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Diversity and Conservation of Cave-Roosting Bats in Central Ghana

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Abstract

Background: Ghana is one of the six bat diversity hotspots on the African continent, yet its caves have not been fully explored for the bats they host.

Research Aims: We aimed to assess the species composition and diversity of five caves in central Ghana and identified those needing immediate conservation attention.

Methods: Using mist-nets, we captured bats over 102 full nights between October 2010 and July 2012 from the Upper Guinean forest and Savannah regions in central Ghana.

Results: A total of 10,226 bats belonging to nine species were recorded. PERMANOVA suggested significant variation in species composition among the caves. A SIMPER analysis revealed *Coleura afra* and *Hipposideros jonesi* to be the main discriminating species between caves, with a dominance of *Hipposideros* cf. *ruber* in all caves. The Bat Cave Vulnerability Index (BCVI) revealed Mframabuom cave from the Upper Guinean forest region as a high priority cave hosting threatened species, yet highly disturbed. The remaining caves were identified as medium priority caves.

Conclusion: The results of the study suggest the need for further research and an immediate conservation strategy as essential for approaching national conservation goals.

Keywords

abundance, Africa, cave, Chiroptera, species richness

With the advent of the Anthropocene, tropical biodiversity has risen to being a top conservation concern among researchers, conservationists and natural resource managers (Voigt & Kingston, 2016). This is mainly due to the rapidly increasing human population and the connected overexploitation of the natural resources and habitats. The tropical region is in many aspects among the most affected by human activities, and particularly the biodiversity of special habitats such as caves remains largely understudied (Williams, 2008). Caves present peculiar features such as constant temperature and humidity, and, with the exception of small zones near the entrances, a total absence of light (Culver & Pipan, 2009, 2010). These characteristics have frequently promoted the evolution of endemic species uniquely adapted to this environment.

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Caves host some of the largest bat colonies of the world and fulfill many functions for bats, mainly the provision of a stable microclimate, protection from predators and as migratory or maternity roosts (Churchill et al., 1997; Glover & Altringham, 2008). Most bats spend half of their life or even more within their cave roost (Avila-Flores & Medellin, 2004; Kunz & Lumsden, 2003). The disturbance of bats in tropical caves is currently regarded as the most serious threat to cave biodiversity, including for the dependent invertebrate food chains (Furey & Racey, 2016). Compared to other regions of the world, only a few studies report on cave-roosting bat diversity in Africa (Churchill et al., 1997; Menzies, 1973). A few caves utilized by bats are reported from the Republic of the Congo, Central and Northern Gabon (Cigna, 2020) and Kenya (Heisch, 1952; Mcwilliam, 1988). Studies from southern Africa suggest at least 12 obligate, 10 facultative and 4 occasional cave-roosting species, out of 75 species known from the region (Cooper-Bohannon et al., 2016). In contrast, although being one of the bat diversity hotspots of the African continent (Herkt et al., 2016), such information is still largely lacking for Ghana.

Ghana, located in western Africa is among the continent's six bat diversity hotspots, and harbours over 84 species (Herkt et al., 2016; Mickleburgh et al., 2002; Weber & Fahr, 2007). The currently explored cave ecosystems host a high biodiversity, including several unique arthropod species (DeWildt, 2007; Philips et al., 2016), and often also large colonies of bats (Nkrumah et al., 2016a, 2017a). To date, no studies have examined bat species richness and diversity within them, which is a vital first step towards conservation. Therefore, in an effort to investigate the conservation significance of caves, and to support conservation decisions, this study aimed (1) to describe the species composition and diversity of bats in selected caves in central Ghana, and (2) to evaluate the conservation priorities of the studied caves.

Methods

Study Area

We sampled five bat caves from two vegetation zones in central Ghana: the Upper Guinean Forest and the Guinea Savannah (Figure 1). The Upper Guinean Forest region is known for its exceptionally high species diversity and endemism in flora and fauna in comparison to the Guinean Savannah (Happold, 1996; Myers et al., 2000). Two caves, Mframabuom and Abutia, separated by a 3.8 km distance and located close to the Kwamang village in the Ashanti Region represented the Upper Guinean Forest region (Figure 2). In the Guinean Savannah, we sampled Mprisi and Dwamerawa caves separated by 0.6 km and close to the Buoyem village, and the Boten cave nearby the Forikrom village (Figure 2). The minimum distance between caves from the two different vegetation zones, Boten and Abutia is 120 km.

