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The influence of body weight on the quantity of food ingested in *Pipistrellus kuhlii* (Kuhl, 1817) and *Pipistrellus savii* (Bonaparte, 1837) (Chiroptera: Vespertilionidae)

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Abstract

The variation in body weight during the summer was monitored in three non-pregnant females of *Pipistrellus kuhlii* and in two non-pregnant females and one male of *Pipistrellus savii*, analysing the influence of this parameter on the quantity of food ingested. The daily percentage increase in body weight of the two species was between 3.5% and 5.1%; the daily percentage decrease in body weight between 3.9% and 5%. There was a significant negative correlation between body weight prior to evening flight and the quantity of food ingested in both species, suggesting a mechanism of negative feedback that permits each specimen to maintain a body weight congruous to the metabolic and mechanical requests imposed by flight, maximising manoeuvrability and minimising both the amount of energy required and risk of predation.

Introduction

The energy cost of flight is very high and, as several authors have demonstrated, increases with body weight (Norberg 1987; Rayner et al. 1989). The metabolic requests of flight have been compared in species of different weights (Carpenter 1985, 1986; Thomas 1975, 1987; Thomas and Suthers 1972) without going into any detail on the influence of individual variation in body weight on the metabolism and physiology of flight (Rayner et al. 1989; Webb et al. 1992). A 5–10% increase in the total weight of a single individual can increase the mechanical potency required for flight by 15% (Rayner et al. 1989). An increase in body weight causes an increase in the wing loading and a consequent worsening of flight performance (Hughes and Rayner 1991). Furthemore, manoeuvrability – defined as the minimum radius of curvature that the animal can obtain in flight – is increased by a low body mass and low wing loading (Thollesson and Norberg 1991).

Bats show two types of variation in body weight during their active periods: 1) daily oscillations (Studier et al. 1970; Studier and Ewing 1971) and 2) long-term variations linked to pregnancy or hibernation (Ewing et al. 1970; Beasley et al. 1984; Speakman and Racey 1987).

An examination of body weight just prior to evening flight is particularly interesting due to the direct influence of weight on both flight and feeding capacity; it also probably influences the bat's ability to flee predators (Ransome 1990). This study presents the results of research conducted on the relationship of body weight before evening flight to quantity of food ingested in two species of male and non-pregnant female bats, *Pipistrellus kuhlii* (Kuhl, 1817) and *Pipistrellus savii* (Bonaparte, 1837).

Material and methods

Early in June 1993 three non-pregnant female Kuhl's bats and a male and two non-pregnant female Savi's bats were captured in the plains of Florence. Both species are insectivorous and are frequently observed flying in urban areas (Lanza 1959).

The animals were kept and tested in a room measuring 3×3×3 m where they had complete freedom of flight, under a natural photo period. Shelters attached to the walls offered the bats refuge during the day. The specimens were kept for about 50 days and then released. During captivity they were fed on mealworms (*Tenebrio molitor*) raised on a regularly renewed substratum composed of bran, proteinic chick food, vegetables and fruit (Wilson 1988; Dondini and Vergari 1995) to which small quantities of mineral salts and powdered calcium were added. Hydrosoluble polyvitamins were added to their drinking water.

After a week of acclimatisation the body weight of each specimen was recorded before and immediately after eating but prior to being given water. Each specimen was weighed on an electronic scale with a 0.1 g degree of precision (Tanita Model 1479). The subjects were fed from 19:30–20:00 (daylight time) – which is about the same time that the bats in the open from the same localities began to hunt – by placing a container full of mealworms inside the room. The bats had unlimited access to the container and ate until satiated.

The quantity of food ingested was calculated by the difference in body weight before and after each meal. The mean weight was calculated by adding the daily weights before feeding and dividing the sum by the days of testing (Wm = W1 + … Wn/n); the daily percentage weight increase was obtained by dividing the mean daily increase (Wi) by the mean weight (Wi% = [Wi/Wm]*100); the percentage daily weight decrease was obtained by dividing the mean decrease (Wd) by the mean weight (Wd% = [Wd/Wm]*100). Regression analysis was made on the ratio between the weight of each specimen prior to feeding and the quantity of food ingested.

Results and discussion

In *P. kuhlii* and *P. savii* individual weight oscillates more or less regularly (Figs. 1, 2). Both species show a daily percentage increase between 3.5% and 5.1% of their mean weight and a daily decrease between 3.9% and 5.1% (Tab. 1).

