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Estimating fresh mass of small mammals in owl diet from cranial measurements in pellets remains

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Abstract - Owl diet is commonly studied through pellet analysis, and it is usually described as prey frequency or biomass. However, frequency does not indicate the relative trophic importance of prey. Biomass estimates, based on mean mass data from the general literature, do not take into account size, sex and geographical variations. We suggest a regression method for better estimating individual mass from cranial bones and mandibles of small mammals, and we provide regressions for 6 species, frequently preyed upon by owls in Italy. For each prey species, at least one variable explained a significant proportion of sample variation and was significantly related to the mass. The bone length-fresh mass relationship is useful only when well-preserved bones are available. Usually, cranial bones in pellets are severely damaged and the number of feasible measurements is limited, therefore multiple regression methods based on several variables are of limited use.

Introduction

Owl diet has been extensively studied, both qualitatively and quantitatively (Mikkola 1983), and mostly through pellet analysis, an easy method that has been well validated (Yalden and Morris 1990). Diet data have been used to describe trophic relationship within owl guilds and among geographical populations (Herrera and Hiraldo 1976, Galeotti and Canova 1994), diet structure (Catalisano and Massa 1987, Sarà and Zanca 1989), and the relationship among prey frequency and availability (Canova 1989).

Diet is usually described both as proportional frequency, and as proportional biomass of each prey type. This latter approach provides more reliable information about the energetic importance of each prey type. However, the average weight of each prey species is usually obtained from literature, without taking into account body mass variations due to geographic location, age, and sex. For example, geographical variation is an important source of body weight variation, as shown by Di Palma and Massa (1981) on the average weight of several rodent species in Sicily. Small mammals constitute the bulk of owl diet (Mikkola 1983).

This paper suggests a method for estimating the individual mass of 6 small mammals, commonly preyed upon by owls. This method, based on linear measurements of cranial bones and mandibles, could improve biomass estimates in owl diet. A similar method was suggested for Nearctic mammals (Hamilton 1980) and for birds (Morris and Burgiss 1988).

Methods

Small mammals were trapped from 1989 to 1993 at several sites in the Po plain, Northwestern Italy. We trapped 3 rodent species, the Savì Pine Vole *Microtus savii* (n=62), the Bank Vole *Clethrionomys glareolus* (n=132), the Wood Mouse *Apodemus sylvaticus* (n=165), and 3 shrew species, the Common Shrew *Sorex araneus* (n=22), the Lesser white-toothed Shrew *Crocidura suaveolens* (n=18) and the Bicoloured white-toothed Shrew *Crocidura leucodon* (n=12), in habitats ranging from woodlands to abandoned fields (Canova and Fasola 1991).

After capture, each individual was weighed and measured, and its reproductive status and sex identified. It was skinned and boiled for five minutes; its bones and skull were extracted, cleaned in a 30% water solution of hydrogen peroxide (120 volumes), dried and stored. Twenty morphological characters were measured on each skull (Fig. 1, 2), using a digital caliper (accuracy: 0.01 mm). Several characters were significantly related to mass, but we retained only those variables which explained at least 50% of the total variance in the mass-cranial measurement regressions.

Double-logarithmic regressions were calculated, and

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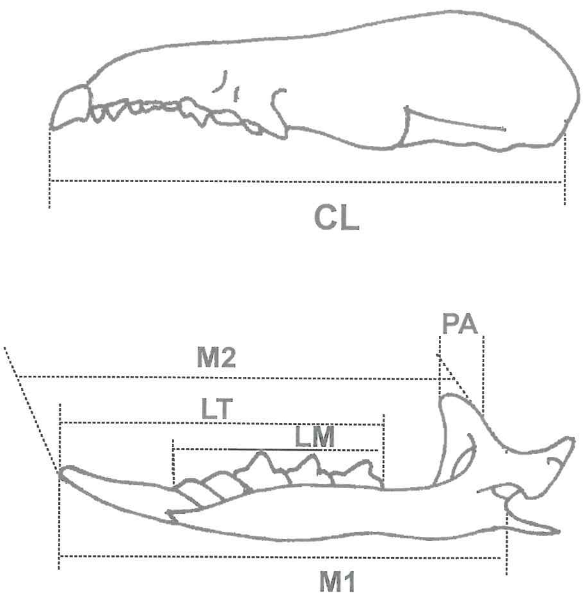

