Results of a survey of Bats of the Cockscomb Basin Wildlife Sanctuary

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Bruce W. Miller, Associate Conservation Zoologist

Carolyn M. Miller, Associate Conservation Zoologist

Wildlife Conservation Society

Gallon Jug, Belize

Phone/fax: 501-21-2002

Email: galljug@btl.net

Introduction

Bats are critical contributors to mammalian biodiversity, particularly in the Neotropics. The order Chiroptera is second only to rodents in diversity: 17 families, approximately 174 genera, and 913 species (Koopman, 1993, 1994). Nine families occur in the New World, six of which only occur in the Neotropics. Approximately 28% of all bat species occur in the Neotropics. The sheer number of individuals and the myriad of food habits represented further support the significant contribution by this group to Neotropical systems.

In Belize, 71 species are known from eight families. Another dozen species that have been reported from adjacent countries in the families Phyllostomidae, Vespertilionidae, and Molossidae are suspected or likely to yet be discovered in Belize. Voss and Emmons (1996) reviewed 10 Neotropical rainforest mammal inventories, and found that species accumulation curves were not asymptotic for any fauna sampled, suggesting that essential field methods were omitted in every case. This has been the case for bats in the Cockscomb Basin Wildlife Sanctuary (CBWS) where previous sampling for bats was limited to mistnets. Such ground-level nets sample less than 10% of the airspace under a typical rainforest canopy and are biased towards species of leaf-nosed bats (Phyllostomidae). Other species, representing the remaining seven families, are seldom captured in such mistnets.

The distributions and status of the species comprising the other seven families in Belize have been poorly understood. This survey was part of an on going atlas project where vertebrate species distributions are being mapped as a continuation of a zoogeographic and protected areas analysis of Belize (Miller and Miller, 1995). A primary focus of this survey was to add to the reference library of vocal signatures by recording the disc-winged bat (*Thyroptera tricolor*, Thyropteridae*)*.

We also report here the results of two previous surveys (May 24, 1995; July 13-14 1996) that used acoustic methods and double-frame harp traps around the headquarters of the CBWS, historically called Quam Bank. We also provide a review of previous bat studies in the CBWS (Appendix 3) and a comprehensive species list (Appendix 1).

Methods

Because previous studies in the CBWS have focused on mistnetting, which is biased toward species of the single family Phyllostomidae (leaf-nosed bats), we concentrated on the other seven families of bats that occur in Belize. In order to provide information on the non-phyllostomid bats, we employed double-frame harp traps and acoustic survey techniques to sample those species of interest.

Acoustic techniques using the Anabat system have proven to be an effective means of identifying free flying bats (Miller and O'Farrell, 1997; O'Farrell and Miller, 1997a; O'Farrell and Miller, 1997b; O'Farrell and Miller, 1999a; O'Farrell and Miller, 1999b; O'Farrell et al., 1999) with the notable exception of the inability of the equipment to detect leaf-nosed bats (Phyllostomidae). Nearly 91% of the 32 known non-phyllostomid bat species of Belize are now identifiable by vocal signatures that have been gathered over the course of a several year study.

Acoustic sampling was conducted using an Anabat II bat detector (Titley Electronics, Ballina, Australia) linked to a laptop computer, using two methods, active and passive monitoring. During active acoustic monitoring, the computer was tended directly and selected incoming calls were archived as voucher records. Passive monitoring allowed acoustic sampling to be carried out simultaneously at a remote site. During passive monitoring (9 and 11 June 1999), ultrasonic sounds were automatically recorded on a computer hard drive (O'Farrell, 1998). Each evening active acoustic surveys continued until bat activity waned and passive monitoring was discontinued with the onset of heavy rains.

