A new species of *Batomys* (Mammalia: Muridae) from eastern Mindanao Island, Philippines

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Abstract.—Murid rodents of the endemic genus *Batomys* are diverse and geographically widely distributed in the Philippines. Four species have been recognized: *B. dentatus* and *B. granti* on Luzon, *B. salomonseni* on several islands comprising the Mindanao faunal region, and *B. russatus* on Dinagat Island. A recent survey of small mammals in eastern Mindanao recorded the presence of *Batomys* on Mt. Hamiguitan, the only other documented occurrence of this genus on Mindanao Island outside of Mt. Kitanglad. Comparison of external morphology as well as cranial and dental features of the Hamiguitan *Batomys* with available specimens of congeners indicates that although it is closely allied to *B. salomonseni*, a number of distinct traits separate it from all its congeners, and we describe it as a new species, *B. hamiguitan*. This species corroborates the hypothesis that the island of Mindanao is comprised of multiple centers of endemism, of which the southeastern highland of Mt. Hamiguitan is one.

The murid fauna of the Philippines comprises a diverse assemblage of rodents exhibiting a wide array of morphological and ecological specializations, ranging from 25 g reddish-brown, vermivorous shrew-mice (*Archboldomys* spp.) to 2.6 kg black and white, folivorous cloud rats (*Phloeomys* spp.). Of the 22 genera and 59 native species recognized to date, 15 genera (71%) and 53 species (95%) are endemic to the Philippines (Heaney et al. 1998, Musser et al. 1998, Rickart et al. 1998, Heaney & Tabaranza 2003, 2005, 2006; Balete et al. 2006, 2007).

In a preliminary assessment of morphological characters of these murid rodents, Musser & Heaney (1992) outlined a hypothesis of their relationships in a phylogenetic context, and organized the fauna intro three major assemblages (Divisions I–III) without implying monophyly of each. The hairy-tailed rats of the genus *Batomys* were treated as members of Division I, the Old Endemics, an assemblage that comprises a diverse group of Philippine murids that exhibit many basal features as well as distinctive specializations. As originally erected, the Old Endemics division consisted of ten genera including *Apomys*, *Archboldomys*, *Batomys*, *Carpomys*, *Celaenomys*, *Chrot-*

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omys, *Crateromys*, *Crunomys*, *Phloeomys*, and *Rhynchomys* (recent reviews have synonymized *Celaenomys* with *Chrotomys*; Corbet & Hill 1992, Musser & Carleton 2005, Rickart et al. 2005). Members of Division I were further clustered into six proposed monophyletic taxa, each defined in most respects by apomorphies in cranial and dental morphologies that reflect unique feeding habits and living conditions. *Batomys* was placed in the *Crateromys* group together with *Carpomys* and *Crateromys*. Musser et al. (1998) provided a comprehensive review of the genus and recognized four species: *B. dentatus* from northern Luzon, *B. granti* from northern and southeastern Luzon, *B. salomonseni* from the islands of Biliran, Dinagat, Leyte, and Mindanao, and *B. russatus* from Dinagat. They found *B. granti* and *B. salomonseni* to be the most similar morphologically but noted the need for larger samples. In this paper, we report larger samples of several of these species but note that *B. dentatus* is still known from a single specimen, and *B. russatus* from only two.

The murid relationships proposed by Musser & Heaney (1992) were strongly supported by phylogenetic analyses utilizing mitochondrial and nuclear genes (Jansa et al. 2006). Jansa et al. (2006) found strong support for an arboreal murid clade encompassing the *Crateromys* group (as defined by Musser & Heaney 1992) and *Phloeomys*. They also found that *B. granti* and *B. salomonseni* are sister taxa but found no molecular support for the monophyly of *Batomys* with respect to *Crateromys* and recommended further studies to clarify generic limits.

A recent survey of the mammals on Mt. Hamiguitan in southeastern Mindanao produced the first records of *Batomys* from that island east of the Kitanglad Range, where *B. salomonseni* occurs (Fig. 1; Heaney et al. 2006, Balete et al.

2008b). Our comparison of *Batomys* from Mt. Hamiguitan with *B. salomonseni* from Mt. Kitanglad uncovered many morphological similarities that imply close relationship but also revealed sufficient differences to warrant the recognition of the former as a distinct species.

Materials and Methods

For comparison with the new species, we used specimens of *B. granti* from the Central Cordillera of Luzon (from or near the type locality) and of *B. salomonseni* from Mt. Kitanglad (the type locality). Because *Batomys dentatus* is more distantly related to *B. granti* and *B. salomonseni* (Musser et al. 1998), we did not include it in our comparisons. Because *B. russatus* occurs geographically near Mindanao, we chose to include it in many of our comparisons, even though it is morphologically distinct from the others.

Museum numbers and geographic sources of specimens examined in this study are listed in Appendix 1. They include specimens collected by the authors and their associates (Heaney et al. 2006, Balete et al. 2008b), as well as specimens from earlier expeditions (Sanborn 1952, 1953; Musser et al. 1998) deposited at the Field Museum of Natural History (FMNH). Specimens were assigned to age categories defined by Musser & Heaney (1992), based on relative body size, reproductive condition, and molar tooth wear. Terminology for external features of the head and limbs follows Brown (1971) and Brown & Yalden (1973). Terminology for cranial and dental features follows Musser & Heaney (1992). Scanning electron micrographs of teeth were made from uncoated specimens.

Measurements (mm) of total length, length of tail (LT), length of hind foot including claws (LHF), and length of ear from notch (LE), and weight in grams
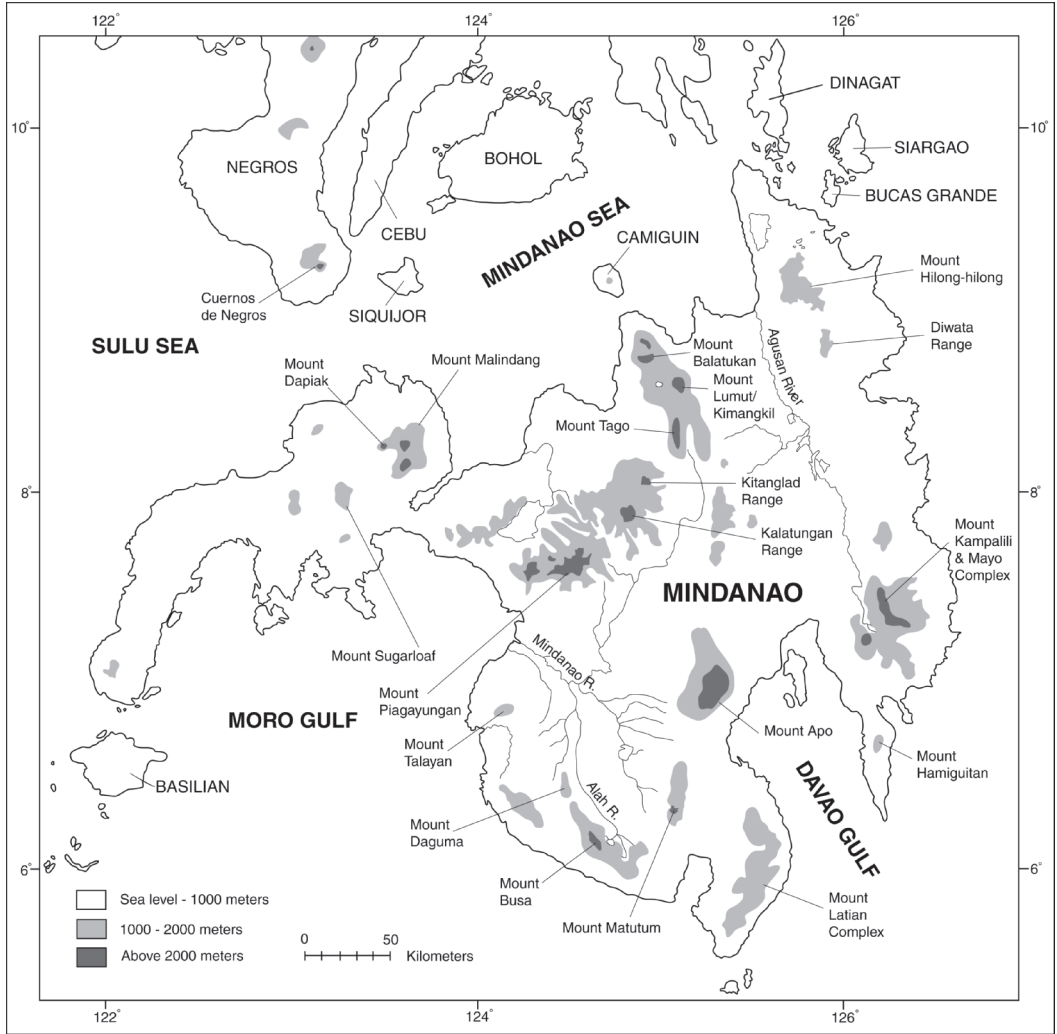
Fig. 1. Map of Mindanao and adjacent islands showing some major topographic features and the distribution of *Batomys hamiguitan* (Mount Hamiguitan), *B. salomonseni* (Kitanglad Range), and *B. russatus* (Dinagat Island).

