

Prediction of Body Weights of Small Mammals from Skull Measurements

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Body weights of small mammals may be predicted with accuracy from measurements of cranial or mandibular dimensions. Stepwise multiple regression techniques were used to generate "best" equations (those with largest coefficients of determination). "Best" predictive equations obtained from cranial measurements usually contained three independent variables, the identity of which varied among species. Equations using only mandibular measurements were less accurate than those based on cranial measurements. In order to obtain predictive equations with maximum accuracy, sample sizes should be at least $N=40$. Logarithmic transformations may improve the predictive accuracy of the equations, but only slightly. Equations such as these may be useful whenever skull measurements can be made but body weights are unavailable. Specifically, weights may be estimated from skeletal elements in pellets regurgitated by owls. From these remains one can use multiple regression equations to determine: (1) the impact of the predator on specific size classes within single mammalian prey species, (2) relative frequency of occurrence of mammalian prey of various sizes, and (3) energy budgets of owls and rates of secondary production.

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1. INTRODUCTION

In the present study we use skeletal remains from museum holdings to assess the feasibility of predicting body weight of small mammals from skull measurements. The technique promises to be useful whenever skull measurements can be made but body weights are not available, and is of particular importance in reconstructing the mass of prey taken by predators, specifically owls. More than 325 avian species representing 18 orders regurgitate indigestible parts of prey as pellets (Below, 1979), and a wealth of literature exists regarding the mammalian prey of the Order *Strigiformes* (owls). Many of these studies did not extract as much information as appears to be available, particularly if one were capable of predicting body weights of prey with accuracy. If the pellets of an owl are collected at regular intervals we contend that not only can one identify what species are being preyed upon, but also that

seasonal and geographic variation in size, mass and caloric content of prey might be assessed as well. If body weight of prey items could be estimated accurately, modern theories of foraging "strategy" (e.g. Schoener, 1971) could be tested. In this regard, we specifically ask the questions: "are the skull measurements routinely available from material retrieved from owl pellets suitable for prediction of body weight of prey?" and "if so, with what precision might we do so?"

2. METHODS

Because owls cause varying amounts of damage to the skulls of small mammals in the process of killing and eating them, we initially identified measurements available from the crania and/or mandibles in owl pellets. For that determination, skulls of rice rats, *Oryzomys palustris* (Harlan), hispid cotton rats, *Sigmodon hispidus* Say and Ord, eastern meadow voles, *Microtus pennsylvanicus* (Ord), Norway rats, *Rattus norvegicus* Berkenhout, and house mice, *Mus musculus* L., were examined that had been obtained from Barn Owl, *Tyto alba* (Scopoli), pellets collected at Presquile National Wildlife Refuge (Jackson *et al.*, 1976) and near Charlottesville, Virginia (see Table 1). The importance of skull or extra-cranial measurements in predicting body weight was assessed from specimens of the hispid cotton rat, eastern meadow vole and white-footed mouse, *Peromyscus leucopus* (Rafinesque), from central Virginia (Table 2). Cranial measurements included least interorbital constriction (IC), basilar length (BL), length of maxillary toothrow (MR), rostral breadth (RB) at the maxillary-premaxillary suture, palatal length (PL), length of the upper diastema (UD), length of the palatal foramen (= incisive foramen; PF) and length of the bony palate (BP) from the posteriormost margin of the palatal foramen to the anteriormost edge of the posterior margin of the secondary palate (Choate, 1973). Mandibular measurements used were length of the diastema (LD), length of the mandibular toothrow (MT) and length of the mandible (ML). Mandibular length was measured from the posteriormost superior edge of the incisive alveolus to the posteriormost margin of the angular process in *Peromyscus* and *Sigmodon*, but in *Microtus* this measurement was taken from the posteriormost inferior edge of the alveolus. Except as noted above, all measurements, as described by DeBlase and Martin (1982), were taken in the same manner on each species. Cranial measurements not taken because the bony elements necessary for them are often lost or damaged (Table 1) included length of nasals (NL), zygomatic breadth (ZB), condylobasal length (CB) and greatest length of skull (GL). Basilar length, a measurement that depends on an intact occiput, is sometimes unavailable from skulls taken from pellets, but was included in our analyses. Other measurements not included because of damage from the owl are cranial depth and cranial breadth, pterygoid breadth and mastoid breadth. Standard body measurements, total length (TL), length of tail vertebrae (LT), hindfoot (HF), ear (EN) and body weight (BW) were obtained from specimen labels. In addition to morphometric variables, specimens of *Sigmodon* were assigned age classes. Our classification is based on the degree of eruption of the third upper molar (M^3) and the degree of ridge wear of M^3 and other cheek teeth. Group 1 (juveniles) is comprised of animals in which M^3 is not fully erupted; in Group 2 (subadults) M^3 is fully

Table 1
 Percentage of selected cranial measurements available from crania of rodents obtained from Barn Owl pellets. Abbreviations are described in the text. The number in parentheses indicates sample size.