Regression analysis reveals a significant inverse correlation between body weight prior to flight and quantity of food ingested in both *P. kuhlii* (P.k. 1: $r = -0.500$, $P < 0.01$, $n = 40$; P.k. 2: $r = -0.435$, $P < 0.01$, $n = 40$; P.k. 3: $r = -0.428$, $P < 0.01$, $n = 40$) and *P. savii* (P.s. 1:

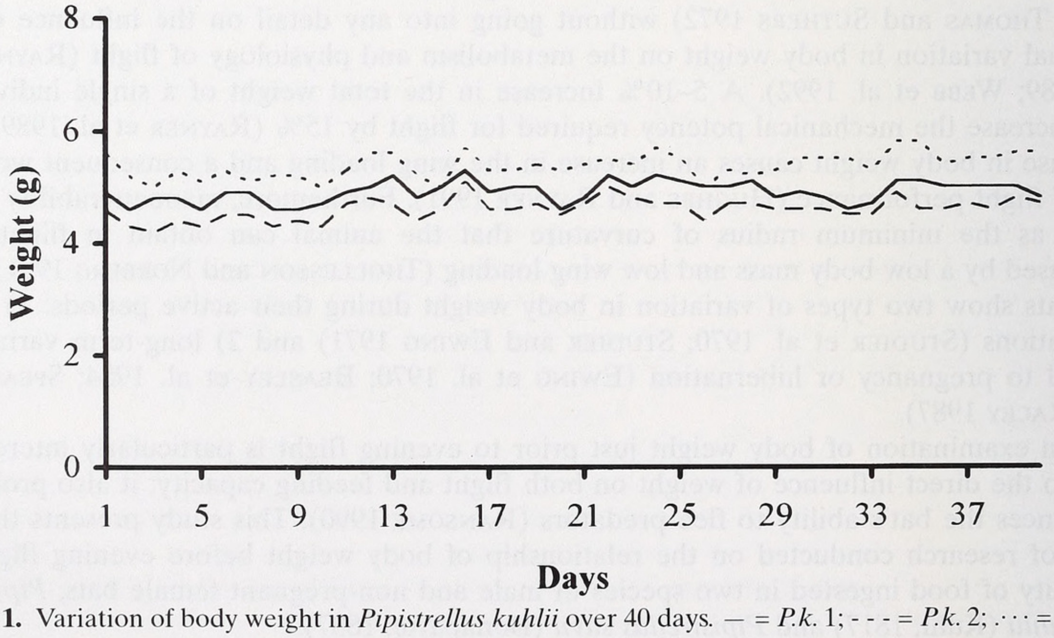

Fig. 1. Variation of body weight in *Pipistrellus kuhlii* over 40 days. — = *P.k.* 1; - - - = *P.k.* 2; · · · = *P.k.* 3.

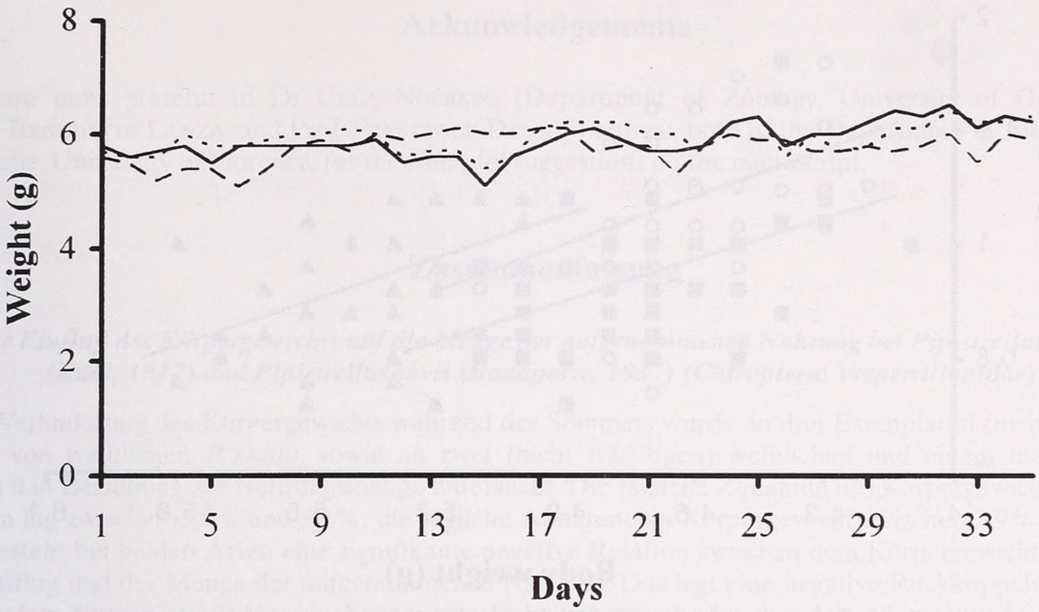

Fig. 2. Variation of body weight in *Pipistrellus savii* over 35 days. ... = *P. s.* 1; - - - = *P.s.* 2; — = *P.s.* 3.