Description of Caves. Mframabuom Cave (N 07°00′ W 01°18′) is located at 420 m a.s.l. It has one entrance viable for humans that leads into two main caverns and to tunnels with roosting bats. Another entrance is accessible only for bats. Each cavern is ca. 10 m by 8 m. Additional information on this cave is provided in Philips et al. (2016).

Abutia Cave (N 06°58′ W 01°16′) is located at 468 m a.s.l. and has a single wide entrance of ca. 12 m which narrows into a tunnel leading to a 15 m by 10 m cavern, that is used by roosting bats. Additional information on this cave is provided in Philips et al. (2016).

Mpirisi Cave (N 07°43′ W 01°59′) is located at 438 m a.s.l. It has three large caverns, each ca. 30 m by 10 m. A small tunnel joins all three caverns. The third cavern has a stream running through, and a 2 m diameter opening at the top that illuminates some sections. The second cavern is darkest, while due to a very wide entrance the first cavern receives the highest illumination during the day. Only the second and third caverns are used by roosting bats. This cave is a shrine cave and additional information is provided in Philips et al. (2016).

Dwamerawa Cave (N 07°43′ W 01°59′) is located at 449 m a.s.l. It has one large cavern with ca. 30 m by 20 m. A stream with larger boulders is present, but there are also some drier sections. There are 3 satellite chambers and tunnels that are also used by roosting bats.

Boten Cave (N 07°35′ W 01°52′) is located 365 m a.s.l. and consist of a large cavern, ca. 20 m by 15 m with 4 smaller satellite caverns of less than 25 m^2. Roosting bats use some of the satellite caverns, some of which are nearly impossible for humans to enter, due to very narrow entrances.

Sampling of Bats. An official permit to sample bats was granted by the Ghana Wildlife Division, and we obtained additional permissions from the local Chiefs of the villages close to the caves. Sampling was conducted over 22 months from October 2010 to July 2012 in six-week intervals, spending two nights at each cave during a visit. We paused for one night between the first and the second sampling night, in order to minimize disturbance to the bats. Bats were sampled with nylon mist-nets of 6 m, 10 m, and 12 m length (Ecotone, Poland). We adapted the number of mistnets set to the width and shape of the cave entrances and used between 1 and 3 nets per cave. We avoided the main emergence time for mistnetting, in order not to get overwhelmed by a high number of captured bats and to ensure the

