Research notes on bats' species assemblage in Madai Cave of Segama Valley, Sabah, Malaysia

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Abstract. Insectivorous bats spend approximately half of their lives in the roost. Most of them are cave-dwelling and use the caves as roosting grounds. Roosts are important for mating, hibernation, rearing young, and a place to socialise, while providing protection from predators in a thermo-stable environment. This study aims to assess the diversity of insectivorous bats at Madai caves in Kunak, Lahad Datu, Sabah over a temporal period of 8 years. The sampling of bats was conducted twice i.e. in August 2010 and in December 2018. Harp traps and mist nets were used to sample bats in all sampling sessions. Eighteen species of bats, including two fruit bats, *Cynopterus brachyotis* and *Rousettus spinalatus*, were identified from the study site. Four insectivorous bat species were found in both years consistently i.e. *Hipposideros cervinus*, *Rhinolophus creaghi*, *R. philippinensis*, and *Chaerephon plicatus*. The species list in 2010 and 2018 differed by more than 50%, which may be a cause of concern and warrants further investigation. Most of the listed species are categorised as Least Concern, under the IUCN Red List of Threatened Species, except for *Rousettus spinalatus*, *Hipposideros ridleyi* and *Miniopterus schreibersii* which are listed as vulnerable. Only *Hipposideros dyacorum* is protected under Sabah Wildlife Enactment (1997). These findings will assist policymakers in making decisions on the importance to conserve the natural habitats of bats.

Keywords: Bats; cave; IUCN; Sabah; virgin jungle reserve.

1. Introduction
The state of Sabah which is located at the northeast region of Borneo is a hotspot for bat diversity, housing 87 of the 102 species recorded throughout the island [1]. This number consists of eight families, including the only fruit bat family of Pteropodidae (16 species) and seven families of insectivorous bats: Emballonuridae (5 species), Rhinolophidae (10 species), Hipposideridae (9 species), Vespertilionidae (40 species), Molossidae (3 species), Megadermatidae (*Megaderma spasma*) and Nycteridae (*Nycteris tragata*). From these, three families i.e., Hipposideridae, Rhinolophidae and Vespertilionidae, are recognised as the narrow-space ensemble of insectivorous bats [2-4]. They are considered common and widely distributed in the caves of Sabah [5]. The members of Hipposideridae and Rhinolophidae are mostly cave-dwelling bats, whereas some members of Vespertilionidae (subfamilies Kerivoulinea and Murininae) are forest-dependent bats. They are highly adapted to forage in the forest and are predicted to be sensitive to land-use change [4]. Like all other bats, insectivorous bats spend approximately half of their lives in the roost, and most are cave-dwelling, using caves to roost. Roosts are important sites for mating, hibernation, rearing young, and a place to socialise with other individuals [5-7]. The roost protects them from predators and provide a thermo-stable environment. Furthermore, a suitable roost site will reduce commuting costs to foraging sites [8].
There has been relatively little cave-bat research conducted in Sabah. Most bat diversity study was carried out in the Gomantong cave and surrounding area. Boonratana and Sharma carried out the first bat report from the Lower Kinabatangan in Kampung Sukau [9]. In 2000, Yasuma (pers. comm) surveyed Gomantong Forest Reserve and Gomantong Virgin Jungle Reserve, reporting twenty-five species of bats. To date, sixteen species of insectivorous bats and four species of fruit-bats were reported from Gomantong and Sukau [1,6,7,9-11] (Table 1).