(WT) were taken from field catalogs of the authors located at FMNH. The length of head and body (LHB) was determined by subtracting length of tail from total length. Length of over-fur (LOF) was measured in the mid-dorsal region. The number of tail scale rings per centimeter (TSR) was counted at a point on the tail one-third of the total length from the base.

Twenty-eight cranial and dental measurements were taken from 18 adult specimens of *Batomys* from Mindanao. The following morphological terms and the limits of their measurements are defined and illustrated in Musser & Heaney (1992): greatest length of skull (GLS), interorbital breadth (IB), zygomatic breadth (ZB), breadth of braincase (BBC), height of braincase (HBC), length of nasal bones (LN), length of rostrum (LR), breadth of rostrum (BR), breadth of zygomatic plate (BZP), length of diastema (LD), palatal length (PL),

post-palatal length (PPL), length of incisive foramina (LIF), breadth across incisive foramina (BIF), distance from posterior edge of incisive foramina to anterior margin of first molars (IF–M^1), length of palatal bridge (LPB), palatal breadth at first molars (PBM^1), palatal breadth at last molars (PBM^3), breadth of mesopterygoid fossa (BMF), length of auditory bulla (LB), breadth across incisor tips (BIT), crown length of maxillary molar toothrow (LM$^{1-3}$), crown length of upper first molar (LM^1), crown breadth of upper first molar (BM^1), length of mandible plus lower incisor (LMI), posterior height of mandible (HM), and crown length of mandibular molar toothrow (LM$_{1-3}$). Measurements were taken by Balete and recorded to the nearest 0.1 mm using dial calipers.

We used SYSTAT 10 for Windows (SPSS, Inc., 2000) for statistical analysis of measurements. Descriptive statistics (mean, standard deviation, and observed range) were calculated for sample groups. Quantitative phenetic variation was assessed through principal components analysis (using the correlation matrix) of log$_{10}$-transformed measurements of adult specimens.

Stomach contents were analyzed in the field for specimens prepared as skeletons and in the laboratory for specimens initially fixed in formalin and subsequently preserved in ethyl alcohol. Stomach contents were scored for presence of arthropod exoskeletons, plant matter, and annelid worms. Results are presented as percentage occurrence of each of the three categories among the total number of specimens examined of each species.

Reproductive autopsies were performed in the field on specimens prepared as skeletons or in the laboratory on fluid-preserved specimens. For males, the testes were scored for position (scrotal or abdominal), size (length × width, in mm), and relative convolution of the epididymis. For females, data were taken on the size and condition of teats (small, large, or lactating), and the number and size (crown to rump length, in mm) of embryos or number of placental scars in the uterus.

The capture and handling of animals in the field was conducted in accordance with animal care and use guidelines established by the American Society of Mammalogists (Animal Care and Use Committee 1998).

Results

Distinct differences are apparent in adult body size and external proportions, as well as in cranial and dental measurements among the four groups of *Batomys* that we examined (Tables 1, 2). Adults of *B. salomonseni* exhibit some detectable sexual dimorphism in external and cranial measurements, but due to small sample size, the sexes were pooled for the comparisons that follow.

We conducted a principal components analysis on a subset of 19 measurements taken from 9 adult specimens of *Batomys* having intact (or nearly intact) crania, and complete external measurements. These included *B. salomonseni* from Bukidnon Province, Mindanao ($n = 4$), *B. granti* from Kalinga and Mountain provinces, Luzon ($n = 3$), and specimens from Mt. Hamiguitan, Davao Oriental Province, Mindanao ($n = 2$). We excluded *B. russatus* from this analysis because it is easily distinguished metrically by its small size (and by numerous morphological features) and because we had only a single skull for comparison. The first four components accounted for 80.7% of the total variance (Table 3). Most variables had positive loadings of high magnitude on component 1 (accounting for 42.6% of the variance), indicating that much of the variation involved size. Component 2 (accounting for 16.5% of the variation) separated individuals primarily on the basis of interorbital breadth, length of palatal bridge, breadth of palate, and length of mandibular tooth row. Compo-

Table 1.—External measurements (mm), body mass (g) and measurement ratios (%) of adult *Batomys*, including a new species from Mt. Hamiguitan, eastern Mindanao. Measurements of sample size (*n*) greater than 3 are given as mean ± 1 *SD* and their ranges; as average for sample sizes of 3 or less. Sample sizes less than *n* are given in parentheses after the range. Variable abbreviations are defined in Materials and Methods section.

	Batomys hamiguitan		*Batomys granti*[b]	*Batomys russatus*[c]	*Batomys salomonseni*[d]
	Holotype	Total specimens[a] *n* = 3	*n* = 5	*n* = 1	*n* = 6
LHB	188	183	193 ± 6.3	151	185 ± 5.9
		171–189	185–197		174–191
LT	125	119	161 ± 13.6	–	137 ± 8.4
		111–125	149–180 (4)		130–150 (5)
LHF	35	35	37 ± 2.4	30	37 ± 1.9
		35–36	33–39		34–39
EAR	25	23.5	22 ± 0.8	18	23 ± 1.4
		22–25	21–23		21–24
WT	180	173	188 ± 22.7	115	190 ± 8.7
		155–183	165–226		180–205
LOF	12–15	12–15 (2)	11–13 (1)	11–12	15–18 (3)
TSR	11	10–11 (2)	9 (1)	15	11–12
LT/HBL	66	63–66	76–90	–	68–81
LHF/HBL	19	18–21	17–20	20	19–20

[a] FMNH 190163 (holotype), 190165, 190166.
[b] FMNH 169126, 188321, 188323, 193689, 193691.
[c] FMNH 189788.
[d] FMNH 147927, 147929, 147931, 148164, 148171, 148172.

nent 3 (12%) separated individuals based primarily on the length and breadth of incisive foramina, length of palatal bridge, and length of tail, and component 4 (9.6%) separated specimens based on length of ear and size of auditory bulla (Table 3). A bivariate plot of specimen scores on components 1 and 2 (Fig. 2, left) reveals that the Hamiguitan *Batomys* is separated from *B. granti* on component 1, and partially separated from *B. salomonseni* on component 2. In a plot of components 3 and 4 (Fig. 2, right), the Hamiguitan *Batomys* is separated from the other taxa on component 3.