Table 1. Wm = mean weight; Wmin = minimum absolute weight; Wmax = maximum absolute weight; Wi = mean daily increase; Wi% = daily percentage weight increase; Wd = mean daily decrease; Wd% = daily percentage weight decrease. *P.k.* = *P. kuhlii*; *P.s.* = *P. savii*.

	P.k. 1	*P.k.* 2	*P.k.* 3	*P.s.* 1	*P.s.* 2	*P.s.* 3
Sex	F	F	F	M	F	F
Forearm (mm)	29.3	30	31.7	32	33	34.1
Wm (g)	4.6	4.7	5.3	5.6	5.9	5.9
Wmin (g)	4.2	4.1	5	5.1	5.3	5.4
Wmax (g)	5	5.1	5.8	6.3	6.4	6.4
Wi (g) (±SE)	0.23 (±0.034)	0.20 (±0.026)	0.24 (±0.043)	0.19 (±0.028)	0.23 (±0.037)	0.23 (±0.043)
Wi%	5.1%	4.2%	4.5%	3.4%	3.9%	4%
Wd (g) (±SE)	0.19 (±0.028)	0.23 (±0.031)	0.25 (±0.034)	0.29 (±0.038)	0.23 (±0.04)	0.28 (±0.055)
Wd%	4.1%	5%	4.8%	5.1%	3.9%	4.7%
Days	40	40	40	35	35	35

r = –0.711, P < 0.01, n = 35; P.s. 2: r = –0.499, P < 0.01, n = 35; P.s. 3: r = –0.599, P < 0.01, n = 35). In both species an increase in body weight negatively influences the quantity of food ingested (Figs. 3, 4). A statistical analysis of the regressions showed no significant differences between the inclination of the straight lines in either species.

An analysis of body weight has shown that this oscillates in time. Nursing females of *Plecotus auritus* show a daily decrease in body weight which is significantly and positively correlated to the minimum temperature of the preceding night (Speakman and Racey 1987). During the period in which the present observations were conducted the thermal excursion was limited and the minimum temperature was always between 17 and 19 °C, which allows us to exclude any appreciable influence of temperature on body weight during testing. This result tends to confirm the observation by Aldridge and Brigham (1988) that a radio transmitter applied to a bat begins to have a notably negative influence on the animal's flight ability when the instrument surpasses 5% of its body weight. Body weight influences manoeuvrability and the alteration of this parameter can increase the risk of capture by nocturnal predatory birds or accidents (Gillette and Kimbrough 1970; Krzanowski 1973; Ruprecht 1979; Perez-Barberia 1991; Speakman 1991; Scaravelli and Aloise 1993).

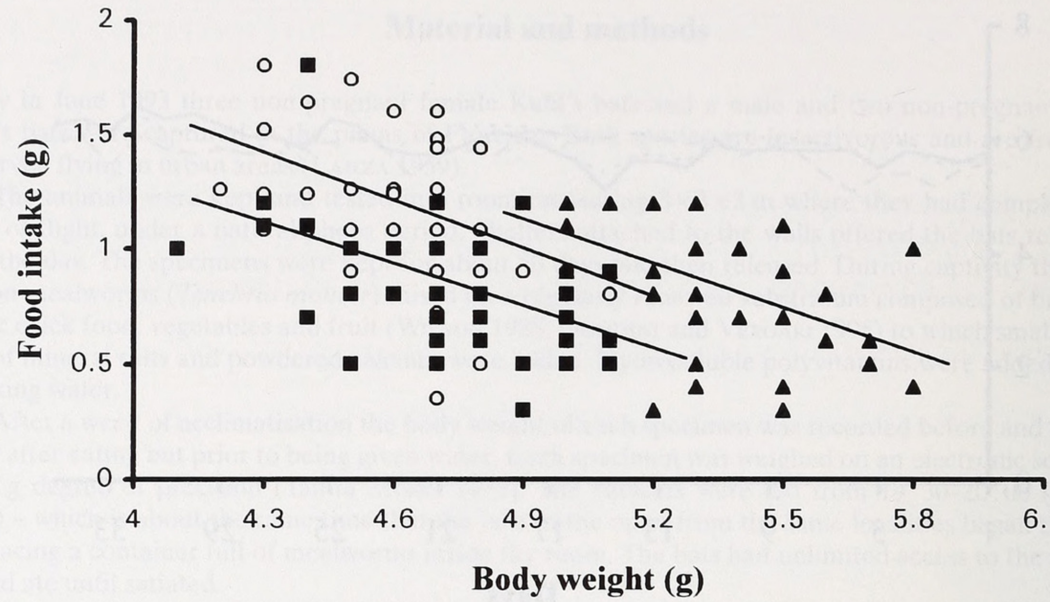

Fig. 3. Regression analysis between body weight (abscissa) and food ingested (ordinate) in 3 specimens of *Pipistrellus kuhlii*. ○ = *P.k.* 1 (y = –0.51x + 6.02, r = –0.500); ■ = *P.k.* 2 (y = –0.258x + 3.2, r = –0.435); ▲ = *P.k.* 3 (y = –0.25x + 3.5, r = –0.428).

