



Proximate, caloric, nitrogen and mineral composition of bodies of some tropical bats

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Proximate (live mass, water, lipid, ash, non-fat organic), caloric, nitrogen, and mineral (sodium, potassium, calcium, magnesium, and iron) concentrations and total body content of individuals of 24 species of Neotropical and Paleotropical bats were determined. Mass-related, concentration patterns were found for all measured variables, except iron. Concentrations increase with size for nitrogen, calcium, and magnesium but are concave, opening upward, for sodium and potassium. These last two elements reach minimal concentrations in bats weighing about 22 and 28 g dry mass, respectively. Total body content of nitrogen and minerals was compared with amounts in similar-sized birds and tetrapodal mammals.

Key words: Bat; Bird; Mammal; Body composition; Nitrogen; Sodium; Potassium; Calcium; Magnesium; Iron.

Comp. Biochem. Physiol. 109A, 601-610, 1994.

Introduction

Studies of body composition of tropical and temperate bats have been limited mainly to variables such as caloric content and lipid levels, which are related to energetics (McNab, 1976). Similar emphases have been applied to other small mammals (Studier, 1979) and birds (Holmes, 1976). That trend relates directly to the implied critical importance of energetics as a probable limiting factor in maintaining adequate nutritional budgets in small endotherms. Recent investigations in birds (Hungerford *et al.*, 1993), other small mammals (Randolph *et al.*, 1991; Willig and Lacher, 1991), and bats (Studier and Kunz, 1994)

have expanded studies of nutrition to include nitrogen and mineral requirements and budgets. Just as body energy concentration (Cummins and Wuycheck, 1971) is essential in the calculation of energy budgets, similar estimates of nitrogen and mineral levels are necessary to establish budgets for those nutrients. Limited data are available on nitrogen and mineral concentration and content in small birds (Bilby and Widdowson, 1971; Sturges *et al.*, 1974; Hagen *et al.*, 1976; Pinowski *et al.*, 1983; Taylor and Konarzewski, 1992) and other mammals (Gentry *et al.*, 1975); however, no data have been published on levels of those elements in bats. We present data on live mass, water, fat, and non-fat organic matter, as well as on nitrogen, sodium, potassium, calcium, magnesium and total iron levels in a broad sample of tropical bat

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Received 31 January 1994; accepted 10 June 1994.

species. Portions of those data are compared with data on temperate bats. Nitrogen and mineral levels in bats are compared with levels in small, tetrapodal mammals and with small birds to investigate whether bat body composition reflects that of other mammals, or if composition is modified by physical demands of flight.

Materials and Methods

Paleotropical bats were collected by members of the 1979 Taylor South Seas Expedition from the Natural History Museum of Los Angeles County from mid-June through early August 1979 from various sites on New Ireland and New Britain Islands in Papua/New Guinea. Those specimens were sent to us as uniformly and finely ground whole bats in individual ziplock bags with labels indicating live and dry mass and gender of each specimen. These samples were re-dried to constant mass at 50–60°C before analyses.

Neotropical bats were mist-netted between 18.00 and 19.30 hr during July 1992 at various sites near the Amazon or Napo Rivers downstream from Iquitos, Perú. Captured bats were held for 1–3 hr in monkscloth or burlap bags, allowing the gut to empty for feces collection. Selected male bats and female bats, which were not obviously pregnant or lactating, were euthanized, weighed to 0.01 g (American Scientific Battery-Powered Scale) to determine live mass, then partially dried. Upon return to the lab, bats were dried to a constant weight at 50–60°C, and dry mass (DM) was determined to 0.1 mg. Dried bats were individually ground to a uniform mixture in a Braun coffee grinder.

Depending on the total DM of each specimen, duplicate or triplicate 0.5 g subsamples (weighed to 0.1 mg) were analyzed for fat, non-fat organic matter, and ash content. Fat was extracted with 50 volumes of petroleum ether in 125 ml Erlenmeyer flasks that were mixed on rotary shakers for 4 hr. Extracted samples were then filtered and rinsed with petroleum ether through pre-weighed filter paper, then dried to constant mass in a hood, and sample fat was determined by DM loss. Fats extracted with petroleum ether are primarily stored, neutral body fats, not including all polar

membrane lipids. These dried samples were then burned in a muffle furnace at 500°C for 6 hr and re-weighed to determine non-fat organic matter and ash content. Individual reported values are means of two or three replicates. Water and fat indices (as g/g lean DM) were calculated from those values. Caloric density (kcal/g DM) was calculated using energy equivalents of 9.4 kcal/g fat and 4.1 kcal/g non-fat organic matter. These procedures are reviewed by Pierson and Stack (1988).

