



ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

ECHOLOCATION CALLS OF THE TWO ENDEMIC LEAF-NOSED BATS (CHIROPTERA: YINPTEROCHIROPTERA: HIPPOSIDERIDAE) OF INDIA: *HIPPOSIDEROS HYPOPHYLLUS* KOCK & BHAT, 1994 AND *HIPPOSIDEROS DURGADASI* KHAJURIA, 1970

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Abstract: We provide the echolocation call characteristics of two endemic Hipposiderid bats, the Kolar Leaf-nosed Bat *Hipposideros hypophyllus* and Durga Das's Leaf-nosed Bat *H. durgadasi* from Kolar district, Karnataka, India for the first time. The calls consisted of a constant frequency (CF) component followed by a frequency modulated (FM) tail. It was found that, on comparison with the call frequencies of other members of the bicolor group of the genus *Hipposideros* previously reported from different parts of southeast Asia, *H. durgadasi*, though larger than *H. cineraceus*, called at a much higher frequency (168.4 – 175.7 kHz). *H. hypophyllus*, on the other hand, called between 103.0 – 106.4 kHz. In this paper we present our findings and analysis of the calls of these endemic species.

Keywords: Call frequency, Durga Das's Leaf-nosed Bat, Kolar Leaf-nosed Bat, ultrasonic calls.

Bat species inventorization has been invasive in nature. However, through the use of newer technology, a shift has been observed from invasive methods to minimally invasive and completely non-invasive methods of studying bats of any given region. One such non-invasive method is acoustic survey (Surlykke et al. 2014). Acoustic surveying is useful for assessing species identity, diversity and distribution, habitat preferences and usage, and is widely useful for species monitoring and conservation management (Teixeira & Jesus 2009).

Bats use echolocation for orientation during foraging and navigation (Broders et al. 2004) and also as a means

DOI: <http://dx.doi.org/10.11609/jott.2783.8.14.9667-9672> | ZooBank: urn:lsid:zoobank.org:pub:DDE6COA2-3CB7-4A6B-82CF-CFCE0BCC3EFF

Editor: Marc W. Holderied, University of Bristol, Bristol, UK.

Date of publication: 26 December 2016 (online & print)

Manuscript details: Ms # 2783 | Received 10 May 2016 | Final received 12 December 2016 | Finally accepted 15 December 2016

Citation: Srinivasulu, B., C. Srinivasulu & H. Kaur (2016). Echolocation calls of the two endemic leaf-nosed bats (Chiroptera: Yinpterochiroptera: Hipposideridae) of India: *Hipposideros hypophyllus* Kock & Bhat, 1994 and *Hipposideros durgadasi* Khajuria, 1970. *Journal of Threatened Taxa* 8(14): 9667–9672; <http://dx.doi.org/10.11609/jott.2783.8.14.9667-9672>

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Funding: The present study was part of a project funded by The Mohamed Bin Zayed Species Conservation Fund (Project Number 152510679) and Rufford Small Grant (RSG) (Project number 16916-1) to Bhargavi Srinivasulu (BS). CS thanks DST-SERB, Govt. of India (DST-SB/EMEQ-239/2013) and HK thanks UGC, Govt. of India (No. F.16-1784 (SC)/2010 (SA-III)) for research grants and fellowship, respectively.

Conflict of Interest: The authors declare no competing interests.

Acknowledgements: We are thankful to the Karnataka Forest Department, for study and collection permissions, field staff at Kolar, and the villagers of Hanumanahalli and Therahalli for their kind cooperation during the study. We acknowledge the Head, Department of Zoology, Osmania University for necessary facilities; G. Devender, T.A. Shah and Aditya Srinivasulu for their help during the field work. We are also thankful to Prof. Gareth Jones of University of Bristol, UK for training in bat acoustic studies. BS acknowledges research grants from the Mohamed bin Zayed Species Conservation Fund and Rufford Small Grants Fund; HK thanks UGC, New Delhi for research fellowship; CS thanks DST-SERB, Government of India, New Delhi for research grant.



of communication between roost members (Voigt-Heucke et al. 2010). Echolocation calls are species-specific and are known to sometimes differ between the genders and even among individuals of the same species (Yovel et al. 2009).

