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ENDEMICS UNDER THREAT: AN ASSESSMENT OF THE CONSERVATION STATUS OF CUBAN BATS

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ABSTRACT - Reviewing available information from published literature, museum database, personal communications and from the authors own field data, the conservation status of Cuban bats has been assessed using six qualitative parameters: abundance, distribution, roosting habits, aggregation level, forest dependence, and degree of endemism. The resulting Red List is analogous to that of the IUCN, species having been included in four categories of risk. Four out of the 26 extant bats of Cuba should be considered endangered, four vulnerable to extinction, twelve potentially threatened, and six in a stable situation. Most of the species of bats endemic to Cuba are under some form of threat. The major threats to the survival of Cuban bats are the destruction of forests and the modification of caves, the latter being critical habitats for the mostly cave-dwelling Cuban bat fauna. We argue that its conservation should be the result of a cooperative effort promoting research and habitat management.

Key words: Bats, Chiroptera, conservation, Cuba, Red List, threatened species.

RIASSUNTO - ***Endemismi minacciati: una valutazione dello stato di conservazione dei chirotteri cubani***. Lo stato di conservazione dei chirotteri cubani è stato valutato a partire da sei parametri qualitativi: abbondanza, distribuzione, roost utilizzati, livello di aggregazione, dipendenza da ambienti forestali e grado di endemismo. A questo scopo sono state esaminate le informazioni bibliografiche, i database dei musei e dati non pubblicati, in parte raccolti dagli stessi autori. La Lista Rossa risultante è analoga a quella dell'IUCN, comprendendo quattro categorie di rischio crescente. Delle 26 specie attualmente presenti a Cuba, 4 sono da considerarsi in pericolo di estinzione, 4 "vulnerabili", 12 "potenzialmente minacciate" e 6 "stabili". La maggior parte delle specie endemiche è in qualche misura minacciata. La deforestazione e l'alterazione delle cavità carsiche, che costituiscono un habitat critico per le molte specie troglofile, rappresentano i principali fattori di rischio per la chirotterofauna cubana, la cui conservazione dipende da uno sforzo comune volto a favorire la ricerca e la gestione ambientale.

Parole chiave: Chiroptera, conservazione, Cuba, Lista Rossa, specie minacciate

INTRODUCTION

The West Indies, in a biogeographical sense following Morgan (2001), are notorious for having undergone proportionately more mammalian extinctions in the late quaternary than any other region of the planet. Despite the fact that these islands occupy a small portion of the world in terms of land surface, 38% of the extinct mammals in the past 500 years have been West Indian species (Morgan and Woods, 1986; MacPhee and Fleming, 1999). Of 94 species of terrestrial mammals that lived in the region during the late quaternary, only 17 remain (Woods, 1990). These large-scale extinctions have occurred in two waves: the first, concentrating around 5000 years before the present, took away large mammals (e.g. large ground sloths, primates and giant rodents) and the second, coinciding with the arrival of Europeans in the New World, consisted of the disappearance of small mammals (e.g. rodents and insectivores). Both have been associated with human activity, either through direct predation or through the introduction of exotic mammals and their pests (Morgan and Woods, 1986; MacPhee and Iturralde-Vinent, 2000).

Bats are the only group that has largely survived the late quaternary mammalian extinctions in the West Indies amounting to 66 known species for the Greater and Lesser Antilles, 56 of which are still extant. Three bat species are now extirpated on these islands but still occur in the mainland, whilst seven are extinct (Rodríguez-Durán and Kunz, 2001; Suárez and Díaz-Franco, 2003; Mancina and García, 2005). Nonetheless, with most native mammal species already gone from West Indian ecosystems, there is a growing concern that the current large-scale destruction of natural habitats and high human population density in the region could also put bats at risk. Therefore, to preserve whatever remains of mammalian diversity in the West Indies the conservation of these islands' bat fauna must receive special attention.

With 26 extant species, Cuba has the richest bat fauna in the West Indies, representing more than 45% of all species in the region (Koopman, 1989; Rodríguez-Durán and Kunz, 2001; Simmons, 2005). Besides including most of the West Indian endemic bat lineages, Cuba also harbours species of closer continental affinities (e.g. several vespertilionids and molossids) that are absent from other West Indian islands. This diversity is favoured by Cuba's relatively large surface area, its geographical proximity to North and Central America, high habitat complexity, and the abundance of roost-rich environments such as cave-bearing karst regions (Nuñez-Jiménez *et al.*, 1988; IGACC-ICGC, 1989).