Calls from each species were identified subjectively (O'Farrell et al., 1999). Confirmation of call identification was possible by comparison to known vocal signatures in an acoustic library compiled throughout Belize and for selected species recorded in Venezuela. All complete vocal sequences, including those that could not be identified (i.e., “unknowns”) were archived digitally. When additional species’ vocal sequences are identified and added to the library, unknown species calls for CBWS may later be matched and identifications confirmed. Although we examined all calls obtained, we used only those sequences that contained frequency

and structural characteristics known for a particular species for determining identifications. If there was doubt or overlap with other species, sequences were disregarded.

Active acoustic sampling sites were selected on the Western Trail, 100 m W of the camp ground (June 9), the Kaway Swamp (June 10), and at the Tapir Beach along the Rubber Tree Trail (June 11). Passive monitoring sites were located in the clearing by the dormitory area (June 9) and a site along the road near the heliconia groves, 200 m W of the warden house by the entrance gate (June 11).

In the Neotropics, mist netting has been particularly effective for leaf-nosed bats (family Phyllostomidae) while harp traps have proved more effective for other families (LaVal and Fitch, 1977; Tuttle, 1976) which were poorly known from CBWS. Concurrent with acoustic surveys, we used four double-frame harp traps (Austbat Research Equipment, Victoria, Australia). Harp traps may be left unattended throughout the night, maximizing sample effort. Bats strike the trap's monofilament lines directing them into a canvas holding bag. They are able to roost beneath a plastic cover that simultaneously prevents escape and protects from the elements.

Traps were set across narrow sections of trails and in one case over a small stream, areas where we anticipated bat activity. Traps were checked for bats between 2030-2100 h each night. Any captures were identified, reproductive condition assessed and key measurements were taken before release. The traps were left in place throughout the remainder of the night and checked again at first light the following morning. Morning captures were likewise processed.

Four sites were selected for trap placement. On June 9, two traps were placed at the junction of the Warrie Loop Trail and the Western Trail. One blocked the Warrie Loop Trail approximately 50 m E of this junction. The other was set ca. 50 m S of the junction across the Western Trail. Two traps were also placed on the Gibnut Trail. The first blocked the trail (ca. 200 m N of headquarters) and the second straddled a small-unnamed stream, a tributary of the South Stann Creek River.

On June 10, all four traps were placed in the vicinity of the Kaway Swamp. Two traps were set across the Warrie Trail and two in the stand of kaway (*Pterocarpus hayesii*). One of these traps was specifically positioned in front of a hollow tree roost where B. Shapley observed bats emerging (and avoiding) her elevated mist-net set the previous week.

On June 11, four traps were set along the Curassow and Rubber Tree Trails. On the Curassow Trail, a trap was placed 50 m E of the River Walk Trail and another 300 m farther east. The remaining two traps were placed on the Rubber Tree Trail, one at the north trailhead

and the other 50 m N of Tapir Beach. These traps corresponded to the placement of traps in a previous survey (July 13-14, 1996).

Results

Acoustic sampling during this period was very productive with 20 species from five families recorded, three not previously reported for CBWS (Table 1). Combined with previous acoustic surveys, twelve species of four families were added to the CBWS bat faunal list (Appendix I). Previous active acoustic sampling sites included the parking lot and road in front of the headquarters building (May 24, 1995; July 13-14, 1996), the clearing edge between the warden house by the entrance gate and the forest (May 24, 1995), along the river bank at the end of the River Trail (July 13-14, 1996). *Centronycteris centralis* was a notable new species for CBWS. However, it was recorded only a few times during the present survey.

Table 1. Summary of acoustic sampling at CBWS.

