## Acoustic detection of an unknown bat species in Okinawa

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**Abstract.** Pipistrelles of the genus *Hypsugo* are among the rarest bats in Japan, known from a handful of records. In June 2018, a sequence of echolocation calls apparently by a bat of this genus was recorded by an automatic ultrasound recorder on the island of Okinawa. The calls closely resemble *H. pulveratus*, a Chinese species never before recorded in Japan, and *H. alaschanicus*, a very rare species in Japan. They also resemble calls of *Hypsugo* sp. bats from a small population recently discovered on nearby Amami-Oshima Island. The extreme rarity in our recordings, combined with lack of detection in Okinawa by other surveys, suggests that the individual was a vagrant. However, given the cryptic nature of the species on Amami, it remains possible that there is a small and likely endangered resident population, underlining the need for further bat surveys on Okinawa and other Nansei Islands.

Key words: acoustic data, automatic recorder, Hypsugo alaschanicus, Japan, vagrancy.

The bat fauna of the Nansei Islands (known as Ryukyu Islands) has been studied for a long time (Ohdachi et al. 2015), but new discoveries are still being made. In recent years, populations of Tadarida cf. latouchei (Funakoshi et al. 2019), Myotis cf. macrodactylus (Ohdachi et al. 2015; Asari and Kimoto 2018b), and Hypsugo sp. (Asari and Kimoto 2018a) were discovered on Amami-Oshima Island; presence of Vespertilio sp. was acoustically detected on Amami-Oshima and Tokunoshima Islands (Funakoshi et al. 2019); and an unknown forest bat was observed on Ishigaki (C. Vincenot, personal communication; V. Dinets, personal observation). Status of some species, such as Nyctalus aviator and Myotis bombinus, is still unknown. Here we report the first record of an unknown bat, tentatively identified as Hypsugo sp., from Okinawa Island (hereafter Okinawa).

### Materials and methods

Okinawa is the largest in Nansei Islands, with total area of ca. 1200 km<sup>2</sup>. It has maritime subtropical climate (average temperature 22.3°C, annual rainfall 2083 mm, Walker 2014). The southern part of the island is densely

populated, while the northern part is mostly forested. The central part, where the data presented here come from, is approximately 60% forested (Walker 2014).

The OKEON Churamori Project (https://okeon.unit. oist.jp/) is conducting ecoacoustic monitoring on Okinawa to study population trends of local fauna (Ross et al. 2018). The main focus of the project is insect and bird research. In 2018, four SM4BAT-FS automatic recorders with SMM-U2 ultrasound microphones (all manufactured by Wildlife Acoustics) were installed in central and northern parts of the island (Table 1) to study bat population dynamics. One of the units (unit 2) was installed in May 2018 on a tree 3 m above ground in dense secondary forest dominated by Taiwanese cherry (Prunus campanulata), with trees mostly 4-6 m tall, on a north-facing hillslope 132 m a. s. l., at 26° 27' 33.865" N, 127° 50' 9.164" E. The location was ca. 3 m from a small brushy clearing and ca. 10 m from a forest road, with openings between trees providing clear flyways (at least 1 m in diameter) connecting the road, the unit site, and the clearing (Fig. 1). The units operate from sunset to sunrise, with 12 dB gain, 256 kHz sample rate, 1.5 ms minimal duration, 20 kHz minimum trigger frequency,

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#	Dates of operation	Coordinates	Elevation, m	Habitat	Operation schedule
1	May 5th, 2018–June 7th, 2019	26° 16' 52" N 127° 44' 39" E	4	semi-urban area with taro fields	2 weeks on, 2 weeks off
2	May 1st, 2018-present	26° 27' 34" N 127° 50' 9" E	132	dense secondary forest (see text)	continuous
3	June 11th, 2018-present	26° 42' 11" N 128° 07' 53" E	12	degraded coastal woodland*	2 weeks on, 2 weeks off; continuous since July 1st, 2019
4	June 11th, 2018-present	26° 43' 19" N 128° 15' 32" E	146	old secondary subtropical rainforest*	2 weeks on, 2 weeks off; continuous since July 1st, 2019

Table 1. Data on OKEON ultrasound recorders on the island of Okinawa, Japan

\* Habitat classification according to Saito (2011).



Fig. 1. Forest habitat at the site in Okinawa, Japan, where a recording of an unknown bat was made.

12 dB trigger level, and 3 s trigger window. The recordings are collected every two weeks, screened manually (as most of them contain only insect calls) and identified to species. Kaleidoscope software by Wildlife Acoustics is used to produce and analyze sonograms.