Depending on the DM of each specimen, duplicate or triplicate 250 mg (weighed to 0.1 mg) samples were digested in 250 ml volumetric flasks using 2.5 ml of boiling, concentrated H₂SO₄ followed by 7.5 ml of a 2:1 (v/v) mixture of 30% H₂O₂ and concentrated H₂SO₄. After appropriate dilution, aliquots of those digestions were analyzed for nitrogen by Nesslerization (Treybig and Haney, 1983), for sodium and potassium levels by flame emission spectrophotometry, and for calcium, magnesium and total iron by atomic absorption spectrophotometry. Details of these analyses are given in Studier and Sevick (1992). Average values for replicates are reported.

Data were stored in Lotus files and analyzed using SYSTAT (Wilkinson, 1989). Most data previously reported for nitrogen and mineral concentrations and total content in each group compared (bats, other mammals, small birds) are from small species (<40 g DM), with very few data for larger species in any of those groups. Reported regression analyses are, therefore, certainly more precise at the lower end of the DM scale. SYSTAT regression analyses allow for identification of data points that are statistical outliers or exert significant leverage within the analysis. No such data points were found; therefore, the few data for bats of large mass do not unduly influence the reported regression lines. Linear and polynomial regression analyses were performed, and only significant regression coefficients are reported for 200 individuals of 24 species of bats and on average values for each of 25 species of birds. Published linear regression analyses for 26 or 27 species of rodents and shrews were used for comparison with bird and bat data. Our data might have been analyzed to yield allometric equations after log–log trans-

formation; and, many physiological functions have been shown to be exponentially related to size (Peters, 1983); however, such analysis would not be comparable with previously published data on body composition.

Since our primary interest in these data is body concentrations and total content of nitrogen and minerals, data for those elements have been analyzed and discussed more thoroughly than proximate and caloric data. Reduced data, shown in Appendix 1, will allow sexual dimorphism differences to be compared, will allow measured variables to be re-calculated in other units, e.g. ash-free or fat-free DM, for comparison to literature data reported in such units, and will allow calculation of regression equations (on transformed data, if desired) or other statistical testing on species averages.

Results

Reduced data for all measured and calculated variables for all bats analyzed are given by species and gender in Appendix 1. Data for individual bats are available on diskette or in hard copy from the authors upon request. Body water content (water in g/100 g live mass) increases slightly, but significantly ($F = 8.643$, d.f. = 192, $r^2 = 0.043$, $P = 0.00369$), with increasing size (DM in g) as expressed by:

$$\text{Water} = 0.0006659 \text{ DM}^2 + 67.19. \\ (\pm 0.0002265) \quad (\pm 0.18),$$

where values in parentheses are standard

errors of the regression coefficient(s) and intercept. The very low r^2 value, however, indicates that water content and the other relations of proximate variables to body size have very low prediction accuracy. Body fat (fat in g/100 g live mass) and fat index (FIND in g/g lean DM) are both inversely related to body size as DM in g ($F = 5.290$, d.f. = 192, $r^2 = 0.027$, $P = 0.0225$; and, $F = 3.615$, d.f. = 192, $r^2 = 0.037$, $P = 0.0288$, respectively) as shown by the equations:

$$\text{Fat} = -0.0004127 \text{ DM}^2 + 3.719, \\ (\pm 0.0001794) \quad (\pm 0.139)$$

and

$$\text{FIND} = \\ -0.0000408 \text{ DM}^2 + 0.00185 \text{ DM} + 0.119. \\ (\pm 0.0000163) \quad (\pm 0.00100) \quad (\pm 0.008)$$

Total body organic content (TORG = non-fat organic matter + fat in g/100 g live mass) is also inversely related to body size as DM in g ($F = 6.942$; d.f. = 192, $r^2 = 0.035$, $P = 0.00911$) as follows:

$$\text{TORG} = -0.0005583 \text{ DM}^2 + 27.46. \\ (\pm 0.0002119) \quad (\pm 0.16)$$

The only other variables found to relate to size were most measured elements. Results of polynomial regression analyses of body concentrations (in mg/g DM) of measured elements as potential functions of body size (DM), with the exception of total iron, which exhibits no relationship, are best expressed by linear or curvilinear equations that are poorly predictive

Table 1. Significant polynomial regression equations of element (E) concentration (in mg/g dry mass) as functions of size (in g dry mass) in tropical bats

E	a	b	c	F	r^2
N	0.002275 ± 0.000731		155.03 ± 0.55	9.679	0.046
Ca		0.2789 ± 0.0204	13.976 ± 0.310	187.33	0.482
Mg	0.0001086 ± 0.0000111		0.9357 ± 0.0084	94.904	0.321
Na	0.0003819 ± 0.0000850	-0.01659 ± 0.00522	4.389 ± 0.043	12.195	0.109
K	0.001697 ± 0.000236	-0.09475 ± 0.01451	9.823 ± 0.119	25.776	0.205

Data for 24 species are included. Values are coefficients and intercepts (\pm SE) for lines of the form $y = ax^2 + bx + c$. In each case, d.f. = 199 and $P < 0.0001$, except for nitrogen (N) where $P = 0.0021$.