Species	1995	1996	1999
Emballonuridae			
Saccopteryx bilineata	X	X	X
Saccopteryx leptura		X	X
Peropteryx kappleri	X	X	X
Peropteryx macrotis	X	X	X
Centronycteris centralis			X
Diclidurus alba	X	X	X
Noctilionidae			
Noctilio leporinus			X
Mormoopidae			
Pteronotus davyi	X	X	X
Pteronotus parnellii	X	X	X
Pteronotus personatus		X	
Mormoops megaphylla		X	X
Vespertilionidae			
Myotis keaysi		X	X
Eptesicus furinalis	X	X	X
Lasiurus blossevillii		X	X
Lasiurus ega		X	X
Molossidae			
Nyctinomops laticaudatus		?	X
Eumops auripendulus		X	X
Molossus rufus	X	X	X
Molossus molossus	X	X	X
Molossus sinaloae		X	X

On June 9, we captured 28 bats of six species. Eleven were captured between sunset and 2100 h; the remaining 17 were processed at sunrise. A single *Mormoops megalophylla*, a species that had previously only been recorded acoustically, was trapped along the Warrie Loop Trail.

The fewest captures of the survey occurred on June 10. Only nine bats of five species were captured: three between sunset and 2000 h, six were processed at sunrise. Three pregnant female *Saccopteryx bilineata* were trapped leaving a hollow tree roost located in the Kaway Swamp. Species caught later in the evening included a single *Pteronotus parnellii* and an assortment of common phyllostomids (*Artibeus watsoni*, *Glossophaga soricina*, *Sturnira lilium*) that were trapped along the forest trails. A non-reproductively active female *S. bilineata* was trapped in front of the roost.

On June 11, there were 16 captures representing four species. Twelve were caught between sunset and 2100 h and the remaining four were processed at sunrise. This was the only site where we recorded the vespertilionid *Myotis keaysi*. With the exception of three species, (*Micronycteris megalotis*, *Artibeus jamaicensis*, and *A. intermedius*), the species composition at this site was the same as in 1996 (Table 2).

The reproductive status of bats from this survey (June) and that of July 1996 suggests that the birth of young occurs coincides with the onset of the rainy season. The July 1996 survey resulted in 36 captures of 10 species with no active males or pregnant females recorded and four lactating and six post-lactating females. The June survey resulted in 58 captures of nine species with only two active males, four pregnant, nine lactating and three post lactating females (Table 2). Trapping success rates were comparable with 4.5 bats per trap night in 1996 and 4.8 bats per trap night during this survey. Table 2 summarizes results of harp trapping and includes data from our previous survey (July 13-14, 1996).

Table 2. Summary of harp trapping at CBWS.

Sampling period: 1996 (B.W. Miller, C.M. Miller and M.J. O'Farrell unpublished data) and 1999 (this report). Age: A=Adult, J=Juvenile, NY=Nursing young; Sex: M=Male, F=Female, Reproductive status: NA=Not active, P= Pregnant, L= Lactating, PL=Post lactating, TE= Testes enlarged.

	1996				1999			
Species	**age**	**sex**	**Reproductive**	**N**	**age**	**sex**	**Reproductive**	**N**
Saccopteryx bilineata					4A	4F	3P, 1NA	4
Mormoops megalophylla					1A	1M	1NA	1
Pteronotus parnellii	6A	6M	6 NA	6	13A	13M	13NA	13
Micronycteris megalotis	1J	1M	1NA	1				
Glossophaga soricina	2A	2F	2PL	2	2A	1F 1M	1 NA, 1TE	2
Carollia brevicauda	2A	2F	2L	2	7A	5F 2M	1L, 2P, 4NA	7
Carollia perspicillata	1J, 4A	4F, 1M	1L, 3PL, 1NA	5				
Sturnira lilium	5J, 2A	6F,1M	1L-1PL 5NA	7	4J, 2A	5F 1M	5NA, 1TE	6
Vampyressa pusilla					1A	1F	1L	1
Artibeus intermedius	1A	1 M	1 NA	1				
Artibeus jamaicensis	3J	2 F,1 M	3 NA	3				
Artibeus watsoni	3J, 2A	4 F,1 M	5 NA	5	2J, 8A	8F 8M	4L, 1PL, 1P, 14 NA	16
Thryoptera tricolor					1NY, 4A	2F 3M	2L, 3NA	5
Myotis keaysi	1J, 3A	3F,1M	4 NA	4	3A	3F	2L, 1NA	3

Disc-winged bats

Of particular interest was the disc-winged bat (*Thyroptera tricolor*). The presence of suction cups on the ankles and wrists allow it to cling to the inner surface of furled heliconia leaves. We were interested in obtaining vocal signatures of this species to augment the library of echolocation calls used to identify free-flying bats. On three previous visits (1995, 1996, 1997) to the CBWS, we failed to locate this species in what appeared to be suitable roost sites.

