

**NEW DISTRIBUTIONAL RECORDS AND ACOUSTIC IDENTIFICATION  
OF HIPPOSIDERID BATS (CHIROPTERA: HIPPOSIDERIDAE)  
FROM SON LA AND LANG SON PROVINCES, NORTHERN VIETNAM**

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Received June 5, 2025. Revised June 22, 2025. Accepted September 30, 2025.

**Abstract.** Son La and Lang Son provinces exemplify the characteristic natural conditions of Vietnam's northwestern and northeastern regions, respectively. Defined by heterogeneous topography, diverse forest ecosystems, and extensive karst cave systems, these provinces constitute critical habitats supporting rich bat faunas, including species of conservation concern. However, local bat populations are increasingly threatened by illegal hunting, rapid urbanization, wind farm development, and other human activities. To assess the current diversity and conservation status of bats, which have been affected by these factors, we conducted intensive field surveys across representative habitats in Son La and Lang Son provinces with a focus on the family Hipposideridae. Six hipposiderid species were recorded during the surveys: *Aselliscus stoliczkanus*, *Hipposideros armiger*, *H. cineraceus*, *H. gentilis*, *H. khaokhouayensis*, and *H. poutensis*. They are distinct in morphological and acoustic characteristics. Among these, *H. khaokhouayensis* is globally rare and threatened, being listed as Endangered in Vietnam's Red Data Book and as Vulnerable on the IUCN Red List of Threatened Species. It was recorded exclusively in Son La province, whereas the remaining five species were captured in both provinces. This study presents the first comprehensive comparative dataset on the echolocation calls of all six hipposiderid species recorded in the study areas, along with new distribution records of *H. khaokhouayensis* in northwestern Vietnam. These findings provide valuable insights into the regional diversity of Hipposideridae and establish a critical baseline for future taxonomic, ecological, conservation, and long-term monitoring research.

**Keywords:** biodiversity, conservation, distribution, echolocation, Hipposideridae.

## 1. Introduction

Lang Son and Son La provinces, representing the northeastern and northwestern regions of Vietnam, respectively, exhibit distinct yet complementary natural conditions, ranging from karst formations with extensive cave systems to montane forests, agricultural zones, and urban areas, that collectively provide favorable habitats for a wide range of bat species [1]-[3]. These natural conditions support highly diverse bat faunas. However, despite their ecological significance, bats and other mammal species of the two provinces have received limited attention from scientists and authorities. To date, only a few studies on mammals, including bats, have been conducted in both Son La and Lang Son provinces [1], [4]-[9]. The rapid urbanization and wind farm development in Son La and Lang Son provinces, respectively, have potentially significant impacts on the natural environment and may influence local bat populations both directly and indirectly [2], [4], [10]. Despite these pressures, bats have received relatively limited attention from local authorities.

Recent research in northern Vietnam has revealed significant regional disparities in bat biodiversity studies and conservation efforts. In Son La Province, field surveys have documented a notable diversity of bat species, including several of conservation concern listed under both national and international threat categories [11]. These findings highlight the ecological significance of the region and the growing threats posed by deforestation, hydropower expansion, and infrastructure development. In contrast, provinces such as Lang Son remain poorly studied, despite undergoing rapid land-use transformation driven by renewable energy initiatives. Studies from other parts of Vietnam (e.g., Cuc Phuong National Park, Cat Ba Biosphere Reserve, and other areas) have revealed high bat species richness, including rare and endemic taxa, reinforcing Vietnam's status as a regional hotspot for bat diversity [11]-[14]. These uneven research efforts highlight the urgent need for regional strategies to monitor and conserve bat populations in ongoing environmental change.

In this context, with the support of the Vietnam Academy of Science and Technology, we conducted comprehensive field surveys of bats across representative natural habitats in Son La and Lang Son provinces. The findings presented in this paper provide updated insights into the regional hipposiderid bat diversity and establish a scientific baseline for future research, ecological monitoring, and conservation. These results are expected to raise awareness among scientists, policymakers, and the public regarding the importance of bat conservation in this rapidly urbanizing region.

