Records of the Australian Museum (2026)
vol. 78, issue no. 1, pp. 69–76
https://doi.org/10.3853/j.2201-4349.78.2026.3006

Records of the Australian Museum
a peer-reviewed open-access journal
published by the Australian Museum, Sydney
communicating knowledge derived from our collections
ISSN 0067-1975 (print), 2201-4349 (online)

A Range Extension and First Voucher Echolocation Call for the New Guinea Big-eared Bat, *Pharotis imogene* (Chiroptera: Vespertilionidae)

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Abstract. The New Guinea Big-eared Bat *Pharotis imogene* is one of the region's least known mammals, with prior confirmed records from only two localities, both in Central Province, Papua New Guinea. We report the recent capture of a *Pharotis imogene* from Kuriva Forestry Station, approximately 50 km north of Port Moresby, extending the species' known range more than 130 km northwest of its previous limit. We describe and illustrate the new specimen and its habitat and provide the first description of this species' echolocation call.

Introduction

The monotypic genus *Pharotis* (Chiroptera: Vespertilionidae) is known only from Central Province in southeast mainland Papua New Guinea (PNG) (Armstrong *et al.*, 2021). Its sole member, the New Guinea Big-eared Bat *Pharotis imogene* Thomas, 1914, is among the most poorly known of all New Guinean mammals. It is known from just two localities southeast of Port Moresby.

The discovery, description, and recent rediscovery of *Pharotis* are described in Hughes *et al.* (2014). Briefly, in 1890, Dr Lamberto Loria collected 45 vespertilionids from near the coastal village of Kamali in Rigo District (Fig. 1) that were initially lodged in the Museo di Storia Naturale in Genoa and assigned by Thomas (1897) to *Nyctophilus timoriensis* (Geoffroy, 1806). The collection was later distributed among several institutions, and only six of these specimens have been relocated (Flannery, 1995; Armstrong *et al.*, 2021). The original description of *Pharotis* (Thomas, 1914) refers only to the type, one of three specimens from the Kamali collection reportedly held at the Natural History

Keywords: Pharotis; Vespertilionidae; New Guinea; range extension; echolocation call; habitat use
ZooBank registration: urn:lsid:zoobank.org:pub:E60066D3-7745-410E-8FB1-FAF3FD2C85E6
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Submitted: 7 August 2025 **Accepted**: 21 August 2025 **Published**: 6 March 2026 (in print and online simultaneously)
Publisher: The Australian Museum, Sydney, Australia (a statutory authority of, and principally funded by, the NSW State Government)
Citation: Woxvold, Iain A., Kyle N. Armstrong, Elyssa M. McLeod, Mellie S. Musonera, Anthony C. Simms, and Stephen J. Richards. 2026. A range extension and first voucher echolocation call for the New Guinea Big-eared Bat, *Pharotis imogene* (Chiroptera: Vespertilionidae). In *Contributions to the Mammalogy of New Guinea*, ed. Tim F. Flannery and Kristofer M. Helgen. *Records of the Australian Museum* 78(1): 69–76. https://doi.org/10.3853/j.2201-4349.78.2026.3006

Museum in London (Flannery, 1995), and provides no insight as to the missing Kamali vouchers. Following its discovery, *P. imogene* was not seen again for more than 120 years and was considered possibly extinct (Flannery, 1995; Bonaccorso *et al.*, 2008) until a single individual was captured in 2012 in a logging concession near Oio village in Abau District, 120 km east of Kamali (Hughes *et al.*, 2014). That specimen is lodged at the PNG National Museum & Art Gallery (PNGNM 27464) (Hughes *et al.*, 2014).

Almost nothing is known of the ecology of *P. imogene* (Hughes *et al.*, 2014; Moratelli & Burgin, 2019; Armstrong *et al.*, 2021). The exact location and habitat at the Kamali type locality were not described (Thomas, 1897, 1914). The Oio individual was captured at the boundary of logged rainforest and an extensive clearing. Its foraging habits are assumed to be similar to those of the closely related long-eared bats (*Nyctophilus* spp.) due to their similar morphologies, but its roosting and foraging habitats are still unknown. All known adult specimens of *P. imogene* are female and the only subadult is male (n = 7; Flannery, 1995; Hughes *et al.*, 2014).