Table 2. Significant polynomial regression equations for total body element (*E*) level (in mg) as functions of size (in g dry mass) in tropical bats

<i>E</i>	<i>a</i>	<i>b</i>	<i>c</i>	<i>F</i>	<i>r</i> ²
N	0.1841 ±0.0171	152.9 ±1.1	-2.565 ±8.628	65619.0	0.998
Fe		0.3537 ±0.0094	0.3908 ±0.1438	1403.8	0.875
Ca	0.3189 ±0.0135	12.04 ±0.83	9.439 ±6.786	3799.9	0.974
Mg	0.008858 ±0.00423	0.8157 ±0.0260	0.2478 ±0.2132	7111.4	0.986
Na	0.01882 ±0.00118	3.747 ±0.073	1.785 ±0.595	12008.0	0.992
K	0.06539 ±0.00323	6.817 ±0.198	8.782 ±1.629	7736.6	0.987

Data for 24 species are included. Values are coefficients and intercepts (± SE) for lines of the form $y = ax^2 + bx + c$. In each case, d.f. = 199 and $P < 0.0001$.

(Table 1). Relationships of total body content (in mg) of measured elements to body size (DM) show highly predictive positive linear or curvilinear relationships (Table 2).

Discussion

The slight increase in relative body water with increasing size found in the tropical bats tested may be associated with decreasing surface area-to-mass ratio that accompanies increasing size in similarly shaped organisms, and consequent relative decrease in evaporative water loss rates (Studier, 1970). Lack of a significant relationship of water index (g water/g lean DM) to size, however, argues strongly against that explanation. The slight increase in relative body water is more likely related to observed slight decreases in body fat fraction, i.e. body water is constant when expressed on a fat-free basis.

Data, reviewed by McNab (1976), show that fat levels in temperate zone bats cycle seasonally and are generally higher in females than in males. His study on limited numbers of neotropical bat species supports gender related trends for insectivorous species and seasonal trends for bats of varying feeding habits; however, seasonal trends are much less dramatic in bats that feed primarily on food of plant origin. Values reported here (Appendix 1) agree well with very low fat levels found by McNab (1976) for bats collected in July. The significant slight decrease in fat index, which, like the water index, is related to

lean dry mass, implies that an actual decrease in body fat occurs with increased body size.

Although sample size is small, *Chiroderma villosum*, especially females, contain much more fat, on either a live mass or lean dry mass basis (Appendix 1), than other species tested. For a fruit eating species (Gardner, 1977), especially in July, such high body fat levels are highly unusual and suggest marked differences in occurrence and activity of enzymes (fatty acid synthetase complex) required for converting carbohydrates to fat.

Many fruit-feeding bats seem to lack the ability to store excess energy as fat and, by storing that excess as glycogen, possess few energy reserves (Studier and Wilson, 1991). Another exception may be the genus *Leptonycteris*, individuals which deposit large stores of subcutaneous fat as well. However, both species of *Leptonycteris* are subtropical, and at least some populations are migratory (Arita and Wilson, 1987).

Lack of a relationship of total ash or non-fat organic matter to size also supports the interpretation that body water is constant when expressed on a fat-free basis. In view of the direct positive relations found for most tested body element concentrations (Table 1), a positive relationship of ash fraction to body size is expected. Greater precision in measuring slight differences in concentrations of elements compared with determination of ash may explain lack of statistical significance.

Lack of a relationship of total ash to size, when coupled to the inverse relation of fat

to size, explains the slight negative correlation of total body organic level to body size.

Lack of an inverse relationship of caloric density to size is surprising in view of the inverse relation of fat to size. Gender relationships are strongly correlated with fat content, with females showing higher caloric content than males in every case but one. *Carollia perspicillata* males show slightly elevated caloric densities, as well as slightly higher fat and fat index values.

Body nitrogen concentrations increase with size in bats (Table 1) and, perhaps, in other small mammals (see Munro, 1969; Gentry *et al.*, 1975). Insufficient data on body nitrogen concentrations for birds are available to complete an appropriate regression analysis; however, data for individual species (Bilby and Widdowson, 1971; Hagen *et al.*, 1976; Pinowski *et al.*, 1983; Taylor and Konarzewski, 1992; and Hungerford *et al.*, 1993) fall very near the regression equations for bats and other small mammals. Since body nitrogen is often assumed to be almost entirely present as protein and most body protein is in muscle, increases in nitrogen concentration with increasing size strongly suggest relatively greater body musculature with increasing size in all small vertebrate endotherms.

