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沖縄科学技術大学院大学

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Author	Vladimir Dinets, Nicholas R. Friedman, Masashi Yoshimura, Masako Ogasawara, Evan P. Economo
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1 **Acoustic detection of an unknown bat species in Okinawa**

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3 Vladimir Dinets^{a*}, Nicholas R. Friedman^b, Yoshimura Masashi^b, Masako Ogasawara^b and Evan

4 P. Economo^b

5 ^a *Science and Technology Group, Okinawa Institute of Science and Technology Graduate*

6 *University, 1919-1 Tancha, Onna-son, Okinawa 904-0495, Japan*

7 ^b *Biodiversity and Biocomplexity Unit, Okinawa Institute of Science and Technology Graduate*

8 *University, 1919-1 Tancha, Onna-son, Okinawa 904-0495, Japan*

9 *Email: dinets@gmail.com, tel. +81-80-1155-7343

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11 Running head: Detection of unknown bat in Okinawa

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14

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

25

26 **Key words:**

27 acoustic data; automatic recorder; *Hypsugo alaschanicus*; Japan; vagrancy

28

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

39

40 **Materials and methods**

41 Okinawa is the largest of Nansei Islands, with total area of ca. 1200 km². It has maritime
42 subtropical climate (average temperature 22.3°C, annual rainfall 2083 mm, Walker 2014). The
43 southern part of the island is densely populated, while the northern part is mostly forested. The
44 central part, where the data presented here come from, is approximately 60% forested (Walker
45 2014).

46 The OKEON Churamori Project (<https://okeon.unit.oist.jp/>) is conducting ecoacoustic
47 monitoring on Okinawa to study population trends of local fauna (Ross et al. 2018). The main
48 focus of the project is insect and bird research. In 2018, four SM4BAT-FS automatic recorders
49 with SMM-U2 ultrasound microphones (all manufactured by Wildlife Acoustics) were installed
50 in central and northern parts of the island (Table 1) to study bat population dynamics. One of the
51 units (unit 2) was installed in May 2018 on a tree 3 m above ground in dense secondary forest

52 dominated by Taiwanese cherry (*Prunus campanulata*), with trees mostly 4–6 m tall, on a north-
53 facing hillslope 132 m a. s. l., at 26° 27' 33.865" N, 127° 50' 9.164" E. The location was ca. 3 m
54 from a small brushy clearing and ca. 10 m from a forest road, with openings between trees
55 providing clear flyways (at least 1 m in diameter) connecting the road, the unit site, and the
56 clearing (Fig. 1). The units operate from sunset to sunrise, with 12 dB gain, 256 kHz sample rate,
57 1.5 ms minimal duration, 20 kHz minimum trigger frequency, 12 dB trigger level, and 3 s trigger
58 window. The recordings are collected every two weeks, screened manually (as most of them
59 contain only insect calls) and identified to species. Kaleidoscope software by Wildlife Acoustics
60 is used to produce and analyze sonograms.

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

66

67 **Results**

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

71 On June 20th, 2018, at 20:08 Tokyo time, the unit recorded one pass by a bat emitting
72 FM/QCF pulses at frequencies 27–37 kHz, sometimes up to 45 kHz, with peak frequency 32–36
73 kHz (Fig. 2). The descriptive statistics of 38 well-recorded pulses are (mean \pm *SD*): start

74 frequency 35.1 ± 3.2 kHz, end frequency 32 ± 1.8 kHz, peak frequency 33.2 ± 1.6 kHz, duration
75 5.2 ± 2.3 ms, interval 3.1 ± 2.2 ms.

76

77 **Discussion**

78 The recording was clearly different from those of all other microbat species known in
79 Okinawa. The peak frequency was higher than in *N. aviator* (peak frequency below 20 kHz, $n =$
80 22 individuals, Funakoshi 2010), and lower than in all other species known from Okinawa. There
81 are no calls with minimum frequency below 40 kHz in our recordings of the five resident species
82 made by this and other units (numbers of recordings $n > 500$ for *R. pumilus* and *M. fuscus*, $n > 50$
83 for *P. abramus* and *M. ryukyuana*, $n = 2$ for *M. yanbarensis*). In addition to echolocating at
84 higher frequencies, *R. pumilus*, *M. yanbarensis*, and *M. ryukyuana* have different types of
85 echolocation signals: *R. pumilus* has FM/CF/FM calls, while *M. yanbarensis* and *M. ryukyuana*
86 have steep FM sweeps less than 4 ms in duration (Ohdachi et al. 2015; J. Preble, personal
87 communication). The only two resident species with similar FM/QCF call structure are *P.*
88 *abramus* with peak frequency above 41.5 kHz and *M. fuscus* with peak frequency above 50 kHz
89 (Ohdachi et al. 2015; Moratelli and Burgin 2019). We did not perform statistical comparison of
90 recordings because there was no overlap in peak frequencies between the recording discussed
91 here and those of other local species. As for *Vespertilio* bats (never recorded on Okinawa but
92 recently detected on Amami-Oshima and Tokunoshima, Funakoshi et al. 2019), *V. murinus*
93 echolocates with peak frequency up to 35 kHz ($n = 187$, Kondo et al. 2012) and is a northern
94 species with only a handful of records south of Hokkaido and Russian-Korean border (Ohdachi
95 et al. 2015; Jo et al. 2018), while *V. sinensis* has very different sonogram (Ohdachi et al. 2015).

96 The bats of Okinawa have been studied for many decades (see bibliography in Ohdachi et al.
97 2015), but vocalizations like those described above have never been recorded before. An
98 extensive 2017–2019 study of forest bats of northern Okinawa that used various trapping
99 techniques and acoustic monitoring did not record such vocalizations, either (J. Preble, personal
100 communication). The extreme rarity in our recordings, combined with lack of detection in
101 Okinawa by other surveys, suggests that the individual was a vagrant. The recording was made
102 in late June, the least probable time for seasonal migration (too late for pre-breeding migration
103 and too early for post-breeding). No tropical storm had passed over Okinawa within the six
104 months prior to the recording date, and no major cold front had passed in three months prior to
105 the recording date, so if the bat was a recent vagrant, it probably reached Okinawa unassisted by
106 strong winds. Given the cryptic nature of the species on Amami, it remains possible that there is
107 a small and likely endangered resident population, underlining the need for further bat surveys
108 on Okinawa and other Nansei Islands.

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

119 *Hypsugo pulveratus*, a widespread and relatively common bat in tropical and subtropical
120 forests of eastern Asia (Moratelli and Burgin 2019), echolocates with the peak frequency of 32–
121 35 kHz, and the single published sonogram of its call looks similar (Furey et al. 2010), but this
122 species has never been recorded on any island farther from the mainland than Hainan, which is
123 separated by only 20 km of water. Okinawa is located more than 500 km from the coast of
124 Zhejiang Province, the nearest known location for *H. pulveratus*.

125 In 2017, a population of *Hypsugo* bats was discovered on Amami-Oshima, an island 140 km
126 northeast of Okinawa (Asari and Kimoto 2018a). It is still unknown if this population represents
127 a new species, a subspecies of *H. alaschanicus*, or *H. pulveratus*. These bats echolocate with a
128 mean peak frequency of 35.35 kHz, and sonograms of their calls look nearly identical to our
129 recording (Asari and Kimoto 2018a).

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

136

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185

186 **Figure captions**

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

189 **Figure 2.** Sonogram of an unknown bat recorded in Okinawa in June 2018.

190

191

192 **Table legend**

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