

## ORIGINAL ARTICLES

## The distribution of *Kerivoula malpasi* and *Kerivoula picta* (Chiroptera: Vespertilionidae) in Sri Lanka

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DOI: <https://doi.org/10.14709/BarbJ.15.1.2022.02>

**Keywords:** distribution, habitat, occurrence, tropical island, endemic

received: August, 20th 2021  
 accepted: April, 13th 2022

### ABSTRACT

Sri Lanka is considered one of the world's biodiversity hotspots. Although Sri Lanka has a rich diversity of bats, *Kerivoula malpasi* is the only bat that is endemic to Sri Lanka, where it is represented by only five records. The other known species of *Kerivoula* in Sri Lanka, *Kerivoula picta*, is more widely distributed. This study maps the current and historical distributions of the two species. Field observations made from 2016 to 2020 are presented, including 41 new locations for *K. picta*, which add the northernmost and easternmost records for the species in Sri Lanka. Details from museum specimens of both species are also presented in order to aid future investigations and promote the conservation of these species in the country.

## INTRODUCTION

*Kerivoula* is one of two genera in the subfamily Kerivoulinae (Vespertilionidae) and contains seven species of Palearctic bats (Moratelli & Burgin 2019). The generic name *Kerivoula* was proposed by J. E. Gray in 1842 and is derived from the Sinhala language, meaning milky bat (Jentink 1904, Kelaart 1998). Two species of *K. hardwickii* sensu lato are found in Sri Lanka: *Kerivoula picta* (Pallas, 1767) and *Kerivoula malpasi* (Phillips, 1932) (Phillips 1932, 1935, 1980, Kelaart 1998, Yapa & Ratnasooriya 2006, Yapa & Ratnavira 2013, Tu et al. 2018, Kotagama & Goonatilake 2019, Moratelli & Burgin 2019). Molecular dating suggests that species within the hardwickii-complex diversified during the Late Pliocene/Early Pleistocene period between 4.03 and 2.72 Mya (Tu et al. 2018).

*Kerivoula picta* is widely distributed in Sri Lanka, Bangladesh, Bhutan, India, Nepal, Myanmar, Vietnam, China, Cambodia, Laos, Thailand, Malaysia, Indonesia, and Laos (Phillips 1935, Corbett & Hill 1992, Molur et al. 2002, Francis 2008, Yapa 2017, Moratelli & Burgin 2019), whereas

*K. malpasi* is endemic to Sri Lanka (Moratelli & Burgin 2019). *Kerivoula picta* is listed as "Near threatened" in the Global IUCN Red List as well as nationally in Sri Lanka. In contrast, *K. malpasi* is nationally categorised as "Critically Endangered", but its status has not been assessed by the global IUCN (MOE 2012, Moratelli & Burgin 2019).

*Kerivoula malpasi* is sometimes treated as a synonym of *Kerivoula hardwickii* (e.g., Simmons & Cirranello 2021), and the species is not currently listed in the IUCN Redlist. However, an analysis of the *K. hardwickii* species complex argued on biogeographic backgrounds that both *Kerivoula crypta* (in southern India) and *K. malpasi* (in Sri Lanka) should be recognized as distinct species (Tu et al. 2018). These authors noted that if these two taxa prove to be conspecific, the name *crypta* has priority (Tu et al. 2018, Moratelli & Burgin 2019, [www.mammaldiversity.org](http://www.mammaldiversity.org)) and *malpasi* should be treated as its subspecies (Tu et al. 2018).

Existing distribution records indicate that *K. picta* has a scattered distribution from the low-altitude regions up to 1372 m. Similarly, *K. malpasi* is known for very few

occurrences in the low-altitude areas, central highlands and northeastern part of the country, ranging up to an elevation of 1260 m (Phillips 1932, 1935, 1980, Bates & Harrison 1997, Kelaart 1998, Molur et al. 2002, Yapa & Ratnavira 2013, Yapa 2017, Edirisinghe et al. 2018, Gabadage et al. 2018, Moratelli & Burgin 2019, GBIF 2021).