Although the species is found from Veracruz, Mexico throughout Central America, it is patchily distributed, but not recorded in El Salvador or Nicaragua (Nowak, 1994; Reid, 1997; Wilson and Findley, 1977). The sole records for this species in Belize are from the CBWS. The first Belize record was reported by Sanborn (1941). Rabinowitz and Nottingham (1989) reported its presence in the Basin with no further details (Appendix 3).

During the day, we focused on finding *T. tricolor*, previously located by S. Silver, L. Ostro, and their field team during the course of other mammal surveys. Several roost sites were located in groves of various *Heliconia spp*. along the entrance road near the warden residence at

the entrance to the sanctuary. We placed a butterfly net over the opening of rolled heliconia leaves to prevent escape. We searched by palpating leaf bases rather than bending leaves down. Two non-active males were captured, photographed (Appendix 2), and retained in order to record vocal signatures after nightfall. Females with nursing young were found in three family groups. They were measured and immediately released.

The retained males were flown under controlled conditions inside screened enclosures after dark. Unfortunately, neither bat produced recordable vocalizations. They were subsequently released outside and no sounds were detected as they flew off.

In an additional attempt to record vocal signatures of this species, we placed a passive monitoring unit near a heliconia grove (June 11), where several family groups were previously observed. It was hoped that vocalizations might be recorded as they took flight from roosts and foraged in the immediate area. A review of the recorded files from the passive unit did not provide any calls that could attributed to the disc-winged bat. All files were matched with known species.

We have had similar experiences with the *Natalus stramineus* (Natalidae), a species in a closely related family. We have flown >36 *N. stramineus* individuals under varied conditions and have not been able to obtain vocal signature recordings. *T. tricolor* has ears that are relatively similar in size and shape to those of *N. stramineus*. The echolocation calls of both species are very quiet (i.e., low amplitude) and were not detected with the Anabat equipment.

We located three family groups, two of which had females with young (June 10). We captured two females carrying nursing young. The two females were measured: forearms were 34.4 and 36.6 mm; mass of a single female was 4.1 g. We did not want to risk dislodging the very small nursing young on the other female and thus did not weigh them. The forearms of the males were 34.0 and 35.1 mm; mass was 3.4 and 4.2 g. A nursing young male had a forearm of 29.8 mm and a mass of 2.7 g.

Because our primary focus was to obtain vocal signatures of *T. tricolor,* we did not attempt to quantify the numbers of individuals or colonies. We did note the numbers flying from leaves when disturbed, consistent with that reported by Wilson and Findley (1977) who summarized the ecology of *T. tricolor*. In Costa Rica, they found that the species occurred in colonies of from 1-9 individuals ($\overline{X}$ =6). They estimated the roosting area for a single colony was approximately 3,000 m^2 and counted 3.7 colonies and 21.9 bats per hectare (Wilson and Findley, 1977).

Discussion

Rabinowitz and Nottingham (1989) reported 16 species of bats known to occur in the CBWS, acknowledging that this was based upon limited sampling. Although to date there still has been no exhaustive or systematic sampling of bats in the CBWS, 42 species, more than half of the species known to occur in Belize, have now been recorded (Appendix 1). Thus the CBWS has the highest species richness yet recorded in any protected area in Belize (Table 3).

Table 3. A comparison of bat species richness in Belize's protected areas where data exists. Figures compiled from the Belize Biodiversity Information System.