Table 1. List of bats present in Gomantong Virgin Jungle Reserve, Gomantong Protected Forest Reserve and Sukau.

| Family          | Species                                                                 |
|-----------------|-------------------------------------------------------------------------|
| Pteropodidae    | *Pteropus vampyrus*, *Cynopterus horsfieldi*, *Cynopterus brachyotis*,  |
|                 | *Eonycteris spelaea*                                                    |
| Hipposideridae  | *Hipposideros diadema*, *Hipposideros cervinus*, *Hipposideros galeritus*, |
|                 | *Hipposideros bicolor*                                                 |
| Rhinolophidae   | *Rhinolophus creaghi*, *Rhinolophus philippinensis*, *Rhinolophus      |
|                 | *arcuatus*, *Rhinolophus borneensis*                                  |
| Vespertilionidae| *Miniopterus magnate*, *Miniopterus australis*, *Miniopterus paululus*, |
|                 | *Myotis gomantongensis*, *Myotis muricola*, *Kerivoula papillosa*       |
| Molossidae      | *Chaerephon plicatus*                                                  |

2. Materials and methods

2.1 Study site
Gomantong, Batu Supu and Madai are considered large caves, compared to other caves in the Lower Kinabatangan-Segama Valley, with edible birds’ nest harvesting being regularly conducted at Gomantong and Madai caves. Madai cave is in the Madai-Baturong Virgin Jungle Forest (VJR; 5,867ha) and consists of two compartments i.e., Madai VJR (Block A) and Baturong VJR (Block B). About 23 to 38 caves are located within this forest reserve, with Madai being the largest of them [12] (Figure 1).

Figure 1. Location of Madai cave and other caves in Lower Kinabatangan and Segama Valley.
2.2 Sampling effort and bat handling
Sampling was conducted twice over a period of eight years apart, in August 2010 and December 2018 for four consecutive nights each. Due to seasonal factors in Sabah, we had modified some sampling protocols [4,13] and operating hours to avoid any animal casualties. Bats were sampled from 8.00 pm to 10 pm every day and the nets and traps were manned every 15-20 minutes. After each collection, the traps were drawn down from the caves instead of leaving it unmanned overnight at the sites.

On-site, three harp traps and eight mist nets were set inside and around the caves in the evening after the bats emerged from the cave. The body weight of the bats was measured in grams (g). In addition, the forearm length (FA), hindfoot (HF), ear and tragus (Ear-tragus), and tail (T) were measured in millimetres (mm) for species identification [1,12,14]. Only fifteen individuals were taken for measurement for each trap checking session and we had reduced the length of time taken to process each bat. This was to avoid massive backlog of collection at any given time and to avoid any unnecessary casualty.

2.3 Data analyses

2.3.1 Inventory sampling efforts and completeness. We calculated the success rate and the sampling efforts in 2010 and 2018. Also, diversity estimation indicators such as Chao1, Chao2, ACE, ICE, First and Second-order Jacknife were computed to evaluate the completeness of our inventories, using EstimateS [12].

2.3.2. Species diversity, species assemblages, guild structure and conservation status. We recorded species and sampling methods that were successfully used to catch the species for future reference. Species diversity and inventory completeness were calculated using diversity indices such as Chao1, Chao2, ACE, ICE, First-order Jacknife, Second-order Jacknife and Bootstrap in EstimateS software [12]. Captured bats were assigned to their conservation status following the IUCN Red List of Threatened Species and Sabah Wildlife Enactment (1997) [12]. Also, we determined their guild structure based on their foraging strategies [4,15].

3. Results and discussions

3.1 Sampling efforts and success rate in Madai cave
We had sampled Madai cave for forty-four (44) trap-nights in both years (2010 and 2018). However, in 2010 we had recorded 179 individuals while 100 individuals were captured in 2018. The number of catches contributed to the success rate, calculated to be 407% in 2010 and 227% in 2018 (Table 2). The indication shows that the bat inventory at Madai cave is incomplete by only documenting 69%-90% of expected bat diversity in 2010, whereas in 2018, the bat inventories incompleteness is recorded at 80-100%. (Table 3). The absence of a species from our surveys did not exhibit that the species is not present in the site [16]. If the surveys are extended, more species will likely be recorded.

| Year | Number of traps | Numbers of nights | Number of catch | Numbers of trap-nights (trapping effort) | Percentage of trapping success |
|------|----------------|-------------------|----------------|------------------------------------------|-----------------------------|
| 2010 | 11             | 4                 | 179            | 44                                       | 407%                        |
| 2018 | 11             | 4                 | 100            | 44                                       | 227%                        |
Table 3. Bat inventory completeness in Madai Cave in 2010 and 2018.

