Title

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Bats (Chiroptera) recorded in the lowland of Southeast Sulawesi, Indonesia with notes on taxonomic status and significant range extensions

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Abstract: This paper reports on a bat survey conducted in November 2011 in Mangolo Nature Park and Rawa Aopa Watumohai National Park, both lowland forests located in Southeast Sulawesi. We recorded 22 species of bats that represents nearly 1/3 of the total bat species known to occur on Sulawesi. Three of these are endemic to Sulawesi and adjacent islands, whereas one species, *Myotis* cf. *ridleyi* was identified as a new distributional record for this island and with further investigation could prove to be an undescribed species. Our record of *Chironax melanocephalus tumulus* provided a range extension to the southeastern arm of Sulawesi. Two specimens of *Hipposideros boeadii* were topotypes and represent the first collections after the description of the type specimen. Collections of *Rhinolophus arcuatus* from this survey were only the second record of this species from island and represent a range extension. Specimens of *Megaderma spasma celebensis* were the first records of this species from Southeast Sulawesi. Species are discussed individually with external, cranial and dental measurements summarized. Based on this survey, the number of bat species now documented from the lowlands of Southeast Sulawesi represents the highest diversity yet recorded from a site on Sulawesi. This region is therefore a high priority for conservation and a hotspot for bat research in Indonesia, especially Sulawesi.

Keywords: bat; conservation; distribution; new records; Sulawesi.

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Introduction

Dominated by Sulawesi, the Wallacea biogeographic region is one of the World's 25 biodiversity hotspots, renowned for exceptional concentrations of endemic species and high rates of habitat loss (Myers et al. 2000). Sulawesi supports the highest level of vertebrate endemism found in Indonesia and is characterized by high faunal diversity (Carletton and Musser 1984, Cannon et al. 2007). For example, 43% of 207 species of Sulawesian mammals are endemic (Musser 1987, Widjaja et al. 2014), with a majority of those being the 72 known bat species, 18 of which are endemic (Bergmans and Rozendaal 1988, Suyanto 2001, Simmons 2005). It contains more endemic mammal species than any other island and is second only to New Guinea in the number of endemic birds and reptiles. The geologic history of the island probably played a major role in engendering its high degree of endemism (Shekelle and Laksono 2004). There are three distinct "arms" that comprise the island, these arms are separated by deep oceanic basins with inadequately known histories and uncertain origins (Hall 2009).

The southeastern arm of Sulawesi belongs to the Province of Southeast Sulawesi administratively. Southeast Sulawesi covers 38,140 km^2 (21% of the total area of Sulawesi), consisting of lowlands (9916.4 km^2, 26%), hills (9535.0 km^2, 25%), and uplands or mountain ranges (18,688.6 km^2, 49%) (BPN Prov. Sultra 2012). Based on the similarities in stratigraphy and sedimentological history, Southeast Sulawesi is thought to share its origin with the Banggai-Sula continental terrane in the eastern part of Central Sulawesi. Both these landmasses are probably derived from the northern margin of the Australian Continent (Hall 1996). It is hypothesized that organisms of Australasian origin arrived in Sulawesi when these landmasses collided and thus through vicariant, tectonic dispersal (Stelbrink et al. 2012). This makes the exploration of this region of particular importance in understanding the biogeography and speciation on the island.

Although deforestation appears to have slowed on Sulawesi, this is an artifact through time as over 80% of lowland forest has already been cleared and access to mid-elevation forests is only now occurring (Cannon et al. 2007). On the other hand, lowland forest is very important for living animals, especially bats, by providing suitable habitat. Species richness of fruit bats decreases with altitude (Medway 1972, Heaney et al. 1989, Azlan et al. 2003, Maryanto et al. 2011). Accordingly, the diversity of fruit trees decreases from lowland area to mountain peaks (Whitmore 1984).

Little is known about the diversity of bats in the region, with only two previous surveys that we are aware of. The first bat collection in this region was by Gerd Heinrich in 1931 as part of the Archbold expedition (Musser 1987). He collected eight species from lowland areas in Wawo and three species from highlands of the Mekongga and Tanke Sakko mountains, and some of those specimens were deposited in the American Museum of Natural History. Between 2000 and 2007, a second bat survey was conducted by Tigga Kingston and colleagues in Rawa Aopa National Park yielded a new species of *Hipposideros* (Bates et al. 2007), although the general results of these surveys have not been published, leaving Southeast Sulawesi's bat diversity largely unexplored.

In 2011, as part of the International Cooperative Biodiversity Groups-Sulawesi project, a team of biologists set out to explore two lowland forested areas in Southeast Sulawesi. The surveys were conducted by a team of mammalogists from the Museum Zoologicum Bogoriense (MZB), Cibinong, Indonesia and the Museum of Wildlife and Fish Biology (MWFB) at University of California Davis, USA.

Materials and methods

Localities

Bat surveys were conducted in two lowland areas in the Mangolo Nature Park and Rawa Aopa Watumohai National Park during November 2011. Mangolo Nature Park is located in Kolaka Regency, between S 03°57′–03°59′ and E 122°35′–122°37′. The nature park area covers 5200 ha and encompasses a range of lowland and hilly topography that is covered by secondary forest and a small amount of primary forest. Surveys were conducted in secondary forest in close proximity to cave systems found in the park. Rawa Aopa Watumohai National Park is located in three regencies; Kendari, Buton and Kolaka, between S 4°00–4°36′ and E 121°46–122°09′. The park protects 105,194 ha of lowland and hilly topography and is comprised of tropical rain forest, mangrove forest, freshwater marsh and swamp, and savannah (Figure 1 and Table 1). The disturbance level is higher in the secondary forest of Mangolo Nature Park. Most of the areas are opened for public activities such as camping and hiking to the hot springs.

Sampling methods

Four-bank harp traps and standard mist nets with various lengths were opportunistically deployed in each location. Harp traps were set across trails that were predicted to be bat flyways and checked at 2000 h, then left open overnight and rechecked at dawn (following the peaks in bat activity at dusk and dawn), these were operated for three consecutive nights before being moved to new locations following Bates et al. (2007). Mist nets were also set along trails, across a river and higher in the canopy. All nets were opened at around 1730 h and checked every hour until 2400 h and then left open until 0600 h at the next morning. Voucher specimens were procured for each species encountered and preserved either as round dry study skins and skulls or whole specimens in 70% alcohol. These were taken for further study at the MZB and MWFB. Taxonomy herein follows Simmons (2005).

Specimens and measurements

A total of 22 species were identified during this survey. External measurements (mm) were taken from all collected individuals (Table 2). They include forearm length (FA), from the extremity of the elbow to the extremity of the carpus with the wings folded; head and body length (HB), from the tip of the snout to the base of the tail; tibia length (Tib), from the knee joint to the ankle; tail length (T), from the tip of the tail to its base adjacent to the anus; hind foot length (HF), from the extremity of the heel to the extremity of the longest digit, not including the hair or claws; ear length (E), from the lower border of the external auditory meatus to the tip of the pinna; tragus length (Tr). Weight (g): fresh body mass taken from each specimen using Pesola scales. Sex, age and reproductive condition were also recorded. All captured bats not collected as vouchers were released at the site of capture.

Skulls were then extracted from the sacrificed specimens, cleaned and measured in the laboratory. The following cranial and dental measurements are included for the specimens that were collected and currently being studied at MZB and MWFB (Table 3): greatest length of skull (GSL), the greatest antero-posterior length of the skull, taken from the most projecting point at the