Figure 1. Shrew skull measurements. CL= condylobasal length, PA= processus articularis height, M1= mandible length (base), M2= mandible length (top), LM= lower molar length, LT= lower tooth length.

equations obtained in the form log W = a + b (log L), where W is the fresh body mass (in grams), and L the cranial measurement (in millimeters). All the measurements were taken on adult individuals, i.e. individuals in reproductive activity from spring to early autumn; a few pregnant females (n=6) were excluded from analysis.

The 6 mammal species we considered account for a great proportion of the owl diet. A preliminary analysis of literature data showed that these mammals account from 81.9% to 66.7% of the total mammals in the diet of the four most widespread owls in Italy (Table 1).

Results

Regression parameters are listed in Table 2 for the shrews, and in Table 3 for the rodents. The correlations bone length-body mass for the shrews are stronger than those for rodents; generally, mandible measurements seem to have a better predictive value in shrews (Table 2), while in rodents the cranial measurements, such as diastema and foramina length and zygomatic width, are better related to mass (Table 3).

All the variables we measured were significantly related to fresh mass, but we list only the variables which explained more than 50% of the variance. This "a priori" choice partially explains why the best variables differed among species, even such phylogenetically close species as the shrews. Condylobasal length, for example, is a good predictor for all shrews, but only in the Common shrew the variance it explains is higher than 50%, while it is lower for the Lesser white-toothed shrew and the Bicoloured white-toothed shrew.