Ecological, distributional and taxonomic traits of the Cuban bat fauna have been relatively well studied compared with that of other West Indian islands (e.g. Silva-Taboada, 1979). However, the biology of individual species of Cuban bats is poorly known, making the assessments of the long term stability of populations a difficult task. Cuban bats (as those of other West Indian islands) may be particularly vulnerable to stochastic natural events such as hurricanes (Gannon and Willig, 1994; Jones *et al.*, 2001) and cave destruction due to erosion (Morgan, 2001; Tejedor *et al.*, 2004). These factors represent an additional cause for concern for the long term survival of individual species. For this reason, evaluations of the conservation status of Cuban bats are urgently needed.

The Red Lists are a well established conservation tool at the global level (IUCN, 2006). However, these lists could be deficient and may not satisfy the need for national conservation priorities (Gärdenfors *et al*. 2001; Possingham *et al*. 2002; IUCN, 2003). The Red List for the Cuban bat fauna is such a case, being markedly deficient in its threat status propositions for the bats of the country. Furthermore, as former infraspecific taxa have been recently elevated to full specific status (Simmons, 2005; Tejedor, in press), several species now considered to be endemic to Cuba were left unassessed, and therefore are not included in the latest global Red List (IUCN, 2006). The main purpose of this paper is to propose a red list based on qualitative parameters that can be used to determine the threat status of Cuban bats, and to discuss the factors affecting their long term survival.

METHODS

We evaluated the Conservation status of bat species in Cuba using an approach similar to those used for the bats of Brazil (Aguiar and Taddei, 1996) and Bolivia (Aguirre, 1999). Because of the lack of substantial biological information and documentation on population trends, which is the most influential of the five criteria for listing species as endangered under the IUCN system (Frankham *et al*., 2002; IUCN, 2006), we estimated the conservation status of Cuban bats using six qualitative parameters that affect extinction risk: relative abundance, distribution, roosting habits, aggregation level, forest dependence, and degree of endemism. Each parameter was divided into classes to which numeric values were assigned, with the highest values corresponding to classes judged more reflective of a high threat status. Hence, we did not follow the guidelines proposed by the International Union for Conservation of Nature and Natural Resources for the creation of red lists at regional levels (IUCN, 2003). The information used in this paper comes from published literature, museum database, personal communications and from our own field data collected in more than ten years of surveys across Cuba.

Each parameter was defined and coded as follows (parameter values within parenthesis):

1. Abundance. Due to the lack of population estimates about Cuban bat species, this parameter was based on the categories of species abundance created by Silva-Taboada (1979). This is a qualitative measure of the abundance of a species based on the quantity of specimens deposited in biological collections combined with the number of collection localities. Although Silva-Taboada’s work is almost 30 years old, and that this index could underestimate species that are

difficult to catch, such as aerial or canopy insectivorous bats, we considered that its categories are still useful to estimate the relative abundance of Cuban bats in the wild. With the exception of *Phyllops falcatus*, which we have upgraded to "uncommon" (considered "rare" before), new available data do not suggest the placement of other species within a different class. In this study, Silva-Taboada's (1979) categories were clustered within three classes as follows: Common species (0; previous Silva-Taboada's categories of "Common" and "Very Common"), which comprises those species abundant in biological collections and with an elevated number of collection localities. Uncommon species (1; ex- "Scarce Species"), whose specimens are scarce in collections, but come from several localities or vice versa. Rare species (2; ex - "Rare" and "Very Rare"), of which only very few individuals have been historically collected in a few known localities.

2. Distribution. For the distributional analysis, the collected data were compiled into a database, which consisted of 1119 records of 26 species (all bat species recorded for Cuba) occurring in 497 different localities (all georeferenced). Using a geographic information system (ArcGIS 9.1, ESRI, 2005), the shape map of Cuba was divided into 549 hexagon cells, each with a 10 km edge (area = 259.8 km^2, Fig. 1). We mapped all collection records of each species and overlaid them on the hexagons–cell map. Then, we recorded the proportion of cells where each species occurred, in relation to the whole set of cells. Using these data, each species was classified according to one of the following classes: Widespread (0), present on more than 5.1% of the cells; Moderated (1), 5-2.1%; Restricted (2), <2%. Although our mapping effort misrepresents localities that have been poorly surveyed, it provides the best resolution we can get from the available data.

3. Roosting habit specialization. According to the degree of specialization for certain types of roosts, we assigned the following classes: Opportunistic species (0), bats that have generalized roosting habitats; in this category we included also species that in more than 40% of the records have been observed using man-made structures as roosts. Dependent (1), bats using only one type of roost in more than 70% of the records. Highly dependent (2), bats using only one type of roost (e.g. cave or tree roost).