On the basis of these results and the diagnostic features detailed below, we recognize the *Batomys* from Mt. Hamiguitan as a new species that we describe as follows.

Batomys hamiguitan, new species
Figs. 3–5, Tables 1, 2

Holotype.—FMNH 190163, adult female, collected on 10 May 2006 (original number of R. S. Quidlat 53; Fig. 3); initially fixed in formalin, now preserved in ethyl alcohol with skull removed. The skull (Fig. 4) is in good condition, except for a broken tip of the right nasal. A sample of muscle tissue was removed from the left thigh in the field; the specimen is otherwise in good condition. It is deposited at FMNH but will be transferred to the National Museum of the Philippines, Manila.

Type locality.—2.5 km S, 0.25 km E Mount Hamiguitan peak, San Isidro Municipality, Davao Oriental Province, Mindanao Island, Philippines, 1128 m; 06°43′03″N, 126°11′01.9″E (Fig. 1; coordinates taken with a GPS unit).

Distribution.—Known only from Mt. Hamiguitan, where specimens were trapped in disturbed transitional lowland dipterocarp/lower montane forest at 950 m elevation, and in primary lower montane forest at 1128 m elevation.

Referred specimens.—Along with the holotype, six other specimens were cap-

Table 2.—Cranial and dental measurements (mm) of adult *Batomys*. Measurements for sample sizes (*n*) greater than 3 are given as the mean $\pm$ 1 *SD* and the range, or as only the mean and range for sample sizes of 3 or less. Sample sizes less than $n = 3$ are given in parentheses after the range. Variable abbreviations are defined in the Materials and Methods section.

	Batomys hamiguitan		*Batomys granti*[b]	*Batomys russatus*[c]	*Batomys salomonseni*[d]
	Holotype	Total specimens[a] $n = 3$	$n = 6$	$n = 1$	$n = 6$
GLS	42.77	42.77 (1)	45.0 $\pm$ 0.30	34.31	43.4 $\pm$ 1.46
			44.8–45.4 (4)		41.6–45.1 (4)
IB	6.46	6.3	6.1 $\pm$ 0.35	5.45	6.4 $\pm$ 0.21
		6.21–6.46	5.6–6.5		6.0–6.6
ZB	22.08	22.08 (1)	22.4 $\pm$ 0.88	18.9	22.3 $\pm$ 0.68
			21.5–23.4 (5)		21.6–23.1 (5)
BBC	17.15	17.15 (1)	16.8 $\pm$ 0.31	14.28	16.6 $\pm$ 0.52
			16.4–17.1(4)		15.8–17.0 (5)
HBC	11.80	11.80 (1)	12.1 $\pm$ 0.26	9.97	12.4 $\pm$ 0.64
			11.8–12.4 (4)		12.0–13.3 (4)
LN	17.61	17.1	18.4 $\pm$ 0.41	12.93	17.8 $\pm$ 0.82
		16.34–17.61	17.8–18.8		16.7–18.9 (5)
LR	15.38	15.3	15.8 $\pm$ 0.57	11.07	15.7 $\pm$ 0.96
		15.04–15.54	15.0–16.6		14.1–16.5 (5)
BR	8.29	8.1	8.7 $\pm$ 0.20	7.16	8.4 $\pm$ 0.59
		7.95–8.29	8.4–8.9		7.7–9.0
BZP	4.20	4.3	4.4 $\pm$ 0.15	3.45	4.5 $\pm$ 0.24
		4.20–4.40	4.2–4.6		4.2–4.8
BIT	2.57	2.4	2.4 $\pm$ 0.17	2.09	2.7 $\pm$ 0.10
		2.29–2.57	2.2–2.5 (4)		2.5–2.8
LD	11.59	11.5	12.8 $\pm$ 0.40	8.75	12.1 $\pm$ 0.57
		11.21–11.62	12.2–13.4		11.3–12.8
PL	19.97	19.7	21.5 $\pm$ 0.32	15.12	20.6 $\pm$ 0.55
		19.47–19.97 (2)	21.0–21.9		20.1–21.6
PPL	15.20	15.20 (1)	17.1 $\pm$ 0.43	13.02	15.8 $\pm$ 0.63
			16.8–17.8 (4)		14.8–16.2 (4)
LIF	8.96	8.2	8.6 $\pm$ 0.33	5.49	7.9 $\pm$ 0.39
		7.17–8.96	8.4–9.3		7.2–8.3
BIF	3.22	3.1	3.1 $\pm$ 0.32	2.53	2.9 $\pm$ 0.33
		2.98–3.22	2.6–3.5		2.5–3.5
IF–M^1	0	0	1.0 $\pm$ 0.25	1.19	1.2 $\pm$ 0.23
			0.7–1.5		0.9–1.6
LPB	6.53	6.4	6.9 $\pm$ 0.33	5.49	7.5 $\pm$ 0.41
		6.24–6.53 (2)	6.5–7.4		7.0–8.1
PBM^1	3.47	3.5	3.8 $\pm$ 0.40	–	3.4 $\pm$ 0.39
		3.47–3.56	3.4–4.6		2.7–3.8
PBM^3	3.93	4.1	4.6 $\pm$ 0.43	3.24	4.1 $\pm$ 0.46
		3.93–4.28 (2)	3.9–5.2		3.3–4.6
BMF	3.18	3.2	3.0 $\pm$ 0.21	2.9	3.2 $\pm$ 0.27
		3.18–3.22 (2)	2.8–3.3 (5)		3.0–3.6 (5)
LB	5.41	5.3	5.6 $\pm$ 0.25	3.96	5.2 $\pm$ 0.19
		5.23–5.41 (2)	5.3–5.9 (5)		5.0–5.5 (5)
HB	5.58	5.1	5.5 $\pm$ 0.12	4.45	5.4 $\pm$ 0.20
		4.67–5.58 (2)	5.4–5.7 (5)		5.1–5.7 (5)
LM$^{1-3}$	8.18	8.0	7.8 $\pm$ 0.33	–	8.0 $\pm$ 0.16
		7.73–8.18	7.3–8.2		7.7–8.2
LM^1	3.56	3.4	3.3 $\pm$ 0.23	–	3.5 $\pm$ 0.21
		3.28–3.56	3.0–3.6		3.2–3.9
BM^1	2.21	2.2	2.3 $\pm$ 0.10	–	2.3 $\pm$ 0.08
		2.21–2.32	2.2–2.4		2.2–2.4

Table 2.—Continued.

| | *Batomys hamiguitan* | | *Batomys granti*[b] | *Batomys russatus*[c] | *Batomys salomonseni*[d] |
	Holotype	Total specimens[a] $n = 3$	$n = 6$	$n = 1$	$n = 6$
LMI	28.13	27.6	29.8 ± 0.78	22.2	28.9 ± 1.03
		26.97–28.13 (2)	29.2–31.4		27.7–30.1
HM	12.29	11.7	13.0 ± 0.32	9.25	12.4 ± 0.55
		11.18–12.29 (2)	12.6–13.5		11.8–13.4
LM$_{1-3}$	7.89	7.8	8.3 ± 0.32	–	8.0 ± 0.17
		7.78–7.89	8.0–8.7		7.8–8.2

[a] FMNH 190163 (holotype), 190166.
[b] FMNH 62503, 62504, 169126, 188321, 193689, 193691.
[c] FMNH 189788.
[d] FMNH 147927, 147929, 147931, 148164, 148171, 148172.

tured at the type locality, including five females deposited at the Field Museum (FMNH 190161, 190162, 190164–190166), and one male deposited at the Central Mindanao University, Musuan, Bukidnon Province. One additional female specimen (FMNH 186819) was taken below the type locality, near a small lake, Tinagong Dagat, 3.75 km S, 1.75 km E Mt. Hamiguitan peak, 950 m, 06°42′26.2″N, 126°11′42.8″E.