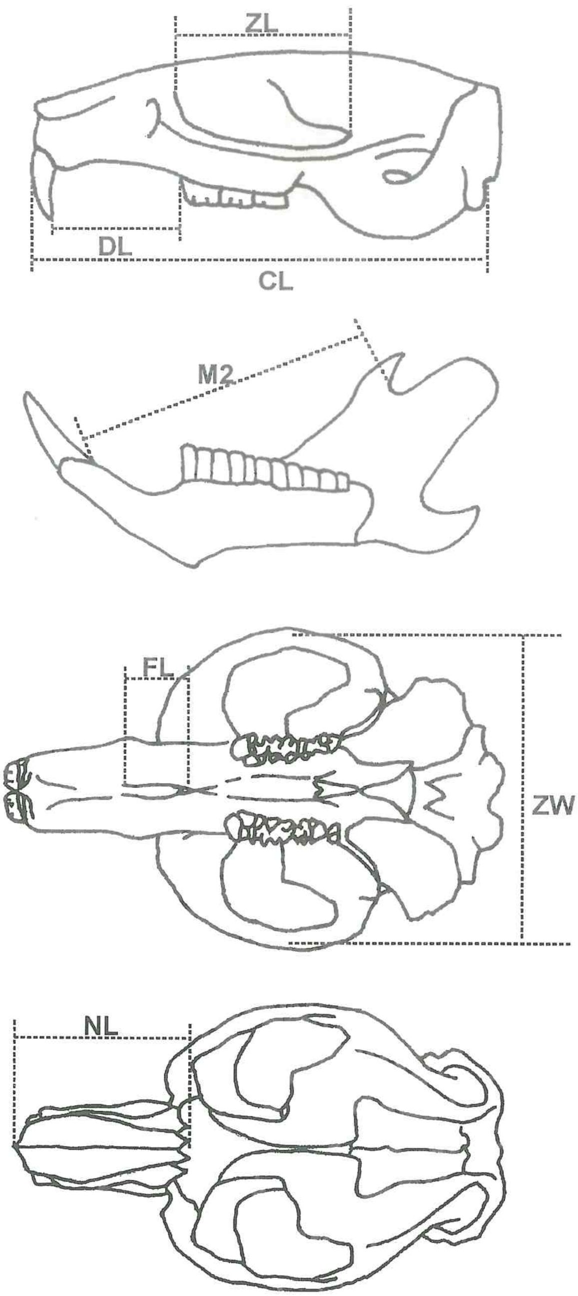

Figure 2. Rodents skulls measurements. CL= condylobasal length, DL= upper diastema length, ZL= zygomatic arc length, NL= snout-frontal length, FL= foramina incisiva length, ZW= zygomatic width, M2= mandible length.

Discussion

The regressions in Tables 2 and 3 allow an easy and reliable estimate of the individual mass of small mammals preyed upon by owls. These equations thus seem to be good tools for analyzing the energetic contribution of each prey to the diet.

The reliability of this method is however weakened by two main shortcomings. First, the explained variances are higher in shrews (Table 2) than in microtines (Table 3). Moreover, the applicability of this method depends on the preservation of the bones found in pellets. Prey bones are subject to severe physical stress, before and during ingestion and digestion (Mikkola 1983). Thus, the preservation of cranial bones range from quite good in the Barn Owl, whose pellets usually include whole craniums, to highly damaged in other species such as the Long-eared Owl (Yalden and Morris 1990). Since the mandible, which is relatively well preserved in pellets, shows a low predictive value at least in rodents, our method works less well for analyzing the diet of some owl species which heavily damage prey bones such as the Long

Table 1. Average frequency of the 6 small mammal species considered in this paper, in the diet of 4 medium-sized owls in Italy.

	PERCENTAGE FREQUENCY	NO. OF STUDIES	SOURCE
Long eared owl *Asio otus*	81.9%	6	1,15,16,17,18,19
Barn Owl *Tyto alba*	73.5%	10	5,6,7,8,9,10,11,12,13,14
Tawny Owl *Strix aluco*	72.2%	6	1,2,3,4,5,6
Little Owl *Athene noctua*	66.7%	2	1,13

1= Gerdol *et al.* 1982, 2= Sarà and Zanca 1989, 3=Arcà 1981, 4=DeBernardi and Patriarca 1988, 5=Groppali 1987,6 = Sarà and Massa 1985, 7=Vicini and Malaguzzi 1988, 8=Sublimi Saponetti 1985, 9= Gerdol and Mantovani 1980, 10=Contoli 1981, 11=Santini and Farina 1978, 12=Martelli 1980, 13=Contoli *et al.*. 1988, 14=Moschetti *et al.* 1995, 15=Casini and Magnani 1988, 16= Galeotti and Canova 1994, 17= Aloise and Scaravelli 1995, 18= Malavasi *et al.* 1995, 19=Plini 1986

Table 2. Parameters of the double-log regressions relating individual fresh body mass (g) to cranial measurements (mm) in the shrews.

SPECIES	VARIABLE	EQUATION	R^2	df	P
Common shrew	CL	log W=-10.43+ 8.96 (log CL)	69.6	18	<0.0001
Lesser white-toothed shrew	M1	logW=-2.96+3.72 (log M1)	78.7	16	<0.001
	LM	logW=-1.71+3.73 (log LM)	74.1	16	<0.001
	LT	logW=-1.99+3.22 (log LT)	72.5	16	<0.001
	CL	logW=-3.57+3.43 (log CL)	71.4	16	<0.001
Bicoloured white-toothed shrew	M2	logW=-3.82+4.54 (log M2)	70.6	10	<0.005
	PA	logW= 0.64+2.92 (log PH)	70.5	10	<0.005
	LM	logW=-2.75+5.12 (log LM)	68.9	10	=0.016

Table 3. Parameters of the double-log regressions relating individual fresh body mass (g) to cranial measurements (mm) in the rodents.