	BL	PL	PF	BP	UD	MR	IC	RB	ZB	NL	CB	GL
<i>Oryzomys palustris</i> (62)	0.0	67.7	80.6	67.7	100.0	100.0	95.2	72.6	0.0	22.6	0.0	0.0
<i>Sigmodon hispidus</i> (24)	8.3	75.0	87.5	87.5	87.5	95.8	95.8	79.2	4.2	0.0	8.3	8.3
<i>Microtus pennsylvanicus</i> (416)	30.5	90.6	93.8	93.0	95.2	95.0	94.0	88.2	23.2	15.2	30.5	30.5
<i>Rattus norvegicus</i> (15)	6.7	60.0	60.0	80.0	60.8	86.7	100.0	53.3	0.0	0.0	6.7	6.7
<i>Mus musculus</i> (52)	0.0	71.2	83.0	71.2	94.0	96.2	100.0	75.0	0.0	11.5	0.0	0.0
Mean of all species (569)	22.9	84.8	90.1	87.7	94.4	95.4	94.9	84.0	1.7	14.8	22.8	22.8

emerged to slightly worn and enamel ridges are complete to nearly complete on other molars; Group 3 (adults) M³ and other molars are moderately to heavily worn but the enamel ridges are readily apparent; in Group 4 (old adults) the enamel ridges are severely worn to completely obliterated.

"Best fit" multiple regression equations for the prediction of body weight from all independent variables and some specific subsets of these variables were obtained by the maximum R^2 and minimum R^2 (R^2 = coefficient of determination) improvement technique developed by J. H. Goodnight (SAS Institute, 1982). The model, by an iterative process, selects the "best" (or "worst" in the case of minimum R^2 techniques) one-variable model as judged by the maximum R^2 obtained in all one-variable equations, then precedes to the "best" two-variable model and so forth. The "best" overall model is that which includes all independent variables that contribute significantly to the prediction of the dependent variable. Minimum R^2 techniques precede in a reverse fashion. Models obtained from the two techniques generally were similar.

We obtained multiple regression equations that included tests of all independent variables, those variables obtained from measurements of skulls only, and those measurements obtained from lower jaws only. These models were calculated in order to compare the importance of skull variables relative to non-cranial measurements and to obtain models using lower jaws only since these are most often retrieved from owl pellets (see Hamilton, 1980).

Two additional samples of trapped *Microtus* from sites on the Senej National Wildlife Refuge, Schoolcraft County, Michigan, and near Charlottesville, Virginia, were measured to test the validity of equations derived from initial data sets if applied to different geographic localities. The only variables measured from the new data sets were those that demonstrated significance in the initial analyses. Additionally, crania of *Microtus* obtained from a large series of Barn Owl pellets were measured to compare predicted weights of mice captured by the owl with the trapped sample. To select the cranial sample that we measured from owl pellets, all skulls were numbered and a random numbers table was used to draw a sample of 100 specimens.

In all statistical tests a significance level of 5% was used, i.e., $P < 0.05$.

3. RESULTS

Initial data sets consisted of measurements of the skulls and post-cranial anatomy of snap-trapped specimens of 142 cotton rats, 47 meadow mice and 48 white-footed mice from south-central Virginia (mostly the Richmond, Virginia area; Table 2). Some measurements were not available as a result of damage incurred during snap-trapping and sample sizes vary accordingly.

Principal components analysis indicates that most of the cranial variables are part of a group of related characters while mandibular measurements may be part of a different group; positive loadings always occurred with cranial variables in the first principal component, but not with mandibular measurements in some instances. The first principal component, which usually represents size-related variables (Blackith &

Table 2
 Body, cranial and mandibular measurements of the cotton rat, *Sigmodon hispidus*, meadow vole, *Microtus pennsylvanicus*, and white-footed mouse, *Peromyscus leucopus* (X=mean, N=sample size and SE=standard error).