## 2. Content

### 2.1. Materials and methods

#### 2.1.1. Bat capture and identification

Field surveys were conducted in four wards of Son La province (To Hieu, Chieng An, Chieng Coi, and Chieng Sinh) from August 9 to 16, 2024. In Lang Son province, two surveys were carried out across five communes (Na Sam, Hoang Van Thu, Thuy Hung, Van Lang, and Hoi Hoan) during the periods of February 7-28, 2023, and March 23-April 13, 2024. These localities encompass representative habitats suitable for bats in each province. The field survey techniques were implemented as described by Dao (2019) [3], Vu (2021) [15], and Vu (2023) [16]. Bats were captured using three mist nets (6 - 9 m in height and 9 - 12 m

in length, mesh size of  $16 \times 16$  mm) and two four-bank harp traps as described by Francis (1989) [17]. Nets and traps were placed at cave entrances and beneath the canopy of plantations and natural vegetation. To optimize capture success, two mist nets were positioned adjacent to harp traps every night, while the remaining net was placed at a separate site. Captured bats were carefully removed from the nets and traps. Their reproductive status and age were assessed according to the criteria of Racey (2009) [18] and Brunet-Rossini and Wilkinson (2009) [19]. All handling procedures adhered to the guidelines of the American Society of Mammalogists (Sikes et al., 2016) [20]. All 65 captured bats were adults and reproductively inactive. Four external morphological measurements, forearm length (FA), ear height (EH), ear width (EW), and noseleaf width (NW), were obtained for each captured bat using digital calipers. Captured bats were identified based on morphological descriptions in the following references: Dao (2019) [3], Vu (2021) [15], Vu (2023) [16], Borrisenko and Kruskop (2003) [21], Kruskop (2013) [22], Wilson and Mittermeier (2019) [23], and Yuzefovich et al. (2021, 2022) [24], [25]. Representative individuals of each species were photographed after identification. All captured bats were released at the capture sites after morphological identification, echolocation recording, and photography.

### **2.1.2. Echolocation recordings and analyses**

Echolocation calls were recorded and analysed following Vu (2021) [15], and Vu (2023) [16]. The PCTape system (sampling rate: 480 kHz; resolution: 16-bit) was employed to record echolocation calls under three conditions: (i) bats emerging from caves, (ii) bats held in the hand, and (iii) bats with free flight within a flight tent of 5 m wide, 5 m long, and 3 m high. Batman software, which displays colour sonograms in real time for every detected call, was co-employed to identify high-quality sequences for recording. The recorded call sequences were subsequently analysed using Selena software. All software and equipment used in this study (PCTape, Batman, and Selena) were custom-developed and produced by the University of Tübingen, Germany.

Hipposiderid bats emit multiharmonic echolocation calls characterized by dominant energy in the second harmonic. Each entire harmonic consists of a constant-frequency (CF) component followed by a downward frequency-modulated (FM) sweep. The constant-frequency component of the second harmonic (CF2), which exhibits the highest energy, remains consistent within individuals across recording contexts. Therefore, the CF2 component was selected for frequency measurement while sonograms were displayed with a Fast Fourier Transform (FFT) size of 512, a Hann window function, and zero-padding to enhance frequency resolution and ensure accurate measurement of CF2 values.

## **2.2. Results and discussion**

### **2.2.1. New distributional records**

A total of 65 bat individuals representing six hipposiderid species were captured during the three field surveys: *Aselliscus stoliczkanus*, *Hipposideros armiger*, *H. cineraceus*, *H. gentilis*, *H. khaokhouayensis*, and *H. poutensis*. All six species were recorded in Son La province, whereas only five morphologically similar species (*Aselliscus stoliczkanus*, *Hipposideros armiger*, *H. cineraceus*, *H. gentilis*, and *H. poutensis*) were recorded in Lang Son province. Every captured individual was an adult, and none exhibited signs of

reproductive activity. Among these six species, three were recorded for the first time from the four wards in Son La province, including *H. armiger*, *H. cineraceus*, and *H. Khaokhouayensis*, whereas all five species (*A. stoliczkanus*, *H. armiger*, *H. cineraceus*, *H. gentilis*, and *H. poutensis*) were newly recorded from the five study communes in Lang Son province.