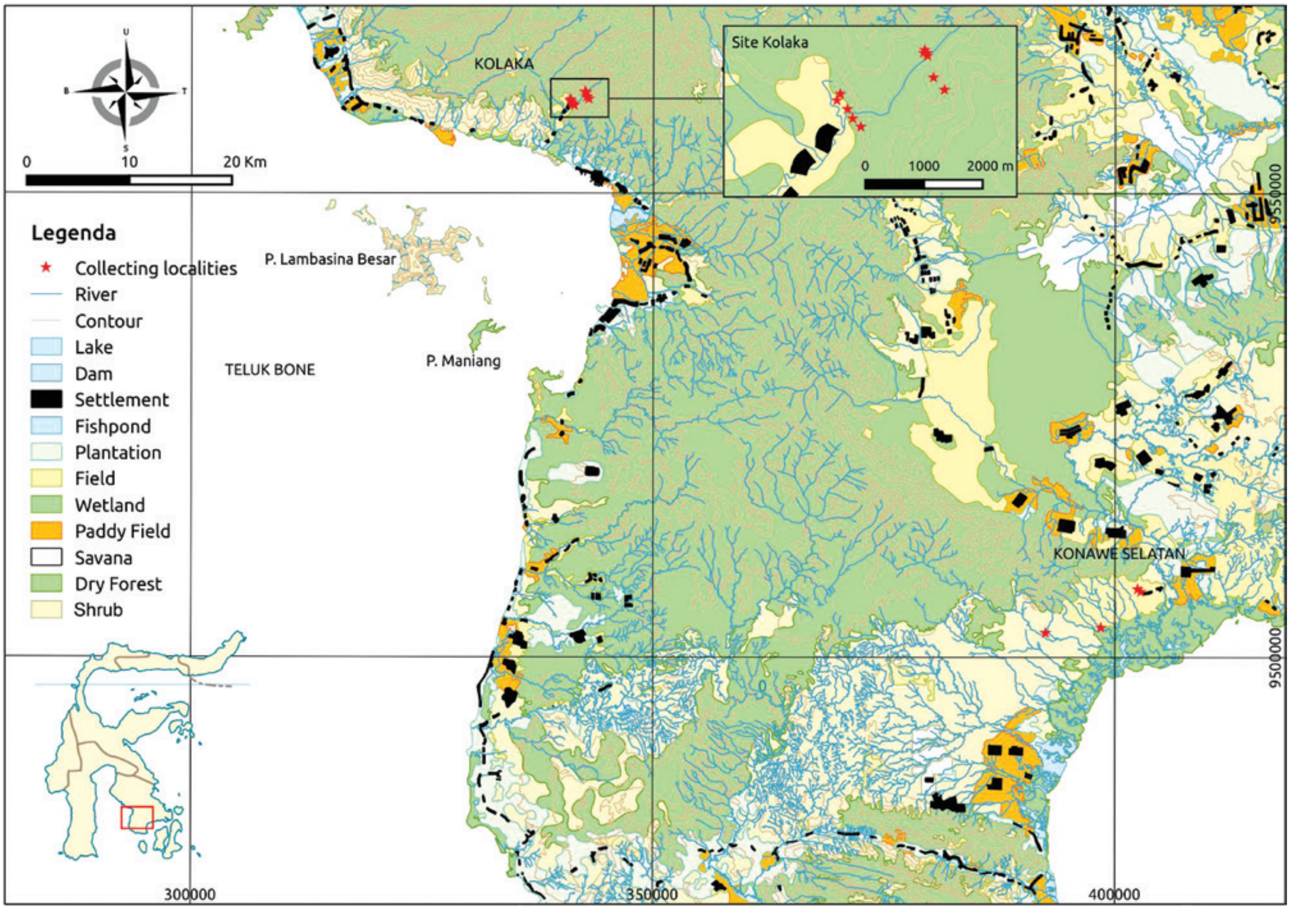

Figure 1: Survey localities in Kolaka (Mangolo Nature Park) and Konawe Selatan (Rawa Aopa Watumohai National Park), Southeast Sulawesi (refer to Table 1).

Table 1: Collecting localities in Southeast Sulawesi (refer to Figure 1).

Site	Latitude	Longitude	Elevation (m)	General habitat
Kolaka (Mangolo Nature Park)				
MANAP1	S 03.9716	E 121.5827	97	Lowland Secondary Forest
MANBP1	S 03.9716	E 121.5821	106	Lowland Secondary Forest
MANBP2	S 03.9758	E 121.5838	134	Lowland Secondary Forest
MANBP3	S 03.9779	E 121.5857	204	Lowland Secondary Forest
MANBPCAMP	S 03.9721	E 121.5828	110	Lowland Secondary Forest
MANBPRIVER	S 03.9711	E 121.5823	100	Lowland Secondary Forest
MANCAVE1	S 03.9812	E 121.5691	75	Lowland Secondary Forest
MANCAVE2	S 03.9828	E 121.5700	104	Lowland Secondary Forest
MANCAVE3	S 03.9842	E 121.5714	150	Lowland Secondary Forest
MANSITE1	S 03.9797	E 121.5673	120	Lowland Secondary Forest
MANSITE2	S 03.9786	E 121.5679	120	Lowland Secondary Forest
Konawe Selatan (Rawa Aopa Watumohai National Park)				
RA2	S 04.4565	E 122.1207	15	Grassland/Forest edge
RA3	S 04.4589	E 122.1237	25	Teaching forest
RA7	S 04.4940	E 122.0849	3	Mangrove/Forest edge
Konawe (Rawa Aopa Watumohai National Park)				
SAVANNA1	S 04.9906	E 122.0308	47	Tropical Savanna

Table 2: External measurements of the specimens collected from Mangolo Nature Park and Rawa Aopa Watumohai National Park (all in mm, except weight in gram).

Species	n	HB	T	E	Tr	FA	Tib	HF	Wt (g)
Chironax melanocephalus (Temminck, 1825)	1♀	55.6	–	10.1	–	42.1	14.3	8.8	–
Cynopterus luzoniensis (Peters, 1861)	10♂10♀	81.9±3.8	10.1±1.7	15.9±1.0	–	60.3±2.4	22.2±1.23	13.6±1.0	27.0±3.4
		(75.4–88.7)	(5.8–12.6)	(13.7–17.6)		(55.3–64.4)	(19.7–24.2)	(12.0–16.0)	(19.5–32.5)
Macroglossus minimus (E. Geoffroy, 1810)	5♂9♀	65.6±4.3	–	15.3±1.1	–	39.9±1.1	15.9±0.9	12.4±1.3	13.1±1.6
		(58.3–74.0)		(13.1–17.0)		(36.8–41.0)	(14.4–17.2)	(10.7–14.0)	(8.5–14.5)
Nyctimene cephalotes (Pallas, 1767)	6♂2♀	95.2±4.2	22.3 ±2.5	16.8±1.5	–	66.1±2.3	25.2±1.5	15.3±1.3	43.9±2.8
		(87.4–100.6)	(17.8–25.4)	(14.2–18.0)		(62.3–69.6)	(22.6–27.0)	(13.7–18.0)	(40.0–49.0)
Rousettus celebensis K. Andersen, 1907	9♂11♀	101.6±8.9	25.5±3.9	17.6±1.2	–	74.8±4.6	34.3±2.4	20.0±1.2	64.2±10.8
		(84.4–115.2)	(19.6–33.7)	(16.3–19.7)		(64.7–80.3)	(28.2–37.3)	(17.6–23.8)	(50.0–78.8)
Thoopterus nigrescens (Gray, 1870)	3♀	110.1±3.6	5.61	15.9±2.5	–	73.7±3.3	30.5±0.8	19.3±0.6	73.3±4.5
		(111.3–106.0)		(13.0–17.6)		(70.0–76.5)	(30.0–31.4)	(18.7–20.0)	(69.0–78.0)
Emballonura alecto (Eydoux and Gervais, 1836)	3♂1♀	50.5±2.6	12.8±0.7	13.4±0.1	5.1±0.3	44.7±0.5	17.0±0.6	7.8±0.6	5.5±1.80
		(48.0–53.2)	(12.0–13.5)	(13.3–13.5)	(4.8–5.4)	(44.2–45.2)	(16.5–17.6)	(7.29–8.54)	(4.00–5.00)
Mosia nigrescens Gray, 1843	1♂	36.7	8.6	10.3	4.0	31.6	10.4	5.1	2.5
Hipposideros cervinus (Gould, 1854)	9♂11♀	50.9±2.8	28.4±2.9	14.4±1.4	–	47.6±1.2	18.9±1.1	7.3±1.3	6.5±0.8
		(44.8–55.0)	(20.8–34.0)	(10.7–16.0)		(45.3–50.2)	(16.4–20.7)	(6.0–8.1)	(5.5–9.0)
Hipposideros pelingensis Shamel, 1940	1♀	102.9	59.1	32.8	–	95.2	40.1	15.4	50.5
Hipposideros boeadii Bates et al. 2007	1♂1♀	49.9±2.1	21.2±1.9	16.1±0.6		40.5±1.7	17.1±0.6	7.9±0.6	7.7±0.3
		(48.4–51.4)	(19.8–22.5)	(15.6–16.5)		(39.4–41.7)	(16.7–17.5)	(7.4–8.3)	(7.5–8.0)
Rhinolophus arcuatus Peters, 1871	10♂10♀	56.6±2.8	19.3±1.6	20.5±0.9	–	49.6±1.0	23.6±0.9	10.6±1.4	10.8±0.9
		(52.1–60.9)	(15.4–21.1)	(18.5–22.1)		(47.4–51.8)	(21.4–25.6)	(6.4–12.1)	(10.0–12.5)
Rhinolophus philippinensis Waterhouse, 1843	9♂11♀	54.0±4.3	25.8±1.9	26.7±1.2	–	50.3±1.2	21.1±0.9	8.5±0.8	8.2±0.8)
		(41.1–59.7)	(22.6–28.5)	(24.8–29.1)		(47.5–51.9)	(18.2–22.6)	(6.8–10.0)	(7.0–9.5)
Rhinolophus celebensis K. Andersen, 1905	1♂4♀	47.2±0.9	21.9±1.4	17.4±1.1	–	42.6±1.9	17.1±1.0	7.5±0.5	6.3±1.2
		(46.8–48.9)	(20.4–24.0)	(16.2–18.8)		(39.9–44.3)	(15.7–18.5)	(7.1–8.1)	(5.0–8.0)
Rhinolophus euryotis Temminck, 1835	6♂14♀	56.2±2.6	18.9±1.8	20.0±1.3	–	49.1±1.1	23.2±0.5	10.4±0.5	10.6±1.0
		(51.2–61.6)	(16.2–21.6)	(17.2–22.3)		(47.3–51.4)	(22.6–24.3)	(9.2–11.2)	(9.0–13.0)
Megaderma spasma (Linnaeus, 1758)	1♂1♀	55.4±1.5	–	37.0±1.4	18.7±0.9	53.0±1.3	31.0±1.6	17.0	18.2±4.6
		(54.3–56.5)		(36.0–38.1)	(18.0–19.4)	(52.1–54.0)	(29.9–31.0)	17.0	(15.0–21.5)
Kerivoula hardwickii (Horsfield, 1824)	1♀	34.8	39.1	11.5	7.9	31.4	14.81	6.8	3.5
Miniopterus australis Tomes, 1858	1♂3♀	47.6±4.2	44.3±1.7	9.8±0.7	5.4±0.1	39.1±0.3	15.7±0.6	7.9±1.1	7.0±2.1
		(43.8–52.7)	(42.0–46.0)	(9.1–10.5)	(5.3–5.6)	(38.8–39.3)	(15.1–16.6)	(6.9–9.5)	(6.0–10.0)
Miniopterus fuliginosus (Hodgson, 1835)	1♀	58.5	55.1	9.9	5.7	46.6	18.7	9.5	13
Myotis horsfieldii (Temminck, 1840)	2♂3♀	50.1±2.3	39.2±1.5	15.9±2.0	7.2±1.2	37.2±1.4	15.9±2.2	11.6±1.9	7.0±0.7
		(47.5–51.0)	(38.9–39.9)	(13.8–19.0)	(6.0–9.2)	(35.3–38.4)	(12.3–16.9)	(8.9–13.0)	(6.0–8.0)
Myotis cf. *ridleyi*	3♀	43.3±5.1	37.6±5.0	11.2±0.7	4.2±0.2	31.9±1.2	12.8±1.1	7.0±1.0	4.4±0.5
		(39.0–49.0)	(33.0–43.0)	(11.0–12.0)	(4.0–4.5)	(30.7–33.1)	(12.1–14.1)	(6.0–8.0)	(4.0–5.0)
Philetor brachypterus (Temminck, 1840)	1♀	57.4	37.2	10.6	6.1	37.6	15.4	9.2	12