The six specimens deposited at the Field Museum are preserved in ethyl alcohol, five with skulls removed and cleaned (FMNH 186819, 190161, 190164–190166). Muscle tissue was removed from the left thigh of each, and the stomach was removed for analysis of contents. Two specimens have broken crania and mandibles (FMNH 190165, 190166), but the others are in good condition.

Etymology.—The species is named after Mt. Hamiguitan, a mountainous ultramafic outcrop and the main topographic feature of the Pujada Peninsula, Eastern Mindanao (Balete et al. 2008b). The specific epithet is used as a noun in apposition. We propose ''Hamiguitan hairy-tailed rat'' as the English common name.
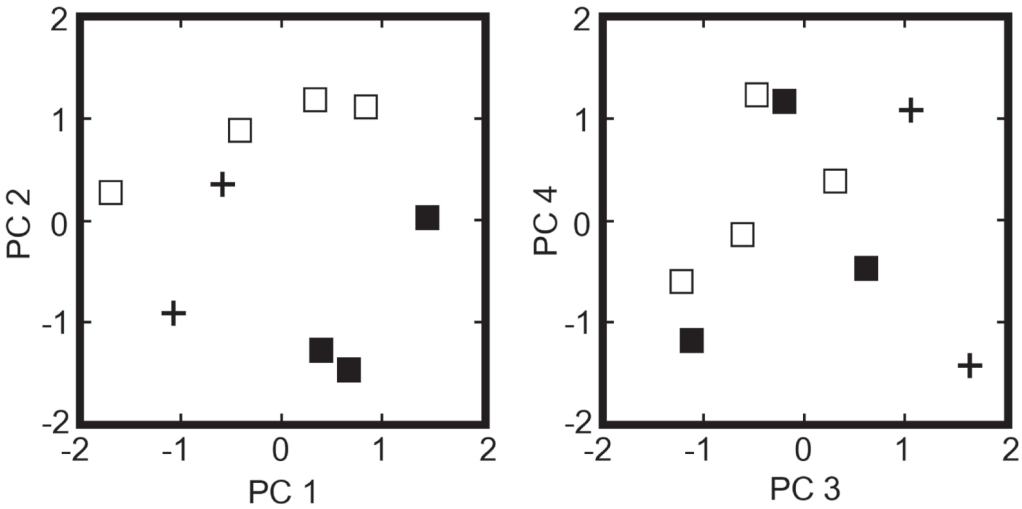

Fig. 2. Results of principal components analysis of measurements of adult specimens of *Batomys* (see Table 3): projections of specimen scores on components 1 and 2 (left) and on components 3 and 4 (right) for *B. granti* (solid squares), *B. salomonseni* (open squares), and *B. hamiguitan* (crosses).

Table 3.—Character loadings, eigenvalues, and percentage variance explained on the first four components of a principal components analysis of log-transformed measurements of adult *Batomys* (see Fig. 2). Variable abbreviations are defined in Materials and Methods.

Variable	Principal component			
	1	2	3	4
LHB	0.752	−0.401	0.170	−0.248
LT	0.530	−0.464	−0.563	−0.362
LHF	0.932	0.022	−0.157	0.233
LE	−0.458	0.144	0.046	−0.758
IB	0.010	0.957	0.134	0.070
LN	0.954	−0.015	0.164	0.190
LR	0.927	0.182	0.172	0.040
BR	0.973	0.133	−0.042	0.003
BZP	0.316	0.087	−0.086	0.176
LD	0.898	0.068	−0.021	0.275
PL	0.922	−0.042	−0.260	0.003
LIF	0.403	−0.414	0.744	−0.242
BIF	0.188	−0.083	0.655	0.380
LPB	0.415	0.588	−0.682	0.074
PBM^3	0.430	−0.658	−0.034	0.174
BMF	0.455	0.453	0.332	−0.111
LB	0.619	−0.230	0.034	−0.537
HB	0.673	0.274	−0.131	−0.453
LM$^{1-3}$	0.329	0.678	0.420	−0.317
Eigenvalue	8.102	3.129	2.279	1.815
Variance explained (%)	42.643	16.468	11.992	9.551

Fig. 3. *Batomys hamiguitan* (FMNH 190163, holotype), adult female from Mt. Hamiguitan, Davao Oriental Province, Mindanao. Photo taken 09 May 2006 by R. S. Quidlat.

Diagnosis.—*Batomys hamiguitan* is distinguished from other members of the genus by the following combination of traits: 1) mystacial and superciliary vibrissae longer than in all congeners; 2) tail absolutely and relatively shorter than in *B. granti* or *B. salomonseni*, absolutely longer but relatively shorter than in *B. russatus*; 3) pelage shorter and coarser than in *B. salomonseni*, longer and coarser than in *B. granti* or *B. russatus*); 4) skull shorter and broader than in *B. granti* or *B. salomonseni*, longer and broader than in *B. russatus*; 5) incisive foramina longer (extending beyond anterior edge of first maxillary molars) than in *B. russatus* or *B. salomonseni*, shorter than in *B. granti*; 6) palate shorter than in *B. granti* or *B. salomonseni*, longer than in *B. russatus*; 7) palatal bridge shorter and narrower than in *B. granti* or *B. salomonseni*, longer and wider than in *B. russatus*; 8) mandible shorter and narrower than in either *B. granti* or *B. salomonseni*, longer and higher than in *B. russatus*; and 9) cusp t9 of M3 consistently present and well developed (usually absent in other species, poorly developed when present).

Description and comparisons.—In general body form *Batomys hamiguitan* is most similar to *B. salomonseni* but differs from it and other congeners in body size, pelage color, and in various external, cranial, and dental features (Tables 1, 2; Figs. 3–5). The new species is of medium body size, with length of head and body that is only slightly shorter than in *B. granti* or *B. salomonseni* (shortest in *B. russatus*) but weighing less than either (Table 1).

The dorsal pelage of *B. hamiguitan* (Fig. 3) is yellowish-brown overall. It is shorter and coarser than in *B. salomon-*
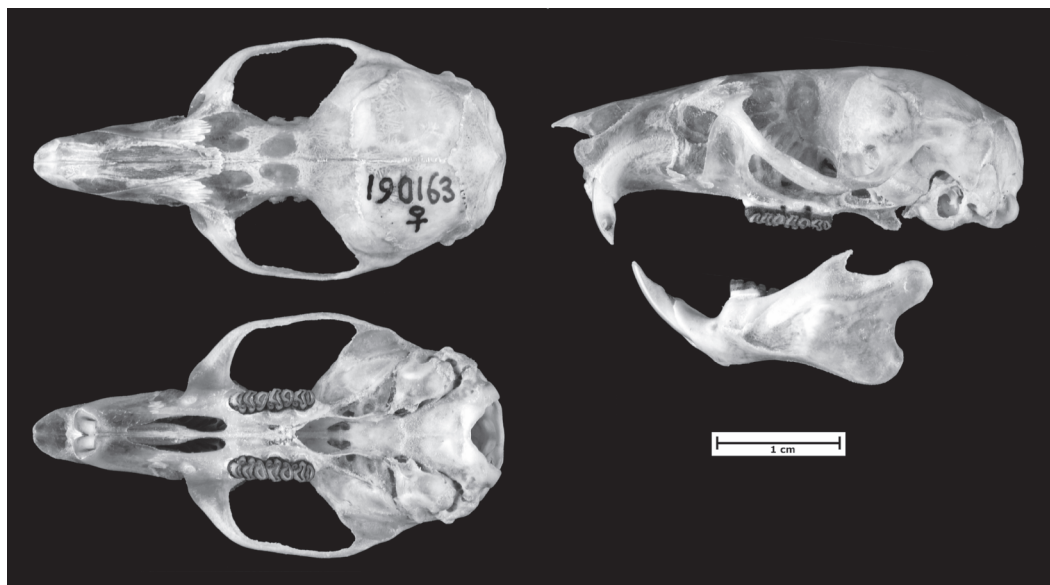
Fig. 4. Dorsal, ventral and lateral views of cranium and lateral view of mandible of the holotype of *Batomys hamiguitan* (FMNH 190163).