All echolocating bats of Okinawa have easily distinguishable vocalizations, with frequencies of echolocation calls below 20 kHz for *N. aviator* (recorded very rarely), and above 40 kHz for all five species (*Rhinolophus pumilus*, *Murina ryukyuana*, *Myotis yanbarensis*, *Pipistrellus abramus*, *Miniopterus fuscus*) known to be resident (Fukui et al. 2004; Funakoshi 2010; Ohdachi et al. 2015; J. Preble, personal communication).

#### Results

Unit 2 has been active for more than 6000 hours and has recorded two of the five echolocating bat species known to be resident on Okinawa (Ohdachi et al. 2015): *R. pumilus* and *M. fuscus*. Both species were recorded almost daily.

On June 20th, 2018, at 20:08 JST, the unit recorded one

pass by a bat emitting FM/QCF pulses at frequencies 27–37 kHz, sometimes up to 45 kHz, with peak frequency 32–36 kHz (Fig. 2). The descriptive statistics of 38 well-recorded pulses are (mean  $\pm$  *SD*): start frequency 35.1  $\pm$  3.2 kHz, end frequency 32  $\pm$  1.8 kHz, peak frequency 33.2  $\pm$  1.6 kHz, duration 5.2  $\pm$  2.3 ms, interval 3.1  $\pm$  2.2 ms.

#### Discussion

The recording was clearly different from those of all other microbat species known in Okinawa. The peak frequency was higher than in *N. aviator* (peak frequency below 20 kHz, n = 22 individuals, Funakoshi 2010), and lower than in all other species known from Okinawa. There are no calls with minimum frequency below 40 kHz in our recordings of the five resident species made by this and other units (numbers of recordings n > 500for *R. pumilus* and *M. fuscus*, n > 50 for *P. abramus* and *M. ryukyuana*, n = 2 for *M. yanbarensis*). In addition to echolocating at higher frequencies, *R. pumilus*, *M. yanbarensis*, and *M. ryukyuana* have different types



Fig. 2. Sonogram of an unknown bat recorded in Okinawa in June 2018.

of echolocation signals: R. pumilus has FM/CF/FM calls, while M. yanbarensis and M. ryukyuana have steep FM sweeps less than 4 ms in duration (Ohdachi et al. 2015; J. Preble, personal communication). The only two resident species with similar FM/QCF call structure are P. abramus with peak frequency above 41.5 kHz and M. fuscus with peak frequency above 50 kHz (Ohdachi et al. 2015; Moratelli and Burgin 2019). We did not perform statistical comparison of recordings because there was no overlap in peak frequencies between the recording discussed here and those of other local species. As for Vespertilio bats (never recorded on Okinawa but recently detected on Amami-Oshima and Tokunoshima, Funakoshi et al. 2019), V. murinus echolocates with peak frequency up to 35 kHz (n = 187, Kondo et al. 2012) and is a northern species with only a handful of records south of Hokkaido and Russian-Korean border (Ohdachi et al. 2015; Jo et al. 2018), while V. sinensis has very different sonogram (Ohdachi et al. 2015).

The bats of Okinawa have been studied for many decades (see bibliography in Ohdachi et al. 2015), but vocalizations like those described above have never been recorded before. An extensive 2017–2019 study of forest bats of northern Okinawa that used various trapping techniques and acoustic monitoring did not record such vocalizations, either (J. Preble, personal communication). The extreme rarity in our recordings, combined with lack of detection in Okinawa by other surveys, suggests that the individual was a vagrant. The recording was made in late June, the least probable time for seasonal migration (too late for pre-breeding migration and too early for post-breeding). No tropical storm had passed over Okinawa within the six months prior to the recording date, and no major cold front had passed in three months

prior to the recording date, so if the bat was a recent vagrant, it probably reached Okinawa unassisted by strong winds. Given the cryptic nature of the species on Amami, it remains possible that there is a small and likely endangered resident population, underlining the need for further bat surveys on Okinawa and other Nansei Islands.

Among the bats known from southern Japan, the recording most closely resembles Hypsugo alaschanicus (Fukui et al. 2013; Ohdachi et al. 2015). Hypsugo alaschanicus is one of the rarest and least known bats in Japan, recorded only a few times in the north of the country (Ohdachi et al. 2015). It was considered a vagrant until a roost was found in Hokkaido (Fukui et al. 2013). In addition, two individuals (phenotypically distinct and likely belonging to a different subspecies) have been collected on Tsushima Island in the 1980s (Yoshiyuki 1989), and one was photographed there in 2019 (V. Dinets, personal observation). Hypsugo alaschanicus is a habitat generalist, common in forests as well as open landscapes (Moratelli and Burgin 2019). However, H. alaschanicus echolocates at slightly higher frequencies (30-50 kHz, peak frequency 34-37 kHz, Fukui et al. 2013) than in our recording.