	Total length (TL)		Tail vertebrae (LT)		Hind foot (HF)		Ear from notch (EN)		Body weight (BW)		Basilar length (BL)		Interorbital constriction (IC)		Rostral breadth (RB)		Upper diastema (UD)		Maxillary tooth row (MR)		Palatilar length (PL)		Palatine foramen (PF)		Bony palate (BP)		Mandibular length (ML)		Mandibular tooth row (MT)		Lower diastema (LD)		
<i>Sigmodon</i>	N	142	141	141	136	140	120	141	138	139	138	137	138	138	138	124	127	141															
	\bar{x}	199.5	77.9	27.7	17.6	65.5	24.5	4.6	5.5	7.5	6.3	13.9	6.6	6.0	17.7	6.6	3.7																
	min.	106.0	25.0	16.0	10.0	12.5	12.7	4.1	4.0	5.0	5.3	10.4	4.0	4.7	14.0	4.2	3.0																
	max.	285.0	133.0	34.0	23.0	165.7	29.2	5.3	6.9	9.9	6.8	17.2	9.2	7.3	21.4	7.5	4.5																
	SE	2.77	1.35	0.27	0.23	2.30	0.27	0.02	0.05	0.09	0.02	0.12	0.07	0.04	0.15	0.04	0.03																
<i>Microtus</i>	N	46	47	47	46	47	44	45	47	47	47	47	45	45	46	45	45	46	45	45	46	45	45	45	46	46	45	45	45	45	45	45	
	\bar{x}	150.9	38.1	20.9	12.5	40.7	24.0	3.7	4.7	8.1	6.8	13.6	5.2	5.9	14.8	6.7	4.0																
	min.	112.0	13.0	18.0	7.0	15.0	19.6	3.4	4.1	6.5	5.8	11.3	4.3	4.9	12.0	5.7	3.0																
	max.	185.0	52.0	23.0	18.0	63.0	27.1	4.0	5.2	9.1	7.5	15.2	5.9	7.0	16.5	7.5	4.5																
	SE	2.59	1.05	0.16	0.29	1.73	0.27	0.02	0.04	0.10	0.06	0.14	0.07	0.07	0.16	0.06	0.05																
<i>Peromyscus</i>	N	48	48	48	45	48	48	48	47	48	47	48	47	46	48	47	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	
	\bar{x}	153.6	65.5	19.2	16.2	48	18.3	4.0	3.9	6.0	3.8	9.6	4.7	3.9	11.4	3.6	3.1																
	min.	113.0	49.0	17.0	14.0	6.1	13.5	3.7	3.3	3.9	3.6	8.1	3.8	3.1	9.9	3.3	2.5																
	max.	178.0	80.0	20.0	19.0	26.0	20.8	4.3	4.7	7.1	4.1	10.8	5.4	8.0	12.9	3.9	3.5																
	SE	2.22	0.89	0.11	0.16	0.73	0.23	0.02	0.05	0.09	0.19	0.10	0.06	0.10	0.11	0.02	0.04																

Reyment, 1971), accounted for a large amount of variation in skull measurements (*Peromyscus*, 59.5⁰/₀; *Microtus*, 74.3⁰/₀; *Sigmodon*, 79.4⁰/₀), although the second principal component added a relatively large amount (6—10⁰/₀). Most individual variables are correlated significantly with body weight (Table 3). In general, it appears that some cranial variables are more closely related to body weight (g) than post-cranial or mandibular measurements (Table 4). "Best" single-variable models, that is, those producing largest coefficients of determination (R^2), either include

Table 3
Pearson product-moment correlation coefficients for body weight vs. morphometric variables (ns=not statistically significant).

	<i>Sigmodon</i>	<i>Peromyscus</i>	<i>Microtus</i>
Total length	0.87	0.93	0.81
Tail length	0.62	0.82	0.58
Hind foot	0.79	ns	0.60
Ear length	0.51	0.43	0.34
Mandible length	0.89	0.89	0.84
Basilar length	0.93	0.92	0.89
Interorbital constriction	0.71	0.56	ns
Mandibular tooth row	0.78	0.51	0.77
Rostral breadth	0.89	0.64	0.84
Upper diastema	0.94	0.77	0.87
Maxillary tooth row	0.71	ns	0.75
Palatilar length	0.94	0.91	0.87
Lower diastema	0.90	0.76	0.45
Palatal foramen	0.91	0.87	0.82
Bony palate	0.82	0.32	0.60

Table 4
Equations for prediction of body weight from skull measurements of some small mammals. See "methods" in text for abbreviations of measurements.