seni (which has sleeker, dark chestnut-brown fur) and is coarser but longer than in *B. granti* (which has pale reddish-brown fur), and in *B. russatus* (which has sleek brownish-red fur). The guard hairs in *B. hamiguitan*, 18–22 mm, are dark gray to black, with the distal 3–4 mm pale yellowish brown to unpigmented; they are longer and mainly with unpigmented tips on the rump region. The over-fur is 12–15 mm, slate gray at the bases, with the distal fifth pale yellowish-brown with short black to grayish-brown tips. The venter is grayish-buff overall, ca. 10–12 mm, grading imperceptibly into the dorsal color and without distinct demarcation between dorsum and venter. The ventral pelage varies from grayish brown to pale reddish-orange in *B. salomonseni*, pale grayish-buff in *B. granti*, to ochraceous in *B. russatus*, with irregular white patches on the venter sometimes present in the latter two species.

The skin around the eye is edged with a narrow band (less than 1 mm) of darkly pigmented skin, from which arises sparse, short, dark hairs, especially on the lower edge of the eye. This narrow, dark band is immediately surrounded by a narrow ring of pale skin. Long, fairly coarse, dark brown hairs are sparse on the inner portion of this pale ring but increase in density at points increasingly peripheral to the eye, gradually merging into the fur that covers the head. In a live specimen (Fig. 3), this pale ring was evident, creating a partial mask-like effect that became inconspicuous in the preserved state. Among other species of *Batomys*, the eye-ring of unpigmented naked skin is persistent in preserved specimens, brought about by the profusion of thick and long dark fur immediately surrounding its edges, creating a characteristic mask-like effect in *B. granti* and *B. salomonseni*, which is not conspicuous in *B. russatus*.

The ears of *B. hamiguitan* are smoothly rounded and slightly longer than in its congeners (Table 1), with the distal two-thirds pigmented dark gray, paler on the inside, covered with short dark and pale brown fur interspersed with a sprinkling of unpigmented (translucent/white)

strands. The basal third is unpigmented, covered with a mix of long and soft unpigmented and pale grayish brown fur with unpigmented bases. The facial vibrissae are longest in *B. hamiguitan*, extending well beyond ears and shoulders, with the mystacial vibrissae reaching to 80 mm, superciliary to 70 mm, and genal up 43 mm. In this respect, it is similar to *B. salomonseni* and *B. russatus* in having very long superciliary vibrissae (up to 45 mm in the former) that extend beyond the margins of the pinna—a trait that easily separates them from both *B. dentatus* and *B. granti* on Luzon (Musser et al. 1998).

The tail of *B. hamiguitan* is absolutely shorter than in *B. granti* or *B. salomonseni* (Table 1) but longer than in *B. russatus* (see Table 4 in Musser et al. 1998). At about 66% of combined head and body length, the tail of *B. hamiguitan* is also relatively shorter than in its congeners (up to 85% in *B. salomonseni* (Table 1; also see Table 4 in Musser et al. 1998). The tail of *B. hamiguitan* is slender, pigmented dark gray and covered with short hair. The possession of a slender tail with short hair suggests a close affinity of *B. hamiguitan* with congeners in the Mindanao Faunal Region, *B. salomonseni* and *B. russatus*, in contrast to the robust and hairy tail of *B. dentatus* and *B. granti* from Luzon (Musser et al. 1998). The tail of *B. hamiguitan* (Table 2) bears 10–11 scale rings/cm (TSR) and is most similar to *B. salomonseni* (up to 12 TSR). Each scale has three associated short hairs that are dark brown in the basal half, paler on the distal half with unpigmented tips. The middle hair is longest, overlapping with up to five scale rows, whereas outer hairs only extend over three scale rows. In contrast, *B. granti* has larger scale rings (9 TSR), and *B. russatus* has the finest (15 TSR).

The front feet of *B. hamiguitan* are short with robust digits that are dorsally unpigmented and covered with short, white hairs and marked by a band of grayish-brown fur tapering from the wrists to about the bases of the inner digits. The pollex bears a wide flat nail, and other digits have claws that are short, sharp, decurved, and opaque. The palmar surface is pigmented pale gray, including the base of palmar pads. The thenar and hypothenar are large and fleshy, and there are three interdigital pads, each about a quarter of the size of the thenar. On both front and hind feet, an ungual tuft of white hairs sprouts from the base of the opaque claws and extends to just short of the claw tips, a pattern also observed in *B. russatus*. In contrast, in both *B. granti* and *B. salomonseni*, the ungual tufts, also white, extend beyond the claw tips of both front and hind feet.

The hind feet of *B. hamiguitan* are absolutely shorter than in *B. granti* or *B. salomonseni* (shortest in *B. russatus*), but relative to HBL *B. hamiguitan* has the shortest hind feet among its congeners (Table 1). The dorsal surface of the hind foot of *B. hamiguitan* has a narrow band of medium grayish-brown fur that extends from the outer side of the leg near the ankle to about the mid-dorsal metatarsal area. The remainder is unpigmented and covered with short hairs (usually white but entirely pale grayish brown in FMNH 190165). In *B. salomonseni*, the entire dorsal skin surface of the hind foot is pigmented pale to medium gray, including the digits in some individuals (FMNH 147929, 147928) and is covered with a mix of medium brown and unpigmented hairs. Both *B. granti* and *B. russatus* have hind feet with unpigmented dorsal skin covered with a mix of short, dark grayish-brown fur with unpigmented tips and entirely unpigmented strands in the former, or with pale russet markings except on the digits in the latter.

The plantar surface, including the thenar, hypothenar and two outer digital pads, is pigmented pale gray (slightly darker on the elongate thenars). The
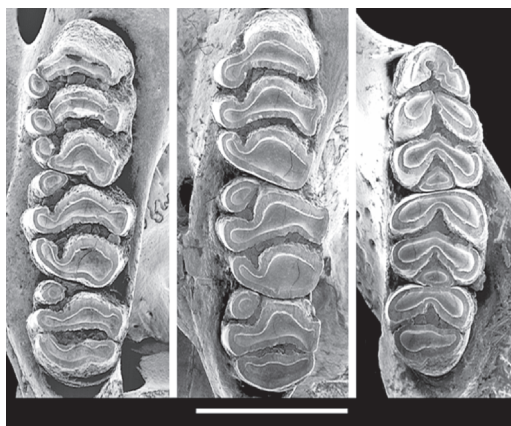
Fig. 5. Occlusal views of the right upper and right lower molar rows of *Batomys hamiguitan*: FMNH 190164 (left), FMNH 190163 (holotype, middle and right). The laminar configuration outlining cusp t9 (labial) on the third upper molar is distinct in a young adult (left); also evident but more worn in the holotype (middle). The short and broadly angled posterior cingulum at the back of first and second upper molar of a young adult (left) are distinct. Note the shorter and rounder lingual cusps of the first and second lower molars of the holotype (right), as well as its cordate and oblong porterior cingulum behind first and second molars, respectively. Scale bar = 5 mm.

plantar pads are small relative to the plantar surface. The hypothenar and outer interdigital pads (1 and 4) are similar in size, barely a third of the length of thenar, whereas the two inner interdigitals (2 and 3) are slightly smaller. In *B. salomonseni*, the plantar surface is pale grayish-brown, darker on the thenar and hypothenar, and the pads are larger relative to the plantar surface, with a hypothenar that is smaller than the two outer interdigitals, and the other interdigitals similar to or larger than the hypothenar. In *B. russatus*, the plantar surface, including pads, is unpigmented, whereas in *B. granti* the surface is generally unpigmented, but the thenar and hypothenar show dark to pale gray spotting in some individuals.