Protected area	Species
Cockscomb Basin Wildlife Sanctuary	43
Rio Bravo C.M.A.	34
Gallon Jug	34
Caracol Archaeological Reserve	24
Bladen Nature Reserve	22
Blue Hole National Park	9
Shipstern Nature Reserve	9
Chiquibul National Park	5
Slate Creek Preserve	3

The species of leaf-nosed bats (Phyllostomidae) that have been found in CBWS are for the most part, widespread throughout Belize. The distributions and status of many of the species comprising the other seven families in Belize that were found at CBWS are less clear. Distribution maps are being prepared for all bats found in Belize as part of an ongoing atlas project for the known vertebrate species as a continuation of a zoogeographic and protected areas analysis of Belize (Miller and Miller, unpub. data). Appendix 1 lists those that are new for the CBWS.

The fact that CBWS has the highest recorded bat species richness of any protected area in Belize may be attributed to the number of surveys that have included multiple sampling methods. More likely, it may be the result of the Basin’s geographic location and resultant high rainfall patterns. For a number of bat species (e.g., *Saccopteryx leptura*) the northern limits of their range may lie in this general area suggesting that the overall species richness in the CBWS may

remain one of the highest in Belize.

Since most bat surveys have been of short duration, many of the rarer species or those with patchy distributions have not yet been recorded. *Centronycteris centralis* is such an example. It is highly likely that with detailed bat surveys employing all sampling methods, including the higher elevations in the Maya Mountains, additional species may be found.

We recommend that the disc-winged bat, unique to the CBWS, be protected and monitored. In particular, it is important that roosting areas be undisturbed by visitors or roadside clearing. *T. tricolor* requires rolled heliconia leaves of a specific diameter and continually relocate as new leaves unfurl and become suitable for roosts.

On three previous visits (1995, 1996, 1997) to the CBWS, we failed to locate this species in what appeared to be undisturbed and suitable roost sites along the trails. This unique species is not expected in the dryer northern areas of Belize, although it is likely to be found in the southern reaches of the Chiquibul National Park. The CBWS is very important to *T. tricolor* as it remains the only known location in Belize for this unique creature. At an average weight of only 3.9 g, less than .0007% of the average weight of a jaguar, we can truly say Cockscomb Basin Wildlife Sanctuary protects all creatures great and small.

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Appendix 1

Bat species reported to occur in the Cockscomb Basin Wildlife Sanctuary

Bat species recorded for Cockscomb Basin Wildlife Sanctuary. X = mist netted or voucher specimen, H= captured in double frame harp trap, A= detected acoustically. CM= Carnegie Museum including McCarthy (1987), USNM= U.S. National Museum, RN= Rabinowitz and Nottingham (1989), S= Shapley (unpublished data), M= (Miller and Miller unpublished data), ♦= new distribution record.

Species	CM	RN	USNM	S	M
Emballonuridae					
Rhynchonycteris naso		X	X		
Saccopteryx bilineata ♦					A H
Saccopteryx leptura ♦					A
Peropteryx kappleri ♦					A
Peropteryx macrotis ♦					A
Centronycteris centralis ♦					A
Diclidurus alba ♦					A
Noctilionidae					
Noctilio leporinus		X	X	X	A
Mormoopidae					
Pteronotus davyi			X		A
Pteronotus personatus ♦					A
Pteronotus parnellii ♦					A H
Mormoops megaphylla ♦					A H
Phyllostomidae					
Micronycteris megalotis ♦					H
Micronycteris schmidtorum				X	
Lonchorhina aurita	X	X			
Phyllostomus discolor			X		
Trachops cirrhosus					
Chrotopterus auritus			X	X	
Glossophaga commissarisi				?	
Glossophaga soricina	X	X	X	X	H
Carollia brevicauda		X	X	X	H
Carollia perspicillata		X	X	X	H
Sturnira lilium	X	X	X	X	H
Vampyressa pusilla ♦					H
Uroderma bilobatum			X		
Artibeus intermedius		X			H