Of the minerals measured, only total iron concentration exhibited no relationship to size. Because total blood volume and hemoglobin mass relate directly and linearly to size in mammals (Peters, 1983), iron concentration should be constant and not size-dependent. No relationship exists between body iron concentration and body size in other small mammals (Gentry *et al.*, 1975) and our analyses of data available for small birds (Bilby and Widdowson, 1971; Sturges *et al.*, 1974; Hagen *et al.*, 1976; Pinowski *et al.*, 1983; Taylor and Konarzewski, 1992; Hungerford *et al.*, 1993) indicate a similar lack of relationship in that class. Average body iron concentrations in small birds (0.308 ppt DM; Sturges *et al.*, 1974) are identical to concentrations in non-bat, small mammals (0.303 ppt DM; Gentry *et al.*, 1975) and both are lower than most values for small bats (Appendix 1).

Among all bats tested, body sodium and

potassium concentrations generally increase with body size (Table 1). The relationships, however, are curvilinear with minimal (Studier *et al.*, 1975) body concentrations of both sodium (=4.03 ppt DM at = 21.7 g DM) and potassium (=7.18 ppt DM at 27.9 g DM). If data for bats of body DM < 50 g are analysed (Appendix 1), no relationship of either mineral to size is found. No relation for either mineral to size was found in other small mammals (Gentry *et al.*, 1975), and analyses of data for birds (from the same sources given for iron above) show no relation to size for potassium and a negative relation for sodium concentrations to body size ($F = 13.51$; d.f. = 23, $P = 0.0013$, $r^2 = 0.381$, regression coefficient \pm SE = -0.1355 ± 0.0037). Average body sodium concentrations in birds (4.10 ppt DM; Sturges *et al.*, 1974) and non-bat small mammals (3.68 ppt DM; Gentry *et al.*, 1975) compare favorably with minimal values for bats; and minimal potassium values in bats are similar to those for birds (8.12 ppt DM; Sturges *et al.*, 1974), but somewhat lower than in other mammals (11.5 ppt DM; Gentry *et al.*, 1975).

In bats, both calcium and magnesium body concentrations increase curvilinearly with body size, with minimal concentrations found at the origin (Table 1). Because concentrations of both elements increase rapidly with DM, comparisons with average values for birds (Sturges *et al.*, 1974) and other small mammals (Gentry *et al.*, 1975) are meaningless. Lack of a relationship of concentrations of each of these minerals to body size in mammals (Gentry *et al.*, 1975) and birds (from the same sources given previously for iron) is very surprising since skeletal mass has been shown to relate allometrically (as an exponential function > 1) to body size in many vertebrates (Kayser and Heusner, 1964; Reynolds and Karlotski, 1977; Prange *et al.*, 1979; Anderson *et al.*, 1979).

At similar dry masses, total body nitrogen content in bats (Table 2) exceeds values for other mammals (Gentry *et al.*, 1975). Greater nitrogen levels in bats strongly suggest that bats exhibit greater muscle mass than quadrupedal mammals of similar size and, furthermore, that musculature required for powered flight in bats exceeds requirements for terrestrial locomotion.

Insufficient appropriate data exist for comparison with birds.

Total body iron content is essentially identical in bats (Table 2) and birds and both are higher than values in other mammals of similar size (Fig. 1). Because many bats have higher blood volumes, RBC counts and hemoglobin levels than other mammals (Kallen, 1977; Riedesel, 1977), higher total body iron levels in bats are expected. These blood measures are also high in many small birds (Pettingill, 1970), which would also be expected to exhibit total iron levels similar to bats. The presence of higher levels of myoglobin in the predominant slow-twitch cells in the flight musculature of both birds and bats may also contribute to the higher iron levels found in those two groups.

Total body contents of sodium and potassium are similar to each other, in that each element in birds increases somewhat less rapidly with size than in bats and other mammals (Table 2; Fig. 1). These differences are minimal among small (<40 g DM) species and become progressively more pronounced in larger species, where bat body content exceeds levels in other mammals. Similarities in total body content of these minerals are expected since sodium is the primary extracellular fluid cation and potassium is the primary intracellular cation in both birds and mammals.

Among the small (<40 g DM) endothermic vertebrates compared, no differences were found in the increases of both calcium and magnesium contents with size (Table 2; Fig. 2). Large bats contain more of both minerals than other mammals or birds of similar size. Because magnesium and calcium are highly sequestered in the skeleton, differences were expected among the three groups tested based on variations in supportive characteristics of skeletons of quadrupeds and physical demands that sustained flight impose on the skeleton. Higher contents of these minerals in very large bats suggest that they store proportionately more of the calcium and magnesium needed for reproduction. Additionally, increased wing loading in larger bats that employ greater flight speeds (Findley *et al.*, 1972) may increase skeletal physical stresses of flight

disproportionately in very large bats but not birds.