Pharotis imogene is listed as Critically Endangered on *The IUCN Red List of Threatened Species* (Armstrong *et al.*, 2021). It was recently included among the global top ten research-priority island endemic bat species (IEBs) based on a combination of extinction risk, taxonomic distinctiveness and data availability (Conenna *et al.*, 2017).

In this paper we aim to: (1) report a range extension for *P. imogene* based on the capture of a single animal at Kuriva Forestry Station, located in the Kairuku-Hiri District of Central Province approximately 50 km north of Port Moresby; (2) describe its echolocation call, and; (3) discuss available data on habitat use.

Materials and methods

Kuriva Forestry Station is managed by the PNG Forest Authority (PNGFA). Covering more than 9,460 ha, it is centred on the Veimauri and Veiya River catchments immediately north of the Hiritano Highway and includes a wide range of habitats with a complex pattern of historical land use. Native forest covers more than 70% of the area, particularly on higher ground in the north and east. Most of this forest has been logged in recent decades. In the south, there are large areas of teak (*Tectona grandis*) plantation of varying age and *kunai* grassland with patches of regenerating scrub.

In 2024, TotalEnergies E&P PNG Limited commissioned a series of multi-disciplinary biodiversity surveys of Kuriva Forestry Station. Fauna surveys were conducted from 30 April to 10 May 2024. The survey team (EM, MM, SJR, AS, IW) was based at the Kuriva Station base, located next to the Veimauri River and the 'Kuriva Teak Plantation Picnic Park' in the station's south. Harp traps were set to