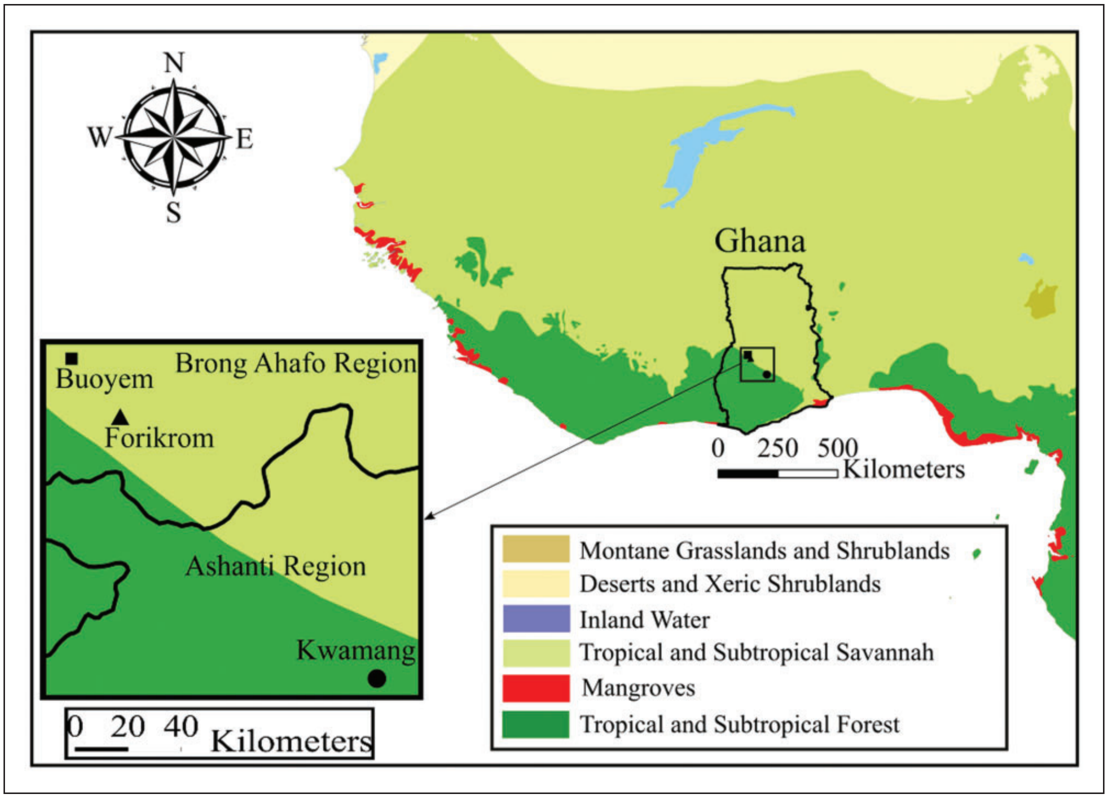

Figure 1. Location of Villages Close to the Five Caves From the Two Vegetation Zones of Central Ghana. Kwamang has the Mframabuom and Abutia caves, Forikrom has the Boten Cave and Buoyem has the Dwamerawa and Mpirisi caves.

wellbeing of the bats. Nets were generally operated throughout the night, i.e., from 19:00 hours, after the main evening emergence was over, until 06:00 hours of the next day. Captured bats were temporarily held in cloth bags and processed within 2 hours. Species were identified using Rosevear (1965) and additionally we consulted Monadjem et al. (2010). To identify recaptures, we temporarily marked bats by taking wing tissue samples using a 2 mm diameter biopsy punch. The collected tissue samples were used for other studies of our group (Baldwin et al., 2014, in press). Small holes in bat wing membrane heal rapidly within 27 days and are therefore non-detrimental to bats (Faure et al., 2009). Temperature and humidity data loggers (Thermochron iButton, Maxim Integrated, San Jose, USA) placed inside all caves allowed monitoring of microclimatic conditions.

Data Analyses. The capture rate was calculated as the number of bats caught per mist net hour (Aguirre, 2002). Data from 102 nights were used in the analysis as we excluded nights characterized by severe weather conditions such as strong rain. We also excluded from the analysis the few recaptured individuals. To assess the differences in species composition among caves, a Permutational Multivariate Analysis of Variance (PERMANOVA), based on the Bray–Curtis dissimilarity index, was employed, using the function 'adonis' from the 'vegan' package in the R statistical software (Joksanen et al., 2013). Adonis provides a more robust technique than the usually used ANOSIM (Analysis of Similarities) and MRPP (Multi Response Permutation Procedure), as it implements a multivariate ANOVA using distance matrices and calculates F-tests based on sequential sum of squares from permutations of raw data to assess the critical alpha statistical significance (Estrada-Villegas et al., 2010). The Tukey HSD (Honest Significant Differences) multiple comparison of means was used to identify caves responsible for the differences if observed. SIMPER analysis (Similarity Percentages-species contributions) was then used to identify the dominant species responsible for the differences (Clarke, 1993). The Bray–Curtis dissimilarity index, calculated in PAST v. 3.0, was used in the SIMPER analysis (Hammer et al., 2001). Environmental data could be only inconsistently collected, due to equipment theft and failures of the loggers. As a result, a rigorous statistical exploration was not possible, as consistent data for all caves were available only between the months of March and May 2012.