The cranial and dental morphology of *B. hamiguitan* (Figs. 4, 5) is similar to congeners (see Thomas 1898, Sanborn 1953, Fig. 6, and illustrations in Musser & Heaney 1992, Musser et al. 1998), but *B. hamiguitan* exhibits several features that are distinctive. The robust skull of *Batomys hamiguitan* is most similar to that of *B. salomonseni* in shape and relative dimensions (compare Figs. 4 and 6) but slightly smaller and shorter, whereas both species are smaller than *B. granti* and larger than *B. russatus* (Table 2). The rostrum of *B. hamiguitan* (Table 2, Fig. 4) is absolutely shorter and narrower than in *B. granti* or *B. salomonseni* (shortest and narrowest in *B. russatus*). The nasals are tapered, extending beyond the premaxillae and are shorter than in *B. granti* or *B. salomonseni* (shortest in *B. russatus*). The braincase is the broadest among the four species, nearly rounded and dorsolaterally inflated, and more than two-thirds as high as wide. *Batomys hamiguitan* has absolutely shorter frontals than *B. salomonseni* or *B. granti* (shortest in *B. russatus*). Relative to both skull length and length of rostrum, however, *B. hamiguitan* has the shortest frontals (less than a third of GLS and less than four-fifths of LR) whereas *B. russatus* has the longest (more than a third of GLS and longer than LR).

The zygomatic breadth of *B. hamiguitan* is a little more than half of the GLS (Table 3), and differs little from that of *B. granti* or *B. salomonseni* in absolute breadth (narrowest in *B. russatus*; Fig. 6). The zygomatic plate (Table 2) is only slightly narrower than in *B. granti* or *B. salomonseni* (narrowest in *B. russatus*), but the orientation of the zygomatic arch relative to the cranium is distinct in *B. hamiguitan*. The attachment of the squamosal root is lower relative to the height of the cranium, and its interior edge forms a wider and deeper sigmoid notch prior to attachment to the jugal. The resulting shape of the zygomatic process is a pronounced backward-dipping arch that is lower posteriorly than in congeners.

The incisive foramina of *B. hamiguitan* (Fig. 4, Table 2) are most similar in
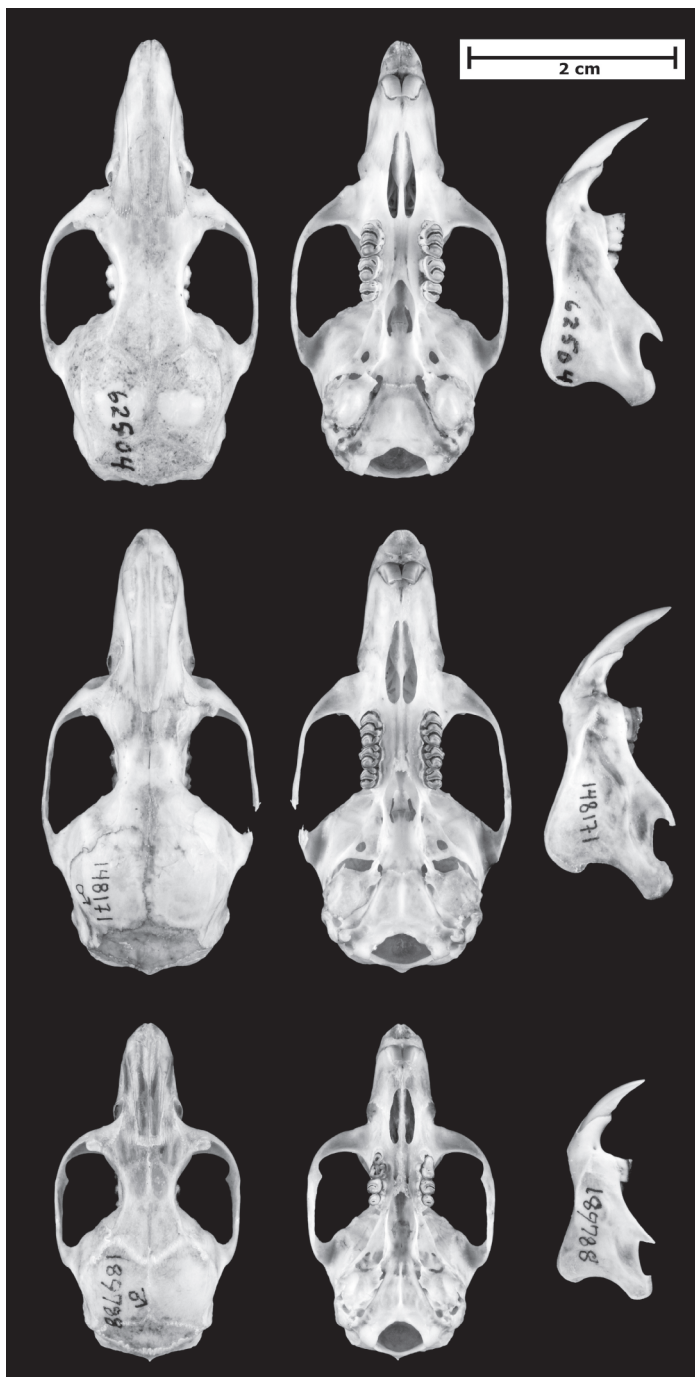
Fig. 6. Dorsal and ventral views of the crania and lateral view of the mandibles of three species of *Batomys*: top, *B. granti* (FMNH 62504); middle, *B. salomonseni* (FMNH 148171); and bottom, *B. russatus* (FMNH 189788).

length to *B. granti*, and in both species are absolutely longer than in *B. salomonseni* or *B. russatus*, but only slightly narrower than in *B. granti* or *B. salomonseni* (narrowest in *B. russatus*; Fig. 6). Also, the incisive foramina of *B. hamiguitan* extend posteriad beyond the anterior margins of the alveoli of M^1 (Fig. 4). In adult specimens of the other species, there is a distinct gap of ca. 1 mm or more between the posterior margins of the foramina and M^1 (Table 2; also see Figs. 8, 24, 25 in Musser et al. 1998). Although this condition appears consistent among adults, three of the four sub-adults of *B. salomonseni* that we examined (FMNH 74853, 92829, 175563) showed similar placement of the incisive foramina relative to the anterior margins of the M^1 as seen in adult *B. hamiguitan*.

The palate and palatal bridge of *B. hamiguitan* (Table 2) are shorter than in either *B. granti* or *B. salomonseni* (shortest in *B. russatus*), but palatal breadth at both M^1 and M^3 (Table 2) varies little among them, being only slightly narrower in *B. hamiguitan* than in *B. granti* or *B. salomonseni* (narrowest in *B. russatus*; Fig. 6). The bullar dimensions of *B. hamiguitan* are similar to those of congeners (Table 2, Fig. 4). The bullae are slightly smaller and positioned lower than in *B. granti* or *B. salomonseni* (smallest in *B. russatus*). The bulla is more similar to *B. granti* and *B. russatus* in the possession of a bony eustachian tube that is wider than that seen in *B. salomonseni*.

