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In search of tropically adapted cattle: does size matter?

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Abstract. The body size of individuals of a species of herbivore in the tropics can be half that of individuals of the same species in temperate zones. This occurs because the tropics do not have the large quantities of high quality, young, green grass leaves needed by large herbivores for growth, gestation, lactation and replenishment of weight lost during the dry season. Instead, the tropics have large quantities of tall grasses containing high levels of fibre and lignin. Herbivores take a long time to masticate and ruminate this, and they take a long time to digest it. This limits their dry matter intake, and consequently the energy and nutrients available to them.

Tropical environments select for cattle with small frame size, while industry selects for large frame size. Industry maintains large cattle through a range of management practices, sometimes with very high costs. It is proposed that smaller framed cows will more regularly achieve condition scores needed for high weaning rates. Higher weaning rates should increase the amount of beef produced per hectare, and smaller framed cows may have lower production costs.

Introduction

Bergmann's Rule (Bergmann 1847), which states that mammals and birds which live in cold environments are larger than those from hot environments, has been confirmed by dozens of studies, for the majority of species, world-wide (e.g. McNamara *et al*. 2016). Hence, mammals and birds are often small in the tropics, then increase to a maximum size in the temperate zones.

The essential activities of growth, reproduction and survival are governed by the rate that animals acquire, process and transform energy, which is closely related to body size and ambient temperature (Smith and Lyons 2011). Not surprisingly then, natural selection pressure acts very strongly on animal body size.

Beef producers and markets for beef cattle select for cattle with large frame size, due to high individual value and transporting and processing efficiencies. However, this is at odds with selection for small frame size by tropical environments. Consequently, large-framed cows are likely to require higher levels of management effort if they are to produce calves as consistently as small-framed cows.

Methods

A review of literature was undertaken to determine the extent that animals conform to Bergmann's Rule world-wide, the reasons for animals being smaller in the tropics, and the potential implications of this for cattle productivity in northern Australia. The review used a variety of search engines to access literature related to Bergmann's Rule.

Results and Discussion

Widespread latitudinal variation in animal body size has been confirmed by many empirical studies. Of interest now are the mechanisms responsible for this, which are mainly climatic factors which directly or indirectly impact animals.

Thermoregulation and body size

As heat flow and heat storage are body size dependent, variation in body size may be an adaptation to variation in ambient temperature (Pluske *et al*. 2010). This has been the conclusion of many empirical studies which found that latitudinal variation in temperature was inversely related to latitudinal variation in the body size of mammals and birds (e.g. Morales-Castilla *et al*. 2012). However, variation in ambient temperature and its relationship with heat conservation and dissipation is a crude explanation of latitudinal variation in body size. For example, several studies of birds and mammals have found that body size variation was correlated with gradients of both temperature and humidity, and hence were closely related with factors which determine food availability (Blois *et a*l. 2008).

Food quality and herbivore body size

It has been proposed that mammal body and skeletal size is largely determined by food quantity and quality during ontogenetic growth (Huston and Wolverton 2011). Hence, herbivores can only attain large body size if large quantities of high quality forage are available for long periods of time.

Globally, the duration and intensity of plant growing seasons are longest in the temperate zones, and then decline towards the tropics and the Arctic/Antarctic (Geist 1987). This aligns with latitudinal variation in the body mass of cervids in North America (Huston and Wolverton 2011). White-tailed deer found at 10^0 north were 65% smaller than individuals of this species at 50^0 north, and similarly, moose at 45^0 north were 45% smaller than moose at 60^0 north. In contrast to this, the body weight of caribou, which are found at the highest latitudes, decreased with latitude, corresponding to the decrease in the duration of the growing season above 50^0 north. Caribou at 80^0 north were 65% smaller than caribou at 55^0 north.

Similar latitude variation in body size occurs in Australia, where the size of five species of native mammals increased with latitude from 10^0 to 45^0 S (Yom-Tov and Nix 1986). In the northern most locations, echidnas were 75% smaller, brush-tail possums were 65% smaller, and western grey, eastern grey and red kangaroos were all around 50% smaller.

The length of the growing season and the availability of green grass leaves is also positively correlated with the live-weight gains of steers in Queensland (Burrows *et a*l. 2010). This is supported by findings that cattle and sheep dry matter intake (DMI) of young grass leaf is considerably higher than that of older grass leaf, and DMI of grass leaf is considerably higher than that of grass stem of the same age (Poppi *et al*. 1981, Drescher *et al*. 2006). This is partly due to differences in the chemical and physical composition of these forages. As grass leaves age, crude protein levels decline and indigestible neutral detergent fibre (NDF) and lignin, increase (ArchimeÁde *et al*. 2000). Similarly, grass leaves have higher crude protein levels and lower indigestible NDF and lignin levels than grass stems (Poppi *et al*. 1980, McLeod *et al*. 1990). Young grass leaf is digested at a faster rate than old leaf or stem (ArchimeÁde *et al*. 2000), allowing this to pass through the rumen more quickly (Lechner-Doll *et al*. 1990), which in turn increases DMI. Furthermore, young grass leaves break into small particles more readily than older leaves (ArchimeÁde *et al*. 2000), which break into smaller particles more easily than stems (McLeod *et al*. 1990). Small particles are digested more quickly and are retained for a shorter time than large particles, enabling higher DMI. Additionally, less chewing and ruminating time needed for forages that more easily break into small particles also increases DMI. It is for these reasons that the DMI of cattle and sheep is negatively related to the fibre and lignin content of forage (Meyer *et al*. 2010), and why DMI declines with forage maturation (Edouard *et al*. 2008).

Consequently, pastures that contain more young leaves for longer periods of time will facilitate higher live-weight gains of cattle. In the tropics, the rapid maturation of C4 grasses, involving increases in fibre and lignin content and corresponding decreases in digestibility, results in lower DMI and reduced animal performance compared with temperate regions. Given that DMI determines the quantity of energy and nutrients available for maintenance, growth and reproduction, and that it is more difficult for large herbivores to maintain sufficient DMI in the tropics, it is not surprising that herbivores are often smaller in tropical regions.

In conclusion, it is likely that good performance of large framed cattle will require longer periods of access to high quality, very young, green grass leaves, and thus, long pasture growing seasons. Compared with southern Australia, young grass leaves mature at a faster rate and represent a smaller proportion of standing dry matter in the northern one-third of the continent. Poor soil fertility, high temperatures during the pasture growing season, and the presence of tall C4 grasses with a high proportion of stems all conspire to produce forage of low quality. Due to the limited availability of high quality young green grass leaves in northern Australia, large framed cattle will experience nutritional stress more often than smaller framed cattle.

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