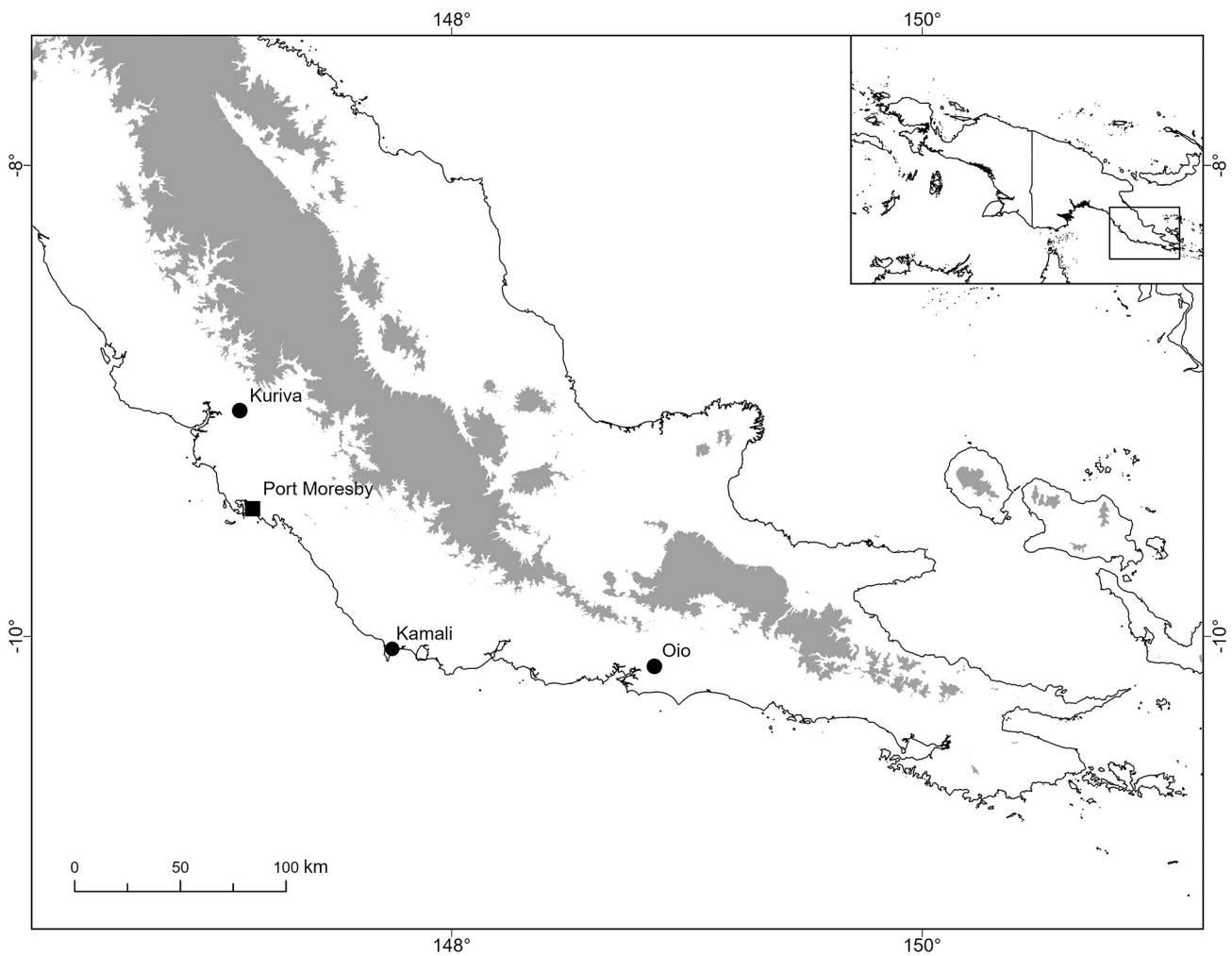

Figure 1. Map showing *Pharotis imogene* localities and the national capital Port Moresby. Shading indicates land above 1,000 m.

capture echolocating bats across an elevational gradient of more than 800 m, from *ca.* 40 m above sea level (asl) near the southern lease boundary to more than 850 m asl in the northeast. However, for logistical reasons, most harp traps were set below 70 m asl near the station base (4/6 positions, 5/8 trap nights).

Voucher echolocation calls were recorded indoors using a 'zip-line' method (Parson & Szewczak, 2009). A small gauge fishing line tied to the animal's lower leg was fixed with a loop at the other end to a horizontal line stretched taut across the room. In this way, flight calls were recorded while preventing possible escape from the poorly sealed building. Terminology of measured call parameters follows Binary Acoustic Technology (2014). Pulse characteristics of *P. imogene* echolocation calls were compared against those of two sympatric species with similar call structure, the Maluku myotis *Myotis moluccarum* Thomas, 1915, and Papuan Long-eared Bat *Nyctophilus microtis* Thomas, 1888, using measurements extracted from a limited sample of quality recordings with SCAN'R software (version 1.8.3, Binary Acoustic Technology, USA).

The specimen was fixed in a 10% formalin solution for two days prior to preservation in 70% ethanol. Tissues (liver) were extracted prior to fixation and preserved in 95% ETOH. Body mass was measured in the field to the nearest 0.1 g using a 10 g Pesola scale. Other measurements were taken from the preserved specimen to the nearest 0.1 mm using digital callipers.

Area estimates were calculated using the area measurement tool in ArcGIS Pro with LiDAR Digital Elevation Model (DEM) data and recent publicly available satellite imagery.

Results

On the night of 3–4 May 2024, an adult female *P. imogene* (Fig. 2a–c) was captured in a harp trap set at the Kuriva Station base (at 9°02'25"S 147°05'59"E) (Fig. 3). The specimen is lodged at the Australian Museum, Sydney (M.56355). The measurements are: head-body (snout–vent)—41.5 mm; ear (from notch)—24.4 mm; forearm—38.8 mm; tibia—18.6 mm; hindfoot (without claw)—9.5 mm; weight—7.2 g.

The trap was located about 60 m from the Veimauri River at the edge of the Kuriva Picnic Park area at 45 m asl. It was positioned in a break along a fence planted with a narrow strip of vegetation separating two lawn areas that serve as a car park and a recreation area (Fig. 3). Surrounding habitats (within *ca.* 1 km) include clearings with buildings and nursery infrastructure, extensive teak plantations east of the Veimauri River, *kunai* grassland and remnant logged forest west of the river, and remnant disturbed riparian forest (Fig. 4).