4. Degree of gregariousness. Gregarious (0), species which regularly form colonies in the order of several hundred or thousand individuals. Slightly gregarious (1), species that form colonies that may approach 100 individuals, although smaller colonies can exist. Not gregarious or solitary (2), species that roost in small groups or in solitude.

5. Forest dependence. Non-forest-dependent (0), bats with high ecological plasticity, capable of exploiting human-transformed habitats (e.g. urban environments); species that we have frequently captured in secondary forest are included here. Forest-dependent (1), tree-dwelling bats or those that are captured in pristine or well-regenerated secondary forest. When information about forest dependence was not available, the parameter was treated as unknown (?).

6. Degree of endemism. Non-endemic (0) and Endemic Species (1).

Our ranking scheme generated a final classification: species with eight points or more were clustered in Category 1 (C1); between seven and six, in Category 2 (C2); between five and three in Category 3 (C3), and two or less in Category 4 (C4). In this classification we appraised lack of information as an aggravation of the threat status. These categories could be analogous to those of the IUCN (2006) as Endangered (C1), Vulnerable (C2), Near Threatened (C3), and Least Concern (C4), in order to identify conservation priorities. Our four categories have the following implications for conservation:

C1: This category includes many endemics and the most endangered bat species, which are very rare or known from very few localities.

C2: Comprises uncommon species having solitary or barely gregarious habits, generally presenting a restricted distribution, which make them vulnerable to extinction.

C3: Includes uncommon or common species with a wide distribution throughout the country. However, due to their ecological specialization (e. g. roost, diet, etc.), changes in habitat conditions could drive some demes to decline severely.

C4: Groups species with stable populations which are frequently collected, have a widespread distribution, and show high ecological plasticity.

For most species, we followed the systematic arrangement of Simmons (2005), whilst for those of the genus *Chilonatalus* that of Tejedor (in press). Although several authors have treated *Phyllonycteris poeyi* as a polytypic species common to Cuba and Hispaniola (e.g. Koopman, 1993; Simmons, 2005), we followed Silva-Taboada (1983) in considering *Phyllonycteris poeyi* a monotypic species endemic to Cuba.

RESULTS

Table 1 summarizes the classification and description of each of the Cuban bat species analysed. Species accounts are provided within each of the four identified categories:

Category 1

Antrozous pallidus koopmani. Endemic subspecies and the rarest of Cuban

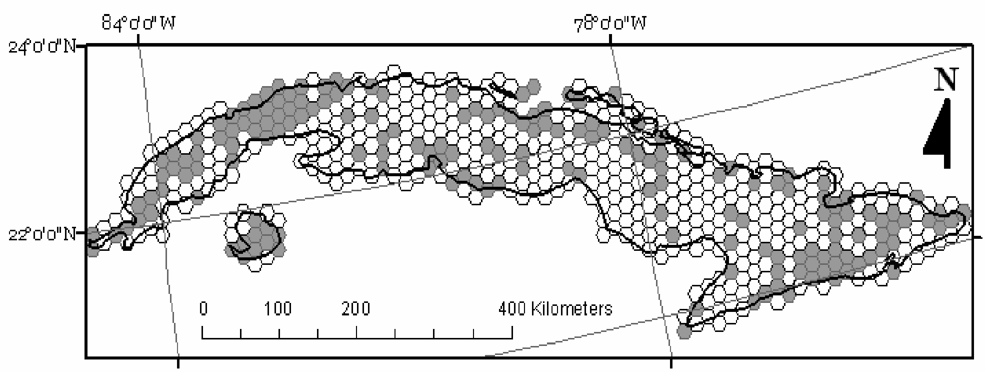

Figure 1 - Map of Cuba divided in 549 hexagon-cells used to estimate the distributional patterns of Cuban bats. Shaded cells represent areas with species occurrence records, while empty cells cover areas without bat records.

bats; only four individuals have been captured alive at three localities but it is common in subfossil deposits of the western half of the island. Silva-Taboada (1979) does not report *A. pallidus* for the central region of the island, but in the 1980's an individual was collected in the Guamuaya mountainous region (Rafael Abreu, pers. comm.), and one of us (C.A. Mancina) has identified a fresh skull from barn owl (*Tyto alba*) pellets obtained in 2002 from Camagüey province. Its roost sites have never been found.

Natalus primus. Endemic species. Until 1992, *N. primus* was known from Cuba only by fossil remains. Actually this bat is known from a single cave (Tejedor *et al.*, 2004).