Of the 13 species belonging to the genus *Hipposideros*, two species, namely—Kolar Leaf-nosed Bat *Hipposideros hypophyllus* Kock & Bhat, 1994 and Durga Das's Leaf-nosed Bat *H. durgadasi* Khajuria, 1970, are endemic to India and are of Endangered status (Molur & Srinivasulu 2008a,b). Until recently, *H. hypophyllus* was reported from Hanumanahalli and Therahalli villages in Kolar District, Karnataka (Kock & Bhat 1994; Bates & Harrison 1997; Molur et al. 2002). Our study has revealed that *H. hypophyllus* is presently known only from the type locality, a subterranean cave in a granite hill in Hanumanahalli Village (Srinivasulu et al. 2014). *Hipposideros durgadasi* was reported from five sites in Jabalpur District, Madhya Pradesh (Khajuria 1970; Topal 1975; Bates & Harrison 1997). This species was recently discovered by us in the vicinity of Kolar town from two locations—Therahalli and Hanumanahalli villages. At the former site, it was found to occupy a subterranean cave on its own, while in the subterranean cave at Hanumanahalli it was found cohabiting with *H. hypophyllus*, *H. fulvus*, *H. speoris* and *Rhinopoma hardwickii* (Kaur et al. 2014; Srinivasulu et al. 2014).

Here we present the echolocation calls of these two endemic leaf-nosed bat species of India for the first time. We carried out the present study in Kolar District (centered 13°7'59.88"N & 78°7'59.88"E), which is the eastern-most district of Karnataka. It is characterized by tropical dry deciduous to tropical thorn vegetation (Champion & Seth 1968). The general topography is undulating rocky terrain with boulder hills interspersed with agriculture fields, dry scrub, and low granite hills. Shallow caves and cave systems are common among the high boulder hills, while subterranean caves are observed in the low granite hills and granite plains (Srinivasulu et al. 2014).

METHODS

The study spanned a period of 29 months from November 2013 to March 2016, during which intensive surveys were carried out to locate the bat species and also to search for further localities and probable roosting sites for these species. In February 2016, we could successfully record the echolocation calls of *H. hypophyllus* and *H. durgadasi* using Pettersson D500X (Pettersson Elektronik AB)—a full spectrum bat detector with an extremely sensitive microphone. On

18th February 2016, two individuals of *H. hypophyllus* (both females) and three individuals of *H. durgadasi* (two females, one male) were captured between 18:50–19:05 hr near the roost at Hanumanahalli using mist nets (Ecotone series of 16x16 mm mesh size) and kept in separate cloth bags. The bats that were captured were taken about 300m away from the roosting site to avoid recording the echolocation calls of other bat species emerging from the cave. The bats were held close to the bat detector for hand-held recordings. Specimens of *H. hypophyllus* were held at elbow's length from the detector, while specimens of *H. durgadasi* had to be held much closer to the microphone of the detector as their calls were almost undetectable if the detector was kept even at elbow's length from the bat. Each recording lasted for three minutes. For release calls the bat detector was held about 2–3 m from the bat being released for specimens of *H. hypophyllus*, again for specimens of *H. durgadasi* the bat detector was held about 1m or less to be able to record their calls and recordings were done as the bats were being released near the roosting site.

The recorded ultrasound calls were analyzed digitally using BatSound (version 4; Pettersson Elektronik, Uppsala, Sweden) to measure frequency of maximum energy (FMAXE in kHz) and duration (in ms) from the power spectra (512 point fast Fourier transform, Hanning window).