Values in parentheses indicate range of the minimum and maximum measurements.
Abbreviations for measurements are provided in the Materials and methods section.

Table 3: Skull measurements of specimens collected from Mangolo Nature Park and Rawa Aopa Watumohai National Park (all in mm).

Species	n	GSL	CBL	CCL	ZB	ONL	IOB	POB	BB	MB	PL	ML
Chironax melanocephalus	1♀	22.4	21.5	20.9	13.9	5.8	4.9	5.1	9.8	9.2	9.7	16.3
(Temminck, 1825)												
Cynopterus luzoniensis	3♂2♀	26.8±1.2	26.1±0.9	25.4±0.9	17.9±0.7	7.5±0.4	5.9±0.3	6.6±0.8	11.8±0.3	11.5±0.2	13.4±0.7	20.5±1.1
(Peters, 1861)		(26.0–29.1)	(25.4–27.9)	(24.6–27.0)	(17.3–19.0)	(7.2–8.2)	(5.6–6.4)	(6.0–7.9)	(11.4–12.2)	(11.2–11.7)	(12.7–14.5)	(19.1–22.2)
Macroglossus minimus	2♂3♀	24.3±0.6	23.1±0.5	21.5±0.4	13.8±0.7	8.1±0.4	4.7±0.2	7.2±0.1	10.4±0.3	9.6±0.2	10.9±0.3	17.8±0.4
(E. Geoffroy, 1810)		(24.2–25.1)	(22.4–23.7)	(21.0–22.1)	(13.2–15.0)	(8.0–8.7)	(4.5–4.9)	(7.1–7.5)	(9.9–10.9)	(9.2–9.8)	(10.6–11.4)	(17.2–18.3)
Nyctimene cephalotes	1♂	30.9	29.7	29.6	20.7	7.9	6.3	5.9	13.5	13.4	15.4	23.3
(Pallas, 1767)												
Rousettus celebensis	4♀	36.4±0.7	34.9±0.7	33.1±0.7	21.5±1.3	12.7±0.5	7.5±0.5	8.0±0.5	14.3±0.5	13.2±0.4	17.9±1.1	27.8±0.9
K. Andersen, 1907		(35.8–37.4)	(34.2–35.9)	(32.2–34.1)	(20.5–23.2)	(12.0–13.2)	(6.9–8.2)	(7.3–8.4)	(13.9–15.1)	(12.7–13.6)	(16.4–19.0)	(27.2–29.3)
Thoopterus nigrescens	2♀	36.2	34.8	33.3	23	10.6	8.03	7.21	14.5	15.3	19.2	27.8
(Gray, 1870)												
Emballonura alecto	3♂1♀	14.9±0.2	13.7±0.2	12.9±0.1	8.6±0.1	6.5±0.5	3.0±0.2	–	7.2±0.1	7.7±0.1	6.2±0.1	10.1±0.1
(Eydoux and Gervais, 1836)		(14.6–15.2)	(13.5–14.0)	(12.8–13.1)	(8.5–8.8)	(5.9–6.9)	(2.8–3.3)		(7.1–7.3)	(7.6–7.8)	(6.1–6.3)	(10.1–10.2)
Mosia nigrescens Gray, 1843	1♂	11.9	10.4	10.1	7.2	1.8	2.8	–	5.8	4.9	2.9	7.7
Hipposideros cervinus	3♂3♀	17.4±0.1	15.3±0.2	14.6±0.1	9.2±0.2	2.8±0.2	2.7±0.1	–	7.3±0.1	6.9±0.1	4.1±0.4	10.7±0.1
(Gould, 1854)		(17.2–17.5)	(15.0–15.5)	(14.4–14.8)	(8.9–9.6)	(2.6–3.0)	(2.5–2.9)		(7.2–7.5)	(6.8–7.0)	(3.8–4.9)	(10.6–10.7)
Hipposideros pelingensis		36.8	33.4	32.7	21.2	6.7	3.71	–	13.2	13.1	14.1	26.9
Shamel, 1940												
Hipposideros boeadii	1♂1♀	18.0±0.2	15.7±0.1	15.1±0.2	10.1±0.1	3.0±0.1	2.7±0.1	–	7.5±0.1	6.5±0.1	4.4±0.1	11.7±0.2
Bates et al. 2007		(17.9–18.2)	(15.7–15.7)	(14.9–15.2)	(10.0–10.2)	(2.9–3.0)	(2.6–2.8)		(7.5–7.6)	(6.4–6.6)	(4.4–4.4)	(11.9–11.5)
Rhinolophus arcuatus	3♂	23.3±0.1	20.9±0.1	19.4±0.1	10.7±0.2	4.6±0.4	2.2±0.1	–	9.4±0.1	7.5±0.2	5.4±0.2	15.1±0.2
Peters, 1871		(23.2–23.4)	(20.9–21.1)	(19.3–19.5)	(10.5–10.9)	(4.2–5.0)	92.1–2.3)		(9.3–9.4)	(7.3–7.7)	(5.1–5.6)	(15.0–15.4)
Rhinolophus philippinensis	3♂4♀	21.9±0.6	19.7±0.6	18.4±0.4	8.8±0.3	4.8±0.3	2.7±0.1	–	7.8±0.6	7.7±0.6	7.1±1.1	13.5±0.3
Waterhouse, 1843		(21.2–22.6)	(18.8–20.4)	(17.9–19.0)	(8.5–9.2)	(4.3–5.1)	(2.6–2.9)		(7.2–8.6)	(7.3–8.6)	(5.3–8.2)	(13.1–14.2)
Rhinolophus celebensis	1♂4♀	18.54±0.32	16.9±0.3	15.6±0.1	8.8±0.1	3.1±0.2	2.4±0.1	–	7.4±0.3	6.4±0.1	4.2±0.1	11.7±0.2
K. Andersen, 1905		(18.2–18.9)	(16.50–17.2)	(15.3–15.7)	(8.8–9.0)	(2.9–3.3)	(2.2–2.5)		(7.0–7.8)	(6.3–6.6)	(4.0–4.4)	(11.3–11.9)
Rhinolophus euryotis	3♂3♀	22.7±0.4	20.3±0.4	18.9±0.2	10.6±0.2	4.2±0.6	2.3±0.2	–	8.9±0.3	7.7±0.1	5.7±0.7	14.9±0.3
Temminck, 1835		(21.9–23.2)	(19.7–20.7)	(18.5–19.1)	(10.4–10.8)	(3.6–5.4)	(2.1–2.7)		(8.4–9.19)	(7.5–7.8)	(5.2–7.0)	(14.5–15.3)
Megaderma spasma	1♂1♀	23.9±0.8	21.6±0.6	21.2±0.4	14.2±0.5	4.6±0.7	4.0±0.1	–	10.6±0.2	9.8±0	6.5±0.3	16.35±0.2
(Linnaeus, 1758)		(23.4–24.5)	(21.1–22.1)	(20.9–21.5)	(13.8–14.6)	(4.1–5.1)	(3.9–4.1)		(10.4–10.7)			(16.2–16.5)
Kerivoula hardwickii	1♀	13.1	12.7	12.0	7.2	5.1	3.2	–	7.0	6.9	6.1	9.1
(Horsfield, 1824)												
Miniopterus fuliginosus	1♀	16.8	16.1	14.5	8.8	7.3	4.2	–	8.3	8.8	9.2	12.4
(Hodgson, 1835)												
Myotis cf. *ridleyi*	3♀	12. 5±0.1	12.0±0.1	11.7±0.7	8.1±0.1	42.2±0.7	3.6±0.1	–	6.3±0.1	6.4±0.4	4.8±0.1	8.6±0.5
		(12.5–12.6)	(12.0–12.1)	(11.2–11.7)	(8.0–8.3)	(3.5–5.0)	(3.5–3.7)		(6.3–6.4)	(6.1–6.7)	(4.5–4.9)	(8.3–9.1)
Philetor brachypterus	1♀	15.5	15.3	14.5	11.1	6.7	4.4	–	7.6	9.2	8.1	12.4
(Temminck, 1840)												