Current information on geographical distribution and habitat preferences is vital for implementing conservation for bats in Sri Lanka. Although historical distribution records exist for both species, these often lack precision (Gabadage et al. 2018, Moratelli & Burgin 2019). Our main objective here is to present new records of the geographical distribution of *K. picta* and *K. malpasi* in Sri Lanka to more precisely understand their current status and geographic distribution in the country. With the inclusion of available museum material obtained in Sri Lanka, we also record these species' morphometric and morphological characters to aid future assessments of their taxonomy and distribution.

## MATERIALS AND METHODS

Field surveys of bats were carried out from July 2016 to December 2020 and involved opportunistic roost surveys as part of ongoing structured projects and expeditions. New records of both species of *Kerivoula* were georeferenced either by handheld GPS receivers or Google Earth. In addition to the original field observations, published historical data and online records from GBIF (<https://www.gbif.org>) were obtained, combined, and mapped. Coordinates of historical records correspond to the nearest town/village at the recorded elevation.

Locations were categorized by provinces and ecosystems following Gunatilleke et al. (2008).

Identification of the species relied on Phillips (1935), Corbett & Hill (1992), Bates & Harrison (1997), and Srinivasulu et al. (2010). *Kerivoula picta* and *K. malpasi* are easily distinguished by both qualitative and morphometric variation. Please refer to Fig. 1 and Tables 1 & 2.

Only one *Kerivoula picta*, encountered at a roosting site of Bambaragala Forest Monastery (BFM) on 17/10/2017, was opportunistically caught using a hand net. The captured bat was kept in a cotton bag until measurements were taken and then released at the capture site. Museum specimens at the Field Museum of Natural History (FMNH), Harrison Institute (HZM), and University of Kansas Biodiversity Institute (KU) were also measured, compared with historical data, and are documented (Table 1 and Fig. SM1). Morphological characters of the bats were noted and external measurements of 11 variables were taken with an Incco-RD10 digital calliper to the nearest 0.1 mm following Srinivasulu et al. (2010).

## RESULTS

*Kerivoula picta* was newly encountered at 41 locations in Sri Lanka. Of the 63 known locations, the majority are in North Central (n=11, 17%) and Western (n=10, 16%) provinces. Fewer records are in Northern (n=3, 5%) and Uva (n=1, 1%) provinces (Fig. 2, and Fig. SM2, SM3). The first

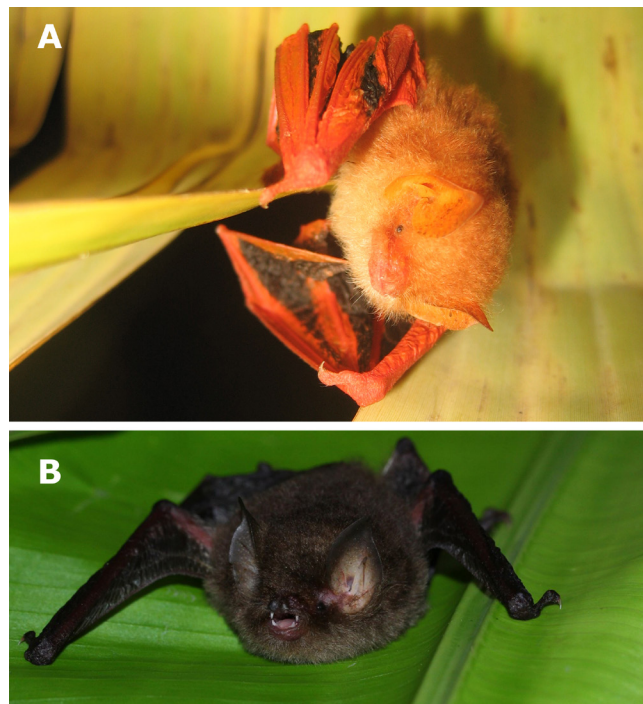


Fig. 1 - *Kerivoula picta* captured at Bambaragala Forest Monastery (A) (Photo credit- Gayan Edirisinghe), *Kerivoula malpasi* captured at Thorangoda (B) (Photo credit-Madhava Botejue).