Species	CM	RN	USNM	S	M
Artibeus jamaicensis	X	X	X		H
Artibeus lituratus	X	X	X	X	
Platyrrhinus helleri			X		
Dermanura phaeotis	X	X	X	X	
Dermanura toltecus			X	X	
Dermanura watsoni	X	X	X	X	H
Desmodus rotundus		X			
Natalidae					
Natalus stramineus			X		
Thyropteridae					
Thyroptera tricolor		X		X	H
Vespertilionidae					
Myotis keaysi					A H
Eptesicus furinalis ♦					A
Lasiurus blossevillii	X	X			A
Lasiurus ega	X	X			A
Rhogeessa tumida ♦					A
Bauerus dubiaquercus			X		
Molossidae					
Nyctinomops laticaudatus ♦					A
Eumops auripendulus ♦					A
Molossus rufus ♦			X		A
Molossus molossus ♦					A
Molossus sinaloae ♦					A

Appendix II

Photographs of Disc-winged Bats from CBWS

(Images by Carolyn M. Miller)

Figure 1. Discs at wrist.

Figure 2. Bat adhering to leaf with discs.

Figure 3. Bat is echolocating with mouth open. Note ear shape.

Appendix III

A chronological review of known bat work in the Cockscomb Basin Wildlife Sanctuary

March 6, 1935, G. M. Allen collected the first record of *Thyroptera tricolor* for Belize (Sanborn 1941). This was a single male collected by along the South Stann Creek River, 15 miles west of All Pines (CM 10582). This location would be just inside the Cockscomb basin placing it in what is now recognized at the Cockscomb Basin Wildlife Sanctuary. Apparently, Allen was a member of the 1935 Blake and Agostini expedition that collected mammals in the Freetown Sittee River area and Stann Creek area. Although other mammals including bats were collected during that expedition the only other record for the CBWS was a Male *Artibeus jamaicensis* collected March 25, 1935 (CM 10581) in the "COXCOMB MTS. 1550 F elevation."

The next records from CBWS are from T. J. McCarthy, who collected bats April 4 and April 8, 1984 (McCarthy, 1987). His contributions are included in Appendix 1 under the Carnegie Museum (CM) records. Species he collected were *Artibeus jamaicensis, Artibeus lituratus, Artibeus phaeotis, Artibeus watsoni, Glossophaga soricina, Lasiurus blossevillii, Lasiurus ega, Lonchorhina aurita,* and *Sturnira lilium*.

The later two species of Vespertilionidae were of interest. The *Lasiurus blossevillii,* at the time called *L. borealis,* was one of the first records for the species in Belize. It is not clear where in the CBWS this bat was actually netted. McCarthy (1987) stated it was "5.3 km NNW of Quam Bank," however the museum tag for the specimen reads "3.4 KM WNW Quam Bank." He reported the same location "5.3 km NNW of Quam Bank" for the three specimens of *Lasiurus ega* he collected (McCarthy, 1987) which agrees with the museum records (CM 91924-CM 91926).

Rabinowitz and Nottingham (1989) also sampled bats for five nights using from one to four mist nets in 1984 during an assessment of small mammals in the Cockscomb Basin. Species they recorded are listed in Appendix 1 (RN).

In 1995, J. F. Jacobs collected bats (May 7-17) and deposited the specimens in the U.S. National Museum (USNM). We are not aware of any reports from this collection and this contribution is included in Appendix 1(USNM).

In May 1995, B. W. Miller and C. M. Miller conducted the first acoustical survey as part of a Belize Audubon Society warden training workshop. Two sites were sampled; in front of the headquarters building in the open area above the road and the forest edge-clearing interface

behind the warden house at the reserve's eastern boundary along the access road. In July 1996, a more detailed survey was conducted by B. W. Miller, C. M. Miller, and M. J. O'Farrell including acoustical surveys and four double-frame harp traps. Results are presented in this report.