Values in parentheses indicate range of the minimum and maximum measurements.
Abbreviations for measurements are provided in the Materials and methods section.

extremity; condyle-basal length (CBL), from the exoccipital condyle to the most anterior projecting point; condyle-canine length (CCL), from the exoccipital condyle to the alveolus of the anterior canine; zygomatic breadth (ZB), the greatest width of the skull across the zygomatic arches; orbital to nasal length (ONL); interorbital breadth (IOB) narrowest point across the frontal bone: post orbital breadth (POB); breadth of braincase (BB), greatest breadth of braincase at the posterior roots of the zygomatic arches; mastoid breadth (MB); palatal length (PL); mandible length (ML), from the posterior part of the condyle to the anterior part of the mandible; maxillary tooth-row length (CM^3), from the alveolus of the upper canine to the back of the crown of the third upper molar; across the upper canine (CC); palatal width at last molar (M^3M^3); palatal width at second molar (M^2M^2); mandible tooth row length (CM_3). All the specimens collected were either deposited in MZB and MWFB. Tissue samples were taken and archived with redundant samples housed at both museums.

Species accounts

Pteropodidae

Chironax melanocephalus (Temminck, 1825)

Specimen examined One individual collected; Mangolo (1♀MZB 35747).

Diagnosis Based on external and cranial measurements (Tables 2 and 3) and diagnostic pelage coloration, one female specimen from Mangolo was determined to be *Chironax melanocephalus tumulus* (Bergmans and Rozendaal 1988) which was described from Sungai Moinakom, Dumoga-Bone National Park, North Sulawesi. This specimen differed from *Chironax melanocephalus melanocephalus* from Java by having smaller external measurements, with strongly contrasting dorsal and ventral fur colors, short tubular nostrils and rounded ears. The pelage of our specimen was similar to the description by Bergmans and Rozendaal (1988): dorsal fur very dark brown, tinged with gray, whereas the ventral fur was essentially whitish with a sharp demarcation between dorsal and ventral fur colors from corner of mouth to anterior ear-base, and from behind the ear across the shoulder to wing insertion.

Remarks This species is known from Thailand, peninsular Malaysia, Sumatra, Borneo, Java and Sulawesi (Payne et al. 1985). The subspecies *Chironax melanocephalus tumulus* was only previously recorded from Northeast and Central Sulawesi. Our record extends this distribution into Southeast Sulawesi. Additional collections of this species were made by our team in the Mekongga Mountains of Southeast Sulawesi (Wiantoro et al. in prep.). The taxonomic status of *C. melanocephalus tumulus* from Sulawesi is still uncertain. Specimens from Sulawesi differ significantly from Kalimantan which was described as *C. m. dyasae* and also Sumatra-Java, *C. m. melanocephalus* (Maharadatunkamsi 2012). Hill (1983) noted that *Chironax* from Java appear more similar to individuals from Malaysia than Sulawesi. We found several diagnostic characters of our Sulawesian specimens indicating a number of developmental features which diverge from their equivalents in other described subspecies and might justify distinction at species level. Our assessment is similar to statements made in the type description for *C. m. tumulus*. A genetic analysis of *Chironax* from throughout the range would be useful to determine whether divergence among subspecies is comparable to interspecific divergence in other fruit bats.

Our only specimen was captured and collected in lowland secondary forest. It was not reproductively active based on the presence of un-swollen nipples and no embryos nor scars.

Cynopterus luzoniensis (Peters, 1861)

Specimens examined 20 individuals were collected: Mangolo (5♀MZB 25711, 35710; WFB 8378, 8387, 8416; 5♂ MZB 25706, 25709, 25712, 35707; WFB 8404) Rawa Aopa (5♀MZB 35648, 35650; WFB 8183, 8454, 8458; 5♂MZB 35646, 35647; WFB 8074, 8432, 8461).

Diagnosis Currently, there are three species of *Cynopterus* recognized from Sulawesi: *Cynopterus brachyotis*, *Cynopterus minutus* and *Cynopterus luzoniensis* (Kitchener and Maharadatunkamsi 1991, Suyanto 2001, Simmons 2005). Based on the measurements (Tables 2 and 3), our specimens all have smaller forearm measurements [60.3 (55.3–64.4)] when compared to *C. b. brachyotis* from Southwest Sulawesi [♂64.5 (62.5–67.6); ♀66.2 (63.4–68.8)], North Sulawesi [♂ 61.5 (60.0–64.0); ♀ 61.7 (60.5–63.5)], Sangihe Islands (♂ 68.5–72.0) and Banggai Islands (♂ 61.3). In addition, our specimens have longer metacarpals than reported for *C. brachyotis*. In comparison with *C. minutus*, our specimens of *C. luzoniensis* from this survey have larger measurements for several key characters [FA (55.3–64.4) vs. (52.9–61.9), E (13.7–17.6) vs. (13.0–15.0), HF (12.0–16.0) vs. (11.0–12.5) and GSL (26.1–29.1) vs. (25.4–28.3) (Suyanto 2001). Generally, our specimens agreed in pelage color previously reported for *C. luzoniensis*: overall grayish olive with less contrasting pelage color than the other *Cynopterus* spp. (Kitchener and Maharadatunkamsi 1991). Our adult males had a lighter colored warm buff (cream yellow) to yellow ochre collar around the throat and extending to the chin, whereas females generally were lighter colored with the neck collar much less distinct and paler.

Remarks We found *Cynopterus luzoniensis* to be abundant in lowland forest at our sample sites. Based on this survey more than hundred individuals were captured, most were released. These animals were captured in a variety of habitats from open forest edge to secondary forest understory, all within 2 m of the ground. The females in our sample exhibited average or swollen nipples indicating active reproduction. The males however had average or unswollen testes.

***Macroglossus minimus* (E. Geoffroy, 1810)**

Specimens examined 14 specimens were collected: Mangolo (2♀ WFB 8367, 8396) Rawa Aopa (7♀ MZB 35652; WFB 8060, 8063, 8070, 8072, 8078, 8464; 5♂ MZB 35653, 35654; WFB 8428, 8067, 8465).

Diagnosis Forearm lengths and cranial measurements from our specimens (Tables 2–4) were similar to those specimens from other parts of Sulawesi. All cranial and external features match the characteristics of this widespread species.

Remarks *Macroglossus minimus* is a widespread species with a distribution that ranges from Thailand to Philippines, Indonesia, Papua New Guinea, Solomon Islands, and N. Australia (Simmons 2005). Hill (1983) assigned specimens from Sulawesi, Peleng Island and Sangihe

Table 4: Dental measurements of specimens collected from Mangolo Nature Park and Rawa Aopa Watumohai National Park (all in mm).