Lasiurus insularis. Rare and endemic species. It has been captured in only nine localities. The crowns of fan-leaved palms (e.g. those of the genus *Thrinax,* Silva-Taboada, 1979) are its only known roost.

Lasiurus pfeifferi. Rare and endemic bat. It is a widespread species, but it is rarely found. It seems to be associated to woodland patches.

Category 2

Chilonatalus macer. Uncommon and endemic species. This moderately gregarious cave-bat is known from only 17 caves.

Nycticeius cubanus. Endemic and uncommon species, although it is locally common in some localities of the Pinar del Río province and Havana City. It has been collected only in the western half of the island.

Nyctinomops laticaudatus yucatanicus. Rare non-endemic subspecies; it has been collected only in four localities of the eastern half of the island. Possibly this bat has a wider distribution because it can use man-made structures as day roosts.

Phyllops falcatus falcatus. Uncommon and endemic subspecies; it has a widespread distribution, but seems restricted to woodland patches (Mancina and García, 2000).

Category 3

Twelve species of Cuban bats are included into this category (Table 1). Seven of these species are cave bats that are highly dependent on hot caves as day roosts. These are *Phyllonycteris poeyi*, *Erophylla sezekorni*, *Brachyphylla nana*, *Nyctiellus lepidus*, *Pteronotus quadridens*, *Pteronotus macleayii*, *Pteronotus parnellii*, and *Mormoops blainvillei*. *Nyctinomops macrotis*, *Eumops glaucinus* and *Noctilio leporinus mastivus*, three non-endemic species, are uncommonly found across Cuba.

Mormopterus minutus, an endemic species, seems to be partially specialized in the use as day roost of the palm *Copernicia gigas*, which occurs only in the centre-oriental region. However, this bat species can be a locally common occupant of man-made structures; therefore urban development could increase the range of the species. However, range expansion may bring *M. minutus* into competition for refuges with other very widely distributed and abundant synantropous bats (e.g. *Molossus molossus*). Therefore, we should not over-emphasize synantropy of *M. minutus* as an element to deduce its conservation status.

Table 1 - Species and data used for analysis. Taxonomy follows Simmons (2005) except for genus *Chilonatalus* (Tejedor in press). Columns indicate: 1, population abundance; 2, distribution; 3, roost habits; 4, aggregation level; 5, forest dependence, and 6, endemism level; T.C. = Threat Categories (see Methods); ?, indicates possible aggravation of the threat status pending forthcoming ecological studies.

Scientific and common name	Distribution	1	2	3	4	5	6	T.C.	IUCN (2006)
Lasiurus insularis Cuban Yellow Bat [1]	Cuba	2	2	2	2	1	1	C1	-
Lasiurus pfeifferi Pfeiffer's Red Bat [1]	Cuba	2	1	2	2	1	1	C1	-
Natalus primus Cuban Greater Funnel-eared Bat[2]	Cuba	2	2	2	0	1	1	C1	-
Antrozous pallidus Pallid Bat [1]	N America and West Indies (only Cuba)	2	2	?	2	1	0	C1	LR: lc
Phyllops falcatus Cuban White-shouldered Bat [3]	Cuba and Hispaniola	1	1	2	2	1	0	C2	LR: nt
Nycticeius cubanus Cuban Evening Bat [1]	Cuba	2	2	0	2	0	1	C2	-
Nyctinomops laticaudatus Broad-eared Free-tailed Bat [4]	Neotropics, West Indies (only Cuba)	2	2	1	1	0	0	C2	LR: lc
Chilonatalus macer Cuban Lesser Funnel-eared Bat [2]	Cuba	1	1	2	0	1	1	C2	-
Nyctinomops macrotis Big Free-tailed Bat [4]	SW of North America, Neotropics, West Indies (only Greater Antilles)	1	1	1	2	0	0	C3	LR: lc
Noctilio leporinus Greater Bulldog Bat [5]	Neotropics, Greater and Lesser Antilles	1	1	1	2	0	0	C3	LR: lc
Erophylla sezekorni Buffy Flower Bat [3]	Cuba, Jamaica, Bahamas and Cayman Islands	0	1	2	0	1	0	C3	LR: lc
Nyctiellus lepidus Butterfly Bat[2]	Cuba and Bahamas	0	1	2	0	1	0	C3	LR: nt
Mormopterus minutus Little Goblin Bat [4]	Cuba	1	2	0	0	0	1	C3	VU: A2c
Pteronotus parnellii Common Mustached Bat [6]	Neotropics, Greater Antilles, Lesser Antilles (only St. Vicent)	0	1	2	0	1	0	C3	LR: lc
Pteronotus macleayii MacLeay's Mustached Bat [6]	Cuba and Jamaica	0	0	2	0	1	0	C3	VU: A2c
Mormoops blainvillei Antillean Ghost-faced Bat [6]	Greater Antilles	0	0	2	0	1	0	C3	LR: nt
Phyllonycteris poeyi Poey's Flower Bat [3]	Cuba	0	0	2	0	0	1	C3	LR: nt
Pteronotus quadridens Sooty Mustached Bat [6]	Greater Antilles	0	0	2	0	1	0	C3	LR: nt
Brachyphylla nana Cuban Fruit-eating Bat [3]	Cuba, Hispaniola, SE Bahamas and Grand Cayman	0	0	2	0	1	0	C3	LR: nt
Eumops glaucinus Wagner's Mastiff Bat [4]	Neotropics, Greater Antilles (only Cuba and Jamaica), Florida (USA)	1	1	0	1	0	0	C3	LR: lc
Monophyllus redmani Greater Antillean Long-tongued Bat [3]	Greater Antilles and S Bahamas	0	0	2	0	0	0	C4	LR: lc
Eptesicus fuscus Big Brown Bat [1]	N to NS America; Greater and Lesser Antilles (Dominica and Barbados)	0	0	1	0	0	0	C4	LR: lc
Tadarida brasiliensis Brazilian Free-tailed Bat [4]	N to S America, Greater and Lesser Antilles	0	0	1	0	0	0	C4	LR: nt
Artibeus jamaicensis Jamaican Fruit-eating Bat [3]	Neotropics, Greater and Lesser Antilles, Bahamas, Florida Keys (USA)	0	0	0	0	0	0	C4	LR: lc
Macrotus waterhousii Big-eared Bat [3]	Central America, Greater Antilles and Bahamas	0	0	0	0	0	0	C4	LR: lc
Molossus molossus Pallas's Mastiff Bat [4]	Neotropics, Greater and Lesser Antilles, Florida Keys (USA)	0	0	0	0	0	0	C4	LR: lc