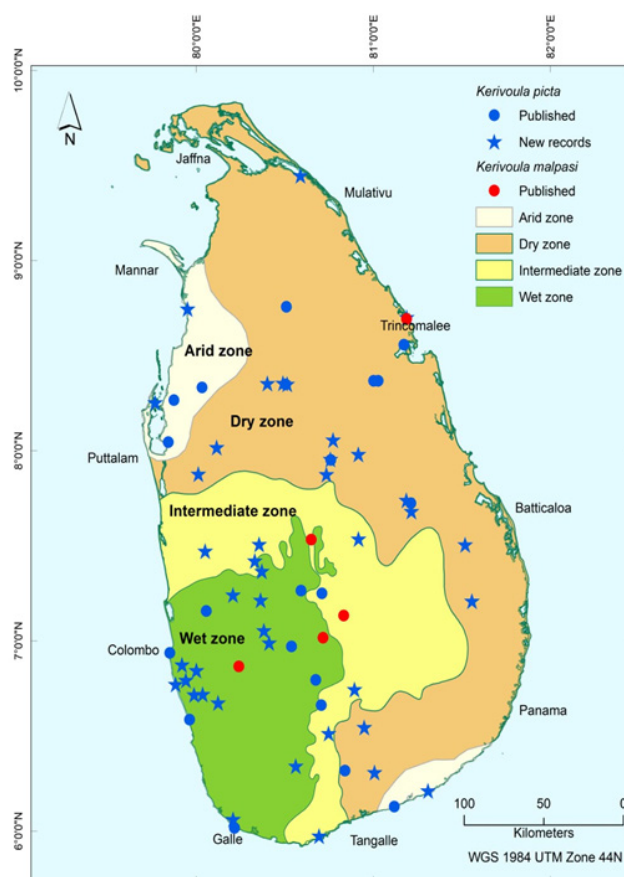


Fig. 2 - Updated distribution map of *Kerivoula picta* and *Kerivoula malpasi* in Sri Lanka. Published locations are based on Phillips 1932, 1935, 1980, Molur et al. 2002, Yapa 2017, Yapa & Ratnavira 2013, Edirisinghe et al. 2018, Gabadage et al. 2018, Moratelli & Burgin 2019, Kelaart 1998, Bates & Harrison 1997, and GBIF 2021. New records are based on personal observations.

record of *K. picta* in Uva Province (at Soragune) extends the species range, which now includes all the provinces in Sri Lanka. Further, our surveys also recorded the northernmost occurrence of the species in Sri Lanka (Chundikulam) and the easternmost record (Athagala; see Fig. 2, Table SM1). *Kerivoula malpasi* was not encountered in our surveys and, considering the vouchers from museums and the historical data, has a much narrow distribution than *K. picta*. This species is only recorded from three administrative provinces, and most of these records are from the Central Province, showing a highly discontinuous and fragmented distribution (Figs. SM3 & SM2).

The distribution of *K. picta* is limited to natural ecosystems except for one instance where we recorded an individual in a tea plantation at Kurunegala in North Western Province.

The habitats where *K. picta* has been mostly recorded were dense forests or woodlands of primary and secondary origin; 49% of the records are from tropical dry mixed evergreen forests, and 33% are from tropical lowland wet evergreen forests. Of the 41 new records, 16 involved individuals found roosting in banana shrubs in natural ecosystems (Fig. SM4).

Historical records of *K. malpasi* correspond to what are now both natural and anthropogenic landscapes, such as tropical dry mixed evergreen forests, tropical montane forests, and man-made ecosystems.

