Dung Beetles of the UK Uplands: Predicting Responses to Future Environmental Change

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Summary:

Studies considering the cumulative impacts of both climate and land use change on species distributions are relatively uncommon. This study contributes to this area using the dung beetles of the UK's Peak District National Park as a study system. A GIS is being used to assemble environmental variables into a consistent spatial framework and model the current and future distributions of dung beetle species. Work is ongoing at the time of abstract submission, but current results predict distributional responses to warming air temperatures in five species, including the potential regional extinction of one by 2050.

KEYWORDS: British uplands; distribution modelling; dung beetles; environmental change; spatial ecology

1. Introduction

Future environmental changes in terms of climate and land-use changes are both predicted to have significant impacts on the distribution of species worldwide (e.g. Thomas et al., 2004, and Kremen et al., 2007). Studies considering the cumulative impacts of both types of change are, however, relatively uncommon. The aim of this study is to contribute to this area, using the dung beetles of the uplands of the Peak District National Park as a study system.

Dung beetles are known to provide a wide range of ecological functions through their movement and consumption of mammalian dung. These functions include the physical breakdown of dung pats; contributing to nutrient cycling processes and controlling parasite populations (Hutton and Giller, 2003, Gardner et al., 2008, and Nichols et al., 2008). Given the importance of these functions, there is concern over how such a crucial group as the dung beetles will respond to climate (Menendez and Gutierrez, 2004) and land use change (Hutton and Giller, 2003, Vessby and Wiktelius, 2003, Gardner et al., 2008) in the future.

2. Methods

2.1. Field Survey

This was the first known dung beetle survey of the UK's Peak District National Park. 32 field survey sites were selected across the moorland, heathland and upland acid grasslands of the National Park between 240 and 600 metres a.s.l. The dung beetle community was surveyed at each site in summer (August 2010) and spring (May 2011) using dung-baited pitfall traps and hand-sorting of naturally occurring sheep dung. For each site, environmental data were also collected, or are currently being sought. This includes air temperature data (two hour intervals for whole year) collected using onsite dataloggers.

2.2. Distribution Modelling

To date, species distributions in terms of presence and absence have been modelled at the landscape scale in relation to elevation using binary logistic regression and the digital elevation model (DEM). By relating elevation to air temperature, predictions have then been generated regarding the effect that the anticipated future rise in air temperature may have on these distributions. By the time of GISRUK

2012 it is expected that similar work will have been completed for variables such as precipitation, grazing density and habitat change, using data derived from GIS maps and remote sensing imagery. This abstract, however, presents the results for the distribution models based only on elevation.

3. Current Results

3.1. Dung Beetles of the Peak District

6,640 individuals of 15 species were recorded in the Peak District during the 2010-2011 survey. This represents 20% of the total number of dung beetle species recorded in Britain.

3.2. Modelling Distributions

For the analysis, only species present at more than three sites and absent from more than three sites were considered. Two species, *Melinopterus prodromus* and *M. sphacelatus* are difficult to separate, so have also been omitted from the analysis. As a result, the distributions of 9 of the 15 recorded species were modelled (Table 1).

Table 1. Dung beetle species (and abundance) in the Peak District National Park. The number of sites where the species was present (32 surveyed in total) and the results from binary logistic regression of occupancy against elevation are also included in the table.

	Species	Total abundance	Sites present	χ^2	p-value	Model coefficient
	A. depressus	551	29			
	A. ater	3683	30			
	A. stercorosus	2	2			
	G. puncticollis	3	2			
	Melinopterus species	54	13			
Included in anaylsis	*A. rufipes*	336	16	11.007	0.001 *	-0.016
	A. lapponum	998	27	4.521	0.033 *	0.013
	A. rufus	73	7	4.456	0.035 *	-0.011
	A. fimetarius	46	18	0.667	0.414	
	N. contaminatus	750	15	0.322	0.571	
	O. haemorrhoidalis	14	4	7.395	0.006 *	-0.022
	P. uliginosus	50	10	1.774	0.183	
	T. fossor	26	5	0.986	0.321	
	G. stercorarius	6	4	7.618	0.006 *	-0.023

Five species showed a significant relationship between occupancy and elevation (Table 1). The relationship was negative for all except one species (*Agoliinus lapponum*). Using Equation 1 adapted from the linear equation, the current probability of occupancy for each species at each elevation was calculated (Table 2).

Probability of occupancy = binary logistic model coefficient * elevation + intercept coefficient (1)

Table 2. Current distribution of dung beetle species across elevation gradient in Peak District. Given as elevation range at which modelling predicts each species is < 20%, ≥ 20%, ≥ 50 %, and ≥ 80 % likely to occur.

	Probability of Occupancy			
Species	**<0.2**	**≥0.2**	**≥0.5**	**≥0.8**
A. rufipes	635 – 405 m	404 – 386 m	385 – 366 m	365 – 0 m

A. lapponum	0 – 270 m	271 – 293 m	294 – 315 m	316 – 635 m
A. rufus	635 – 261 m	260 – 234 m	233 – 207 m	206 – 0 m
O. haemorrhoidalis	635 – 268 m	267 – 254 m	253 – 241 m	240 – 0 m
G. stercorarius	635 – 269 m	268 – 256 m	255 – 243 m	242 – 0 m

3.3. Future Climate Change

A significant linear relationship between air temperature (recorded by dataloggers at each site) and elevation (R^2 = 0.241, $F_{1:24}$ = 7.634, p = 0.011) was identified, indicating 0.59 °C decrease in temperature per 100 m ascent. According to the medium emissions scenario, summer temperatures in the region are predicted to increase by 2.5 °C by 2050 (Defra, 2010) which equates to a 425 m uphill isotherm shift.