RESULTS

We recorded a total of 12 calls (both hand-held and release) of both these species of bats. The echolocation calls of the leaf-nosed bats studied were of typical form with a constant frequency component followed by a frequency modulated tail (CF-FM calls). A total of seven calls of *Hipposideros hypophyllus* (five calls from two hand-held individuals and two calls when these individuals were being released) were recorded. Of the two individuals of *H. hypophyllus* captured for the recording, three hand held and one release call were recorded of the first individual and two hand held and one release call of the second individual was recorded. Of these only the best pulses with good signal to noise ratio were used for the analyses. The frequency at maximum energy (FMAXE) of echolocation calls of *H. hypophyllus* in flight ranged between 103.0–105.3 kHz (Mean±SD: 103.9±0.82 kHz) (n=15) with an average duration of 6.30±1.07 ms (range, 4.3–8.5 ms) (Table 1; Fig. 1A; Audio 1), while in hand held bats it was 100.7–106.4 kHz (Mean±SD: 104.7±0.91 kHz) (n=20) with an average duration of 7.97±1.42 ms (range, 4.5–12.4 ms)

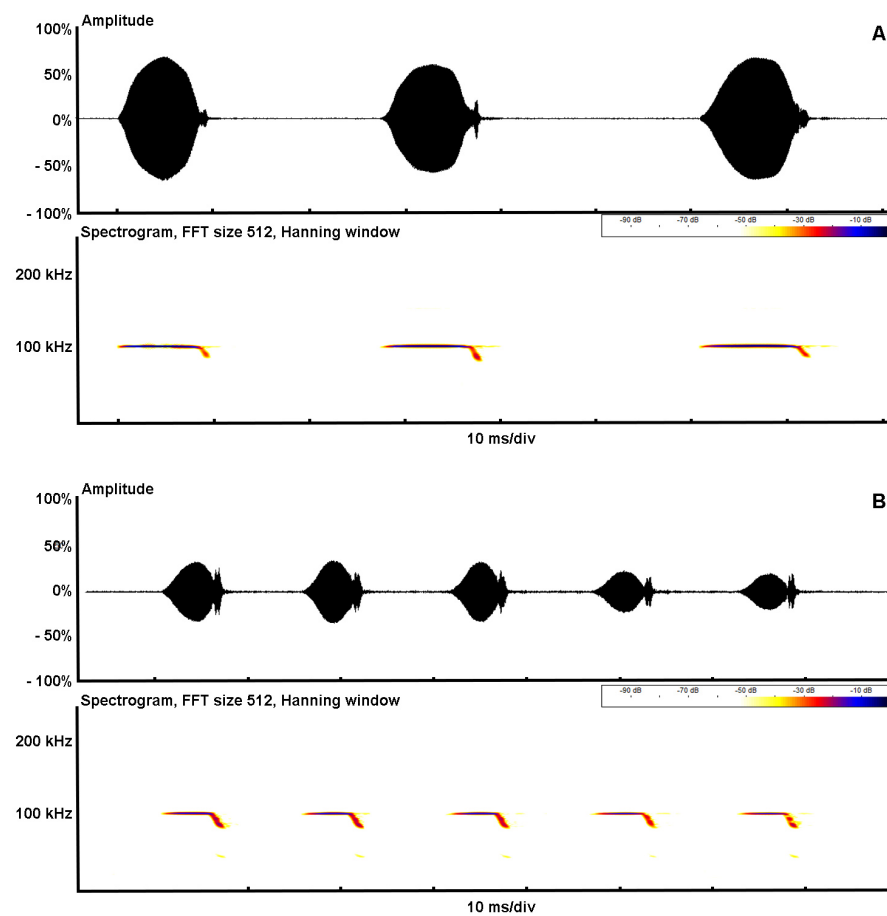


Figure 1. Spectrogram of echolocation call of Kolar Leaf-nosed Bat *Hipposideros hypophyllus* from Kolar District, Karnataka, India; (A) in flight and (B) hand-held.

(Fig. 1B). A total of five calls of *H. durgadasi* (four calls from three hand-held individuals and one call from one single individual during release) were recorded. Of the three individuals of *H. durgadasi* captured, we could record only one hand held call for the first individual, two hand held calls of the second individual and one hand held call and one release call of the third individual. The frequency at maximum energy (FMAXE) of echolocation calls of *H. durgadasi* in flight ranged between 174.6–175.7 kHz (Mean±SD: 175.1±0.33 kHz) (n=10) with an average duration of 7.96±0.94 ms (range, 6.58–9.8 ms) (Table 1; Fig. 2A; Audio 2), while it was 168.4–173.5 kHz (Mean±SD: 170.5±0.63 kHz) (n=20) with an average duration of 6.17±0.9 ms (range, 3.4–8.2 ms) with hand-held recording (Fig. 2B). All the bats were released safely after recording the echolocation calls between 19:15–19:30 hr on the same night.