Cave bat community structure was assessed by calculating species richness and diversity. To predict expected

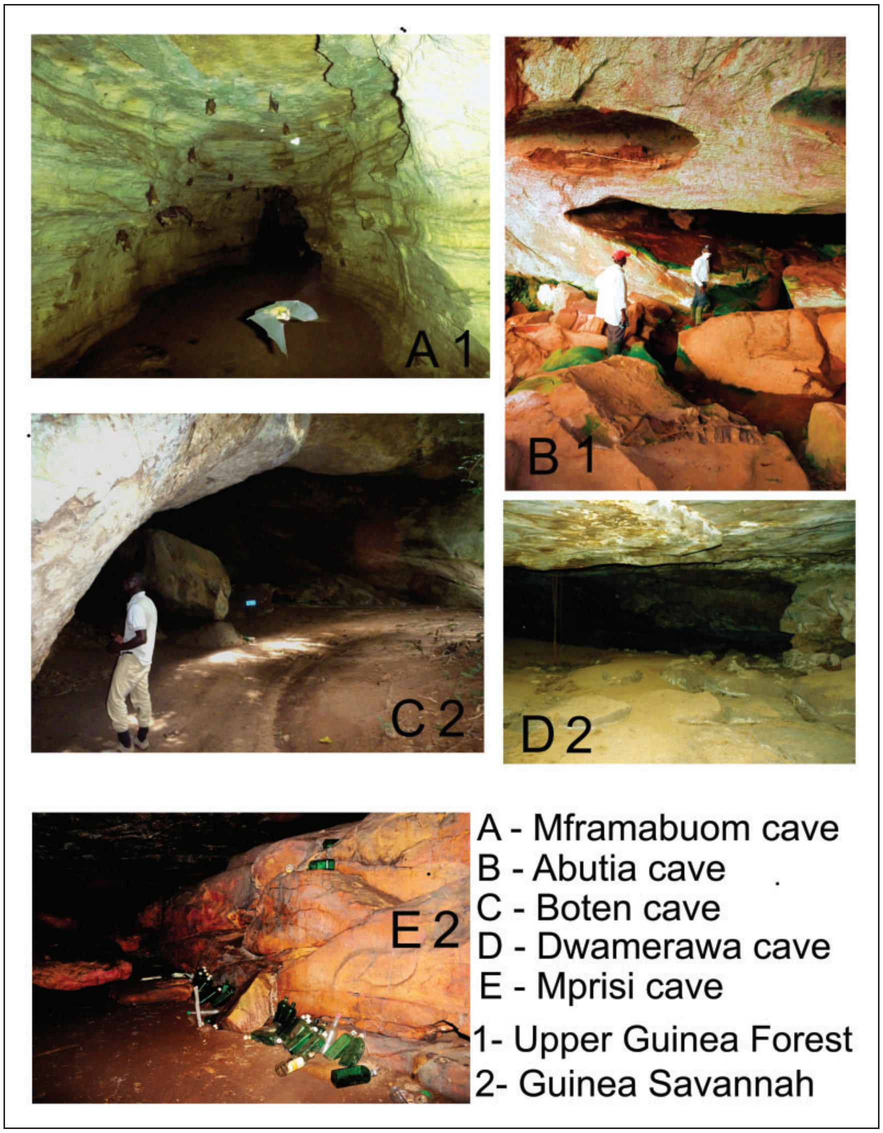

Figure 2. Sampled Bat Caves in Ghana and Their Location Within the Two Vegetation Zones.

species richness, the first order Jacknife (Jack1) in EstimateS was used (Colwell & Elsensohn, 2014), for its particular ability to account for the movement heterogeneity of mobile animals such as bats (Brose & Martinez, 2004). To develop sample-based accumulation curves, the data were rarefied using the 'Species Diversity' function in EcoSim (Gotelli and Entsminger, 2013) with 1,000 iterations to sample from capture pool data to bring capture data to the same abundance level. Significance was accepted at 95% confidence during simulation. Species diversity of the five caves were compared using Rényi generalised entropy function (Southwood & Henderson, 2000). Analysis was carried out using the DivOrd program package (Tothmeresz, 1993). The Rényi diversity (*HR*) scale parameter (α) corresponds to four well-known diversity indices (Lövei, 2005; Tothmeresz, 1998). At $\alpha = 0$, *HR,* corresponds to the logarithm of the species numbers in community. As α increases towards 1, *HR* corresponds to Shannon diversity. As $\alpha = 2$, *HR* corresponds to Simpson diversity and lastly, as α approaches infinity (∞), *HR* comes close to the Berger-Parker dominance index (Berger & Parker, 1970; Magura et al., 2010). Thus, at smaller values of α, *HR* is more influenced by rare species within the community while an increase of α towards infinity indicates a domination of the community by the most common species (Tothmeresz, 1998).