[1] Family Vespertilionidae; [2] Natalidae; [3] Phyllostomidae; [4] Molossidae; [5] Noctilionidae; and [6] Mormoopidae.

Category 4

Six species seem to have stable populations (Table 1), all having a widespread distribution and abundant populations. These bats also show a high ecological plasticity and most use man-made structures as day roosts. Some of them (e.g. *Artibeus jamaicensis* and *Monophyllus redmani*) are very common in agricultural fields or highly degraded forest patches.

Occurrence revised

Eumops perotis gigas has been considered by Silva-Taboada (1979) to be the rarest of Cuban bats. It is an endemic subspecies, whose holotype is known from a single individual captured in 1839. The locality type was assigned to “El Taburete”, which is included in the Sierra del Rosario Biosphere Reserve. Since 1996 we have carried out surveys in the Reserve, but we have not found any individual (Mancina, 1998; Mancina, 2004). Since the subspecies description, no individual has been captured in Cuba. Considering the current distribution range of the species (Best *et al*., 1996), and the uncertainty of the origin of the holotype of *E. perotis gigas*, we agree with Carter and Dolan (1978) that this Cuban record is a catalogue mistake. These authors re-assigned the type locality of *Eumops p. gigas* to Amazonia, Brazil.

DISCUSSION

Of the 26 bat species reported from Cuba four could be considered (using the IUCN analogous of our categories) endangered (C1), four vulnerable (C2), twelve near threatened (C3), and six stable (C4). With the exception of *Nyctinomops laticaudatus* (possibly a recent colonizer), all taxa considered threatened in this study (C1 and C2) have been described as species or subspecies endemic to Cuba (Silva-Taboada, 1979). Of the seven bat species currently thought to be endemic to Cuba, three are included here into Category 1 and two in Category 2; the two remaining endemic species are included in Category 3. Consequently, none of the Cuban endemic bat species seem to be in long term stable conditions.

Among the Cuban bats considered threatened in this study, several species belonging to the families Molossidae and Vespertilionidae are widely distributed and probably stable at a continental level (IUCN, 2006; see Table 1). Nevertheless, in the Antilles, Cuba is the only island where they are found; therefore their continuous presence in the West Indian subregion depends on the survival of the populations present in Cuba.