The basicranial region of *B. hamiguitan* is similar to that of *B. salomonseni*. Specifically, the carotid circulatory pattern is the derived condition that is also characteristic of B. *dentatus*, *B. granti*, and *B. salomonseni*, rather than the basal murid pattern seen in *B. russatus* (see Fig. 28 in Musser et al. 1998). The alisphenoid strut is absent in *B. hamiguitan*, as it is in *B. granti*, *B. russatus*, and *B. salomonseni*; a strut is present in *B. dentatus* (see Fig. 26 in Musser et al. 1998).

Basic dental features are similar among all species of *Batomys*, differing mainly in relative dimensions (Table 2, Figs. 4, 6; also see Figs. 12–15, 21 in Musser et al. 1998). The upper incisors of *B. hamiguitan* emerge at right angles to the rostrum, have smoothly rounded tips (tapered inward to straight in younger specimens), and a slightly convex and smooth anterior surface of yellowish-orange enamel. The breadth across the incisor tips is most similar to *B. granti* and is slightly narrower than in *B. salomonseni* (narrowest in *B. russatus*). The diastema is absolutely shorter than in either *B. granti* or *B. salomonseni* but longer than *B. russatus* (Table 2).

The molar tooth row of *B. hamiguitan* is most similar to *B. salomonseni* (Table 2, Fig. 5), with both being absolutely shorter than in *B. granti* and longer than in *B. russatus*. The molars of *B. hamiguitan* have the same high crown and broad cuspidate rows seen in other *Batomys* but are closer to *B. granti* and *B. salomonseni* in relative size than to the smaller *B. russatus*. Compared with either *B. granti* or *B. salomonseni*, however, the maxillary molars of *B. hamiguitan* have smaller lingual cusps t1, t4 and t7, as well as smaller cusps t8 on M^1 and M^2 (normally fused with the posterior cingulum in older specimens). Similarly, the mandibular molars of *B. hamiguitan* have shorter and rounder metaconids and entoconids, as well as smaller posterior cingula than in *B. granti* or *B. salomonseni*.

In *B. hamiguitan*, lingual cusps t1, t4, and t7 are distinct, whereas the remaining cusps in each row are fused and marked only by broad laminar outlines (Fig. 5). As with congeners, medial cusps t2, t5, and t8 on M^1 are broadly domed anteriorly and each constitutes about 75% of the occlusal surface of its respective cuspidate row. On the second row, cusp t5 is merged with the labial t6, but in younger individuals of *B. hamiguitan*, t6 can be easily observed (FMNH 186819,

190161). On the third row, t8 is fused with the posterior cingulum to form an even broader occlusal surface than in the upper two rows, the latter forming an arcuate extension of the posterior laminar outline. Among the six specimens of *B. hamiguitan* that we examined, however, only the holotype (FMNH 190163) has no evident trace of a posterior cingulum.

On both M^2 and M^3 of *B. hamiguitan*, the first row of cusps lacks t2 but retains a prominent, circular to ovate, lingual cusp t1. The labial cusp t3 is usually vestigial, manifested only by a narrow cingular shelf on the lower anterolabial edge of each molar, although in the holotype (FMNH 190163) a small but distinct t3 is evident on M^2 (Fig. 5). In contrast, t3 of the same molar on *B. salomonseni* is persistent and distinct on at least 75% of the 21 specimens we examined. As on the first molar, the remaining cusps in the second and third rows of M^2 and M^3 of the new species are fused into broad basins with laminar outlines. *Batomys hamiguitan* is notable in retaining a distinct trace of t9 in the lingual laminar outline of M^3. This persistence of t9 on M^3 is evident in all the specimens that we examined (Fig. 5) but is most evident among young adults (e.g., FMNH 190161, 190164). This condition may depend on the age of the individual, and the evidence of t9 is less likely to be retained as the molars become worn. For instance, among specimens of the other species that we examined, only the two subadults (FMNH 74853, 92829) of *B. salomonseni* exhibited this characteristic (see also Fig. 12 in Musser et al. 1998), whereas all adults, except for oldest, retain an undifferentiated laminar outline framing the basin of the fused cusps t8 and t9.

The mandible of *B. hamiguitan* (Table 2, Fig. 4) is similar in most respects to that of its congeners, differing only in relative size and condition of a few features. *Batomys russatus* has the shortest and smallest mandible among conge-

ners (Fig. 6, Table 2). *Batomys hamiguitan* is closest to *B. granti* and *B. salomonseni* in length of the dentary but differs from them in its smaller and narrower angular process, shorter and narrower condyloid process, and a shorter coronoid that is broadly angled from the condyloid process. The mandibular molar toothrow and lower incisors of *B. hamiguitan* are shorter than in *B. granti* or *B. salomonseni* (Table 2, Fig. 5). On both M_1 and M_2 of the holotype, the posterior cingulum is cordate and small relative to the breadth of the occlusal surface of the second and third cuspidate rows, and barely a third of the width of the third row. In contrast, the posterior cingulum of M_1 and M_2 in *B. salomonseni* is absolutely and relatively wider, accounting for as much as half of the width of the occlusal surface of the third cuspidate rows (see for instance Fig. 14 in Musser et al. 1998) and is wider still in *B. granti*, accounting for as much as two-thirds of the width of the occlusal surface of the third row (FMNH 188321). The shape of the posterior cingulum, however, appears to vary with age of the individuals. In the younger specimens of *B. hamiguitan*, the shape varies from almost round to oblong. On the other hand, the cordate posterior cingulum in *B. salomonseni* (see Fig. 14 in Musser et al. 1998) appears to be more common among young individuals than among adults we examined, which have a more round to oblong-shaped posterior cingulum especially on M_2.

Ecology and conservation.—In a recent survey of the mammals of Mt. Hamiguitan (Balete et al. 2008b), *Batomys hamiguitan* was recorded in transitional lowland/montane forest at 950 m and in primary montane forest at 1128 m. At ca. 545 m elevation, extensive trapping effort (924 trap-nights) failed to record *B. hamiguitan*. Its occurrence in upper montane and mossy forest at higher elevations could not be ascertained because no

trapping was conducted above the type locality. *Batomys hamiguitan* appears to be relatively more abundant in primary montane forest at the type locality (1128 m) than in transitional lowland/montane forest at 950 m (0.91% and 0.12% trap success, respectively, using the same bait). Elevational distribution and habitat associations of *B. hamiguitan* are similar to those of *B. granti* and *B. salomonseni*. On Mt. Kitanglad, *B. salomonseni* was documented from residual montane forest at 1450 m up to old-growth mossy forest at 2375 m, and in the Central Cordillera of Luzon, *B. granti* was recorded in montane and mossy forest between 1600 m and 2480 m (Heaney et al. 2006, Musser et al. 1998). In contrast, *B. russatus* appears to be limited to the lowlands on Dinagat Island (Musser et al. 1998).

Vegetation at the type locality and the adjacent site on Mt. Hamiguitan where specimens were recorded was dominated by Podocarpaceae, including *Podocarpus*, *Dacrycarpus* and *Dacrydium* spp., as well as Araucareaceae (*Agathis*) and Myrtaceae (*Syzygium* spp.). Mountain agoho (*Gymnostoma* sp.) was present but uncommon above 1000 m. Understory and forest floor vegetation included erect pandans (*Pandanus* spp.), tree ferns (*Cyathea* spp.) and lianas, rattans (*Calamus* spp.), and climbing pandans (*Freycinetia* spp.). Ferns, pitcher plants (*Nepenthes* spp.) and orchids were common epiphytes. Mosses, lichens, and liverworts covered trunks and branches of trees and understory vegetation. Canopy height was typically 5–7 m, with sections along ridges that were reduced to barely 0.5 m high (locally referred to as "bonsai forest"). Thin to moderate layers of leaf litter and humus covered the forest floor (Balete et al. 2008b).