DISCUSSION

The species belonging to the genus *Hipposideros* in southern Asia are divided into five 'species groups' (Srinivasulu & Srinivasulu 2012). Both the species dealt

here belong to the large 'bicolor-species group', which includes seven species, namely: Dusky Leaf-nosed Bat *H. ater*, Ashy Leaf-nosed Bat *H. cineraceus*, Durga Das' Leaf-nosed Bat *H. durgadasi*, Fulvus Leaf-nosed Bat *H. fulvus*, Andersen Leaf-nosed Bat *H. pomona*, Kolar Leaf-nosed Bat *H. hypophyllus*, and Cantor's Leaf-nosed Bat *H. galeritus*. The Kolar Leaf-nosed Bat and the Cantor's Leaf-nosed Bat belong to the 'galeritus subgroup', and the others belong to the 'bicolor subgroup' of the 'bicolor-species group'. The species belonging to the bicolor subgroup are characterized by the absence of any supplementary leaflets and small-size (forearm length ranging between 33.0–44.0 mm) (Srinivasulu et al. 2010). The species belonging to the *galeritus* subgroup are characterized by the presence of one to two supplementary leaflets and small to medium size (forearm length ranging between 37.0–51.5 mm) (Srinivasulu et al. 2010).

Call frequency and the body size in hipposiderids are negatively correlated (Zhang et al. 2000). The present study reveals that *H. durgadasi* from Karnataka however does not fit this scheme. Although the forearm length of

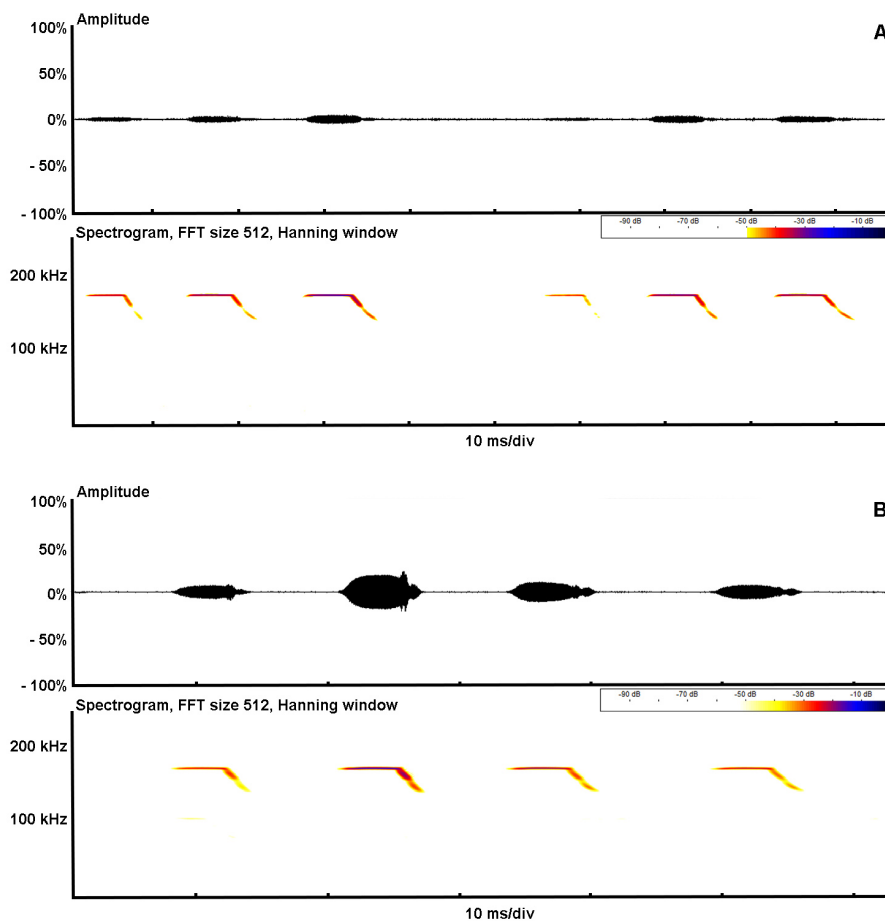


Figure 2. Spectrogram of echolocation call of Durga Das's Leaf-nosed Bat *Hipposideros durgadasi* from Kolar district, Karnataka, India; (A) in flight and (B) hand-held.