**Figure 1. Locations and distance between To Hieu and Hum Caves  
(Background map derived from Google Earth Pro imagery)**

Remarkably, *H. khaokhouayensis* is a globally rare and threatened species. One female and one male were captured at an unnamed cave in To Hieu Ward (hereafter referred to as To Hieu Cave, which was also named as Son La City Central Cave), located within the Forest Science Centre of Northwestern Vietnam (21°17'48.46"N, 103°56'46.10"E). Of the other two species newly recorded from the study sites in Son La province, *H. cineraceus* was found cohabiting with *H. khaokhouayensis* in the same cave, whereas *H. armiger* was recorded exclusively from another unnamed cave near Hum village (hereafter "Hum cave"), Chieng An ward (21°22'39.30"N, 103°55'33.61"E). Both To Hieu and Hum Caves are approximately 9.17 km apart and are well known in Son La province for local tourist attractions (Figure 1). These new records not only extend the known distribution ranges of the five species in the study sites of both provinces but also underscore their dependence on cave roosts across diverse landscapes, including urban areas, rural areas, and mountain forests.

### 2.2.2. Morphological and acoustic identification

The captured individuals distinctly displayed the diagnostic external morphological features of their respective species. Each of the six hipposiderid species was readily distinguishable by external morphology (Figure 2, Table 1). *Aselliscus stoliczkanus* is easily identified by its distinctive trident-shaped noseleaf, characterized by three vertical ridges on the posterior leaf. The forearm lengths of individuals captured in Son La and Lang Son provinces ranged from 41.5 to 43.8 mm and 41.8 to 43.9 mm, respectively. This species possesses a complex noseleaf, comprising a well-developed anterior horseshoe that does not completely cover the muzzle and a prominent, upward-curving lancet. The ears are moderately large relative to body size, pointed, and distinct. The dorsal fur is typically grayish-brown to dark brown, with distinctly paler ventral fur.



**Figure 2. Representative portraits of *H. armiger* (A), *H. poutensis* (B), *H. khaokhouayensis* (C), *H. gentilis* (D), *A. stoliczkanus* (E), and *H. cineraceus* (F) from Son La province**

*Hipposideros armiger*, the largest among the five *Hipposideros* species, is easily recognized by its robust body and forearm lengths of individuals captured in Son La and Lang Son provinces ranged from 86.6 to 96.3 mm and 85.8 to 96.5 mm, respectively. It has a broad and complex noseleaf, with a large frontal leaf that nearly covers the muzzle and a broad posterior leaf. The ears are large, rounded, and well-separated. Its dense fur is dark brown to reddish-brown dorsally and slightly paler ventrally.

In contrast, *Hipposideros cineraceus* is the smallest among the five species, with forearm lengths of individuals captured in Son La and Lang Son provinces ranging from 33.8 to 35.3 mm and 33.6 to 35.5 mm, respectively. It possesses a narrow frontal noseleaf covering the muzzle and a relatively simple posterior leaf. The ears are pointed and proportionally large relative to body size. Its dorsal fur is grayish-brown with lighter ventral fur, giving it a soft and delicate appearance.

*Hipposideros gentilis* is a medium-sized species, with forearm lengths of individuals captured in Son La and Lang Son provinces ranging from 40.2 to 43.7 mm and 40.5 to 43.6 mm, respectively. It has a moderately broad noseleaf, with an upright yet relatively low posterior leaf. The ears are medium-sized and pointed. The dorsal fur is uniformly medium to dark brown, with slightly paler ventral coloration.

*Hipposideros khaokhouayensis* is distinguished by a relatively narrow frontal leaf and a rounded posterior leaf. The narrow frontal noseleaf has an expanded internarial septum forming a distinctive oval, disc-like shape, and lacks supplementary leaflets beneath the anterior leaf. The lateral margins of the posterior and anterior leaves are connected at their bases. Its ears are broad with blunt tips. The pelage varies from light gray-brown to dark brown.

*Hipposideros poutensis* possesses a narrow frontal leaf and a posterior leaf that is less pronounced and more triangular. The ears are moderate in size and slightly rounded at the tips. The fur is dark brown both dorsally and ventrally, giving it a more uniform coloration compared to the other species.