The voucher echolocation call of *P. imogene* is shown in Fig. 5, alongside representative (non-voucher) call sequences of similar structure from two sympatric species that were also present at the site—*Myotis moluccarum* and *Nyctophilus microtis*. Table 1 presents measurement data on 13 pulse characteristic variables for each species. The echolocation pulses of *P. imogene* are longer in duration than those of the *N. microtis* example, and they occupy a lower frequency band and are somewhat straighter (less curvilinear) than pulses of both *M. moluccarum* and *N. microtis* (Fig. 5; Table 1).

Discussion

The Kuriva record extends the known range of *P. imogene* some 132 km northwest of the Kamali type locality (Fig. 1). Kuriva lies about 250 km northwest of the easternmost site at Oio. Considering all habitats below 100 m asl, the reported upper limit for *P. imogene* (Moratelli & Burgin, 2019; Armstrong *et al.*, 2021), the species' potential range between Kuriva and Oio is about 4,700 km^2. However, some of these habitats may be unsuitable for *P. imogene*.

Habitat requirements of *P. imogene* remain largely unknown. It is often stated that *P. imogene* occupies savanna woodland or rainforest patches in savanna (Bonaccorso, 1998; Bonaccorso *et al.*, 2008; Moratelli & Burgin, 2019). This is due to Kamali's position, and that of an unconfirmed record from nearby Kapa Kapa village, near the eastern limit of the Central Province savannas in one of the country's driest areas (McAlpine *et al.*, 1983; Bryan & Shearman, 2008). However, the Kapa Kapa specimen (now lost) was never identified as *P. imogene* (see Hughes *et al.*, 2014), and the exact location and habitat at the Kamali capture site were not reported (Thomas, 1897, 1914). In fact, Kamali is surrounded by a complex array of habitats, with vegetation mapping (Hammermaster & Saunders, 1995) and recent satellite imagery showing eucalypt savanna, mangroves, low swamp vegetation, remnant or regenerating alluvial forest, coconut plantation, gardens, and extensive areas of open habitat all present within 3 km of the village. Moreover, both the Kuriva and Oio sites receive substantially higher rainfall than Kamali (McAlpine *et al.*, 1983; Bryan & Shearman, 2008) and lie outside of the savanna zone; the closest mapped occurrences of savanna (or denser monsoon forest/scrub with *Eucalyptus*) south of the cordillera are more than 12 km from Kuriva and 50 km from Oio (Hammermaster & Saunders, 1995).

Both the Oio and Kuriva specimens were captured in open sites. Natural vegetation within 5 km of the Oio and Kuriva capture sites is predominantly rainforest with some areas of freshwater swamp vegetation (Hammermaster & Saunders, 1995); however, much of this habitat has been removed or heavily disturbed through logging, and there are no records of *P. imogene* from the forest interior. The Oio site is surrounded by a large expanse of logged rainforest, but the specimen was captured in a narrow strip of open habitat along a logging skid trail that opened out to an approximately 100 ha area of grassland and former coconut plantation (Hughes *et al.*, 2014). The Kuriva specimen was captured in an approximately 7 ha area of continuous open habitat (grassland with scattered trees, buildings and plant nursery infrastructure) within a broader modified landscape dominated by teak plantation and grassland with patches of riparian forest and logged foothill forest. It is not possible to determine if captured individuals were foraging at the trap sites or if they were travelling between foraging and roosting sites. There is currently no information on *P. imogene* foraging or roosting habitat.