Species	n	CM^3	CC	M^3M^3	M^2M^2	CM_3
Chironax melanocephalus (Temminck, 1825)	1♀	7.5	4.4	4.7	4.5	7.7
Cynopterus luzoniensis (Peters, 1861)	3♂2♀	9.1±0.4	5.9±0.3	8.3±0.3	8.1±0.5	10.5±0.7
		(8.5–9.6)	(5.4–6.3)	(7.9–8.8)	(7.6–8.7)	(9.4–10.7)
Macroglossus minimus (E. Geoffroy, 1810)	2♂3♀	7.9±0.4	4.8±0.2	5.7±0.4	5.8±0.3	8.7±0.4
		(7.5–8.7)	(4.4–5.0)	(5.2–6.2)	(5.3–6.2)	(8.1–9.1)
Nyctimene cephalotes (Pallas, 1767)	1♂	10.8	5.7	9.4	9.1	11.9
Rousettus celebensis K. Andersen, 1907	4♀	13.5±0.3	7.4±0.1	9.6±0.3	9.4±0.2	14.6±0.3
		(13.1–14.9)	(7.3–7.7)	(9.2–9.9)	(9.2–9.6)	(14.3–15.1)
Thoopterus nigrescens (Gray, 1870)	2♀	12.5	7.4	12.1	11.3	13.7
Emballonura alecto (Eydoux and Gervais, 1836)	3♂1♀	5.7±0.1	4.6±0.1	3.3±0.2	3.2±0.2	5.6±0.2
		(5.5–5.7)	(4.4–4.7)	(2.9–3.5)	(2.9–2.4)	(5.4–6.0)
Mosia nigrescens Gray, 1843	1♂	4.1	2.8	4.8	4.5	4.5
Hipposideros cervinus (Gould, 1854)	3♂3♀	5.8±0.1	3.7±0.1	5.8±0.1	6.0±0.1	6.5±0.3
		(5.7–6.0)	(3.5–3.9)	(5.7–5.9)	(5.8–6.2)	(6.2–7.0)
Hipposideros pelingensis Shamel, 1940		14.3	8.3	13.0	11.4	15.9
Hipposideros boeadii Bates et al. 2007	1♂1♀	6.6±0.1	4.3±0.1	6.8±0.1	7.1±0.01	7.1±0.7
		(6.5–6.6)	(4.2–4.3)	(6.8–6.81)	(7.0–7.1)	(7.1–7.2)
Rhinolophus arcuatus Peters, 1871	3♂	8.3±0.3	6.01±0.2	7.8±0.1	8.0±0.05	9.4±0.3
		(7.9–8.6)	(5.8–6.2)	(7.7–7.9)	(7.9–8.1)	(9.1–9.7)
Rhinolophus philippinensis Waterhouse, 1843	3♂4♀	7.3±0.3	4.3±0.25	6.33±0.35	6.18±0.26	7.90±0.24
		(6.8–7.7)	(3.9–4.5)	(5.9–6.8)	(5.9–6.6)	(7.7–7.9)
Rhinolophus celebensis K. Andersen, 1905	1♂4♀	6.7±0.1	4.3±0.2	6.1±0.1	6.3±0.1	6.9±0.4
		(6.6–6.8)	(4.1–4.5)	(5.9–6.3)	(6.2–6.3)	(6.1–7.2)
Rhinolophus euryotis Temminck, 1835	3♂3♀	8.5±0.2	5.7±0.2	7.7±0.2	7.8±0.2	9.1±0.1
		(8.2–8.7)	(5.4–6.0)	(7.6–8.1)	(7.5–8.1)	(8.8–9.2)
Megaderma spasma (Linnaeus, 1758)	1♂1♀	8.9±0.2	5.1±0.1	7.1±0.3	8.1±0.2	10.2±0.3
		(8.8–9.1)	(5.1–5.1)	(6.8–7.3)	(7.9–8.2)	(9.9–10.4)
Kerivoula hardwickii (Horsfield, 1824)	1♀	5.2	4.1	2.3	2.4	5.5
Miniopterus fuliginosus (Hodgson, 1835)	1♀	6.5	5.2	3.7	4.1	6.7
Myotis cf. *ridleyi*	3♀	4.4±0.04	3.9±0.05	5.2±0.2	4.6±0.1	4.4±0.1
		(4.3–4.4)	(3.8–3.9)	(5.1–5.4)	(4.5–4.7)	(4.3–4.5)
Philetor brachypterus (Temminck, 1840)	1♀	5.6	4.6	4.3	3.4	6.3

Values in parentheses indicate range of the minimum and maximum measurements.
Abbreviations for measurements are provided in the Materials and methods section.

Island to the subspecies *lagochilus*. In both survey areas, these animals were captured in a variety of habitats from open forest edge and secondary forest understory. Of the five males captured only one individual had scrotal testes. Two females had average nipples and the remainder had swollen nipples. All females were perforate and all four females that were prepared as museum skins had embryos. This suggests earlier breeding than previous reported reproductively active females from Sulawesi in February and March (Bergmans and Rozendaal 1988). Wiantoro (2011) predicted the reproductive biology of this species differs from one locality to another. In Waigeo Island, males and females have been reported to be reproductively active in May.

Macroglossus minimus has been reported to be a strong flier and can be found from lowlands to upper mountain elevations (Suyanto 1994). This species is widely distributed and sympatric with *Cynopterus luzoniensis*, *Rousettus celebensis* and *Thoopterus nigrescens* at several other localities (Maryanto et al. 2011).

Nyctimene cephalotes (Pallas, 1767)

Specimens examined Eight individuals were collected: Mangolo (1 ♀, WFB 8400; 5 ♂ MZB 36131; WFB 8328, 8333, 8397, 8417) Rawa Aopa (1 ♀ WFB 8466; 1 ♂ WFB 8179).

Diagnosis *Nyctimene cephalotes* was recorded in Rawa Aopa and Mangolo and identified as *Nyctimene cephalotes cephalotes*. There are two species of *Nyctimene* known from Sulawesi, *N. cephalotes* and *N. minutus*. All of our specimens differ from *N. minutus* in being larger (Corbet and Hill 1992, Suyanto 2001) [e.g. FA 66.1 (62.3–69.6) vs. (51–55) and GSL 30.9 vs. 29.1]. In addition, they also differ from the possibly conspecific *N. rabori* from the Philippines in being smaller (Heaney and Peterson 1984, Corbet and Hill 1992). All specimens have a full mid-dorsal dark brown stripe extending from the neck to the base of tail. In contrast *N. minutus* only has a mid-dorsal stripe 2/3 the length of the body not including the tail (Suyanto 2001).

Remarks Of the six males examined only two had swollen testes, while one of the females had swollen nipples. Bergmans and Rozendaal (1988) documented that one male collected in January from North Sulawesi had large descended testes and two females were pregnant.

Rousettus celebensis K. Andersen, 1907

Specimens examined 20 individuals were collected: Rawa Aopa (1 ♀, MZB 35645) Mangolo (10 ♀ MZB 35714, 35717, 35719, 35720, 35721, 35723, 36128; WFB 8384, 8410, 8413; 9 ♂ MZB 35715, 35718, 35722; WFB 8369, 8379, 8399, 8411, 8412).

Diagnosis All the specimens had longer fur and haired tibia compared to the specimens of other *Rousettus* in collections, however, all measurements fell within the range recorded by Rookmaaker and Bergmans (1981) (Tables 2–4). *Rousettus celebensis* differs from the other three *Rousettus* in Sulawesi (*Rousettus bidens, Rousettus amplexicaudatus* and *Rousettus linduensis*) by the combination of its fur distribution and teeth dimension (Rookmaaker and Bergmans 1981).

Remarks This species is abundant in Mangolo Nature Park. Some caves in this area provided important roosting sites, whereas Rawa Aopa did not have many caves for potential roost sites. All males had unswollen testes, three females had average nipples, four females had swollen nipples and three females had unswollen nipples, indicating they were not fully reproductive at either site.

Thoopterus nigrescens (Gray, 1870)

Specimens examined Three individuals were collected: Mangolo (2 ♀ MZB 36130; WFB 8389) Rawa Aopa (1 ♀ WFB 8170).

Diagnosis *Thoopterus nigrescens* apparently is a lowland forest species with a distribution including Sulawesi, Sula Island, Sangihe Island, Talaud Island, and Morotai (Bergmans and Rozendaal 1988, Simmons 2005). In mainland Sulawesi, Bergmans and Rozendaal (1988) recorded size variation within Sulawesi, with northern specimens averaging smaller and southwestern larger. They reported no records from Southeast Sulawesi. Therefore these are the first records from Southeastern Sulawesi. We also documented this species in the Mekongga Mountains (Wiantoro et al. in prep.). Based on this survey, our measurements fell into those recorded for specimens of the northern population and are smaller than southwestern specimens: FA (70.0–76.5) vs. (71.5–78.3) vs. 81.0; GSL 36.2 vs. (33.7–37.1) vs. 36.9; CBL 34.8 vs. (32.8–35.7) vs. 34.9 (measurements for northern and southwestern female specimens were taken from Bergmans and Rozendaal 1988).