To evaluate the conservation priorities for the studied caves, we used the Bat Cave Vulnerability Index (BCVI), a recently developed approach for prioritizing bat caves in the tropics (Tanalgo, 2018). The index integrates the two components Biotic Potential Index (BP) and Biotic

Vulnerability Index (BV) to obtain a cave prioritization. The BP measures species richness, abundance, relative abundance, and the species attributes (endemism and conservation status: gathered from the World Conservation Union (IUCN) www.iucnredlist.org). The BP ranges from 1 to 4, with 1 being the highest and 4 the lowest value. The BV considers the cave's geophysical features and the anthropogenic threats including morphology, accessibility, tourism potential, guano exploitation and the presence of temples/shrines. The BV measures on a scale of A to D, with A representing the highest vulnerability to anthropogenic disturbance, and D standing for no or minimal disturbance. The combination of BP and BV yields a cave prioritization system, where 1 A, 1B and 2 A indicate highest priority; 1 C, 1 D, 2B to 3 D are medium priority; and caves in the category 4 A-4D indicate a low necessity of conservation action. Definition of conservation priority and details on using BCVI is available in Tanalgo (2018).

Results

We recorded a total of 10,226 bats in the five studied caves (Table 1). The bats used the caves year-round. Overall, we found 9 species, with 6 species in the Mframabuom, Mpirisi and Dwamerawa caves and 7 species in Boten and Abutia caves (Tables 1 and 2). The overall predicted species richness for all caves was $S_{jack1} = 9 \pm 0.02$. Among the caves, species richness was predicted to be highest at Mprisi, and lowest at the Mframabuom cave (Figure 3). Species richness for Mframabuom and Abutia might be expected to increase with more sampling as their curves did not reach the asymptote (Figure 3). *Hipposideros* cf. *ruber* dominated all caves with 81% of the total number of captures. *Hipposideros jonesi* were recorded only in the Upper Guinean Forest area in Kwamang at the Mframabuom and Abutia caves (Table 2). *Rousettus aegyptiacus* and *Coleura afra* were recorded only in the Guinea Savannah caves, with the first occurring only in the Mprisi cave, while the later was found in all three caves: Mprisi, Forikrom and Dwamerawa (Table 2).

Species composition differed significantly among the caves (PERMANOVA: $DF = 4$, $F = 22.09$, $P = 0.005$). Tukey HSD multiple comparisons of means revealed that Mprisi and Mframabuom differed significantly from each other ($P = 0.05$). The SIMPER analysis showed that *Coleura afra* and *Hipposideros jonesi* were the two species that mainly discriminated between Mprisi and Mframabuom caves. Total contribution of these two species to community dissimilarity was 47%, with 25% coming from *Coleura afra* and 22% from *Hipposideros jonesi*.

Species diversity showed a clear ranking of the five caves (Figure 4). The diversity profiling indicated that the Boten cave was more diverse than all other caves for both rare ($\alpha < 0.1$) and dominant species (as α approaches infinity). The least diverse cave was Dwamerawa in Buoyem. The standard deviation of temperature and humidity suggest a relatively more stable environment for caves in the Upper Guinean Forest area than in the caves in the Guinea Savannah area (Table 1).

An evaluation using the BCVI indicates different vulnerabilities and priorities for the five studied caves (Table 3). The BP indicates that none of the studied cave is a Level 1 cave. Mframabuom cave in the Upper Guinea Forest and Dwamerawa cave in the Guinea Savannah were identified as Level 2, with relatively large bat populations. All other caves (Abutia, Mprisi, Boten) were classified as Level 3, with mainly common species and small population. The BV identified the Mframabuom and Boten caves as the most vulnerable (BV status of A) as a result of easy accessibility, guano exploitation, tourism activities and cave lighting. The remaining caves Mprisi, Dwamerawa and Abutia had a BV status of B, indicating that they are accessible but with only minimal signs of disturbance. The combination of BP and BV revealed Mframabuom as a cave with high priority for bat conservation (BCVI = 2 A) with the remaining four caves having only medium priority (Table 3).