In summary, fat and total organic content, although quite variable, decrease and water content increases with increasing body size expressed. Although body fat levels in tropical bats are routinely lower than in temperate species, occasional species, e.g. *Chiroderma villosum*, especially females, show much higher fat concentrations than other tropical species. Except for iron, where no relationship exists, concentrations of other measured elements increase with increasing body DM. Sodium

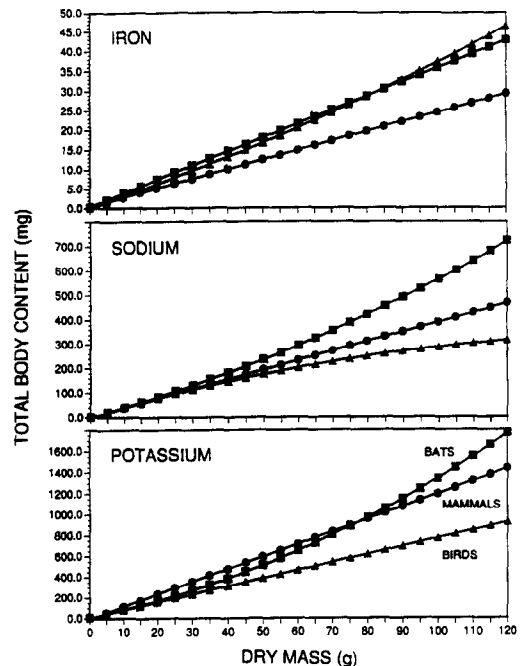


Fig. 1. Solutions to regression equations relating total body iron (top), sodium (middle) and potassium (bottom) content (in mg) to body size (dry mass = DM in g) in bats (squares), other small mammals (circles) and small birds (triangles). Equations for bats (24 species) are given in Table 2. For other small mammals (rodents and insectivores), linear regression equations for 25 or 26 species are given by Gentry *et al.* (1975). Polynomial regression equations (coefficients \pm SE) for small birds (21–24 species) were calculated from average values reported by Bilby and Widdowson (1971), Sturges *et al.* (1975), Hagen *et al.* (1976), Pinowski *et al.* (1983), and Taylor and Konarzewski (1992). In birds, total body iron content = $0.000765 \pm 0.000187 \text{ DM}^2 + 0.294 \pm 0.027 \text{ DM} + 0.0904 \pm 0.2480$ ($F = 4164$; d.f. = 20; $P < 0.0001$; $r^2 = 0.998$); sodium content = $-0.0124 \pm 0.0017 \text{ DM}^2 + 4.12 \pm 0.25 \text{ DM} + 0.771 \pm 2.558$ ($F = 1186$; d.f. = 23; $P < 0.0001$; $r^2 = 0.991$); and potassium content = $7.690 \pm 0.076 \text{ DM} + 4.85 \pm 3.31$ ($F = 10334$; d.f. = 23; $P < 0.0001$; $r^2 = 0.998$).

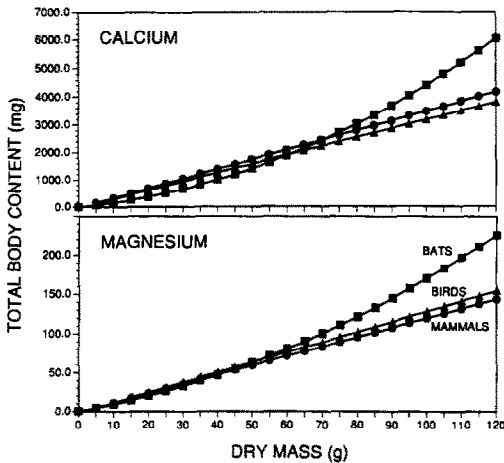


Fig. 2. Solutions to regression equations relating total body calcium (top) and magnesium (bottom) content (in mg) in relation to body size (dry mass = DM in g) in bats, other small mammals, and small birds. See legend for Fig. 1 for more details. In birds, total body calcium content = 32.0 ± 0.6 DM + 19.0 ± 18.5 ($F = 2801$; d.f. = 23; $P < 0.0001$; $r^2 = 0.992$), and total body magnesium content = 1.31 ± 0.02 DM - 1.56 ± 0.48 ($F = 7021$; d.f. = 23; $P < 0.0001$; $r^2 = 0.997$).

levels in large bats are higher than in other mammals, whose sodium levels are higher than in similar-sized birds. Magnesium and calcium increase most rapidly in very large bats but are otherwise similar in all three groups. Total body potassium tends to be lower in birds than in similar-sized bats and other mammals. Total body iron content is higher in birds and bats than in other mammals of similar size. Mineral compositions, therefore, do not consistently align bats with other (tetrapodal) mammals or flying endotherms (birds).