Considering all available evidence: (1) *P. imogene*'s use of savanna is unconfirmed—if it does occupy savanna, then recent data indicate that the species does not rely on savanna as some authors have previously suggested; (2) the Oio specimen shows that *Pharotis* may be found in areas dominated by rainforest, but it remains unknown whether the species utilizes the forest interior or is reliant on open

Figure 2. Live adult female *Pharotis imogene* captured at Kuriva Forestry Station. Several field characters useful in distinguishing *Pharotis* from similar-looking New Guinean species of *Nyctophilus* are visible, including the relatively large nose-leaves with the anterior leaf having a convex dorsal margin (vs. median depression or notch) and the posterior leaf with deep concavities (terminology follows Thomas, 1914), and the uniquely shaped tragus. (Photos: S. J. Richards).

habitats; (3) building on the Oio evidence, the Kuriva data confirm that *Pharotis* can be found in heavily modified landscapes, but the specific habitat features that are required to support the species remain unknown. Kuriva station is a suitable place to explore some of these themes, given its accessibility, the presence of a wide variety of habitats and the confirmed presence of *P. imogene*.

The echolocation call of *P.* imogene is described here for the first time. In general, the pulses of *P. imogene* are relatively short and broadband in structure compared to other species that produce frequency modulated pulses. Nevertheless, the call type is typical of species that forage within and around the clutter of vegetation and glean insects from surfaces (Denzinger & Schnitzler, 2013), and this species is syntopic with other gleaners that produce broadband calls.

With the echolocation call of *P. imogene* now described, the use of passive acoustic recorders (PARs) may help to detect its presence on other surveys. It also provides the opportunity to re-examine existing recorded datasets to determine if the species has been overlooked elsewhere. However, care must be taken when attempting to distinguish the calls of *P. imogene* from those of other species, especially sympatric vespertilionids with similar call structures such as *Myotis*

Figure 3. Harp trap in position at the Kuriva *Pharotis imogene* capture site, Papua New Guinea. (Photo: I. Woxvold).

moluccarum and *Nyctophilus microtis*. When inspecting a spectrogram, the call of *P. imogene* can be recognized from pulses with a minimum frequency of approximately 30 kHz, which is *ca.* 10 kHz lower than pulses of *M. moluccarum* and *ca.* 20 kHz lower than those of *N. microtis*. However, typical PAR datasets often include wide variation in the characteristics and quality of calls from each species. Low-quality recordings, such as when the bat is close to the edge of the microphone's reception zone, might not be reliably attributable to *P. imogene*; for example, it is possible that a provisional identification of *P. imogene* could be derived from a 'low frequency' example of *M. moluccarum*. With so few data currently available, any false positives may disproportionally influence future assessments of the species' conservation status, and the presence of *P. imogene* should be confirmed through capture whenever possible.

Acknowledgements. The data presented here were collected during surveys undertaken by TotalEnergies E&P PNG Limited (TEP PNG), with support of the PNG Forest Authority (PNGFA) and BMT Commercial Australia Pty Ltd. We are particularly grateful to Michael Henson, Ninning Jal and Rebecca Melepia of TEP PNG's Zero Net Deforestation Program (ZND), and to Craig Heatherington and Jeremy Visser of BMT, for their encouragement and support. We also thank the PNG National Research Institute (NRI) and the PNG Conservation and Environment Protection Authority (CEPA) for providing relevant visas, research approvals, and export permissions. Voucher specimens and tissue samples described in this paper were exported from PNG under Export Permit no. 24098. Thanks also to Sandy Ingleby and Tim Flannery of the Australian Museum for providing morphological measurements of preserved specimens, and to Phaedra Kokkini of the Natural History Museum, London, for providing information on their Pharotis specimens. Harry Parnaby, Sandy Ingleby and Stephen Jackson provided valuable comments on an earlier version of the manuscript.

Figure 4. Satellite image of the *Pharotis imogene* capture site (yellow star) at the Kuriva Station base.

