant reduction of their activity levels post –hurricane (Fig 10 b).

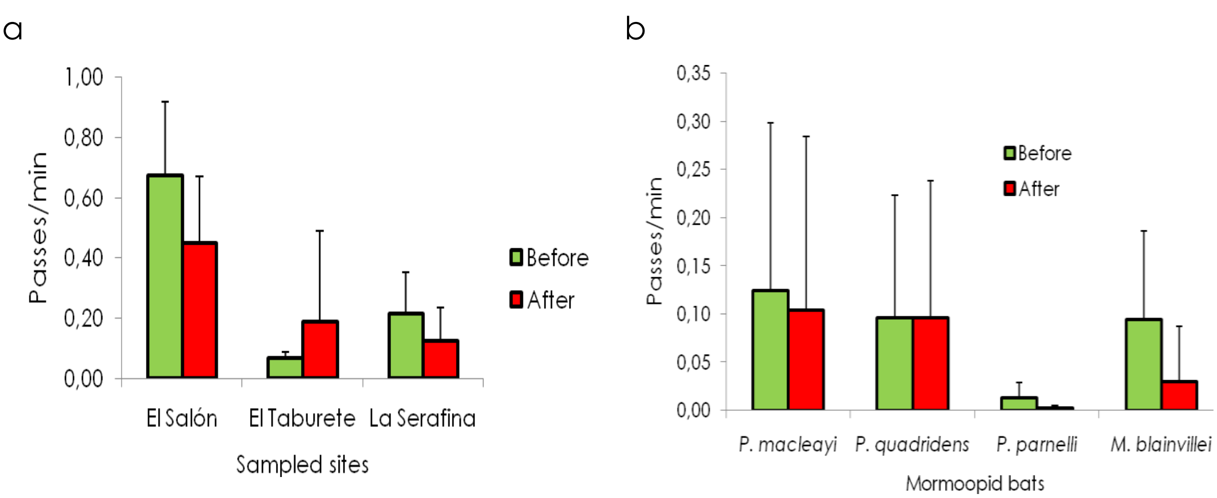

Figure 10. Activity levels (passes/min) of insectivorous bats before and after Hurricanes Gustav and Ike in "Sierra del Rosario" Biosphere Reserve. a. Overall activity on three sites, b. variation in the activity of mormoopid bats.

We have not quantitative information about the changes in the available resources before and after the hurricanes. The hurricanes caused widespread defoliation and alteration to vegetation and it could to origin long periods of food shortages mainly the fruits of canopy trees and flowers. To evaluate the nutritional condition of bats, we compared the body mass of adult males of the three most abundant phytophagous bats on the Reserve before and after the hurricanes. We observed a significant reduction in the body mass in *Monophyllus redmani* (Student test = 4.4, $p < 0.0001$) and *Artibeus jamaicensis* ($t = 5.1$, $p < 0.0001$), as well as *Phyllonycteris poeyi*, although the latter was not significant ($t = 1.05$, $p > 0.05$) (Fig. 11). The low nutritional condition in these species after the hurricanes, are indirect effects of hurricanes, and could have negative effects to long term on the reproductive success and therefore on the local populations of these species. Future studies will be necessary to test this hypothesis.

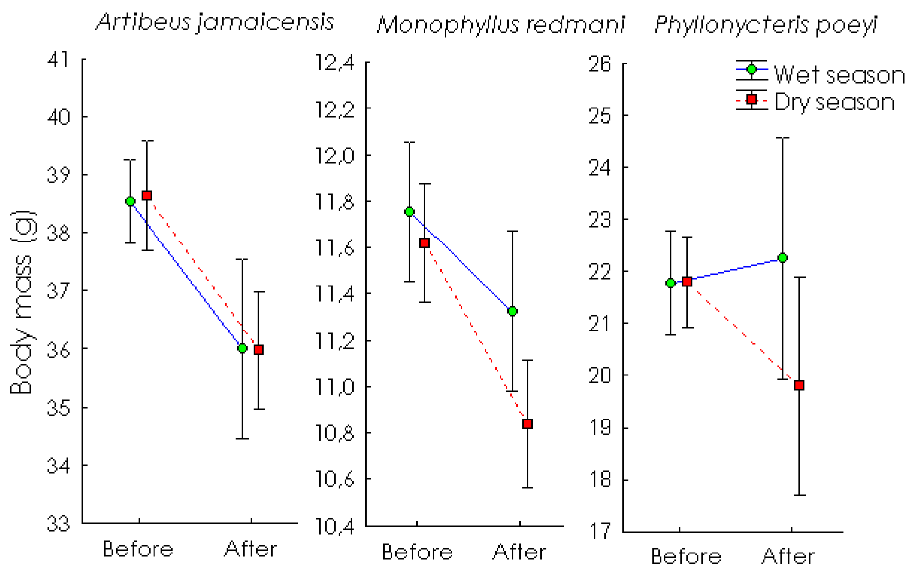

Figure 11. Differences, related to hurricanes and season, in body mass of adult males of the three most abundant phytophagous bats in "Sierra del Rosario" Biosphere Reserve.

The effects of the hurricanes for the bats are species-specific, and the rate of recovery of their population could depend on the severity of the hurricanes (Gannon y Willig, 2009). Compared to other catastrophic events that have impacted the Caribbean region, the Hurricanes Gustav and Ike reached the western region of Cuba with relatively low intensity. Our data suggest no population declines to short and mid terms of the bat species at Biosphere Reserve; we found highest capture rate of bats than expected six moths after the hurricanes, indicating that these events could to cause a low rate of mortality. These results are contrasting with that observed on other Antillean bat populations, where dramatic reductions post-hurricane have been observed (Jones et al., 2001; Pedersen et al., 2009). Nevertheless, the high capture rates of phytofagous bats after the hurricanes also could be related to a reduction in foraging height that made bats more susceptible to capture in mist nets. The modification in the foraging behavior could be related to changes in food resources and vegetation structure.

ACKNOWLEDGEMENTS

This study would not have been possible without the field assistance of: Raimundo López, "El Chispa", Rene Barba, Alex, Anabelle, Gustavo Blanco, Arturo Hernández, Angel D. Álvarez, Alejandro Gamboa, and Ilsa María Fuentes. Thanks to the staff of the Sierra del Rosario Ecological Station for its support during field work.

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