Acknowledgements—We thank James Dale Smith and other members of the 1979 Taylor South Seas Expedition from the Natural History Museum of Los Angeles County for sending us samples of the paleotropical bats and associated data. Richard Mills of International Expeditions and Peter Jenson of Explorama Tours provided logistical support for which we are very grateful. We thank Jeffrey LeFleur, Katherine Mattais, Brenda Sandy Flores, and Heather McNamara for help in the laboratory. Dr Robert E. Ricklefs provided useful comments on this manuscript. This study was supported in part by a Faculty Development Grant from The University of Michigan-Flint. This is contribution number 80 of the Biological Diversity of Latin America Program of the Smithsonian Institution's National Museum of Natural History.

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Appendix on facing page

Appendix 1

Body composition by sex (S, M = males, F = females) of some tropical bats in sequence according to Wilson and Reeder (1993). Primary foods (F) consumed are indicated for each species (F = fruit, I = insects, N = nectar, O = omnivore). Variables include sample size (*n*); live mass (MASS in g); water (HOH), fat, ash and non-fat organic (NFO) concentration (all in g/100 g live mass); caloric density (kcal in kcal/g dry mass); water index (WIND) and fat index (FIND) (in g/g lean dry mass); and concentration of indicated elements (each in mg/g dry mass). Each pair of values shows mean (above) and standard error of the mean (below).

Species	<i>n</i>	F	S	Mass	HOH	Fat	Ash	NFO	kcal	WIND	FIND	N	Fe	Ca	Mg	Na	K
<i>Dobsonia pammierensis</i>	2	F	M	277.50	72.00	1.945	5.12	21.65	3.090	2.776	0.075	166.49	0.421	37.55	1.487	5.153	12.181
				4.60	0.95	0.008	0.14	0.31	0.115	0.147	0.006	1.36	0.028	3.30	0.082	0.011	0.703
<i>D. praedatrix</i>	2	F	M	194.00	70.20	1.415	5.36	23.02	3.691	2.474	0.050	164.13	0.266	31.50	1.419	5.065	10.576
				2.83	0.07	0.329	0.48	0.73	0.008	0.020	0.010	1.39	0.010	1.17	0.046	0.210	0.162
<i>D. praedatrix</i>	2	F	F	160.00	69.64	1.495	5.00	23.84	3.762	2.414	0.052	162.75	0.271	28.17	1.298	5.052	10.639
				3.54	0.16	0.145	0.38	0.07	0.075	0.031	0.006	0.86	0.012	1.43	0.039	0.195	0.187
<i>Rousettus amplexicaudatus</i>	20	F	F	51.54	68.27	6.005	4.87	20.86	4.528	2.658	0.235	152.83	0.438	19.35	0.939	4.207	8.984
				0.66	0.35	0.425	0.08	0.18	0.070	0.025	0.018	1.42	0.017	0.64	0.025	0.056	0.132
<i>Rhynchonycteris naso</i>	4	I	M	3.94	66.23	3.685	5.65	24.42	4.061	2.205	0.122	156.60	0.395	12.09	0.738	3.929	8.307
				0.09	0.51	0.159	0.26	0.38	0.053	0.043	0.004	0.92	0.004	0.41	0.016	0.083	0.125
<i>R. naso</i>	2	I	F	4.63	64.55	4.215	4.40	26.83	4.295	2.067	0.135	157.17	0.393	10.78	0.786	3.827	7.489