Discussion

This study represents the first attempt to characterise bat communities from caves in Ghana. Although numerous

Table 1. Recorded Microclimatic Variables, Summary of Capture Data and Sampling Efforts per Cave.

Caves	Microclimatic variables $\bar{x} \pm SD$ (n = 59)[a]		Total number of captured bats		Total hours worked	Total length of mist-nets used (m)
	Temperature (°C)	Humidity (%)	Individuals	Species		
Mframabuom Cave[b]	26.0 ± 0.0	100.0 ± 0.0	2,629	6	256	258
Abutia Cave[b]	24.6 ± 0.2	100.0 ± 0.3	1,888	7	215	216
Mpirisi[c]	24.3 ± 0.7	88.5 ± 2.9	1,619	6	158	276
Dwamerawa[c]	24.6 ± 0.3	89.7 ± 1.7	2,375	6	198	348
Boten Cave[c]	27.0 ± 0.3	86.0 ± 2.9	1,715	7	226	402

[a]Data recorded daily from 17 March to 14 May 2012 at 06:00 hours; [b]Caves in Upper Guinean Forest region; [c]Caves in Guinea Savannah region.

Table 2. Proportions of Bats Recorded From Each Cave.

Species	Mframabuom Cave[a]	Abutia Cave[a]	Mpirisi Cave[b]	Dwamerawa Cave[b]	Boten Cave[b]
Coleura afra	0.00	0.00	5.06	8.13	5.36
Hipposideros abae	13.05	9.75	2.16	9.56	6.01
Hipposideros cf. *ruber*	83.57	77.17	91.29	79.45	72.42
Hipposideros jonesi	1.90	0.69	0.00	0.00	0.00
Macronycteris gigas	0.84	1.64	0.00	0.72	0.58
Myonycteris angolensis	0.04	0.05	0.12	1.52	4.96
Rhinolophus landeri	0.00	0.11	0.00	0.00	0.93
Rousettus aegyptiacus	0.00	0.00	0.86	0.00	0.00
Nycteris macrotis	0.61	10.59	0.49	0.63	9.74

[a]Caves in Upper Guinean Forest region; [b]Caves in Guinea Savannah region.

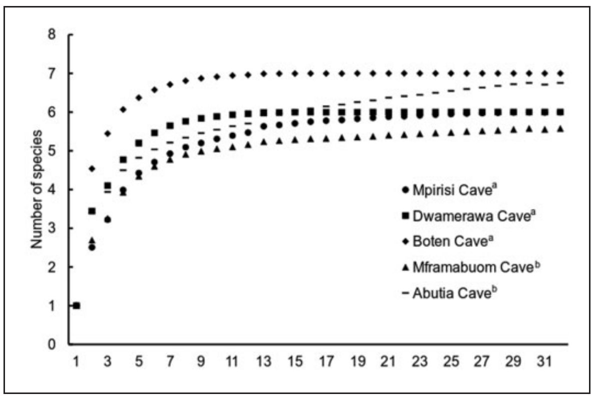

Figure 3. Sample-Based Rarefaction Curves for the Five Studied Caves Based on 1000 Iterations. [a]Guinea Savannah caves. [b]Upper Guinean Forest caves.

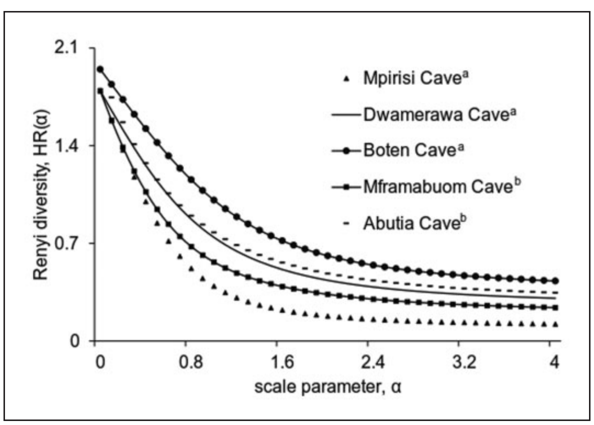

Figure 4. Rényi Diversity Profiling of the Five Studied Caves. [a]Guinea Savannah caves. [b]Upper Guinean Forest caves.