| Estimator indices | 2010            | 2018            |
|-------------------|-----------------|-----------------|
|                   | Expected species richness | Inventory completeness (%) | Expected species richness | Inventory completeness (%) |
| Chao1             | 16.98           | 82%             | 8.0              | 100%            |
| Chao2             | 16.73           | 84%             | 8.3              | 96%             |
| ACE               | 18.03           | 78%             | 8.4              | 95%             |
| ICE               | 16.71           | 84%             | 9.18             | 87%             |
| First-order jacknife | 17.64          | 79%             | 9.82             | 81%             |
| Second-order jacknife | 20.17          | 69%             | 9.98             | 80%             |
| Bootstrap         | 15.6            | 90%             | 8.94             | 89%             |

3.2 Species diversity, species assemblages, guild structures and conservation status

In this study, 279 individuals of bats were captured, comprising of eighteen species in Madai cave. These include two species of fruit bats, *Cynopterus brachyotis* and *Rousettus spinalatus*. Some species were more commonly caught either in harp traps, mist nets, or both methods. The most abundant species and consistently sampled were *Rhinolophus creaghi* and *Rhinolophus philippinensis*, besides *Hipposideros cervinus* and *Chaerephon plicatus* (Table 4). The usage of harp trap is proven successful in the cave and karst ecosystem in previous studies [16-18]. However, our surveys’ deployment of harp trap and mist net had increased the chances of trapping several rare species, i.e., *Hipposideros dyacorum* and *Emballonura alecto*.

The species composition varied hugely between the two sampling years, which was partly contributed by the changes in the sampling stations, leading to changes in vegetation. For instance, in 2010, we sampled Madai cave and the Madai cave boardwalk, which cuts across into the cave's forest. Meanwhile, in 2018, the sampling was conducted at Madai cave, Kampung Madai and forest trails near the cave, covering different vegetation such as small orchards, forest edge, and the forest itself.

The overall assemblages of eighteen species were dominated by two families: Vespertilionidae (6 species; 33%) and Hipposideridae (5 species; 28%). The only fruit bat family, Pteropodidae, contributed two species to the assemblages (Table 5). Changes to assemblage composition were frequently related to environmental, anthropogenic, and spatial gradients because species tend to be most abundant around their optimal environmental conditions [12]. From the surveys, six species of insectivorous bat were assigned to both edge-gap and narrow-space insectivores (38%), and five species each were assigned to edge-gap insectivores and narrow-space insectivores (31%) (Table 5). The guild structure composition was as expected since our surveys only focused on the cave ecosystem [15].

Most of the species reported in this study were categorised as Least Concern (LC) under the IUCN Red List of Threatened Species except for three species: *Rousettus spinalatus, Hipposideros ridleyi* and *Miniopterus schreibersii*, which were identified as vulnerable. Meanwhile, only *Hipposideros dyacorum* is protected under the Sabah Wildlife Conservation Enactment (Schedule 2) (Table 5). In addition, *H. dyacorum* is recognised as endemic to Borneo [1] and has Sundaic ranges that are restricted to Borneo and Malay Peninsula [16]. Species diversity reported from the Madai cave is relatively comparable to the diversity of insectivorous bats from other caves and limestone karst in this region, such as Gunung Senyum, Peninsular Malaysia (15 species, [3]), Central Mindanao (14 species, [19]), and Cebu Island (16 species, [19]) in the Philippines, yet still low compared to Sangkulirang limestone karst, in East Kalimantan (36 species,[16]).
Table 4. Species diversity, sampling methods and species occurrence at Madai cave, Kunak, Sabah.