				0.10	0.74	0.530	0.15	0.36	0.094	0.035	0.016	3.07	0.027	0.17	0.045	0.006	0.177
<i>Saccopteryx bilineata</i>	3	I	F	9.21	65.93	3.173	4.62	26.27	4.110	2.140	0.102	153.33	0.380	18.38	0.978	4.457	8.085
				0.42	1.00	0.358	0.12	0.76	0.071	0.082	0.011	2.24	0.015	0.75	0.057	0.341	0.315
<i>S. bilineata</i>	5	I	M	8.06	66.11	2.521	4.82	26.54	3.983	2.113	0.080	154.41	0.374	18.77	0.975	4.366	8.441
				0.15	0.79	0.313	0.04	0.55	0.057	0.060	0.009	0.95	0.013	1.00	0.045	0.229	0.121
<i>S. leptura</i>	1	I	F	4.42	65.79	2.760	4.91	26.54	4.016	2.090	0.088	152.27	0.483	14.93	0.791	3.707	8.278
<i>Aselliscus tricuspidatus</i>	10	I	F	3.70	66.36	5.081	5.99	22.56	4.219	2.347	0.177	160.08	0.481	16.71	0.905	4.544	9.910
				0.10	1.05	0.545	0.33	0.77	0.079	0.093	0.017	1.19	0.023	0.70	0.036	0.035	0.169
<i>A. tricuspidatus</i>	10	I	M	3.48	66.10	3.551	5.76	24.90	4.085	2.218	0.119	158.72	0.530	17.71	0.866	4.350	9.623
				0.06	1.04	0.292	0.46	0.78	0.082	0.113	0.011	2.05	0.009	0.69	0.019	0.099	0.157
<i>Macroglossus minimus</i>	5	N	F	13.92	67.61	3.564	5.13	23.69	4.103	2.361	0.125	150.97	0.475	15.46	0.895	4.321	9.143
				0.60	0.92	0.514	0.14	0.83	0.98	0.100	0.020	2.21	0.036	0.76	0.039	0.138	0.232
<i>M. minimus</i>	3	N	M	14.43	67.77	4.577	5.08	22.57	4.271	2.451	0.166	153.15	0.433	15.77	0.900	4.145	9.150
				0.93	0.55	0.573	0.30	0.22	0.123	0.022	0.021	6.28	0.027	0.26	0.049	0.147	0.262
<i>Hipposideros diadema</i>	11	I	F	36.58	66.20	4.256	6.95	22.59	3.984	2.264	0.145	148.51	0.579	20.94	0.934	4.433	9.506
				0.86	0.84	0.424	0.21	0.66	0.076	0.084	0.014	1.14	0.014	0.36	0.031	0.070	0.155
<i>H. diadema</i>	15	I	M	33.40	66.48	3.946	7.00	22.49	3.919	2.249	0.134	150.28	0.572	22.50	0.934	4.553	9.468
				0.70	0.32	0.330	0.16	0.20	0.056	0.019	0.012	1.20	0.016	0.65	0.014	0.056	0.091
<i>H. galeritus</i>	7	I	M	7.14	67.59	4.108	6.01	22.03	4.049	2.403	0.146	148.27	0.444	15.37	0.851	4.442	9.851
				0.07	0.76	0.407	0.16	0.45	0.107	0.086	0.015	0.78	0.014	0.96	0.026	0.125	0.166
<i>H. galeritus</i>	3	I	F	7.60	67.52	5.020	5.79	21.92	4.287	2.463	0.184	147.90	0.400	13.54	0.812	4.276	9.570
				0.57	0.36	0.514	0.33	0.38	0.111	0.059	0.022	2.51	0.022	0.77	0.054	0.123	0.244
<i>Phyllostomus hastatus</i>	4	O	F	73.17	65.94	2.607	4.93	26.53	3.988	2.104	0.083	162.40	0.242	18.23	1.129	4.017	8.377
				1.90	0.79	0.246	0.09	0.86	0.046	0.077	0.008	0.55	0.016	0.47	0.052	0.127	0.200
<i>P. hastatus</i>	5	O	M	82.18	66.63	2.259	4.96	26.15	3.927	2.157	0.073	163.27	0.250	17.52	1.053	3.911	8.777
				5.41	0.98	0.349	0.25	0.77	0.066	0.095	0.012	1.80	0.005	0.47	0.051	0.098	0.246
<i>Glossophaga soricina</i>	4	N	F	9.32	68.41	2.801	4.22	24.56	4.097	2.382	0.097	160.25	0.232	12.65	0.911	4.781	11.212
				0.22	0.66	0.308	0.08	0.55	0.051	0.068	0.010	2.15	0.012	0.22	0.022	0.024	0.311