The six hipposiderid bat species recorded in the study sites also exhibited distinct echolocation call frequencies, providing reliable acoustic features for species identification (Figure 3, Table 1). These differences reflect species-specific adaptations in foraging ecology and habitat use. *A. stoliczkanus* in Son La and Lang Son provinces

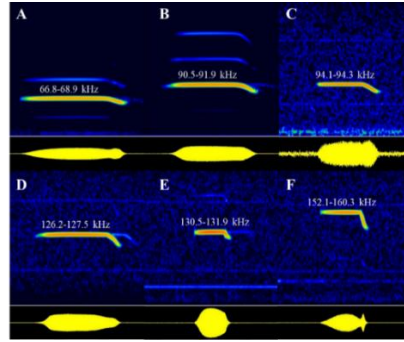
produces high frequency echolocation calls ranging from 130.5 to 131.9 kHz and from 130.1 to 131.6 kHz, respectively. These short constant-frequency calls are typical of trident bats and are suited for detecting fluttering insect prey in cluttered environments. This frequency range distinctly separates it from all five *Hipposideros* species recorded in the present study.

**Table 1. Morphological measurements and CF2 values of bats captured in Son La and Lang Son provinces. Data are presented as sample size (n) with ranges given as minimum–maximum.**

Species name	Province	n	FA	EH	EW	NW	CF2
<i>A. stoliczkanus</i>	Son La	12	41.5-43.8	9.5-11.2	6.1-8.9	5.1-6.1	130.5-131.9
	Lang Son	3	41.3-43.1	9.4-11.0	6.2-8.6	5.0-5.9	130.1-131.6
<i>H. armiger</i>	Son La	9	86.6-96.3	29.9-33.6	23.9-29.8	8.5-12.9	66.8-68.9
	Lang Son	6	86.2-95.9	29.6-32.8	23.6-28.9	8.3-12.6	66.2-69.6
<i>H. cineraceus</i>	Son La	3	33.8-35.3	15.1-15.5	14.1-15.5	-	152.1-160.3
	Lang Son	5	33.6-35.5	15.0-15.8	14.1-15.5	-	152.0-159.6
<i>H. gentilis</i>	Son La	10	40.2-43.7	21.7-23.7	16.3-18.7	4.1-5.1	126.2-127.5
	Lang Son	6	40.5-44.0	21.5-23.9	16.0-18.5	4.0-4.5	126.0-126.8
<i>H. khaokhouayensis</i>	Son La	2	44.5; 50.8	26.8; 28.2	18.6; 19.5	6.2; 6.6	94.1; 94.3
<i>H. poutensis</i>	Son La	6	62.3-64.0	21.5-22.8	19.2-19.9	7.5-7.9	90.5-91.9
	Lang Son	3	62.5-63.8	21.3-22.6	19.0-19.6	7.6-8.0	90.8-91.6

*H. armiger* emits relatively low-frequency calls in the range of 66.2 to 69.6 kHz. Its call frequency is significantly lower than that of any other species recorded in the study area, making it acoustically distinctive. In contrast, *H. cineraceus* produces the highest frequency calls among the six species, ranging from 152.0 to 160.3 kHz. These extremely high-frequency CF calls are associated with its small body size and are specialized for fine-scale prey detection in dense vegetation. This call range does not overlap with any other species in the assemblage, providing a clear acoustic identification.

*H. gentilis* emits echolocation calls at a frequency range of 126.0 to 127.5 kHz, placing it close to, yet still distinguishable from *A. stoliczkanus*. While both species use high-frequency CF calls, their call frequencies do not overlap, allowing for clear acoustic identification. *H. khaokhouayensis* can also be identified by its call frequency, ranging from 94.1 to 94.3 kHz. This narrow and consistent frequency range distinguishes it from both higher- and lower-frequency calling species. Its calls are particularly distinct from those of *H. gentilis* and *H. cineraceus*, which operate at much higher frequencies. *H. poutensis* emits CF calls between 90.5 and 91.9 kHz, which are slightly lower than those of *H. khaokhouayensis*. Although both species call within a similar range, their frequencies do not overlap, and the subtle difference, when considered alongside morphological traits, enables accurate species identification.