## DISCUSSION & CONCLUSION

Our study recorded 41 new sightings of *K. picta*, including the northernmost and easternmost records for the species in

**Table 1** - Morphometric variables for *Kerivoula picta* from Bambaragala Forest Monastery, Sri Lanka (live) and museum specimens, in mm. *Kerivoula malpasi* morphometrics from Phillips (1935), Gabadage (2018) and museum specimens in HZM and KU.

Measurements	<i>Kerivoula picta</i>				<i>Kerivoula malpasi</i>			
	Bambaragala Forest Monastery (live)	FMNH 95020 Kantale	FMNH 95049 Kantale	FMNH 96304 Weyangoda	Phillips, 1935 Kumbalgamuwa	HZM 3.31606 Pallama	Gabadage et. al, 2018 Thoranagoda (live)	KU 135734 Trincoma lee, Nilavelli
Sex	Male	Female?	Male	Female	Female	Male	Male	Female
Head+Body Length	39.03	40.00	35.00	39.00	43.00	39.7	40.37	39.01
Tail Length	35.73	36.00	34.00	36.00	35.00	42.4	38.50	44.0
Hind Foot Length	6.05	6.00	7.00	7.5	5.00	7.1	6.70	7.51
Ear Length	14.27	12.00	13.00	13.05	15.00	10.8	12.53	10.06
Ear Width	7.03	-	-	-	-	7	6.20	5.05
Tragus Length	9.00	-	9.00	9.05	-	-	5.98	-
Forearm Length	34.32	33.05	29.23	34.00	32.00	31.8	32.47	31.02
Wingspan Length	208	-	-	210	-	165	230	193
3rd Metacarpal Length	34.05	-	29.22	36.91	-	32.7	34.77	29.07
Tibia Length	15.84	15.79	14.23	16.52	-	16.6	17.21	15.03
Calcar Length	12.04	11.27	11.05	14.23	-	9.5	13.44	7.23

Note- The museum specimens were long preserved in fluids and their measurements may differ from live-measured individuals

**Table 2** - Detailed morphological features of *Kerivoula picta* captured at Bambaragala Forest Monastery, Sri Lanka and of *Kerivoula malpasi* captured at Thorangoda, Sri Lanka (Gabadage et al. 2018).

Morphological characters	<i>Kerivoula picta</i> (Male)	<i>Kerivoula malpasi</i> (Male)
	Present specimen	Gabadage et al. 2018
Nose shape	Simple nostrils	Simple nostrils
Head	Muzzle small, moderately long and rather pointed, more or less thickly covered with long hairs which overhang the mouth; eyes small and shaded by the ears	Muzzle relatively small; eyes small; face covered in hair except for the nostrils, which are angled slightly downwards and outwards; the whiskers are conspicuous and protrude beyond the hairs on the snout
Ears	Large and distinctly funnel-shaped, bluntly pointed at the tips. Bright orange colour hairs on base of the ears; few bright orange colour short hairs in the middle of the ears	Mostly naked but dark brown colour, few short hairs present. Relatively large, funnel-shaped, tip-rounded
Tip of the ear	Bright Orange colour hair present	Hair absent
Tragus	Long and slender, terminating in fine point; a prominent notch present	Long and attenuated, narrowing gradually to a sharp point; slightly concave, with a less angular tip; a prominent notch present
Chin	Bright Orange colour, few short hairs present around the chin	Light brown, few short hairs present around the chin
Throat	Bright Orange colour, few short hairs present	Light brown, few short hairs present
Dorsal area	Bright Orange or light Orange colour, hair present throughout head and body	Dark brownish to grey or light brown, hair present throughout head and body
Ventral area	Dark Orange hair present in the nape, Bright Orange hair present on the chest. Light Orange hair present on the abdomen	Dark brown hair present on the nape and the chest. Light grey and light brown hair present on the abdomen
Antebrachial membrane	Present (Semi-transparent, thin in texture)	Present (Semi-transparent, thin in texture)
Wing membrane	Well developed; antebrachial membrane bright orange colour, wing membrane bright orange to bright scarlet along the forearms and fingers, the remainder black; uropatagium is bright orange and nearly transparent	Well developed; the patagium and the skeletal elements supporting the patagium are naked; wings and uropatagium are brown; nearly transparent
Forearm, metacarpals and phalanges	Naked	Naked
Dorsal surface of tibia	Dark Orange, short hair present	Light brown, short hair present
Interfemoral membrane Dorsum	Dark Orange, short hair present	Light brown, short hair present
Interfemoral membrane Venter	Short hair absent	Light brown, short hair present
Wing attached to	The base of the toes	The base of the outer toe
Penis (Foreskin)	Bright orange, short hair present	Light brown, short hair present