Best single variable model	
<i>Sigmodon</i>	BW=16.21 PL-160.83; $R^2=0.91$, df=131
<i>Peromyscus</i> ¹	=2.90 BL-36.44; $R^2=0.84$, df=47
<i>Microtus</i>	=5.87 BL-101.06; $R^2=0.80$, df=43
Best cranium model	
<i>Sigmodon</i>	=10.91 PL+2.23 BL+8.74 IC-181.10; $R^2=0.92$, df=114
<i>Peromyscus</i> ²	=1.20 BL+4.25 UD+2.42 RB-40.24; $R^2=0.91$, df=42
<i>Microtus</i>	=10.75 PF+18.66 RB+3.55 UD-130.82; $R^2=0.87$, df=43
Best mandibular model	
<i>Sigmodon</i>	=26.63 LD+6.34 ML+13.08 MT-228.94; $R^2=0.80$, df=113
<i>Peromyscus</i>	=5.41 ML-6.45 MT-21.68; $R^2=0.82$, df=47
<i>Microtus</i>	=9.67 MI-102.62; $R^2=0.68$, df=43

¹ BL is often absent; second best single variable is PF. Best model is: BW=11.21 PF-36.08; $R^2=0.77$, df=43. ²Second best cranium model: BW=9.17 PF+4.04 RB-42.23; $R^2=0.83$, df=45.

palatilar length (cotton rat), or basilar length (white-footed mouse, meadow mouse).

Comprehensive models composed of all statistically significant, independent, variables produced greater R^2 values, but none were more than 0.07 greater than "best" single-variable models (Table 4). Accuracy of the "best" comprehensive models as judged by mean body weight \pm one standard error of the estimate is relatively good (*Sigmodon*, 65.5 ± 6.0 ; *Microtus*, 40.7 ± 4.4 ; *Peromyscus*, 16.6 ± 1.6). In general, the regression technique chosen did not greatly influence the R^2 value or the variables appearing in the "best" equation. Analysis of residuals indicated that some weight-related variation remained to be explained and that the relationship between some of the independent variables and body weight was curvilinear (see Zar, 1974). Logarithmic transformation of variables in such instances may increase the goodness of fit (Sokal & Rohlf, 1969), but in the present instance, such transformations only slightly improved some equations and did not improve others as judged by R^2 values. The largest improvement of R^2 in such cases was 0.04.

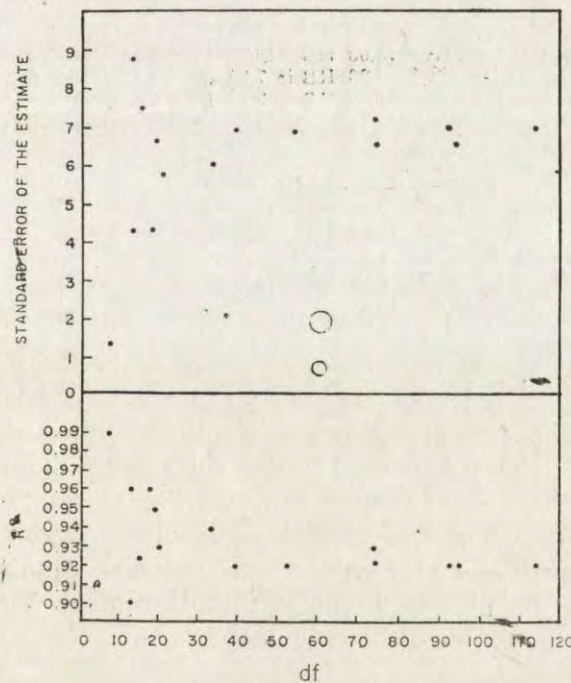


Fig. 1. Variations in the standard error of the estimate and coefficient of determination (R^2) of the best cranium model for the cotton rat (Table 4) as a function of degrees of freedom (df). Values were generated from randomly selected subsets of data (see text).