this species was greater than that of *H. cineraceus*, the FMAXE was much higher than that of *H. cineraceus* from Southeast Asia (Maximum FMAXE: 159.6kHz) and China (Maximum FMAXE: 163.5kHz; Douangboubpha 2007; Zhang et al. 2009; Phauk et al. 2013) or *H. ater* from India and China (Maximum FMAXE: 169.5kHz) (Jones et al. 1994; Douangboubpha 2007; Table 1).

We suspect that detection of these bats using acoustic signals will be challenging, and limited only by the sampling rates of the bat detector and sensitivity of the microphone. Further field experiments are planned to devise protocols that would help in non-invasive detection of these endangered and endemic species. Additional research efforts in and around Kolar District, and even in other localities in peninsular India, need to be conducted in order to ascertain the presence or absence of the species and to advance our knowledge about their ecology.

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Table 1. Echolocation call frequencies and forearm lengths of species belonging to *bicolor* group of genus *Hipposideros* (* indicates authors unpublished data)

Species	Forearm length (mm)	FMAXE (kHz)	Region	Reference
<i>H. ater</i>	35.46–37.02	163.1–169.5	Madurai, Tamil Nadu, India	Jones et al. 1994
	39.5–40.3	-	Myanmar	Douangboubpha 2007
	-	139.5	Sabah, Borneo	Francis & Habersetzer 1998
<i>H. cineraceus</i>	31.7–36.0	155.5–163.5	Guangxi & Yunnan, China	Zhang et al. 2009
	32.4–37.2	134.8–154.1	Thailand	Douangboubpha 2007
	-	148.42	Thailand	Hughes et al. 2010
	-	154.0–158.1	Myanmar	Douangboubpha 2007
	-	149.2–150.6	Cambodia	Phauk et al. 2013
	33.0–35.5	-	Viet Nam	Borissenko & Kruskop 2003
<i>H. durgadasi</i>	34.65–36.03	174.6–175.7	Hanumanahalli, Karnataka, India	Present study
<i>H. fulvus</i>	38.73–39.67	151.5–162.5	Madurai, Tamil Nadu, India	Jones et al. 1994
	38.48–39.86*	145.4–156.8	Telangana, Karnataka, India	Srinivasulu et al. 2015
<i>H. pomona</i>	38.1–39.7	-	Southern India	Bates & Harrison 1997
	40.0–42.0	123.7–128.2	Valparai plateau, Tamil Nadu, India	Wordley et al. 2014
	40.5–44.2	120.8–129.0	Yunnan, Guangdong & Hainan, China	Zhang et al. 2009
	-	137.41	Thailand	Hughes et al. 2010
	-	128.3–139.7	Cambodia	Phauk et al. 2013
	-	127.3–140.2	Thailand	Douangboubpha et al. 2010
	-	120–126	Lao PDR	Francis 2008
	-	122–127.7	Bac Kan, Viet Nam	Furey et al. 2009
	-	124.3–134.1	Quang Ngai, Viet Nam	Son et al. 2016
	-	132.1–137.2	Myanmar	Struebig et al. 2005
<i>H. hypophyllus</i>	37.97–39.89	103.0–105.3	Hanumanahalli, Karnataka, India	Present study
<i>H. galeritus</i>	47.06–47.95*	112.7–115.9	Karnataka, India	Srinivasulu et al. 2015
	48.18–50.02	-	Borneo	Fukuda et al. 2009
	-	98.5–102.5	Cambodia	Phauk et al. 2013
	42.0–51.43	-	Sarawak, Malaysia	Sazali & Aziz 2012

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