studies have been carried out to investigate bat communities in the country, none reported on the cave fauna (e.g., Barrière et al., 2009; Decher & Fahr, 2007; Weber & Fahr, 2007). Studies reporting from cave environments either focused on zoonoses (Corman et al., 2015; Pfefferle et al., 2009) or the ecology of selected species (Nkrumah et al., 2016b, 2017a). Overall, we identified 9 bat species using the five caves, which closely matches the predicted species richness, and thus indicates a near complete sampling. We found up to 7 species to share a single cave roost. Similar numbers of species are reported from 10 tropical caves in Namibia (Churchill et al., 1997) and from 17 Puerto Rican caves (Rodríguez-Durán, 1998), although there are also reports of up to 13 species from a cave in Brazil (Trajano & Gimenez, 1998). Species richness in Ghanaian caves could actually be higher than reported here due to the presence of cryptic species e.g., within *Hipposideros* cf. *ruber* (Baldwin et al., in press), mist-netting biases, and few investigated caves. The morphologically indistinguishable morphotype C and D of *Hipposideros* cf. *ruber* are confirmed in Mframabuom, Abutia and Boten caves, while Mprisi and Dwamerewa have morphotype B, C, and D (Baldwin et al., in press).

The diversity profiling suggests a high diversity of rare species in comparison to only a few common species, confirmed also by the dominance of *Hipposideros* cf. *ruber*. Although there is a high relative abundance particularly of *Hipposideros* cf. *ruber* in the caves, such large numbers of individuals control insect populations, and thus contribute to balancing the ecosystem (Dornelas et al., 2011), and the maintenance of guanophile communities (Furey & Racey, 2016).

The Ghanaian caves were used by bats year-round, suggesting a stable microclimate, which is a key factor for roost selection (Churchill et al., 1997; McNab, 1982). Significant differences in species composition among the caves may result from the location of the two main caves (Mframabuom and Mprisi). The two species that mainly discriminated between the Mframabuom and the Mprisi cave, *Coleura afra* and *Hipposideros jonesi,* shows distinct distributions. The emballonurid *Coleura afra* is found in Western Africa mainly in the Guinea Savannah area ((Happold & Happold, 2013), and therefore its presence in caves in the savannah vegetation can

Table 3. Conservation Priority Level of the Five Studied Caves Based on the Bat Cave Vulnerability Index, in Combination of the Biotic Potential Index and Biotic Vulnerability Index.

Bat cave	Biotic Potential Score	Biotic Potential Index	Biotic Vulnerability Scores	Biotic Vulnerability Index	Bat Cave Vulnerability Index[a]	Priorities	Critical factors
Mframabuom Cave[b]	90885	2	1.3	A	2A	High	Large population, threatened species present, easily accessible, and highly disturbed.
Abutia Cave[b]	56780	3	1.7	B	3B	Medium	Small population, easily accessible, and minimal disturbance.
Mpirisi[c]	33577	3	1.6	B	3B	Medium	Small population, easily accessible, and minimal disturbance.
Dwamerawa[c]	68243	2	1.6	B	2B	Medium	Large population, few threatened species present, easily accessible, minimal disturbance.
Boten Cave[c]	52436	3	1.3	A	3A	Medium	Small population, easily accessible, and highly disturbed.

[a]Based on Tanalgo et al. (2018); [b]Caves in Upper Guinean Forest region; [c]Caves in Guinea Savannah region.

Table 4. List of Known Caves in Ghana, With Coordinates, Elevation and Information Whether They Host Bats.