Remarks *Thoopterus nigrescens* reproductive activity varied seasonally. During this survey, one female had swollen nipples and the other two had average (small but not swollen) nipples. According to Bergmans and Rozendaal (1988) sub-adult specimens were collected from October to March, and reproductively active animals were collected in January–March. Males were reported with small testes in January and March.

Emballonuridae

Emballonura alecto (Eydoux and Gervais, 1836)

Specimens examined Four individuals were collected: Mangolo (3♂ MZB 35745, 37598, 37600; 1♀ MZB 37599).

Diagnosis There are two species of *Emballonura* reported from Sulawesi. *Emballonura alecto* and *Emballonura monticola*. All our four collected specimens match *E. alecto* in having larger skulls and slightly longer forearms. Compared to the recorded subspecies, *E. alecto alecto* from North Sulawesi by Hill and Rozendaal (1989), all the collected specimens from this survey have smaller forearms, (44.2–45.2) vs. (46.3–49.9) and thus may represent a morphologically distinct population.

Remarks This species was found only in Mangolo and was captured in harp traps set in secondary forest as they left their cave roost sites. During this survey, all the collected specimens were reproductively inactive.

Mosia nigrescens Gray, 1843

Specimen examined One individual was collected; Rawa Aopa (1♂ WFB 8456).

Diagnosis The Rawa Aopa specimens had a forearm length of 31.6 mm with a weight only 2.5 g. All other cranial and external features conform to this species (Tables 2–4). The size was very small, rostrum flattened and nostrils widely separated. We assign these specimens to *Mosia nigrescens* which also has a distinctive penis form in contrast with other species (Griffiths et al. 1991). The penis of the specimen from this survey has a wormlike shape that was long and slender.

Remarks *Mosia nigrescens* is the smallest emballonurid in Indonesia with a range including Sulawesi, Moluccas, Ambon and Papua New Guinea (Suyanto 2001, Simmons 2005). Formerly *Mosia* was recognized as a subgenus of *Emballonura* (Corbet and Hill 1992), but it differs in the sternohyoid muscle and longer penis that warrants recognition at the generic level (Bonaccorso 1998, Griffiths et al. 1991, Suyanto 2001). The Sulawesi form is included in *Mosia nigrescens papuana* (Bonaccorso 1998) which ranges through the north of Moluccas to mainland Papua. Hill and Rozendaal (1989) identified the specimens from North Moluccas as *M. n. papuana* which differ from *Mosia nigrescens nigrescens* from Central Moluccas, Buru Island, Ambon and Seram.

Our single specimen was caught in the secondary forest in a harp trap. The testes were average sized and not swollen. Much of the life history and reproductive biology of this species is still unknown because of the few captures and encounters with this species in the wild.

Hipposideridae

Hipposideros cervinus (Gould, 1854)

Specimens examined 20 individuals were examined: Mangolo (9♂ MZB 35696, 35687, 35688, 35691; WFB 8207, 8208, 8229, 8318, 8321; 11♀ MZB 35689, 35690, 34592, 35693, 35694, 35695, 35697; WFB 8216, 8228, 8323, 8324).

Diagnosis The forearm length of these specimens fell into the range of *Hipposideros cervinus*. According to Hill (1983) and following Jenkins and Hill (1981), specimens from South and Central Sulawesi were *Hipposideros cervinus cervinus*. Hill and Rozendaal (1989) recorded specimens from North Sulawesi as slightly larger with the forearm length 48.4–50.6 mm and weight 7.5–11.0 g. Our animals ranged a bit smaller on FA and weight than Northern Sulawesi specimens (Table 2). This taxon warrants further examination.

Remarks This species was very abundant in Mangolo Nature Park. We caught more than 80 individuals in a harp trap from dusk until 2000 h (most were released). Caves in this area provided ideal roosting sites for this species. No individuals were reproductively active: one female had average nipples and all others had unswollen nipples, while all males had unswollen testes.

Hipposideros pelingensis Shamel, 1940

Specimen examined One individual was collected; Mangolo (1♀ WFB 8360).

Diagnosis *Hipposideros pelingensis* is one of the larger hipposiderids in Indonesia; this individual had a forearm length of 95.3 mm and a weight of 50.5 g. The tibia measurement was shorter (40.11 mm) than *Hipposideros dinops*, but longer than *Hipposideros diadema*. The fur had no white patches or spots on the shoulders and sides.

Remarks Tate (1941) stated that specimens from Peleng and Sulawesi were the same species as *Hipposideros dinops* from Solomon Island being. We agree with Flannery (1995) and Simmons (2005) that the specimens from Sulawesi are *Hipposideros pelingensis* and are distinct from *H. dinops* which are separated by 1800 km with no known populations on intervening islands. Based on the diagnostic characters reported by Shamel (1940) *H. pelingensis* is similar to *H. dinops* from Solomon Island except that it has shorter tibia (38.2–41.0 mm) vs. 44.0 mm. This species probably roosts in caves (Corbet and Hill 1992) but a colony was not found during this survey and only one individual was caught. The female with unswollen nipples was caught in the proximity of a cave.

Hipposideros boeadii Bates et al. 2007

Specimens examined Two individuals were collected: Rawa Aopa (1♂ MZB 35644; 1♀ WFB 8429).

Diagnosis The forearm length of the female specimen fell into the range of *Hipposideros boeadii*, but the male had a slightly shorter forearm compared to the range reported for *H. boeadii*, 39.4 mm vs. (40.5–42.7 mm) (Table 2). However, there are few specimens of this species and so the variation in measurements is poorly known.

Remarks *Hipposideros boeadii* is a recently described species and little is known about its life history (Bates et al. 2007). These specimens represent topotypes as they were collected at the type locality in Rawa Aopa. These two specimens were the first records for this species after the description and were collected in secondary forest in harp traps. The species is only known from this park. The male had swollen testes and the female had average nipples. According to Bates et al. (2007), the female specimens caught in August had recently completed mating.

Rhinolophidae

Rhinolophus arcuatus Peters, 1871

Specimens examined Twenty individuals were examined: Mangolo (10♀WFB 8237, 8241, 8245, 8246, 8254, 8261, 8272, 8280, 8307, 8314; 10♂MZB 35659, 35680, 35686; WFB 8210, 8231, 8253, 8264, 8277, 8278, 8334).

Diagnosis All the characters and measurements were close to those reported for *Rhinolophus arcuatus* (Peters, 1871). The external, cranial and dental measurements fell into the range of *Rhinolophus arcuatus* which had been recorded by Csorba et al. (2003) (Tables 2–4). Externally and cranially this species is very similar to *Rhinolophus euryotis*, but it differs in the structure of the anterior noseleaf. All of our specimens of *R. arcuatus* were characterized by a noseleaf having a narrow anterior emargination less than halfway to the internarial region and wider, broad and ovate-pyriform sella. *R. euryotis* has a shallow emargination, its margin thickened and a shallow median groove that terminates at the edge of the narial depression, and a posteriorly directed projection (Hill 1988).

Remarks Our specimens are the second record of this species from Sulawesi and a represent range extension to Southeast Sulawesi. Hill (1988) recorded a single male specimen of *Rhinolophus arcuatus* from Permana Cave, Tentena Poso, Central Sulawesi. According to him, his specimen from Sulawesi seems likely *Rhinolophus arcuatus proconsulis* Hill, 1959 from Borneo. However, sufficient representation may show the Sulawesian population to be subspecifically distinct (Bergmans and Rozendaal 1988). From our series we were unable to shed any more light on this taxonomic question and therefore did not assign a trinomial determination. Based on the collected specimens, all males had unswollen testes and five females had average nipples, five had unswollen nipples.

Rhinolophus philippinensis Waterhouse, 1843

Specimens examined 20 individuals were examined: Mangolo (11 ♀ MZB 35728, 35729, 35730, 35732, 35734, 35740, 35741, 35742; WFB 8326, 8347, 8348; 9♂MZB 35731, 35733, 35735, 35379; WFB 8283, 8293, 8340, 8343, 8354).