3.4. Responding to Climate Change: Two Example Species

This isotherm shift was factored into binary logistic regression modelling of species distributions to predict distributional response of species to climate change.

Acrossus rufipes (L. 1758) is widespread and common in Britain. It was found to have a negative relationship with elevation in the Peak District (Table 1) and is therefore expected to increase its range to higher elevations as the climate warms.

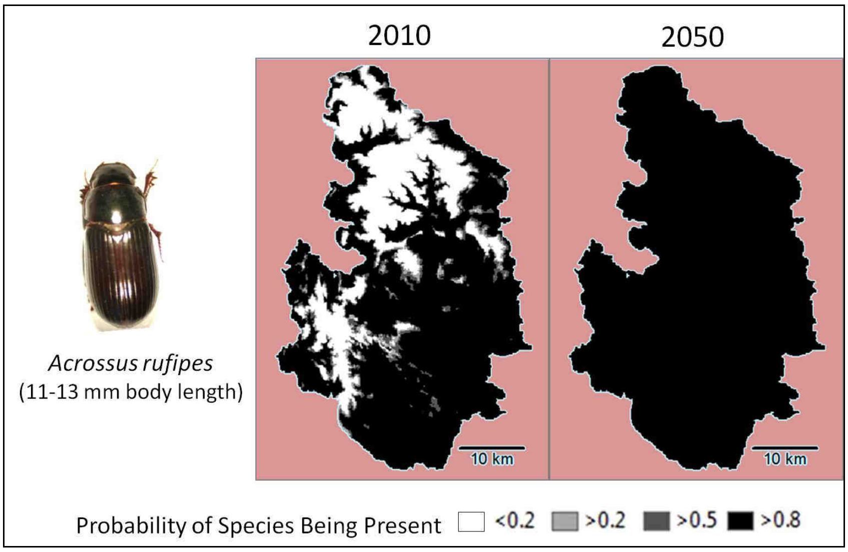

Figure 1. Predicted distribution of *Acrossus rufipes* in the Peak District with the 2.5 °C increase in temperature in 2010 and in 2050 (assuming 2.5 °C increase in temperature (Defra, 2010)).

Agoliinus lapponum (G. 1808), on the other hand, is a northern species reaching its southern limit in the Peak District. It was found to have a positive relationship with elevation in the Peak District (Table 1) and is therefore expected to see a dramatic reduction in available habitat with a warming climate. This may lead to a regional extinction of the species.

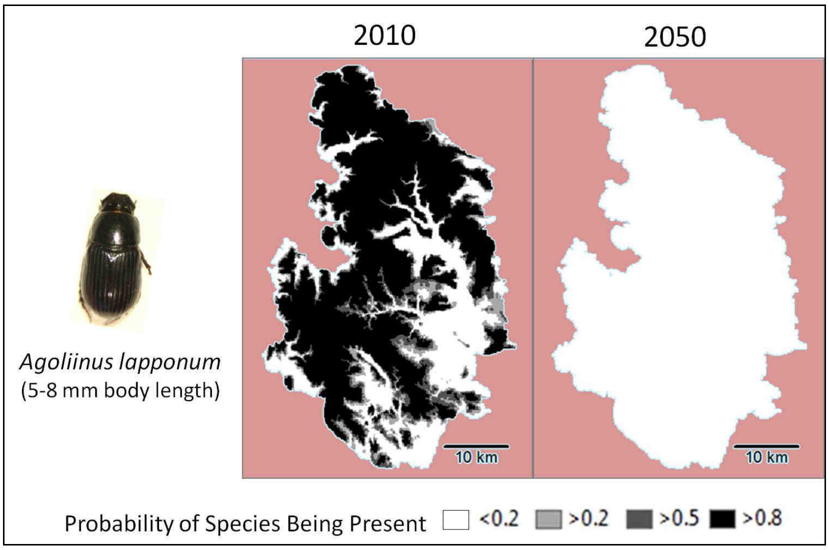

Figure 2. Predicted distribution of *Agoliinus lapponum* in 2010 and in 2050 (assuming 2.5 °C increase in temperature (Defra, 2010)).

4. Discussion

The level of species diversity recorded in the Peak District survey is in line with that recorded in other British uplands (Snowdonia, North Pennines) (Birkett et al., in prep.). In line with documented evidence for many other montane species (e.g. Menendez, 2007, and Chen et al., 2011) the results presented here suggest that most dung beetles species in the Peak District are likely to see an uphill expansion in habitat available to them as the air temperature warms. *Agoliinus lapponum*, however, is predicted to suffer an uphill contraction, possibly to the point of regional extinction by 2050. This will result in community composition change at individual sites, with potential implications for ecosystem function provision. Ongoing work will investigate discover how future changes in precipitation, grazing density and habitat may affect species distributions.

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(1,412 words)

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