Modeling Black-footed Ferret Energetics: Are Southern Release Sites Better?

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Introduction

Several models have been developed to estimate prey requirements and to assess habitat suitability of release sites for the black-footed ferret (*Mustela nigripes*) (e.g., Stromberg and others, 1983; Powell and others, 1985; Biggins and others, 1993). None of these models, however, addressed possible differences in energetic requirements between sites due to climatic differences within the ferret's historical range. We used a simplified energetics model to examine the effect of variation in environmental conditions on ferret energetic requirements. The aim of the study was to determine whether the ferret might be more successful in one area than another.

The Model

The total daily energy expenditure (E_{DEE}) of any mammal can be conceptualized as the sum of all mutually exclusive sources of energy expenditure (E_x) (Wunder, 1975; Powell and others, 1985). For a nonreproductive, fully grown adult, E_{DEE} can be modeled in the general form:

$$E_{DEE} = E_s + E_a + E_t$$

where E_s is the energy cost of resting; E_a is the energy cost of activity, including, in this case, running (E_r), digging (E_d), and standing (E_{st}) (Powell and others, 1985); and E_t is the energy cost of thermoregulation. We included thermoregulatory costs below the animal's lower critical temperature (T_{LC}) only and divided this into the cost above ground (E_{ta}) and below ground (E_{tu}). The inclusion of thermoregulation in the model was conditional upon Ta input. We estimated the total energy requirements of the animal for one day (in kJ) as:

$$E_{DEE} = E_s + E_r + E_d + E_{st} + [\text{if } Ta_a < T_{LC}]\ E_{ta} + [\text{if } Ta_u < T_{LC}]\ E_{tu}$$

where E_i is estimated as M_i x t_i (M_i is the energetic cost of activity i in kJ per hour; t_i is the time spent in activity i in hours per day), Ta_a is the ambient temperature above ground, and Ta_u is the temperature within the burrow (details in Harrington, 2001).

Model parameter estimates were from the literature, with empirical data on black-footed ferret metabolism from Harrington (2001) and Harrington and others (2003) and site temperature data (Ta_a) from meteorological records.

Model Simulations

For three hypothetical sites in the extreme north, south, and middle of the ferret's historical range, the model was run for 11 different activity scenarios ranging from complete rest within burrows to 5 hours active above ground (activity data from Powell and others, 1985). For each model run, Ta_a was chosen at random from a hypothesized normal distribution approximating nighttime temperature for each site in summer and winter. Ta_u was chosen at random from a range of values from the literature for summer and winter (same for all sites). Means and variances were based on 100 runs of the model for each of the 11 activity scenarios, for each site, in winter and summer.

Results

Assuming all activity scenarios are carried out at all sites in winter and summer, the model predicted higher energy requirements in the north than in the south in winter. In summer, energy requirements were predicted to be lower in the south than in the middle of the ferret's range. All other comparisons were nonsignificant. In all cases, variability within a site and season was high due to the inclusion of all possible activity scenarios in the simulations. Separating the analysis into low, medium, and high activity levels revealed that although trends tended to be similar (higher in the north than in the south), differences between sites were greatest at high activity levels and during winter. For resting ferrets, no differences between sites were detected; this was, however, an artifact of the model resulting from the use of a constant value

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for Ta_u. If burrow temperatures do vary between sites, overall intersite differences are likely to be greater.

Discussion

Although our model predicted statistically significant differences in energy requirements between northern and southern sites, these differences were small (<100 kJ per day between sites or about 11 percent of total mean expenditure during winter) and would require only small increases in prey consumption (one black-tailed prairie dog [*Cynomys ludovicianus*], the ferret's main prey, provides between 4,000 and 5,000 metabolizable kJ of energy; Powell and others, 1985). More biologically meaningful differences were found in consideration of energetic limits.

If maximum sustained metabolic rates for ferrets are limited at five times the basal metabolic rate (as they are for most other animals; Hammond and Diamond, 1997), maximum daily energy expenditure may be limited to approximately 1200 kJ per day, or less. Plotting predicted energy required per day in relation to above ground temperature demonstrated that, on this basis, high activity levels may be prohibitive at temperatures below -35°C (fig. 1). Although ferrets have been observed above ground at temperatures as low as -40°C (Richardson and others, 1987), it is not known how long they can stay above ground at such extremes. Ferret movements are shorter in colder temperatures; on the coldest days, ferrets simply may not be able to remain above ground. Ferret movements in late winter are principally for mating (Richardson and others, 1987); thus, restricted activity at this time could adversely affect reproductive potential.

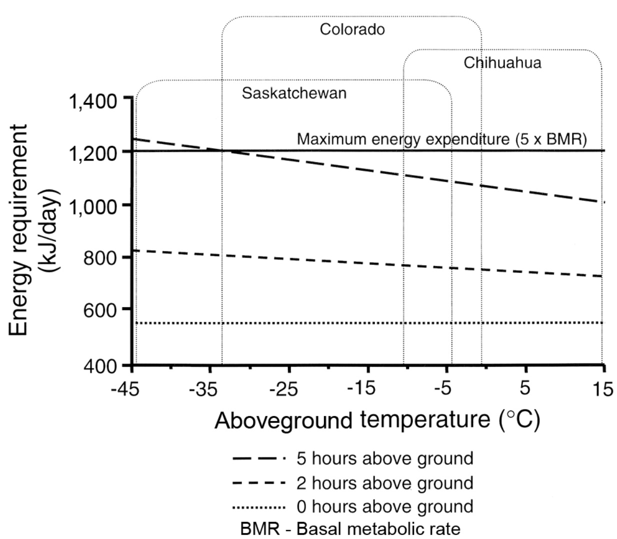

Figure 1. Predicted daily energy requirements for a black-footed ferret (*Mustela nigripes*) in winter in relation to aboveground temperature and amount of time spent above ground. Bracketing lines depict the range of winter temperatures for example sites. Activity was modeled to include mostly running with some time spent standing; Ta_u was set at 7.5°C (midpoint of the winter range).

Management Implications and Questions Remaining

This study does not provide definitive answers regarding the effect of climatic variability on ferret energy requirements. It does suggest, however, that ferret energetics and climate may be important factors to consider in evaluating potential release sites. If ferrets are to be successfully reintroduced into the wild, management plans should seek to minimize sources of stress to the extent possible. Winter energy requirements may be reduced by selecting more southerly reintroduction sites. As with all models, our predictions will require field validation. Questions remaining include (but are not limited to) the following. Is water stress greater in the south? How much do burrow temperatures vary between sites (and can ferrets manipulate their own burrow temperature by selecting depth)? How does ferret activity vary throughout their range (and in response to climate)?

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