Table 2 - Continuation

Morphological characters	<i>Kerivoula picta</i> (Male)	<i>Kerivoula malpasi</i> (Male)
	Present specimen	Gabadage et al. 2018
Testes	Bright orange, short hair present	Light brown, short hair present
Anus	Bright orange, short hair present	Light brown, short hair present
Hind feet	Well-developed, bright orange short hair present	Well-developed, light brown short hair present
Calcar	Very well-developed but with no lobe, bright orange short hair present	Well-developed, light brown short hair present
Tail	Enclosed with uropatagium membrane	Enclosed with uropatagium membrane

Sri Lanka. These findings effectively increase its known extent of occurrence as well as its area of occupancy in Sri Lanka. In addition, our study confirmed the continued presence of *K. picta* in all the administrative provinces where it had been previously recorded (Fig. SM2). Recent observations on its ecosystem associations agree with previous reports and information. Its roosting sites and habitat associations are predominantly in tropical humid forest habitats of Sri Lanka. Similarly, according to our observations, a few historical records documented this species from other vegetative associations and human-modified habitats.

Despite searches at sites where *K. malpasi* were historically reported and at other sites, we failed to register any additional records of Sri Lanka's only endemic bat species. The five previous records of this species (Fig. 2) lie mainly in the central highlands, and one from Trincomalee, in the northeast. According to the limited information available, the species is said to roost singly in banana fronds (Gabadage et al. 2018). *Kerivoula malpasi* has been reported in both natural and man-made ecosystems such as dry mixed evergreen forests, tropical montane forests, paddy fields, home gardens and banana plantations (Phillips 1932, 1935, 1980, Bates & Harrison 1997, Kelaart, 1998, Molur et al. 2002, Yapa & Ratnavira 2013, Yapa 2017, Gabadage et al. 2018, Moratelli & Burgin 2019).

Few published occurrence records for bats are available in Sri Lanka due to the lack of long-term monitoring studies. The historical records we used date back to 1935, and bat distributions might have shifted over this extended period. It is noteworthy in this context that our recent field observations of *K. picta* validated that this species is present in all provinces where it was historically reported. Such information on current distribution is lacking for *K. malpasi* and would deserve further attention.

## ACKNOWLEDGEMENTS

We thank Dr. Paul Bates of Harrison Institute, UK, Maria Eifler of Mammals Division, Biodiversity Institute of the University of Kansas and Dr. Pipat Soisook of Princess Maha Chakri Sirindhoran Natural History Museum, Prince of Songkla University, Thailand, for their valuable assistance

in providing museum specimen details. We also thank Dr. Buddhika Madurapperuma for preparing the map and Sameera Karunarathne for his immense support.

**Author contributions:** GE and AB conceived the idea. AB designed the study, wrote the manuscript, coordinated museum specimen data. GE prepared the morphometric and morphological tables. DG commented on the manuscript. BP and DD commented and edited the manuscript.

**Supplementary Material:** The online version contains supplementary material available at <https://doi.org/10.14709/BarbJ.15.1.2022.02>.

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