| Family       | Species                          | Sampling methods | Year | 2010 | 2018 |
|--------------|----------------------------------|------------------|------|------|------|
|              |                                  | Mist net | Harp trap |      |      |
| Pteropodidae | Cynopterus brachyotis            | √        |          | 2   | -    |
|              | Rousettus spinalatus             | √        |          | -   | 2    |
| Hipposiderida| Hipposideros diadema             | √        |          | 6   | -    |
|              | Hipposideros cervinus            | √        |          | 38  | 3    |
|              | Hipposideros dyacorum            | √        |          | 3   | -    |
|              | Hipposideros galeritus           |          |          | -   | 5    |
|              | Hipposideros ridleyi             |          |          | 1   | -    |
| Rhinolophidae| Rhinolophus creaghi              | √        |          | 28  | 57   |
|              | Rhinolophus philippinensis       | √        |          | 21  | 14   |
| Vespertilionida| Miniopterus magnater            | √        |          | 4   | -    |
|              | Miniopterus schreibersii         | √        |          | 33  | -    |
|              | Miniopterus paululus             | √        |          | -   | 4    |
|              | Myotis macrotarsus               | √        |          | 7   | -    |
|              | Myotis muricola                 |          |          | 33  | -    |
|              | Myotis horsfieldii               |          |          | 1   | -    |
| Emballonurida| Emballonura alecto               |          |          | 1   | -    |
| Molossida    | Miniopterus schreibersii         | √        |          | 1   | 14   |
|              | Myotis horsfieldii               |          |          |     |      |
|              | Myotis horsfieldii               |          |          |     |      |
|              | Chaerephon plicatus              | √        |          |     | 1    |
|              | Cheiromeles torquatus            |          |          |     | 1    |

Table 5. Conservation status according to the IUCN Red List of Threatened Species and Sabah Wildlife Conservation Enactment (1997) and bats' foraging strategies at Madai cave.

| Family       | Species                          | Conservation Status | Foraging strategy |
|--------------|----------------------------------|---------------------|-------------------|
|              |                                  | IUCN    | WCE    |                  |
|              |                                  | LC      | NP     | NF                |
| Pteropodidae | Cynopterus brachyotis            | LC      | NP     | NF                |
|              | Rousettus spinalatus             | VU      | NP     | NF                |
| Hipposiderida| Hipposideros diadema             | LC      | NP     | E/Ni              |
|              | Hipposideros cervinus            | LC      | NP     | Ei                |
|              | Hipposideros dyacorum            | LC      | P(2)   | Ni                |
|              | Hipposideros galeritus           | LC      | NP     | Ni                |
|              | Hipposideros ridleyi             | VU      | NP     | Ni                |
| Rhinolophidae| Rhinolophus creaghi              | LC      | NP     | Ni                |
|              | Rhinolophus philippinensis       | LC      | NP     | Ni                |
| Vespertilionida| Miniopterus magnater            | LC      | NP     | Ei                |
|              | Miniopterus schreibersii         | VU      | NP     | Ei                |
|              | Miniopterus paululus             | LC      | NP     | Ei                |
|              | Myotis macrotarsus               | LC      | NP     | E/Ni              |
|              | Myotis muricola                 | LC      | NP     | E/Ni              |
|              | Myotis horsfieldii               | LC      | NP     | E/Ni              |
| Emballonurida| Emballonura alecto               | LC      | NP     | Ei                |
| Molossida    | Chaerephon plicatus              | LC      | NP     | E/Ni              |
|              | Cheiromeles torquatus            | LC      | NP     | E/Ni              |

Notes: LC- Least Concern; VU- Vulnerable; P- Protected; NP – Not Protected; NF- narrow space (understorey) frugivore/nectarivore; Ei-edge-gap insectivores; Ni- narrow space insectivores; and E/Ni- both edge-gap and narrow space insectivorous

4. Conclusion
The presence of several rare species with noteworthy conservation status indicates the importance of the Madai cave ecosystem in maintaining bat diversity in the eastern coast of Sabah and Malaysia in general. It highlights the need to enhance bats’ protection and conservation in Sabah through the revision and
remapping of the conservation status in the Sabah Wildlife Conservation Enactment 1997. These findings will assist policymakers to enhance and expand their conservation and management on the natural habitats of bats.

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