Age classes, as indicated by tooth wear, do not contribute significantly to improvement of R^2 . Tooth wear is apparently subject to a variety of factors (see below), and although tooth wear varies significantly with age and body weight, its impact in the prediction of body weight is masked by factors having close correlations with body mass.

The sample size required for maximum predictive accuracy seems to be approximately 40 individuals. Coefficients of determination and standard errors of the estimate of randomly chosen subsets of the data for the cotton rat vary widely at sample sizes of 8–20 skulls but become stable at about $N=40$ (Fig. 1), and do not increase appreciably at higher sample sizes.

Table 5

"Best" cranium and mandibular models for *Microtus pennsylvanicus* collected from three different localities. Abbreviations for independent variables are given in Table 2. (R^2 =coefficient of determination, df=degrees of freedom, SE=standard error).

Locations	Equations	R^2	df	SE
Cranial models				
South-central Virginia	BW=18.68 RB+10.75 PF+3.55 UD-130.82	0.87	43	4.45
Charlottesville, Virginia	5.26 RB+ 7.85 PF+7.20 UD- 88.24	0.77	44	4.98
Schoolcraft Co., Michigan	10.72 RB+ 3.45 PF+8.65 UD- 99.26	0.80	47	3.45
All specimens	6.14 RB+ 4.96 PF+9.83 UD- 96.24	0.76	136	5.22
Mandibular models				
South-central Virginia	BW= 9.67 ML-102.62	0.68	43	6.65
Charlottesville, Virginia	10.67 ML-120.82	0.52	44	7.01
Schoolcraft Co., Michigan	8.50 ML- 87.02	0.54	47	5.13
All specimens	9.43 ML-100.42	0.65	135	6.38

Equations generated for *Microtus* collected at three different locations are similar (Table 5). Covariance analysis (location included as a classification variable) indicates there is significant interlocality variation in the data set. Mean weights for the voles from these localities are: south-central Virginia, 42.6 g; Charlottesville, Virginia, 37.4 g; and Michigan, 40.8 g. Using mean cranial measurements for south-central Virginia, estimates of body weight using cranial equations are quite similar to the actual sample means; south-central Virginia, 41.5 g; Charlottesville, 36.3 g; Michigan, 40.0 g.

4. DISCUSSION

Undigested skeletal, integumentary and dental materials egested by mammalian and avian predators have been of persistent importance to

biologists, both in determining food habits of predators and in learning about prey species. Evans and Emlen (1947), among many others, have provided ecological commentary on feeding habits of owls based on known ecological requirements of mammalian prey, while conversely, Choate (1971) extracted information on the distribution and ecology of various New England mammals from data obtained from owl pellets. Reports of occurrence and/or range expansion of mammalian species based on remains in pellets regurgitated by owls are especially numerous (e.g. Baker & Alcorn, 1953; Long & Kerfoot, 1963). Perhaps the use of such materials reached its all-time extreme when Caboń-Raczyńska and Ruprecht (1977), after analyzing pellets from 804 collections from across the country, estimated the population density of the common vole, *Microtus arvalis* (Pallas), for all of Poland.

Studies of feeding and life histories of owls have been largely directed along the lines of food habits within and among populations of a given species (e.g. Herrera, 1974), of owls in special geographical areas or habitat (e.g. Weller *et al.*, 1963; Johnston, 1972; Blem & Pagels, 1973), comparisons of different owl species in the same area (e.g. Kirkpatrick & Conway, 1947; Marti, 1974) or seasonal variation in diet (e.g. Fitch, 1947). In most instances only the species of prey item and total counts of each species are determined. Data amassed from these studies more recently have allowed for study of the comparative feeding ecology or behavior of certain owl species, and in an obvious progression from these, some work has been done on owl energetics or biomass of prey as assessed from pellet analyses (e.g. Graber, 1962; Otteni *et al.*, 1972; Marti, 1973, 1976). In such studies, biomass of prey (usually mammalian) consumed has been calculated primarily from assigned weights obtained from the literature (e.g. Craig & Trost, 1979), or from a combination of sources including the literature, local trapping and museum records (e.g. Marti, 1974, 1976; Herrera & Jaksic, 1980). Seldom, however, is there an independent confirmation of the actual weight of the individual prey items. How accurate is this practice? We contend it may not be a valid representation in some instances. Body weight of small mammals is affected by many factors, including age (see Morris, 1973) and different phases of population cycles. Bashenina (1969), Brown (1973) and Adamczewska-Andrzejewska (1973) among others have reported on seasonal differences in rate of growth of small mammals. Essentially, in temperate areas, animals born in spring or summer grow quickly whereas growth of individuals born in fall or early winter is slowed or arrested. Also, recruitment or differential mortality may result in changes in mean body weight of populations in the field. For example, in the present study we observed that a sample of 11 adult cotton rats