All eight individuals of *B. hamiguitan* were captured in traps baited with roasted coconut coated with peanut butter; none were captured in traps baited with live earthworms. This is a strong indication of its herbivorous habits, similar to those of *B. salomonseni* on Mt. Kitanglad (Heaney et al. 2006). Stomach contents of six individuals contained almost exclusively finely chewed white to dark brown vegetable matter, as well several pieces of roughly chewed cotyledons. No evidence of earthworms or arthropods was found in their stomachs. As with *B. salomonseni* on Mt. Kitanglad (Heaney et al. 2006) and *B. granti* on Mt. Isarog (Rickart et al. 1991, Heaney et al. 1999), the diel activity pattern of *B. hamiguitan* appears to be exclusively nocturnal (there were no daytime captures).

Two primiparous females captured in May (FMNH 190165, 190166) were pregnant, each with a single embryo (CRL: 4 mm and 13 mm, respectively). Three other young adult females captured during the same period were nulliparous (FMNH 190161, 190162, 190164). A young adult (FMNH 186819) captured in July had a swollen left horn of the uterus that was highly vascularized, indicating reproductive activity. In *B. salomonseni* on Mt. Kitanglad, pregnancies were observed in March and several juveniles were captured during the same period. Litter size based on the number of embryos was 1 or 2 (Heaney et al. 2006).

Four additional species of native, non-volant small mammals occurred at the sites where the new species was recorded (Balete et al. 2008b), including two insectivores (*Crocidura beatus* and an undescribed species of *Podogymnura*) and two murid rodents (*Bullimus bagobus* and *Rattus everetti*). Both *C. beatus* and *B. bagobus* are endemic to the Mindanao Faunal Region, and *R. everetti* is widespread throughout most of the oceanic islands of the Philippines; the undescribed *Podogymnura* is potentially restricted to the Mt. Hamiguitan range (Heaney et al. 1998, 2006; Balete et al. 2008b). Additionally, *Rattus exulans*, a non-native species, was recorded in disturbed areas

adjacent to the type locality. It appeared to be restricted to narrow patches of cogon (*Imperata cylindrica*) in recently burned areas surrounding the shoreline and exposed dry lake bed of Tinagong Dagat, and along the established foot trail through the montane forest. *Rattus exulans* was not recorded in the intact forest where the native species occurred (Balete et al. 2008b).

Trapping data from the high elevation habitats where *Batomys hamiguitan* occurs (transitional lowland/montane and primary montane forest) indicate that it is a moderately common species, comparable in relative abundance to *B. salomonseni* on Mt. Kitanglad (Heaney et al. 2006, Balete et al. 2008b). Balete et al. (2008b) noted moderate habitat disturbance at sites where the new species was recorded, mainly involving hunting of large mammals and mountaineering, but there was no direct exploitation and the population of *B. hamiguitan* appeared stable where it occurred. However, several potential factors existed that might negatively affect *B. hamiguitan*, including mining of adjacent ultramafic outcrops, unregulated tourism, and hunting of small mammals for food by local people (Balete et al. 2008b). We recommend a direct assessment of the vulnerability of this species to these activities, as well as increasing the current area of Mt. Hamiguitan Wildlife Sanctuary to ensure protection of representative habitats on Mt. Hamiguitan.

Biogeography.—Few mountains on Mindanao have been sampled extensively, and only Mt. Kitanglad has been surveyed thoroughly (Heaney et al. 2006). The limited data suggest that the mountains of central Mindanao share a fairly homogeneous small mammal fauna, perhaps associated with the rather homogeneous geological history of this part of Mindanao (Musser & Heaney 1992, Sajona et al. 1997, Heaney et al. 2006). Because the several mountain masses of eastern Mindanao are both physically isolated (Fig. 1) and of different geological origin from one another (Sajona et al. 1997), we predicted that they would each be found to support endemic species of mammals, as we have seen in parallel situations on Luzon Island (Rickart et al. 1998, 2005; Balete et al. 2006, 2007, 2008a). The discovery of *Batomys hamiguitan* is consistent with this prediction and also strengthens the perception of a general pattern of endemism in highland areas across the entire Philippines (Heaney & Rickart 1990, Steppan et al. 2003, Heaney 2004, Jansa et al. 2006, Balete et al. 2007, 2008a).

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Appendix 1
Specimens Examined

We examined all of the available specimens of *Batomys* housed at the Field Museum, Chicago (FMNH; $n = 46$). Specimens were prepared as study skins with cleaned skulls, complete skeletons, or fixed in formalin and stored in 70% ethyl alcohol (some with skulls subsequently removed and cleaned).

Batomys granti ($n = 7$).—Luzon Island, Kalinga Province, Balbalan Municipality, Barangay Balbalasang, Amlicao, 1800 m, 17°26′30″N, 121°04′15″E (FMNH 169126); Mountain Province, Mt. Data (FMNH 62503, 62504); Bauko Municipality, 0.1 km E south peak Mt. Data, 2290 m, 16.85888°N, 120.86078°E (FMNH 188323), 0.75 km N, 0.6 km E south peak, 2241 m, 16.86287°N, 120.86108°E (FMNH 188321); Barlig Municipality, 0.4 km N, 0.4 km W Mt. Amuyao peak, 2480 m, 17.01727°N, 121.12393°E (FMNH 193689); 1.75 km N, 0.4 km W Mt. Amuyao peak, 1885 m, 17.02929°N, 121.12466°E (FMNH 193691).

Batomys salomonseni ($n = 30$).—Mindanao Island, Bukidnon Province, Kitanglad Range, Mt. Kitanglad, 10.6 km S, 2.8 km W Sumilao Poblacion, 1450 m, 8°11′20″N, 124°55′20″E (FMNH 167385); 10.7 km S, 2.9 km W Sumilao Poblacion, 1450 m, 8°11′10″N, 124°55′10″E (FMNH 167386); 11.5 km S, 2.2 km W Sumilao Poblacion, 1500 m (FMNH 167384); Mt. Imbayao, 15 km S, 7 km E Baungon, San Vicente Municipality, 1800 m, 8°9′N, 124°45′E (FMNH 146719, 146720, 147103, 147104); Mt. Nangkabulos, 16.5 km S, 4 km E Camp Phillips, 1900 m, 8°10.5′N, 124°51′E (FMNH 147927, 147929, 147933, 147934, 147944, 148163–148165); Mt. Nangkabulos, 15.5 km S, 4 km E Camp Phillips, 2250 m, 8°9.5′N, 124°51′E (FMNH 147931, 147940, 147941, 148170–148173); Mt. Dulang-dulang, 15 km S, 11 km W Dalwangan, Malaybalay City, 2375 m, 8°7.5′N, 124°56′E (FMNH 148033, 148034); Mt. Kitanglad, 5000 ft (1524 m), (FMNH 92823, 92826–92829); Mt. Kitanglad, 1600 m (FMNH 74843).

Batomys russatus ($n = 1$).—Dinagat Island, Surigao del Norte Province, Loreto Municipality, Bgy Cambinlio, Balitbiton, 350 m, 17°27.5′N, 122°04.1′E (FMNH 189788).

Batomys hamiguitan ($n = 8$).—See ''Taxonomic description'' above.