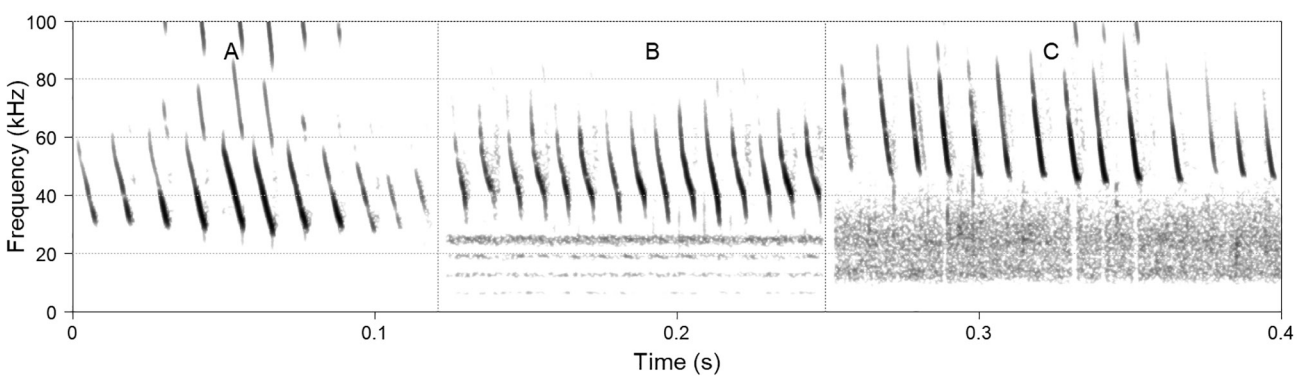

Figure 5. Representative echolocation call sequence portions of *Pharotis imogene* (*A*), *Myotis moluccarum* (*B*) and *Nyctophilus microtis* (*C*). Time between pulses has been compressed.

Table 1. Selected variables extracted from high quality examples of pulses from *P. imogene*, plus representatives from *M. moluccarum* and *N. microtis* (using SCAN'R software; Dur—duration, Fmax—maximum frequency, Fmin—minimum frequency, Fk—frequency at the knee, Tk—time at the knee, Sk—slope at the knee, Fc—characteristic frequency, Tc—characteristic time, Sc—characteristic slope, Supper—slope of upper portion, Slower—slope of lower portion, Se—end slope, Curv—curvature, n—number of pulses measured).

	Dur (ms)	Fmax (kHz)	Fmin (kHz)	Fk (kHz)	Tk (ms)	Sk (kHz/ms)	Fc (kHz)	Tc (ms)	Sc (kHz/ms)	Supper (kHz/ms)	Slower (kHz/ms)	Se (kHz/ms)	Curv (^P)
Pharotis imogene n = 6													
mean	6.21	56.13	29.19	40.26	3.17	-4.46	34.44	4.78	-2.94	-5.49	-2.99	-3.24	1.22
sd	0.50	3.48	1.56	7.08	1.69	0.57	7.24	1.61	0.86	1.38	0.78	1.05	0.10
max	6.96	59.97	31.50	52.39	5.57	-3.74	49.17	6.15	-1.43	-4.42	-1.99	-1.43	1.36
min	5.68	51.62	26.86	33.05	0.93	-5.15	30.43	1.74	-3.97	-8.17	-4.29	-4.46	1.07
Myotis moluccarum n = 7													
mean	6.10	71.59	37.78	55.19	1.97	-5.17	46.11	4.48	-2.61	-8.48	-4.20	-4.83	1.35
sd	0.80	1.95	3.12	1.89	0.41	1.05	3.15	0.86	0.86	1.12	0.62	1.57	0.20
max	7.89	75.26	41.40	57.92	3.02	-3.20	50.76	6.38	-0.35	-6.52	-2.99	-0.35	1.62
min	4.87	66.58	32.56	51.37	1.39	-6.86	42.27	3.13	-3.85	-9.90	-5.10	-6.53	1.03
Nyctophilus microtis n = 16													
mean	3.13	83.11	50.73	61.42	1.66	-11.05	56.62	2.42	-8.04	-13.57	-6.66	-8.29	1.35
sd	0.94	4.52	5.43	6.28	0.60	2.13	10.41	1.14	2.88	1.88	1.96	3.11	0.21
max	4.52	89.58	61.75	72.78	2.55	-8.73	76.15	3.94	-2.94	-10.83	-4.39	-2.94	1.59
min	1.97	76.35	46.67	54.96	0.58	-15.06	47.01	0.70	-11.75	-15.91	-10.41	-12.30	1.06

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