captured in traps in November had an average weight of 85.6 g (63.5—107.4), while all rats (adults and old adults) collected in March weighed 79.2 g (57.0—119.0). The overall mean weight of the entire sample was 65.5 g (Table 2). What is the weight to be assigned to this species? Obviously, some independent means of evaluating body weight of prey items would be of benefit.

Use of equations that describe the relationship between skeletal measurements and body weight must be made with care. The goal of predictive equations, of course, is to accurately estimate the dependent variable. How well an equation does this is a function of at least two things: (1) the amount of variation in the dependent variable explained by the equation (i.e. absolute predictive ability), and (2) the accuracy of prediction versus some other method of measurement (i.e. relative predictive ability).

Absolute predictive ability is indicated by coefficients of determination and by standard errors of estimates. In the present examples, the former are relatively large and the latter fairly small, indicating that most variation in the dependent variable is accounted for and that absolute predictive ability is fairly good. Equations based on cranial measurements were always better than those based on mandibular dimensions. The equations for predicting body weight from mandibular measurements were similar to those computed by Hamilton (1980), although he used only mandibular lengths.

For indication of relative predictive ability, one must have comparative materials obtained by more direct techniques. For example, Brown (1973) found that weight of individual *Microtus pennsylvanicus* varies widely over 24 hour periods (± 6.5 g) and this does not include weight losses due to parturition. Our predictive equations seldom produce differences this great. This is not to imply that predictive equations are as accurate as direct measurements, but given large daily variations in weight due to lipid cycles, varying amounts of food in the digestive tract and the like, predictions of body weight from skull measurements may produce relatively accurate estimates. Seasonal and annual variations may also be superimposed on daily weight changes. These differences, however, may be due to real variations in growth or age of surviving populations and supposedly would be reflected in skull measurements as well. Seasonal variation in growth limits use of age as a predictor of body weight and interferes with use of temporal variables in predictive equations. In the present case, we found that age (i.e. tooth wear; our age classes) did not enhance our predictions. On the other hand, with awareness of seasonal adjustments in growth rates, use of measurements of the skull, when combined with data on tooth wear, may also provide

evidence on the status of the prey population. For example, if fresh owl pellets collected in temperate areas in late winter contain small skulls with teeth that are worn to adult status, the biomass of the prey represent individuals born the preceding fall. Table 6 indicates how weights of two age classes (adults and "old adults", see methods) may differ. Also, it should be noted that a simple predictive model based only on palatilar length was capable of accurately estimating body weights even though there was significant seasonal variation. We believe that intrinsic cycles of lipid reserve provide most of the difference between actual and predicted values.

Table 6

Actual and predicted (body weight=16.21 PL-160.83) mean body weights of all *Sigmodon* in the initial data set and adults in the initial data set collected in November and March and old adults collected in March (see text). Numbers in parentheses indicate the mean palatilar length used in obtaining the predicted weights.

	All individuals	Adults		Old adults March
		Nov.	March	
N	140	11	14	13
Actual body weight	65.5	85.6	68.3	90.9
Predicted body weight	64.5 (13.9)	82.4 (15.0)	74.2 (14.5)	88.8 (15.4)

Students of avian predation still question whether pellet composition accurately reflects available prey populations. The answer seems to be, "probably not". In a Virginia study that utilized both trapping and analyses of pellets of the Barn Owl, Jackson *et al.* (1976) found that the cotton mouse, *Peromyscus gossypinus* (Le Conte) which represented nearly half of the trapped specimens, was not present in pellets; conversely, three other species were detected only by their presence in pellets (also see Jaksic & Yanez, 1979). Davis (1938) found that least shrews, *Cryptotis parva* (Say), made up a high percentage of the mammals taken by Barn Owls but surmised that Barn Owls did not actively select shrews; the concentration of least shrews at that time simply was great relative to other mammals. In a 20-year study of owl predation on small mammals in Missouri, Korschgen and Stuart (1972) noted that through such long-term studies unusually high small mammal populations may be detected. They further noted that avian predation does not accurately reflect relative abundance in populations of average size. Earlier, Pearson and Pearson (1947: 146), after studying small mammal populations in Pennsylvania using both trapping and owl pellet analyses, succinctly summarized their thoughts on small mammal representation

in owl pellets by stating:... "owls do not catch a representative sample of the small mammal population — nor do trappers". Somewhat prophetically, they concluded that "Despite certain limitations... (one can learn) what species are present... the approximate dates when young of prey species are born... the number of litters... when the young become grown, and when the species enters or emerges from hibernation or estivation". We add to that statement our belief that much more information remains to be extracted. Figure 2 presents body weights as

