

Energetics and Geometry of Huddling in Small Mammals

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Huddling in small mammals appears as an efficient response to low ambient temperatures with important consequences in thermoregulatory energy savings. These energy savings have been ascribed to a decrease in the exposed area in relation to the animal's volume. It has been proposed that during huddling reductions in the exposed area and in the metabolic rate are equal functions of the number of grouped individuals with a common exponent of $-1/3$. However, reported data shows a great variability of this exponent. In this paper we present a geometrical and energetic analysis on several huddling efficiencies in small mammals and in geometric bodies. Our theoretical analysis shows a variability in the efficiency of huddling, depending on the morphological characteristics of the geometric bodies. At the same time original and literature information show an analogous interspecific variability in small mammals. Finally, a general mathematical expression is proposed which represents and explains the energetic and geometric specific variations of huddling in small mammals.

Introduction

Among the different behavioral thermoregulatory adjustments of endotherms, huddling in small mammals appears as an efficient response to low ambient temperatures. This may have important consequences in regard to energy saving and also in the allocation of energy, which in turn will affect the individual's fitness (Wunder, 1978; Bozinovic *et al.*, 1988).

This behavior has at least three main consequences: (a) low metabolic rates (Trojan & Wojciechowska, 1969; Gebczynski, 1969; Fedyk, 1971; Tertilt, 1972; Vogt & Lynch, 1982; Karasov, 1983; Contreras, 1984; Andrews & Belknap, 1986); (b) low rates of food ingestion (Springer *et al.*, 1981), and (c) an increase in survival time at low temperatures (Sealand, 1952).

The energy expenditure reduction during huddling has been ascribed to a decrease in the exposed area in relation to the animal's volume (Pearson, 1947; Sealand, 1952). Contreras (1984) pointed out that the reduction of the exposed area and hence the decrease in heat exchange with the environment is a function of the number of grouped individuals, with an exponent of $-1/3$:

$$A_h/A = n^{-1/3} \quad (1)$$

where A_h is the area of n grouped individuals; A the area of n non-grouped individuals, and n the number of individuals. The same author pointed out that the expected reduction in energy expenditure should also be proportional to the $-1/3$