Region/Town	Cave	Coordinates	Elevation	Presence of bats
Ashanti/Kwamang	Mframaboum Cave[1,2,3]	N 07°00′ W 01°18′	420	Present
Ashanti/Kwamang	Abutia Cave[2,3]	N 06°58′ W 01°16′	468	Present
Ashanti	Water Cave[1,2]	N 07°44’ W 01°59’	425	Absent
Brong Ahafo/Buoyem	Mprisi Cave[1,2,3]	N 07°43′ W 01°59′	438	Present
Brong Ahafo/Buoyem	Dwamerawa Cave[3]	N 07°43′ W 01°59′	499	Present
Brong Ahafo/Forikrom	Boten Cave[3]	N 07°35′ W 01°52′	365	Present
Eastern/Abesua	Kaese Cave[1,2]	N 06°38’ W 01°25’	580	Absent
Eastern/Abesua	Kyireabe Cave[1,2]	N 06°38’ W 01°25’	580	Absent
Eastern/Abesua	Wiafe Cave[1,2]	N 06°38’ W 01°25’	580	Absent
Eastern/Abesua	Prati Cave[2]	–	–	Absent
Greater Accra/Shai Hills	Sayu Cave[1,2]	N 05°56’ E 00°03’	160	Present
Greater Accra	Adwuku Cave[2]	–	–	Absent
Greater Accra	[a]Hioweyo Caves[2]	–	–	Absent
Volta/Likpe Todome	[a]Likpe Caves[1,2]	N 07°10’ E 00°36’	626	Present
Volta/Akpomu	Akpomu Falls[1,2]	N 06°53’ E 00°28’	480	Absent
Volta/Agodome	[a]Kokosiaba Caves[1,2]	N 06°49’ E 00°23’	430	Absent
Volta/Obom	Obom Cave[1,2]	N 05°60’ W 00°11’	246	Absent

References: [1]Philips et al. (2016), [2]DeWildt (2007) and [3]This Study; [a]More than one cave in the Town but cave names unknown.

be expected (Boten, Dwamerawa and Mprisi). Similarly, the West African endemic *Hipposideros jonesi* is closely linked to forested environment (Fahr, 2013; Fahr & Ebigbo, 2003; Hayman, 1964; Nkrumah et al., 2017b), and as such is regularly observed in caves from the Guinean forest region (Mframabuom and Abutia). However, further investigation is needed as cave characteristics such as luminance, cave area, entrance size, temperature and humidity may influence species composition and diversity of bats in caves.

BCVI is an effective conservation decision tool for prioritization bat cave conservation needs (Deleva & Chaverri, 2018; Quibod et al., 2019). It identified the Mframabuom as a top conservation priority cave, and the remaining four as medium priorities. Human activities such as bat hunting, cave lightning, cave sweeping, guano exploitation, cave tourism (Tanalgo, 2018) greatly disturb most of the studied caves. The continual persistence of bats in these caves, especially at Mframabuom, suggests the bats may tolerate disturbance to a certain degree, but may abandon roost permanently when disturbance increases unabated (Nkrumah et al., 2016a).

Implications for Conservation

Globally, concern for cave conservation is on the rise due to their unique characteristics that make them vulnerable in the Anthropocene (Williams, 2008). The connectedness of caves with the surrounding environment mean human activities affecting the surroundings of the cave also have significant influence on the cave fauna. Unfortunately, threats such as habitat loss, climate change, mining, agriculture, groundwater overexploitation and contamination, which represent the critical factors threatening cave ecosystems (Mammola et al., 2019) are common around Ghanaian caves. To take sound conservation decisions, urgent and accelerated research is needed in Ghana to provide reliable data on bat diversity within caves. Currently, only few caves have been explored (Table 4). Threats like cave tourism, easy accessibility, cave lighting, cave camping and cleaning by religious groups, and drumming and dancing – e.g. in the Mframabuom cave - greatly displace the bats. These threats are ubiquitous in most Ghanaian caves, with devastating consequence for the overall cave biodiversity. Activities such as guano exploitation for agricultural activities might have already disturbed the guanophile community in the Boten caves. The Mframabuom cave, which potentially might host true troglobites with loss of eyes and pigmentation (Philips et al., 2016), may have already lost several species to these kinds of threats.

Assessment of the Gladysvale cave in South Africa suggest that they once hosted more diverse bat colonies (Avery, 1995), however, today it is bat-free. With unchecked disturbances, a similar fate might await some of the caves investigated in this study. Without rapid conservation action, especially at Mframabuom, the bat population may decline or completely abandon the roost, which in consequence will affect the general cave biodiversity (Nkrumah et al., 2016a). Currently, no legal frameworks exist in Ghana for the direct protection of cave-roosting bats. To ensure the survival of biodiversity in high conservation priority caves especially bats, we strongly advocate an immediate implementation of relevant policies and regulations for cave-roost protection at the national level.

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Declaration of Conflicting Interests

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