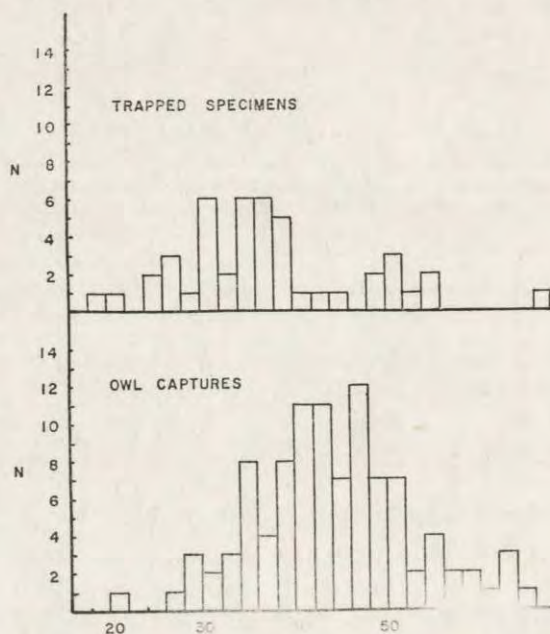


Fig. 2. Body weights of snap-trapped *Microtus pennsylvanicus* and weights as predicted from crania from owl pellets from the same region.

determined by snap-trapping and from crania obtained from owl pellets in the same general area (near Charlottesville, Virginia). Several caveates notwithstanding, i.e. that the osteological remains of very young prey may be digested and that the bones of large prey may never be consumed (Raczyński & Ruprecht, 1974), it is now generally agreed that the contents of pellets fairly accurately reflect the diet of the owl. Assuming this is true, it appears from Fig. 2 that an owl might "select" particular size classes from within a species of mammalian prey. This may be a result of differential activity of age classes of the mammal, ability of the owl to capture mammals of particular sizes, and other

factors. Knowledge of a skewed selection pattern takes on particular significance if one wishes to convert prey to energy terms, since the energy content of small mammals does not appear to vary linearly with weight (Brisbin, 1970).

A final warning is in order: those who wish to use craniometric analyses to estimate body weight should calculate equations for specimens collected from their specific study locality. Not only have we shown that significant interlocality variation may occur, but Sikorski (1982) has demonstrated significant craniometric variation between individuals of the same species collected from different habitats in the same general area.

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SZACOWANIE MASY CIAŁA MAŁYCH SSAKÓW W OPARCIU O POMIARY
CZASZKI

Streszczenie

Podjęto próbę szacowania masy ciała gryzoni na podstawie stopnia jego skorelowania z wybranymi pomiarami czaszki i żuchwy (Tabela 1). Zastosowano w tym celu równanie regresji wielokrotnej (najszerzy współczynnik determinacji) (Ryc. 1). „Najlepsze” równanie dla prognozy uzyskano z pomiarów czaszkowych, zawierających zazwyczaj trzy niezależne zmienne, tożsamość których jest różna u różnych gatunków (Ryc. 2, Tabela 2—5). Pomiary żuchwy dawały mniej dokładne szacowanie w porównaniu do pomiarów czaszki. Dokładność zależy także od liczebności próby, która nie może być mniejsza niż $N=40$. Przekształcenie logarytmiczne może tylko nieco poprawić przewidywaną dokładność równania. Szacowanie takie może być wykorzystywane np. przy ocenie masy ciała ssaków łowionych przez sowy (Tabela 6). Równania regresji wielokrotnej można użyć do określenia: (1) wybiórczości drapieżnika w stosunku do klasy wielkości ofiary, (2) względnej częstotliwości występowania różnej wielkości ofiar, (3) budżetu energetycznego sów i poziomu produkcji wtórnej.