According to IUCN (2006), only two bat species from Cuba, *Pteronotus macleayii* and *Mormopterus minutus*, are considered Vulnerable. However, our analysis suggested that both species could be downgraded to the category Near Threatened. In the case of *P. macleayii* the conservation status suggested by IUCN (2006) should be limited to Jamaican populations where *P. macleayii* is less abundant and has a more restricted distribution than in Cuba (Mancina, 2005). Our analyses, on the other hand, show that at least eight species could be threatened. These differences depend on several factors: the six qualitative parameters chosen to define threat status (in the absence of population trend estimates), the use of field data that were not available to the global Red List, and some new taxonomic arrangements, which also suggest that the regional assessment of endangered species is highly sensitive to taxonomic revisions. Two of the most endangered Cuban bats, *Antrozous pallidus* and *Natalus primus* are of special concern, comparing their current abundance and distribution to their fossil and subfossil remains. *Antrozous pallidus*, of which only four individuals have been collected, is commonly found as subfossil remains throughout the island (Silva-Taboada, 1979; Mancina and García, 2005). Similarly, the only known colony of the cave bat *Natalus primus*, restricted to the western tip of Cuba, seems to be a relict of a formerly widespread and relatively large population, given that remains of this species are among the most common bat fossils found nowadays throughout the island (Silva-Taboada, 1979; Tejedor *et al.*, 2004). A third species, *Lasiurus insularis*, is uncommonly found in fossil deposits but in a higher percentage than would be expected by its current abundance, suggesting that its current population is smaller than it was in the recent past.

The causes of such declines are unknown. Non-human factors such as climate change, natural cave erosion (in the case of cave-dwelling bats), and the devastating effects of hurricanes have been suggested as threats to bat populations in the Antilles (Pedersen *et al.*, 1996; Morgan 2001; Jones *et al.* 2001; Tejedor *et al.* 2004). Nonetheless, these species range reduction being apparently recent (post-Pleistocene, Silva-Taboada 1979), the influence of human activity in the near extinction of some of the currently rarest Cuban bats cannot be ruled out.

Cuba, as other Antillean islands, is frequently affected by hurricanes. These catastrophic disturbances cause remarkable changes in habitat structure; therefore, severe hurricanes could affect bat populations and contribute to the extinction of local demes. However, cyclical disturbances like these are not recent phenomena. They have been historically affecting the West Indies at least since the last major climate change several thousands of years ago. The well-established bat communities of the region (Rodríguez-Durán and Kunz, 2001) suggest that hurricanes, although capable of producing severe population declines, have not been a major cause of extinction in the West Indies. Species roosting in more exposed situations, such as foliage or tree hollows, likely suffer greater direct mortality than cave-dwelling species (e.g., Gannon and Willig, 1994; Jones *et al*. 2001).

In Cuba, caves are very abundant, especially in the karstic rocks that cover 80% of the Cuban archipelago (Nuñez-Jiménez *et al.*, 1988). Sixteen species of Cuban bats can use caves as day roosts (ten of these are strictly cave bats), representing 61% of the total number of bats known for the island (Silva-Taboada, 1979). Caves can shelter multispecies assemblages, especially high densities of phyllostomids (e.g. *Phyllonycteris poeyi* and *Brachyphylla nana*), and mormoopids (*Pteronotus* spp.). Hot caves are frequent in Cuba, having speleo-morphological traits that produce very low levels of air ventilation. Some bats such as *Phyllonycteris poeyi* and *Pteronotus spp* roost in very large numbers and are known to select roosting sites that result in the entrapment of the metabolic heat they produce (Silva-Taboada, 1977). This phenomenon generates extreme conditions of temperature (28 - 40º C) and humidity (>90%) inside these caves (Cruz, 1992) which reduces energy expenditure and water loss in bats (Rodriguez-Durán, 1995). Therefore, for these bats there should be a critical minimum number of individuals for the colonies to be viable, making these species vulnerable to reductions in population numbers.

Despite several natural factors threatening bat populations, humans nowadays pose the most serious threats to bat populations in Cuba, including the modification of their natural habitat and both the incidental and intentional extermination of bat colonies. In Cuba, since Spanish colonial times, bat guano has been used for agricultural fertilization. The exploitation of bat guano causes stress to bat populations as well as changes in the climatic condition of the caves. The large amount of guano produced by huge colonies contributes to the maintainance of favourable conditions in the roost by its hygroscopic attributes. Changes in the microclimate could make a cave unsuitable for some bat species. Cruz (1992), examining 30 hot caves, found that seven out of nine sites where guano extractions occurred showed a decrease in temperature, and six had completely lost their bat fauna. Other threats to cave populations are the use of caves as storehouses and refuges that cause the blocking of entrances and hamper bat emergence. Also, tourists and speleologists disturb cave-bat communities and are especially dangerous in maternity roosts where they can cause high newborn mortality by arousing lactating females, which may drop their offspring to the ground from where they cannot recover them.