Appendix (cont.)

Species	n	F	S	Mass	HOH	Fat	Ash	NFO	kcal	WIND	FIND	N	Fe	Ca	Mg	Na	K
<i>G. soricina</i>	6	N	M	7.93	68.74	2.272	4.65	24.33	3.955	2.389	0.080	162.24	0.227	12.59	0.997	4.618	11.052
<i>Carollia</i>	3	F	F	0.38	0.63	0.327	0.19	0.96	0.040	0.098	0.014	1.89	0.010	0.35	0.036	0.067	0.149
				12.64	67.34	2.939	4.42	25.30	4.104	2.275	0.102	158.15	0.225	10.34	0.866	3.720	9.242
<i>C. brevicauda</i>	2	F	M	0.72	0.47	0.752	0.42	0.64	0.163	0.089	0.029	3.88	0.008	1.08	0.051	0.203	0.121
				11.97	66.23	1.460	4.69	27.61	3.842	2.051	0.045	158.65	0.255	12.52	1.056	3.776	9.679
<i>C. perspicillata</i>	8	F	F	0.26	0.26	0.055	0.20	0.01	0.013	0.020	0.002	1.61	0.006	0.10	0.010	0.058	0.166
				15.74	68.23	3.136	4.33	24.30	4.142	2.395	0.111	163.43	0.272	12.09	0.977	4.335	9.836
<i>C. perspicillata</i>	7	F	M	0.29	0.48	0.351	0.14	0.49	0.072	0.067	0.015	1.51	0.010	0.38	0.027	0.053	0.200
				16.13	68.39	2.572	4.31	24.72	4.047	2.362	0.088	163.27	0.230	11.72	0.978	4.262	10.623
<i>Artibeus glaucus</i>	5	F	F	0.24	0.61	0.331	0.15	0.36	0.043	0.055	0.011	1.26	0.011	0.64	0.029	0.033	0.208
				9.32	69.47	2.609	4.24	23.67	4.065	2.515	0.096	164.58	0.347	13.24	1.056	4.543	10.464
<i>A. glaucus</i>	7	F	M	0.56	0.95	0.369	0.15	1.14	0.062	0.131	0.016	1.83	0.009	0.15	0.026	0.240	0.297
				8.60	69.08	2.395	4.74	23.78	3.957	2.430	0.084	163.23	0.376	12.31	0.951	4.298	10.561
<i>Artibeus jamaicensis</i>	6	F	F	0.24	0.54	0.141	0.12	0.51	0.041	0.061	0.005	0.77	0.008	0.29	0.028	0.089	0.300
				58.91	67.52	2.500	5.15	24.83	3.937	2.275	0.085	157.95	0.433	17.55	0.957	4.340	7.410
<i>A. jamaicensis</i>	6	F	M	0.20	0.88	0.227	0.07	0.97	0.036	0.114	0.010	2.14	0.010	0.41	0.013	0.180	0.207
				57.06	66.96	1.862	5.37	25.80	3.810	2.152	0.060	159.41	0.403	17.36	1.013	4.107	8.118
<i>A. lituratus</i>	1	F	M	0.98	0.41	0.283	0.11	0.43	0.043	0.043	0.009	2.05	0.012	0.45	0.051	0.115	0.199
				75.72	67.85	2.560	5.17	24.42	3.938	2.290	0.086	149.90	0.439	19.21	1.178	4.267	7.771
<i>A. lituratus</i>	2	F	F	0.84	0.64	0.64	2.95	5.77	3.947	1.995	0.091	156.69	0.380	18.96	0.959	3.915	7.344
				8.04	0.68	0.53	0.00	0.14	0.084	0.030	0.016	5.26	0.051	0.90	0.042	0.130	0.206
<i>A. obscurus</i>	2	F	M	32.94	66.82	1.863	5.13	26.19	3.847	2.146	0.061	154.02	0.417	16.67	1.110	3.599	8.975
				0.39	1.34	0.735	0.01	2.07	0.102	0.185	0.028	2.16	0.011	0.60	0.027	0.009	0.003
<i>Chiroderma villosum</i>	1	F	M	19.02	64.34	5.740	5.79	24.13	4.354	2.150	0.192	136.01	0.433	16.13	0.770	3.685	7.517
				20.06	62.10	8.645	5.44	23.81	4.767	2.144	0.306	134.33	0.434	13.81	0.806	3.562	6.885
<i>C. villosum</i>	3	F	F	1.06	1.61	2.021	0.30	1.81	0.228	0.134	0.086	0.66	0.066	0.65	0.066	0.209	0.447
				11.02	63.90	2.090	5.11	28.90	3.906	1.880	0.061	149.18	0.568	12.55	1.007	3.551	10.653
<i>Platyrrhinus helleri</i>	1	F	M	19.61	69.47	2.010	4.66	23.86	3.900	2.440	0.070	160.79	0.453	12.65	1.003	4.234	9.504
<i>Uroderma bilobatum</i>	2	F	M	16.46	69.24	2.168	4.95	23.64	3.889	2.422	0.076	150.17	0.514	13.97	1.072	4.115	9.295
<i>Myotis nigricans</i>	1	I	F	0.76	0.32	0.470	0.46	0.31	0.145	0.000	0.017	0.75	0.000	1.45	0.091	0.519	0.029
				4.71	66.83	1.700	4.74	26.73	3.867	2.120	0.054	151.61	0.425	14.63	0.889	3.683	8.850
<i>Myotis riparius</i>	2	I	F	5.52	66.30	3.694	5.05	24.96	4.138	2.210	0.123	157.85	0.411	12.72	0.822	4.205	8.040
				0.23	0.54	0.875	0.43	0.09	0.189	0.010	0.031	1.23	0.005	0.62	0.078	0.308	0.619
<i>M. riparius</i>	3	I	M	5.64	68.02	2.910	5.04	24.02	4.016	2.361	0.101	158.02	0.423	13.19	0.891	4.182	8.459
<i>Miniopterus</i>	4	I	M	0.74	1.26	0.217	0.36	0.97	0.056	0.157	0.010	2.80	0.026	0.24	0.035	0.122	0.313
				7.10	70.07	2.285	5.20	21.90	3.795	2.543	0.083	149.10	0.351	13.08	1.044	4.560	10.409
<i>Miniopterus</i>	9	I	F	0.08	0.69	0.368	0.09	0.14	0.113	0.082	0.014	1.87	0.007	0.14	0.053	0.085	0.142
				7.47	68.77	4.150	5.44	21.57	4.147	2.545	0.155	148.57	0.351	18.57	0.961	4.588	9.810
				0.22	0.35	0.426	0.17	0.31	0.082	0.039	0.017	1.99	0.010	0.52	0.031	0.071	0.155