*Hypsugo pulveratus*, a widespread and relatively common bat in tropical and subtropical forests of eastern Asia (Moratelli and Burgin 2019), echolocates with the peak frequency of 32–35 kHz, and the single published sonogram of its call looks similar (Furey et al. 2010), but this species has never been recorded on any island farther from the mainland than Hainan, which is separated by only 20 km of water. Okinawa is located more than 500 km from the coast of Zhejiang Province, the nearest known location for *H. pulveratus*.

In 2017, a population of Hypsugo bats was discovered

on Amami-Oshima, an island 140 km northeast of Okinawa (Asari and Kimoto 2018a). It is still unknown whether this population represents a new species, a subspecies of *H. alaschanicus*, or *H. pulveratus*. These bats echolocate with a mean peak frequency of 35.35 kHz, and sonograms of their calls look nearly identical to our recording (Asari and Kimoto 2018a).

If there is a new, cryptic taxon endemic to Amami-Oshima and possibly Okinawa, it is extremely rare and almost certainly critically endangered. This new discovery underlines the need for further bat surveys on Okinawa and other Nansei Islands. In particular, the status of *Hypsugo* on Okinawa has to be elucidated: is it a resident or a vagrant? Our recording was made in summer, so we can exclude the possibility of it being a winter visitor or a passage migrant, but vagrancy from Amami-Oshima or elsewhere is not impossible.

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#### References

Asari, Y. and Kimoto, Y. 2018a. An unknown species of bats captured at Amami Oshima. Honyurui Kagaku (Mammalian Science) 58: 67–71 (in Japanese with English abstract).

- Asari, Y. and Kimoto, Y. 2018b. Bat species found during capturing and acoustic surveys in Amami-Oshima Island, Japan. Fauna Ryukyuana 47: 1–6 (in Japanese with English abstract).
- Fukui, D., Agetsuma, N. and Hill, D. A. 2004. Acoustic identification of eight species of bat (Mammalia: Chiroptera) inhabiting forests of southern Hokkaido, Japan: potential for conservation monitoring. Zoological Science 21: 947–955.
- Fukui, D., Mochida, M., Yamamoto, A. and Kawai, K. 2013. Roost and echolocation call structure of the Alashanian pipistrelle *Hypsugo alaschanicus*: first confirmation as a resident species in Japan. Mammal Study 38: 61–66.
- Funakoshi, K. 2010. Acoustic identification of thirteen insectivorous bat species from the Kyushu District, Japan. Honyurui Kagaku (Mammalian Science) 50: 165–175.
- Funakoshi, K., Yamasita, K., Kitanokuchi, T., Tanaka, H., Otubo, S., Ohiro, R., Uchihara, A., Osawa, T., Watanabe, K., Nagayama, T., et al. 2019. Ecological studies on the bat species of Tokunoshima Island and those of Amami-Oshima Island, Japan, with special reference to Ryukyu tube-nosed bat, *Murina ryukyuana*. Honyurui Kagaku (Mammalian Science) 59: 22–42.
- Furey, N. M., Mackie, I. J. and Racey, P. A. 2010. The role of ultrasonic bat detectors in improving inventory and monitoring surveys in Vietnamese karst bat assemblages. Current Zoology 55: 327–341.
- Jo, Y. S., Baccus, J. T. and Koprowski, J. L. 2018. Mammals of Korea: a review of their taxonomy, distribution and conservation status. Zootaxa 4522: 1–216.
- Kondo, N., Fukui, D., Kurano, S. and Kurosawa, H. 2012. A maternity colony of *Vespertilio murinus* in Ozora, Abashiri District, Hokkaido. Honyurui Kagaku (Mammalian Science) 52: 63–70.
- Moratelli, R. and Burgin, J. C. 2019. Family Vespertilionidae (Vesper bats). In (Wilson, D. E. and Mittermeier, R. A., eds.) Handbook of the Mammals of the World. Vol. 9. Bats, pp. 716–982. Lynx Edicions, Barcelona.
- Ohdachi, S. D., Ishibashi, Y., Iwasa, M. A., Fukui, D. and Saitoh, T. 2015. The Wild Mammals of Japan, Second edition. Shoukadoh, Kyoto, 512 pp.
- Ross, S., Friedman, N. R., Dudley, K., Yoshimura, M. and Economo, E. P. 2018. Listening to ecosystems: data-rich acoustic monitoring through landscape-scale sensor networks. Ecological Research 33: 135–147.
- Saito, K. 2011. Forest age distribution in Kunigami-village, Okinawa, based on forest registry data. Papers on Environmental Information Science 25: 245–250.
- Walker, R. 2014. Okinawa and the Ryukyu Islands. Tuttle Publishing, Boston, 288 pp.
- Yoshiyuki, M. 1989. A Systematic Study of the Japanese Chiroptera. National Science Museum, Tokyo, 242 pp.

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