In spite of the threats mentioned above, the abundance of karstic regions and the presence of bat caves in areas protected throughout the island put the cave-dwelling bats among the less threatened species. However, given that the degree of fragmentation of Cuban landscape probably limits dispersal between sites, a metapopulation structure is likely to be at work for several bat species. In such a case, the protection of colony-hosting caves outside reserves would be critical for the survival of these species.

Apart from direct disturbance of cave-dwelling bats at their roosts, the destruction of forests is perhaps the major threat to Cuban bat populations. Since Europeans first arrived to Cuba, deforestation has been progressive. In the XVI century, 88-92% of Cuban land surface was covered by forests. At the beginning of XX century only 41% remained. In the 70´s deforestation reached 85% of the surface, a peak in the history of the island, due to sugarcane development (del Risco, 1995). The scale of such deforestation might have severely impacted many bat populations, especially tree-dwelling bats such as the lasiurines which nowadays are among Cuba's rarest bats. The joint effects of severe deforestation and hurricanes possibly had a great impact on forest-dependent bat populations.

More ecological studies are necessary, including complete inventories as well as research on habitat use, to better understand the requirements of the endangered species. Research should not be promoted only within established protected areas, as many bat populations occurs outside reserves. In addition, guano extraction in caves hosting threatened species, large aggregations, or maternity colonies, should be regulated through professional management. The conservation of the Cuban bat fauna should be the result of a cooperative and holistic approach. Long-term, collaborative efforts toward conserving extant colonies should be undertaken and encouraged with local communities and decision makers. Such collaboration should include research, habitat management, and the promotion of conservation awareness, increasing the likelihood that suitable habitats and therefore viable bat populations will be preserved.

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REFERENCES

Aguiar L.M.S. and Taddei V.A. 1996. Workshop sobre a conservação dos morcegos Brasileiros. *Chiroptera Neotropical*, 1(2): 24-30.

Aguirre L.F. 1999. Estado de conservación de los murciélagos de Bolivia. *Chiroptera Neotropical*, 5(1-2): 108-112.

Best T.L., Kiser W.M. and Freeman P.W. 1996. *Eumops perotis*. *Mammalian Species*, 534: 1-8.

Carter D.C. and Dolan P.G. 1978. Catalogue of types specimens of Neotropical bats in selected European museums. Special Publications, The Museum, Texas Tech. Univ., 15: 1-136.

Cruz J. de la 1992. Bioecología de las grutas de calor. *Mundos Subterraneos*, 3: 7-21.

ESRI 2005. ArcGIS 9.1 Geographic Information System. Environmental Systems Research Institute Inc., Redlands, CA, USA.

Frankham R., Ballou J.D. and Briscoe D.A. 2002. Introduction to Conservation genetics. Cambridge University Press. Cambridge, UK.

Gannon M. R. and Willig M. R. 1994. The effects of Hurricane Hugo on bats of the Luquillo Experimental Forest in Puerto Rico. *Biotropica*, 26: 320-331.

Gärdenfors U., Hilton-Taylor C., Mace G.M. and Rodríguez J.P. 2001. The application of IUCN Red List criteria at regional levels. *Conservation Biology*, 15: 1206-1212.

IGACC-ICGC (Instituto de Geografía de la Academia de Ciencias de Cuba –

Instituto de Cartografía y Geodesia). 1989. Nuevo Atlas Nacional de Cuba. Ed. Alber. España.

IUCN 2003. Guidelines for Application of IUCN Red List Criteria at Regional Levels: Version 3.0. IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK. ii + 26 pp.

IUCN 2006. IUCN Red List of Threatened Species. <www.iucnredlist.org>. Downloaded on September 30, 2006.

Jones K. E., Barlow K.E., Vaughan N., Rodríguez-Durán A. and Gannon, M.R. 2001. Short-term impacts of extreme environmental disturbance on the bats of Puerto Rico. *Animal Conservation*, 4: 59–66.

Koopman, K.F. 1989. A review and analysis of the bats of the West Indies. In: Biogeography of the West Indies: past, present and future. Ed. C. A. Woods, Sandhill Crane Press, Inc. Gainesville, Florida, 635-644.

Koopman K.F. 1993. Order Chiroptera. In: Wilson D.E. and Reeder D.M. (eds), Mammals species of the world, a taxonomic and geographic reference. Smithsonian Institution Press, Washington D.C., 137-241.

MacPhee R.D.E. and Flemming C. 1999. *Requiem aeternum*: the last five hundred years of mammalian species extinctions. In: MacPhee R.D.E (ed.), Extinctions in near time: causes, contexts, and consequences. Kluwer Academic/Plenum Publishers, New York. 333-372.