SPECIES	VARIABLE	EQUATION	R 2	df	P
Bank vole	DL	log W=-0.55+ 2.32 (log DL)	54.7	79	<0.001
	ZW	log W=-2.21+ 3.17 (log ZW)	61.7	66	<0.001
Savi' Pine vole	CL	log W=-2.01+ 2.44 (log CL)	55.0	46	<0.001
	NL	log W=-0.29+ 1.94 (log NL)	60.4	42	<0.001
	FL	log W=-0.44+ 1.32 (log FL)	59.1	50	<0.001
Wood mouse	CL	log W=-3.58+ 3.61 (log CL)	68.2	84	<0.001
	DL	log W=-1.01+ 2.79 (log DL)	61.9	114	<0.001
	ZL	log W=-1.71+ 3.09 (log ZL)	59.8	96	<0.001
	M2	log W=-1.26+ 2.53 (log M2)	59.4	112	<0.001

Table 4. Comparison of fresh prey body mass in a sample of Barn owl pellets (n=31). Average weights from: (1) Lyneborg (1972), (2) Van der Brink (1969), (3) our method. * mass values from Lovari *et al.* (1976), ** total weight calculations included only the species for which we had estimates based on our regression method.

	FREQUENCY		AVERAGE WEIGHT			DIFFERENCES BETWEEN ESTIMATES (%)	
	(n)	(%)	(1)	(2)	(3)	(1)-(3)	(2)-(3)
Neomys fodiens	1	0.8	16.5	16.5	-	-	-
Sorex araneus	4	3.4	32	40.0	33.2	3.6	20.5
Crocidura suaveolens	9	7.8	58.5	36.0	74.9	21.9	51.9
Crocidura leucodon	2	1.8	18.0	21.0	22.4	19.6	6.3
Arvicola terrestris	2	1.8	260.0	260.0	-	-	-
Microtus savii *	46	40.0	630.2	630.2	772.8	18.5	18.5
Apodemus sylvaticus	28	24.4	504.0	588.0	534.2	5.7	10.1
Micromys minutus	12	10.4	96.0	84	-	-	-
Muridae ind.	3	2.6					
Passeriformes ind.	8	6.9					
Weight **			1243	1315	1438	13.6	8.5

eared Owl. A second shortcoming is that the equations estimate the "probable" body mass of the individual mammal (Morris and Burgiss 1988, Yalden and Morris 1990). Body mass of small mammals may vary in relation to social and temporal factors (Gurnell 1985, Curchfield 1990); the mass values obtained from our equations are therefore an estimate of the probable body mass, that can fluctuate widely over the life span of the prey.

Errors shall however be lower than those occurring when all prey items are given the same mass value taken form the general literature (Morris and Burgiss 1988). Table 4 compares the prey mass calculated using our method with those calculated from literature data; the latter method clearly underestimated the actual prey mass of our material. This suggests that the regression methods here proposed should be adopted whenever possible, in order to reduce errors in prey mass estimates.

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Riassunto - La dieta degli Strigiformes viene di norma espressa come frequenza e biomassa delle prede rinvenute nelle borre. Tuttavia, la frequenza delle prede non fornisce alcuna informazione sulla loro importanza energetica. Inoltre, il peso medio delle prede viene normalmente ricavato da fonti bibliografiche che non tengono conto della variabilità geografica, temporale e individuale. Abbiamo calcolato le regressioni fra variabili osteometriche di cranio e mandibola e peso individuale, per le 6 specie di insettivori e roditori maggiormente predate dagli Strigiformes italiani. Per ciascuna specie-preda è stata individuata almeno una variabile osteometrica altamente correlata al peso individuale. Proponiamo l'uso di questo metodo, facilmente applicabile e più preciso di quelli normalmente adottati negli studi descrittivi sulla nicchia alimentare dei rapaci notturni.

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