Diagnosis The taxonomy of *Rhinolophus philippinensis* remains unresolved, complicated by the apparent sympatry of two distinct morphotypes. Two forms of *R. philippinensis* were recorded sympatrically within its range in northern Queensland, Australia (Csorba et al. 2003). Based on the echolocation calls, Kingston and Rossiter (2004) reported three distinct, sympatric size morphs of *R. philippinensis* in the Wallacea's region, including Sulawesi. Although it is difficult to compare our specimen with these three morphs because we did not record any echolocation call, we also clearly documented two size classes. The small form was represented by specimens (MZB 35741, MZB 35730 and MZB 35728) that possessed a shorter forearm, darker fur and, large ears. We also collected a large form (MZB 35379, 35731, 35733 and 35734), with a larger forearm. To further complicate the diagnosis of our bats, our smaller specimens of "*philippinensis*" agree in all measurements to the smallest reported race, *maros* which was considered to be a senior synonym of *alleni* and *sanborni* (Tate 1943, Flannery 1995). This changing of the taxonomic status of *R. maros* has caused confusion in identification of the smaller form as *R. philippinensis*. *Rhinolophus maros* (Tate and Archbold 1939) was described from Talassa, near Maros, South Sulawesi. Tate (1943) synonymized *R. maros* with *R. philippinensis* and then Laurie and Hill (1954) also put *maros* and its subspecies into synonymy of *R. philippinensis*. We agree with Flannery (1995), Csorba et al. (2003) and Simmons (2005) that based on sympatry of two forms of "*philippinensis*" on the Cape York Peninsula and now Southeast Sulawesi that there are at least two species involved in *R. philippinensis* complex and more study is needed.

Remarks Both forms of this species were caught in the same mist net and harp trap set in secondary forest in Mangolo Nature Park. Further study is needed to confirm the taxonomic status of these two forms. Among our specimens, one large form male had swollen testes and the others had unswollen testes. Three large form females had swollen nipples, whereas all the others had unswollen nipples.

Rhinolophus celebensis K. Andersen, 1905

Specimen examined Five individuals were collected: Mangolo (♂ MZB 35702; ♀ MZB 35703, 35699, 35700, 35701).

Diagnosis *Rhinolophus celebensis* is a small to medium sized rhinolophid bat. The external measurements of our specimens from Mangolo Nature Park had no striking differences from specimens from North Sulawesi recorded by Hill and Rozendaal (1989). Furthermore, external, cranial and dental characters fell into the range of *R. celebensis* recorded by Csorba et al. (2003) (Tables 2–4). All specimens from Sulawesi belong to *R. c. celebensis* (Koopman 1994).

Remarks *Rhinolophus celebensis* is one of the most common bats in Sulawesi. We recorded this species in secondary forest and more than 50 individuals were released from trapping locations. It probably roosts in caves although a roost was not found. All the female specimens had average or large nipples, whereas two males had swollen testes. According to Csorba et al. (2003) this species was also recorded in primary forest in Talaud Island.

Rhinolophus euryotis Temminck, 1835

Specimens examined 20 individuals were examined: Mangolo (14 ♀ MZB 35660, 35661, 35662, 35663, 35664, 35665, 35666, 35667, 35669, 35684, 35685; WFB 8255, 8258, 8259; 6 ♂ MZB 35658, 35672, 35675, 35676, 35679; WFB 8414).

Diagnosis External and cranial measurements of *Rhinolophus euryotis* are very similar to *Rhinolophus arcuatus*. *Rhinolophus euryotis* is characterized by having a whitish strip on the median longitudinal groove that divides the anterior noseleaf and raised edges extending from the median edges to the internarial region. Our specimens show these traits.

Remarks Tate and Archbold (1939) recorded *Rhinolophus euryotis* specimens from Sulawesi indicating that these differed from *euryotis* from western New Guinea by having shorter forearm (48–51 mm). They proposed that Sulawesi specimens belonged to nominate *Rhinolophus euryotis euryotis*. Bergmans and Rozendaal (1982) described a new species, *Rhinolophus tatar* from North Sulawesi and noted that if the *R. euryotis* specimens from Sulawesi recorded by Tate and Archbold (1939) were *R. tatar*, then possibly *R. tatar* was distributed throughout Sulawesi. However, Hill (1983) considered *R. tatar* as a subspecies of *R. euryotis* based on comparison with all forms of *euryotis*. Recently, Koopman (1984) recognized specimens from Sulawesi as *R. e. tatar*. We agree with Koopman (1984) and based on the external, cranial and dental characters and measurements, our specimens belong to *Rhinolophus e. tatar*. *Rhinolophus euryotis* was caught sympatrically with *Rhinolophus arcuatus*, *Rhinolophus philippinensis* and *Rhinolophus celebensis* in Mangolo Nature Park. It was quite common in harp traps and hundreds of individuals were released at the point of capture. All males and most females were non-reproductive, but one female had an embryo.

Megadermatidae

Megaderma spasma (Linnaeus, 1758)

Specimens examined Two individuals were collected: Rawa Aopa (1 ♂ MZB 35655; 1 ♀ WFB 8460).

Diagnosis *Megaderma* is readily identified by the large oval ears, joined above the forehead, bifid tragus, and simple, erect noseleaf on the muzzle (Bates and Harrison 1997). The two specimens from Rawa Aopa were smaller in size compared to specimens from other islands. External, skull and dental measurements (see Tables 2–4) fell into the range of *Megaderma spasma celebensis* as reported by Shamel (1940). He reported the skull of *M. s. celebensis* as smaller than *M. s. spasma* from Philippines with GSL 24.8–25.0 mm. Externally *celebensis* showed less pattern, with the color of back and belly not sharply contrasted. After comparing our specimens to the type and description provided by Shamel (1940), we confirm that *Megaderma* from Southeast Sulawesi belong to *M. s. celebensis,* although Hill and Rozendaal (1989) assigned their collected specimens from North Sulawesi and Sangihe Island to *M. s. spasma*. Clearly more work is needed with this group in Indonesia.

Remarks Our specimens represent a range extension and first record of the *Megaderma spasma celebensis* from Southeast Sulawesi. This species is hard to capture and not very common in both survey sites. Only two individuals were caught in a mist net. The male had unswollen testes though the female had swollen nipples but no embryos or other sign of reproductive activity.

Vespertilionidae

Kerivoula hardwickii (Horsfield, 1824)

Specimen examined One individual was collected; Rawa Aopa (1♀MZB 35002).

Diagnosis All cranial and external measurements of this specimen conformed to this species. The forearm length (31.44) was closer to the range of *Kerivoula hardwickii* from South of Sulawesi (31.7–35.6), but smaller than reported by Hill and Rozendaal (1989) for *K. hardwickii* from Talaud Island, a small island near Sulawesi (37.1).

Remarks The subspecific variation of *Kerivoula harwickii* remains unclear (Hendrichsen et al. 2001). According to Corbet and Hill (1992), there was no consistency in size throughout the known distribution of this species. However, Francis (2008) stated that this species may represent a complex of species. More review is necessary, though few specimens are known from Southeast Sulawesi: only one individual was caught in a harp trap during this survey. Our specimen had average nipples which indicated no active reproduction. According to Medway (1969) a lactating female with a single infant was collected in January.

Myotis horsfieldii (Temminck, 1840)

Specimens examined Five individuals collected: Mangolo (3♀WFB 8385, 8390, 8391; 2♂WFB 8366, 8392).

Diagnosis *Myotis hosfieldii* is a medium sized *Myotis*, its feet are large, exceeding half of the length of tibia, the wing is attached to the outer edge of the metatarsals and the anterior braincase is elevated above the rostrum (Bates and Harrison 1997, Hendrichsen et al. 2001). Corbet and Hill (1992) suggest specimens from Sulawesi belong to *Myotis horsfieldii horsfieldii*. This subspecies is distributed from Malaya to Sulawesi. Recent records from Malaysia to Java were provisionally referred to the nominate race *M. h. horsfieldii*, but did not include an analysis of this species from Sulawesi (Bates et al. 1999). Our specimens from Mangolo appear slightly larger than those recorded specimens from Vietnam with the tibia averaging 16.2 vs. 15.9 mm. Other measurements were within the range reported for this species (Tables 2–4). Further review of the Sulawesi form is still needed.

Remarks These specimens were collected in secondary forest. None of the individuals were reproductively active.

Myotis cf. *ridleyi*

Specimens examined Three individuals collected: Rawa Aopa (3♀MZB 34112, 36206, 36887).

Diagnosis The identification of these specimens remains uncertain. We referred them to *Myotis ridleyi* based on dentition (second premolar missing) and their small overall size (Tables 2–4). The most similar species known from Sulawesi *Myotis ater* is larger and has both premolars. Our bats represent either a significant range extension, having never been recorded on Sulawesi (closest records are from Borneo) or could represent an undescribed taxon, more analysis is needed.

Remarks In 1989, Hill and Rozendaal recorded a specimen of *Myotis ater* from Malenge Island as the first of the species to be recorded from Togian Islands (North Sulawesi region), but we are not sure this identification is correct. This specimen was unusual as it too lacked the second premolar from both sides of the upper and lower jaws. The measurements from this specimen were: FA 37.4, GSL 14.0, CBL 13.4, CCL 12.7, BB 6.4, MB 7.0, CM^3 5.5, which were larger than our specimens. All three specimens were captured in harp trap or mist net in secondary forest. One of the females was reproductively active, with swollen nipples.