**Figure 3. Representative echolocation calls of *H. armiger* (A), *H. poutensis* (B), *H. khaokhouayensis* (C), *H. gentilis* (D), *A. stoliczkanus* (E), *H. cineraceus* (F) from Son La province**

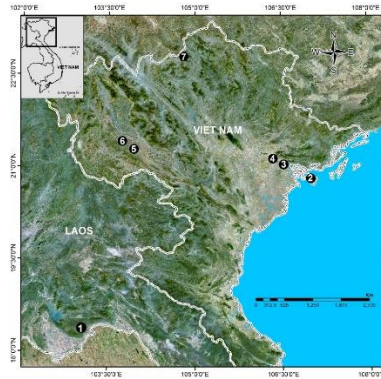
### 2.2.3. Remarks on new records

The earliest documented records of bat species in the study wards of Son La province were provided by Dao (2019) [3], who reported three hipposiderid species: *A. stoliczkanus*, *H. larvatus*, and *H. pomona*. Subsequent taxonomic revisions have clarified the status of these taxa. Specifically, *H. gentilis* and *H. poutensis* have been recognized as distinct species in accordance with updated classifications [15], [23], [26]. Yuzefovich et al. (2021) noted that the population previously identified as "*H. pomona*" in northern Vietnam undermines the subspecific classification of *H. gentilis sinensis*, suggesting that earlier records of *H. pomona* in Son La and Lang Son provinces likely resulted from misidentification of *H. gentilis* [24]. Similarly, Yuzefovich et al. (2022) indicated that records of *H. larvatus* from northern Vietnam, including Son La and Lang Son provinces, were based on misidentified specimens of *H. poutensis* [25]. The present study confirms the presence of both *H. gentilis* and *H. poutensis* in the two study provinces (Figure 2, Table 1).

To date, two species of the genus *Aselliscus* are recognized in Vietnam: *A. stoliczkanus* and *A. dongbacanus*, which differ in the size and shape of their upper canines, as well as in genetic characteristics [23]. Examination of museum specimens and individuals captured in the two study provinces revealed upper canines consistent with the diagnostic features of *A. stoliczkanus* [2], [3]. Furthermore, genetic data obtained from the captured individuals support this morphological identification (unpublished data by the authors).

To Hieu ward represents the second known locality within Son La Province for the occurrence of *H. khaokhouayensis* [15], [16]. The first record of this species in the province was from Tham Cave, Thuan Chau commune (21°25'26.93"N, 103°44'44.02"E), located approximately 25.18 km from the cave site in To Hieu ward (Figure 1). The constant frequency values of the two individuals captured in To Hieu ward were nearly identical to those recorded from Tham Cave and other localities in Vietnam. However, these values were notably higher than those reported from populations in Laos [27], [28]. Echolocation characteristics of this globally rare species have been described in detail by Vu (2023) [29] and Pham et al. (2024) [30]. To date, the species has been recorded from at least six localities in Vietnam [15], [29], [31].





**Figure 4. Distribution records of *H. khaokhouayensis*, including its type locality in Laos (1), Cat Ba National Park (2), Nham Duong area (3), Con Son-Kiep Bac area (4), To Hieu Cave (5), Tham Cave (6), and Tay Con Linh Mountains (7) in Vietnam. Map diagram created by Nguyen Tran Vy**

All six sympatric hipposiderid species documented in the two study provinces are distinguishable by both morphological characters and echolocation traits. The recorded second harmonic constant frequency values provide a useful basis for species-level acoustic identification and monitoring within the city. However, echolocation call frequencies can be influenced by factors such as sex, age, geographic variation, habitat type, and other ecological conditions [32], [33]. Therefore, caution is advised when applying these reference values to other localities, as misinterpretation could result in ambiguous or inaccurate identifications. Comparative studies of echolocation call parameters between bats from the study provinces and other regions are needed to clarify patterns of species variation and to support broader ecological and taxonomic research on hipposiderid and other bat species across their ranges.

### 3. Conclusions

The study wards and communes in Son La and Lang Son provinces are home to at least six species of hipposiderid bats representing two genera: *Aselliscus stoliczkanus*, *Hipposideros armiger*, *H. cineraceus*, *H. gentilis*, *H. khaokhouayensis*, and *H. poutensis*. These species are readily distinguishable by both morphological characteristics and echolocation frequencies. This study presents the first comparative echolocation dataset for these species in the region. The results provide a valuable reference for species-specific acoustic identification and can support long-term monitoring and future ecological research in the two study provinces and surrounding areas.

**Acknowledgments.** The study was supported by the Vietnam Academy of Science and Technology through the Grant UQĐTCB.07/23-25.

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