MacPhee R.D.E. and Iturralde-Vinent M.A. 2000. A short history of Greater Antillean land mammals: biogeography, paleography, radiations, and extinctions. *Tropics*, 10:145-154.

Mancina C.A. 1998. Adiciones a la ecología y morfología de *Phyllonycteris poeyi* y *Monophyllus redmani clinedaphus* (Mammalia: Chiroptera: Phyllostomidae). *Poeyana*, 466: 1-10.

Mancina C.A. 2004. Bat community structure in an evergreen forest in western Cuba. *Poeyana*, 491: 8-12.

Mancina C. A. 2005. *Pteronotus macleayii*. *Mammalian Species*, 778: 1-3.

Mancina C.A. and García L. 2000. Notes on the natural history of *Phyllops falcatus* (Gray, 1839) (Phyllostomidae: Sterodermatinae) in Cuba. *Chiroptera Neotropical*, 6(1-2): 123-125.

Mancina C.A. and García L. 2005. New genus and species of fossil bat (Chiroptera: Phyllostomidae) from Cuba. *Caribbean Journal of Science*, 41(1): 22-27.

Morgan G.S. and Woods C.A. 1986. Extinction and the zoogeography of West Indian land mammals. *Biological Journal of the Linnean Society*, 28: 167-203.

Morgan G.S. 2001. Patterns of extinction in West Indian bats. In: Woods C.A. and Sergile F.E. (eds), Biogeography of the West Indies, patterns and perspectives. CRC Press, Boca Raton, 369-407.

Nuñez-Jiménez A., Viñas-Bayes N., Acevedo-González M., Mateo-Rodríguez J., Iturralde-Vinent M. and Graña-González A. 1988. Cuevas y carsos. Editorial Científico-Técnica, La Habana, 431 pp.

Pedersen S.C, Genoway H.H. and Freeman P.W. 1996. Notes on bats from Montserrat (Lesser Antilles) with comments concerning the effects of hurricane Hugo. *Caribbean Journal of Science*, 32(2): 206-213.

Possingham H.P., Andelman S.J., Burgman M.A., Medellín R.A., Master L.L. and Keith, D.A. 2002. Limits to the use of threatened species lists. *Trends in Ecology and Evolution*, 17(11): 503-507.

Risco del E. 1995. Los bosques de Cuba: su historia y características. Editorial Científico-Técnica, La Habana, 94 pp.

Rodríguez-Durán A. 1995. Metabolic rates and thermal conductance in four species of neotropical bats roosting in hot caves. *Comparative Biochemstry Physiology*, 110A(4): 347-355.

Rodríguez-Durán A. and Kunz T.H. 2001. Biogeography of West Indian bats: an ecological perspective., In: Woods C.A. and Sergile F.E., eds.). Biogeography of the West Indies. Patterns and Perspectives. 2nd edición CRC Press. Boca de Ratón, Florida, 355-368.

Silva-Taboada G. 1977. Algunos aspectos de la selección de hábitat en el murciélago *Phyllonycteris poeyi* Gundlach in Peters 1861 (Mammalia: Chiroptera). *Poeyana*, 168: 1-10.

Silva-Taboada G. 1979. Los Murciélagos de Cuba. Editorial Academia. La Habana, Cuba, 423 pp.

Silva-Taboada G. 1983. Interrelaciones en el subgénero *Phyllonycteris* (Mammalia: Chiroptera: Phyllostomidae). *Ciencia Biologica.,* 10: 117-121.

Simmons N.B. 2005. Order Chiroptera. In: Wilson D.E and Reeder D.M. (eds), Mammal Species of the World: a taxonomic and geographic reference, third edition, Johns Hopkins University Press, Vol. 1, 312-529.

Suárez W. and Diáz-Franco S. 2003. A New fossil bat (Chiroptera: Phyllostomidae) from a Quaternary cave deposit in Cuba. *Caribbean Journal of Science*, 39(3): 371-377.

Tejedor A. (in press). Systematics of funnel-eared bats (Chiroptera: Natalidae). *Bulletin of the American Museum of Natural History*.

Tejedor A., Silva-Taboada G. and Rodríguez-Hernández D. 2004. Discovery of extant *Natalus major* (Chiroptera: Natalidad) in Cuba. *Mammalian Biology*, 69 (3): 153-162.

Woods C.A. 1990. The fossil and recent land mammals of the West Indies: an analysis of the origin, evolution, and extinction of an insular fauna., In: International Symposium on: Biogeographical aspect of insularity. *Accademia Nazionale dei Lincei, Roma*, 641-680.