Philetor brachypterus (Temminck, 1840)

Specimen examined One individual collected: Rawa Aopa (1♀ WFB 8457).

Diagnosis The only specimen we collected of this species differed from a female specimen collected from Dumoga-Bone National Park, North Sulawesi in having longer forearm of 37.64 mm. Hill and Rozendaal (1989) provided measurements for the specimen from North Sulawesi as FA; 33.6, GSL: 14.0, CBL: 13.7, CCL: 13.2, ZB: 10.4, IOB: 5.2, POB: 4.6, BB: 8.1, MB: 8.7, CM^3: 4.8 and WT: 8.2 g. Further specimens are needed to determine whether the difference in forearm length is significant. Our specimen had dark brown dorsal fur, and a greyer ventral fur. It resembled *Pipistrellus* externally, but had only one upper premolar and the first upper incisor long, narrow with two cusps.

Remarks *Philetor* is considered to be monotypic. According to Hill (1966) it can be distinguished by a number of characters in combination, i.e. narrow wings with a short fifth digit, flattened head and long and narrow first upper incisor in contrast to the second upper incisor.

Our specimen, collected in a harp trap, showed signs of active reproduction by having swollen nipples and a single embryo.

Miniopteridae

Miniopterus australis Tomes, 1858

Specimens examined Four individuals were collected: Mangolo (3♀ WFB 8309, 8358, 8368; 1♂ WFB 8351).

Diagnosis Measures from our specimens fell within the range given by Hill and Rozendaal (1989) *Miniopterus australis tibialis*. FA 39.1 (38.8–39.3) vs. 39.0–40.6; Tib 15.7 (15.1–16.6) vs. 15.8–16.9.

Remarks According to Hill (1983) it was not possible to identify *Miniopterus* on obvious morphological features other than size. *Miniopterus australis* is the smallest *Miniopterus* in the Indo-Malayan region with the forearm length 34–40 mm. Specimens of *M. australis* from the western part of the range were generally smaller than those from the more easterly localities (Hill 1983). Our specimens conformed to those collected from Sulawesi and Moluccas and belong to *M. a. tibialis*. Many individuals were reproductively active. Two females each had a single embryo, whereas one male had average testes. All the specimens were caught in secondary forest of Mangolo Nature Park. This species probably roosts in caves and was abundant within the park.

Miniopterus fuliginosus (Hodgson, 1835)

Specimen examined One individual was collected Rawa Aopa (1♀ WFB 8452).

Diagnosis The single female specimen from Rawa Aopa has the same external measurements as *Miniopterus fuliginosus* from Sumatra (see Huang et al. 2014), but larger than *M. fuliginosus* (reported as *Miniopterus schreibersii*) from Vietnam (Hendrichsen et al. 2001). This animal is also larger than *Miniopterus australis* from Mangolo, and *Miniopterus pusillus* from North Sulawesi (Hill and Rozendaal 1989).

Remarks Previously this species was identified as *Miniopterus schreibersii* (see Tian et al. 2004). It was split from *M. schreibersii* sensu lato into three species, i.e. *M. schreibersii* (Europe/N. Africa/Near East), *M. fuliginosus* (Asia) and *Miniopterus oceanensis* (Australia) (Chiozza 2008). The range of *M. fuliginosus* is widespread through the Asia region. Further taxonomic work with a combination of morphological and genetic methods may show that there are additional species in the complex.

This specimen was caught in secondary forest in a mist net. It had average nipples.

Discussion

A total of 22 species of bats were recorded in our recent survey in lowland areas of Southeast Sulawesi; 11 species were recorded from Rawa Aopa and 15 species from Mangolo. Combining our findings with previous surveys, 30 bat species have been recorded from the lowlands of Southeast Sulawesi including the following eight species not recorded during our survey: *Acerodon celebensis, Myotis ater, Cynopterus brachyotis* and *Hipposideros diadema* (recorded by Gerd Heinrich, listed in mammal collection of American Museum of Natural

Table 5: Endemic species recorded in Southeast Sulawesi, with notes on the IUCN Red List status and population trend (IUCN 2016).

Species	Note
Hipposideros pelingensis	Endemic Sulawesi and adjacent small islands; IUCN: near threatened with population trend is decreasing; it is rarely species in Southeast Sulawesi
Hipposideros boeadii	Endemic Southeast Sulawesi, only known form the type locality, Rawa Aopa; IUCN: data deficient; 15 individuals were recorded by Kingston et al. and only two individuals from the recent survey
Rousettus celebensis	Endemic Sulawesi and adjacent small islands: IUCN: least concern with population trend is decreasing; this species is abundant in forest habitat including in our survey site
Acerodon celebensis[a]	Endemic Sulawesi and adjacent small islands; IUCN: least concern; colony of this species had been found in Southeast Sulawesi, Central Sulawesi and North Sulawesi (unpublished data of the senior author), major threat of this species in almost all region in Sulawesi is hunting for bushmeat.

[a]Recorded by Gerd Heinrich.

History); *Murina florium*, *Kerivoula papillosa*, *Phoniscus jagorii* and an unidentified *Hipposideros* (recorded by Kingston et al. 2006). This represents one third or 41% of recorded Sulawesian bats. This highlights the importance of lowland Southeast Sulawesi for bat conservation. This survey was effective because we combined methods of harp traps and mist nets (set at ground level as well as in the canopy of trees). The harp traps were particularly effective for capturing of echolocating bats. Combining these methods has proven effective in other Indonesian studies as well (Kingston et al. 2006).

We are certain that there are other species to be documented from this region, and that absence of species from this survey does not reflect absence from the sites, or in lowland Southeast Sulawesi. To expand our knowledge of the distribution of species from this region, we recommend surveys at differing times of the year and surveying additional lowland sites. There are some protected areas and forests in Southeast Sulawesi that remain unexplored, for example: Lamedae Nature Reserve, Tanjung Ameleo Faunal Reserve, Tanjung Batikolo Faunal Reserve and Murhum Forest Park.

Our surveys also recorded two species that represent either significant range extensions to Sulawesi (first records for that island) or in fact could represent undescribed taxa.

Our specimens of *R. arcuatus* become the second documented record of this species in Sulawesi. Previously, Hill (1988) recorded only a single specimen of this species from Central Sulawesi. Also, our record of *Myotis* cf *ridleyi* is very interesting. If this species is found to be *M. ridleyi*, this would represent a significant range extension to include Sulawesi. Based on size differences we believe that these individuals may represent a new taxon. Further work is required to analyze both of these anomalous records through additional field surveys and examination of museum specimens. We collected and archived tissues for both species. A genetic assessment might yield information regarding the true identity of these two bats.

The number of bat species now documented from the lowlands of Southeast Sulawesi represents the highest diversity yet recorded from a site on Sulawesi. Suyanto and Wiantoro (2012) recorded 15 species from Maros, the lowland area in South Sulawesi. Maryanto et al. (2011) collected 17 species of fruit bat from lowland to the high altitudinal in Lore Lindu National Park, Central Sulawesi. The fact that in one survey we recorded several range extensions and new records on Sulawesi and new records for Sulawesi indicates there is much work still needed to clarify the Chiropteran diversity on the island. The recent discovery and description of a new species of bat (Bates et al. 2007) and our possibly new taxa supports that the lowlands of Southeast Sulawesi remain an important hotspot for bat research in Wallacea. In addition, four of 18 endemic Sulawesian bats were recorded in Southeast Sulawesi, one of which is still only known from the type locality (Table 5). By definition, endemic species with limited distribution often makes them rare and vulnerable to the effects of habitat loss. Therefore, it is important to consider their presence in protected area management plans, such as those we studied in Southeast Sulawesi.

Land use changes of lowlands on the island have no doubt greatly altered the distribution and species assemblages. According to Kehutanan (2002) the rate of deforestation in Southeast Sulawesi was 41,814 ha/year in 1985–1997. Recently, Global Forest Watch (2016) reported 297,316 ha of tree cover loss in Southeast Sulawesi between 2001 until 2014 with 32,623 ha lost in 2014. These anthropogenic forces underscore the need to maintain lowland forests and wetlands in a protected state. These protected areas are the remaining refugia for species diversity on the island, including bats. While the existence of the fruit bats in lowland forest of Southeast Sulawesi is very important for the regeneration and conservation of forest in this region, in view of their ecological services in the pollination process and seed dispersal of many plant species (Kunz et al. 2011). Surveys such as ours are important to convince governmental and private stakeholders of the value of these protected areas to conserve Sulawesi, and Indonesia's, native biodiversity.

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