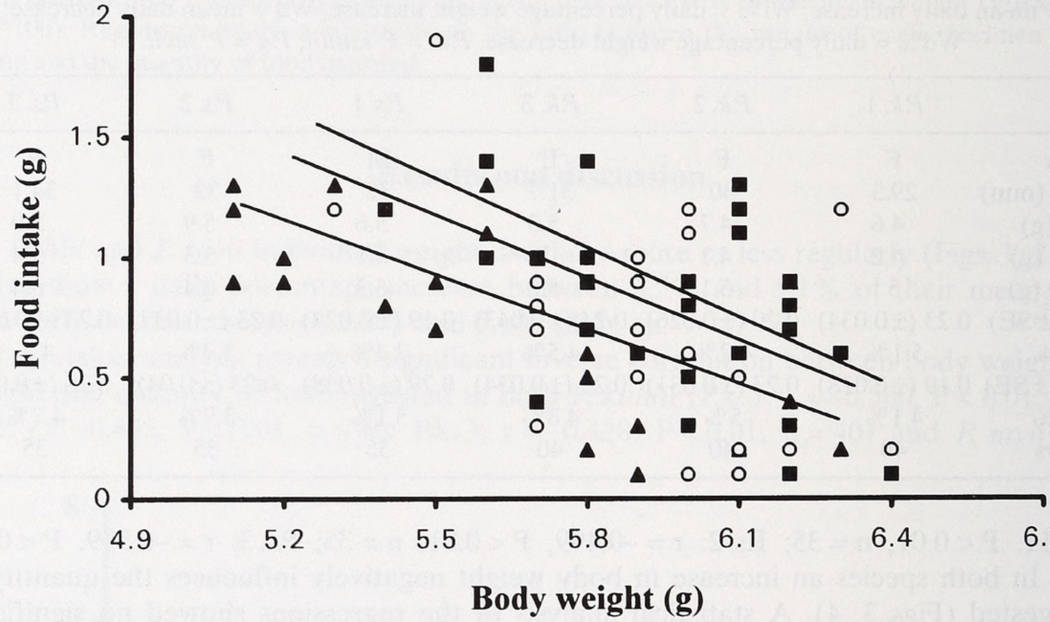

Fig. 4. Regression analysis between body weight (abscissa) and food ingested (ordinate) in 3 specimens of *Pipistrellus savii*. ▲ = *P.s.* 1 (y = –0.36x + 4.8, r = –0.711); ○ = *P.s.* 2 (y = –0.44x + 5.98, r = –0.499); ■ = *P.s.* 3 (y = –4.9x + 6.68, r = –0.599).

Thus, bats probably maintain their body weight within strict limits so as not to compromise their flight ability. Prior to hibernation and in pregnant females, when an increase in weight is inevitable, the negative consequences are apparently overcome by muscular modifications which allow the animals to adapt to the increased load (Rayner et al. 1989).

It can thus be hypothesized that males and non-pregnant females are subject to a process of negative feedback between the quantity of food ingested and body weight, which maintains the latter within limits compatible with the mechanical and metabolic requests of flight. Such a limit maximises manoeuvrability and minimises both the energy cost and risk of predation.

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Zusammenfassung

Der Einfluß des Körpergewichts auf die Menge der aufgenommenen Nahrung bei Pipistrellus kuhlii (Kuhl, 1817) und Pipistrellus savii (Bonaparte, 1837) (Chiroptera: Vespertilionidae).

Die Veränderung des Körpergewichts während des Sommers wurde an drei Exemplaren (nicht trächtigen) von weiblichen *P. kuhlii*, sowie an zwei (nicht trächtigen) weiblichen und einem männlichen *P. savii* in Beziehung zur Nahrungsmenge untersucht. Die tägliche Zunahme des Körpergewichts beider Arten lag zwischen 3,5% und 5,1%; die tägliche Abnahme an Körpergewicht zwischen 3,9% und 5%. Es besteht bei beiden Arten eine signifikante negative Relation zwischen dem Körpergewicht vor dem Nachtflug und der Menge der aufgenommenen Nahrung. Das legt eine negative Rückkoppelung nahe, die jedem Exemplar erlaubt, ein Körpergewicht beizubehalten, das den Anforderungen des Fliegens hinsichtlich Stoffwechsel und Mechanik entspricht. Die Manövrierfähigkeit wird maximiert und der Betrag der benötigten Energie wie auch das Risiko, selbst erbeutet zu werden, werden minimiert.

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